AGRICULTURE & FOOD eNEWSLETTER

ISSN: 2581-8317

VOLUME 08 - ISSUE 02
FEBRUARY 2026

MONTHLY ONLINE MAGAZINE IN AGRICULTURE, HORTICULTURE, FOOD TECHNOLOGY AND ALLIED SUBJECTS

AGRIFOODMAGAZINE.CO.IN

EDITORIAL BOARD

www.agrifoodmagazine.co.in

Editors & Reviewers	
Dr. Manoj Kumar Mahawar (ICAR-CIRCOT)	Dr. Venkata Satish Kuchi (YSRHU)
Dr. R. S. Singh (Dr. RPCAU, Pusa)	Dr. Bapi Das (ICAR-NEZ)
Prof. Umesh Thapa (BCKV)	Dr. Basant Kumar Dadarwal (MPUAT)
Prof. Fatik Kr. Bauri (BCKV)	Dr. Suddhasuchi Das (KVK Malda, UBKV)
Dr. Pynbianglang Kharumnuid (IARI)	Mr. Sourav Mondal (DAE)
Dr. Amit Kumar Singh (BAU, Banda)	Dr. N. Senthilkumar (Annamalai University)
Dr. S. K. Bishnoi (ICAR-IIWBR, Karnal)	Dr. Shashikumar J.N. (UAS)
Dr. Nagendra Kumar (DRPCAU)	Dr. M. Ananthi (TNAU)
Dr. Pradip Kumar Sarkar (ICAR - EZ)	Dr. Subhrajyoti Chatterjee (CUTM)
Dr. J. Beslin Joshi - Scientist (CWRDM)	Dr. Sukamal Sarkar (RKMVERI)
Dr. Sujayasree O.J. (IIHR)	Dr. Manali Chakraborty (CUH)
Dr. Kariyanna B. (UAS Raichur)	Dr. Trina Adhikary (PAU)
Dr. Udit Kumar (DRPCAU)	Mr. Mahesh Dattatray Patil (VNMKV)
Dr. K Prasad (DRPCAU)	Dr. Babli Mog (ICAR-DCR, Puttur, Karnataka)
Dr. Chandan Karak (BCKV)	Dr. Ritu Jain (ICAR - IARI)
Dr. Vivek Kumar Singh (DDA - GOI)	Dr. V. Anandhi (TNAU)
Dr. Bhagwat Saran (GBPUAT)	Dr. Sahil J. Sindhi (JAU, Khapat- Porbandar)
Dr. Gopal Shukla (NEHU, Tura)	Dr. Arkendu Ghosh (BAU - Ranchi)
Dr. Nirmal Kumar Meena (AUK)	Dr. Ruchi Chauhan (IARI, Tutikandi Farm, Shimla)
Dr. K. Rama Krishna (CUTN)	Dr. C.S. Sumathi (TNAU)
Dr. Anil Kumar (SRI - DRPCAU)	Dr. Abhishek Tripathy (SOADU, Bhubaneswar)
Dr. V. Kasthuri Thilagam (ICAR-IISWC)	Dr. P.M. Shanmugam (TNAU)
Dr. Apurba Pal (BAU, Sabour)	Dr. Abhijit Das (LPU)
Dr. Amit Kumar Barman (WBUAFS)	Mr. Vijay Kamal Meena (ICAR)
Dr. Arun Kumar Tiwary (BAU, Ranchi)	Dr. Sarath Chandran M.A (ICAR-CRRIDA)
Dr. S.B Satpute (MGM NKCA, Aurangabad)	Dr. Babita Singh (ICAR - IARI)
Dr. Prabhu Narayan Meena - ARS (ICAR- NRCIPM)	Dr. Abhisek Tripathy (SOADU)
Dr. K. Venkata Subbaiah (YSRHU)	Dr. D. Leninraja (TNAU)
Dr. Monika Ray (OUAT)	Dr. Prasanna Pal (NDRI)
Dr. Devaramane Raghavendra (NC-IPM)	Dr. Artha Kundu (IARI)
Dr. A. Mohanasundaram (ICAR - IINRG)	Dr. Koyel Dey (BAU, Ranchi)
Dr. Sharmistha Pal (ICAR-IISWC)	Dr. Shubham Jain (Eklavya University)
Dr. Ipsita Samal (ICAR)	Mr. Perminder Singh Brar (Dr. YSPUHF)
Dr. Tensirani Pradhan (GIETU, Odisha)	Dr. Prativa Anand (ICAR-IARI)
Dr. Jayoti Majumder (BCKV)	Dr. G. Venkatesh (ICAR – CRIDA)
Dr. Debashish Hota (SOADU)	Dr. S. AnandhaKrishna Veni (TNAU)
Dr. Nongmaithem Raju Singh (ICAR-RCER)	Dr. Jagadeesh Bathula, FCRI, Siddipet
Dr. S. Karthikeyan (HRS, OOTY, TNAU)	Dr. Amrit Lal Meena (IIFSR)
Dr. Kaushik Kumar Panigrahi (OUAT)	Dr. K. Vanitha (ICAR- DCR, Puttur)
Dr. A. Thanga Hemavathy (TNAU)	Dr. Ningthoujam Peetambari Devi (ICAR-NEH)

Dr. Nityamanjari Mishra
Editor-in-chief

Mr. Shuvo Saha
Manager

Mr. Paritosh Halder
Technical Head

INDEX

Agriculture & Food: e-Newsletter **Volume 08 – Issue 02 – FEBRUARY 2026**
www.agrifoodmagazine.co.in

Article id.	Article title	Page
52700	CRISPR Genome Editing: A New Era in Vegetable Crop Improvement	01
52701	Precision Horticulture and Digital Technologies in Vegetable Farming	05
52702	Biostimulants and Attractants for Enhancing Pollination in Vegetable Crops	09
52703	Valorization of Oilseed Meals into Value-Added Proteins: Processing Technologies, Functional Properties, and Sustainable Applications	12
52704	Qualitative Assessment of Packaged Drinking Water in India: A Review	18
52705	Zero Tillage Farming of Maize & its Importance	24
52706	Microbial Dark Matter in Alfisols: Uncultivated Microbial Species and their Role in Zinc Solubilization	27
52707	Climate-Smart Vegetables: Producing Nutritious Food under Changing Climatic Conditions	29
52708	Adoption of Oil Extraction Machinery: A Pathway to Enhanced Farmers' Income	32
52709	Understanding the Ghani Method of Oil Extraction: How it Work, Its Benefits and Why it is Still Used	36
52710	Plant-Derived Melatonin for Insect Management: Principles and Mechanism	39
52711	Red Bhendi: A Nutrient-Rich, High-Value Vegetable for Health and Income	42
52712	Climate Resilience in Seemanchal, Bihar: Facing Uncertainty with Strength and Strategy	46
52713	Developing a Nutrient Density Score for Upland Rice	49
52714	Predicting Carbon Sequestration Potential Using Generative Models	52
52715	Designing a 3D Soil Temperature–Moisture Cube for Predicting Crop Yield Under Moisture Stress	55
52716	Management of Major Insect Pests in Ginger	57
52717	New Approaches in Plant Disease Resistance with Special Reference to Genome Editing	59
52718	Semiochemicals: A Tool for the Management of Pink Bollworm in Cotton	61
52719	Artificial Intelligence in Indian Agriculture: Applications, Challenges and Future Prospects	64
52720	Seaweed – The Ocean's Gift to Farming	67
52721	Agrometeorological Approaches for Climate-Smart and Climate-Resilient Agriculture: Current Advances, Challenges and Future Directions	70
52722	Article on Soilless Cultivation of Vegetable Crops	73
52723	Trace the Truth: Food Traceability - The Silent Shield Defeating India's Food Adulteration Crisis	78

INDEX

52724	Recent Trends Organic Farming in Vegetable Crops for Sustainable Production	81
52725	Host Plants of Muga – The Green Gold Behind Golden Silk	87
52726	Dragon Fruit: The Exotic Superfruit	89
52727	Water Management in Agriculture	92
52728	Biotechnological Aspects of Crop Improvement in Vegetable Crops	96
52729	Technological Applications of Reverse Osmosis in the Dairy Industry: Principles, Process Optimization, and Industrial Relevance	102
52730	Advances in Post-Harvest Management strategies of Vegetable Diseases	105
52731	Implementing A Circular Economy: Mitigating Waste and Carbon Footprints	107
52732	Generating Diversified Income through Oil Palm-Based Intercropping and Border Crops	109
52733	Remote Sensing–Based Vegetation Indices for Monitoring Crop Stress and Damage	112
52734	Cities of Waste and Oceans of Plastics	115
52735	The Growing Threat of Light Pollution in Modern Cities	118
52736	Market Dynamics Behind India's Rising Egg Prices	120
52737	Processing and Development of Value-Added Products of Vegetable	122
52738	Pre & Post Harvest Handling of Vegetables	126
52739	Carbon Credits: How can Farmers Monetize through Group Approach?	132
52740	Agro-Processing for Value Addition	136
52741	Government Programmes for Increasing Family Financial Security	139
52742	Crop Insurance Schemes for Farmers' Benefit	142
52743	Structural and Functional Aspects of Agriculture Market	146
52744	The Secret Life of Food Additives: How Tiny Ingredients Shape What We Eat	148
52745	Year Wise MSP (Minimum Support Prices) Fixed by Commission for Agricultural Cost and Prices (CACP) for Different Kharif Crops	151
52746	Lisianthus: The Rising Star of Modern Floriculture	153
52747	Applications of Crop Modeling in Agriculture	157
52748	Vegetables: Pillars of a Nutritious and Harmonious Diet	160
52749	Shrikhand: A Traditional Indian Fermented Dessert in the Context of Emerging Plant-Based Milk Alternatives and Sustainability	162
52750	Prime Editing in Crop Improvement: From Cutting DNA to Writing the Genetic Code	168
52751	Monsoon Variability and Its Agricultural Implications in Haryana During 2025	171

INDEX

52752	Cultivation of Wheat (*Triticum aestivum*)	177
52753	Vertical Farming of Strawberry in PVC Pipes	180
52754	Cashew Apple: From By-Product to Value-Added Resource	182
52755	Use of Plant Growth Regulators (PGRs) & New Chemicals for Enhancing Vegetable Production	185
52756	Artificial Intelligence in Precision Agriculture	189
52757	Melatonin: The Secret Weapon Protecting Our Fruits and Vegetables from Disease	191
52758	Invisible Shields: How Nanotechnology Is Empowering Horticultural Crops to Survive Environmental Stress	194
52759	Seeds Under Stress: How Climate Change is Reshaping Grain Quality and Reproductive Success	197
52760	Krishi Vigyan Kendras: Bridging the Gap Between Agricultural Research and Farmers' Fields	201
52761	Vegetable Grafting for Enhanced Vegetable Production	203
52762	The Importance of Colored Fruits in Human Health	208
52763	Nutraceutical Benefits of Citrus: The Science behind Citrus Superfood	214
52764	SWOT Analysis of Sweet Corn (*Zea Mays saccharate* L.) Cultivation in Rajasthan State of India	217
52765	Millets in Focus: The Aftermath of International Year of Millets (2023)	221
52766	Battling the Hidden Enemy: Stem Borer Infestation in Your Paddy Fields	224
52767	International Seed Certification: Bridging Global Borders through Quality Seeds	226
52768	Role of Microproteins in Crop Improvement	228
52769	Distribution, Biochemical Roles, and Nutritional Significance of Trace Elements in Milk: Implications for Human Health and Dairy Processing	230
52770	Role of Irradiation Technology in Post-Harvest of Fresh Fruits and Vegetables	234
52771	Role of Cold Plasma Technology in the Shelf-Life Extension of Fresh Fruits and Vegetables	238
52772	Development of High-Protein Millet Pancake & Dosa Mix- A New Product Concept	241
52773	Development of Moringa Pista Ice Cream	244
52774	Drone Application - Flight of Courage	248
52775	Role of Pseudocereals as Climate-Resilient Crops in Bihar	250
52776	Development of Camel Milk Powder- A New Product Concept (Specialty Nutrition)	253
52777	Development of Salted Buttermilk with Electrolytes- A New Product Concept (Functional Beverage)	256

INDEX

52778	Next-Generation Farming: Integrating AI and Blockchain in Agriculture	260
52779	Plastic Pandemic: Challenges and Innovations in Reducing Single-Use Waste	262
52780	History of Induced Breeding of Fish: An Overview	265
52781	Breeding Better Pulses: Seeds of India's Protein Revolution	267
52782	*Paecilomyces lilacinus*: An Effective Biological Control Agent for the Management of Plant-Parasitic Nematodes	270
52783	*Pseudomonas putida*: A Versatile Plant-Associated Bacterium for Sustainable Agriculture and Environmental Applications	274
52784	*Ganoderma lucidum*: The "Reishi" Mushroom - A Comprehensive Review of its Pharmacological Potential and Biotechnological Applications	278
52785	The Volatile Frontier: Harnessing Microbial Scents for Sustainable Pest Management	282
52786	Nematodes as Nutrition for Higher Trophic Levels	284
52787	Management of N Fertilizer in Rice Field: A Review	286
52788	ENSO–IOD Coupling and Monsoon Response in the Indian Ocean Basin During 2014–2025	288
52789	Indigenous Technical Knowledge (ITK) for Pest Control	291
52790	Urban Heat Island Effect and Rising City Temperatures	292
52791	Hydroponics: An Intensified Agriculture Practice to Improve Food Production	294
52792	Quantum Dots in Agriculture: A Tiny Technology Transforming Farming	297
52793	Cleaner Shipping and Coral Bleaching: An Unintended Climate Impact	300
52794	Mapping the Raptors of Tamil Nadu Marks a Statewide Effort to Conserve the Region's Top Predators	302
52795	Innovative Strategies for Utilising Farm Residue to Drive Yield Gains in 2026	304
52796	A Success Story on Postpartum Anestrus Management and Sustainable Dairy Farming	308
52797	A Success Story on Profitable Dairy Farming Through Postpartum Anestrus Management in Dairy Cattle	310
52798	Plastic-Degrading Bacteria in Mangrove Ecosystems: A Natural Approach to Microplastic Pollution	312
52799	PM2.5 Air Pollution in India: Trends, Urban Dynamics, and Environmental Agricultural Impacts	315
52800	Chakhao Black Rice of Manipur: From Cultural Heritage to Emerging Livelihood Opportunity	318
52801	Panicle-Level Grain Distribution in Paddy: A Quantitative Approach	320
52802	Advances in Drying Technologies	323
52803	9 Perennial Flowers that can take the Heat	326
52804	Seaweed A Crop for Future: Blue Transformation in Action	330

INDEX

52805	Novel Technologies for Quality and Safe Food: Strengthening the Food System from Farm to Fork	337
52806	Green Technology Innovations that Could Save the Planet	340
52807	Reducing Drudgery: Solar Technology Impact on Rural Women Time	343
52808	Chronic Stress and Physiological Consequences Among Secondary School Students	345
52809	Onion Cultivation: A Profitable Crop for Farmers in Angul District, Odisha	348
52810	Nanosensors and Nanotechnology in Agriculture: Precision Tools, Sustainable Outcomes, and the Critical Path to Field Implementation	351
52811	Transfer of Technology Through Seed Production Program's at KVK Farm, Amroha: Case Study	354
52812	Transfer of Technology Through Extension Functionaries Training Program for Extension Workers/FPO's/SHG's/Progressive Farmers/Social Worker's	356
52813	Popularization of Groundnut Variety GG-34 Among Farmers Under Cluster Frontline Demonstrations (CFLDs): Success Story	358
52814	Technology Transfer through Vocational Training Program for Un-Employment Rural Youth/Farm Women's	360
52815	Impact Assessment of New High Yielding Variety of Basmati Rice Pusa Basmati-1847 Under Front Line Demonstrations in District Amroha of Western Uttar Region: Case Study	362
52816	Technology Transfer Through On & Off Campus Farmers & Farm Women Training Program	364
52817	Impact Assessment of New High Yielding Variety of Basmati Rice Pusa Basmati-1885 Under Front Line Demonstrations in District Amroha of Western Uttar Region: Case Study	369
52818	Fermented Organic Manure (FOM): Benefits and Applications	370
52819	Green Hydrogen Gas and Dispensing Stations: Uses and Applications	372
52820	Climate Smart Agriculture: Opportunities and Challenges	374
52821	Breeding Approach to Develop Climate Resilient Crops: Current Status and Future Prospects: A Review	377
52822	Climate Resilient Crop Varieties	380
52823	Popularization of Sesame Variety GT-06 Among Farmers Under Cluster Frontline Demonstrations (CFLDs): Success Story	382
52824	Biofortification: A Long-Term Solution to Improve Global Health	385
52825	Present Status and Future Planning, Quality Seed Production Technology, Post-Harvest Uses and Uses of Linseed (*Linum usitatissimum*)	389
52826	Present Status, Production Constraints and Future Research Strategies in Oilseed *Brassica* Species	393
52827	Crop Diversification as a Risk Reduction Strategy in Modern Agronomy	398
52828	Cultivation of Mango (*Mangifera indica* L.)	401
52829	Resource-Use Efficient Agronomy for Climate-Resilient Agriculture	405

AGRICULTURE & FOOD e-Newsletter

INDEX

52830	Precision Nutrient Management as a Tool for Sustainable Crop Productivity	408
52831	From Daily Wage Labourer to Lac Farmer: The Inspiring Journey of Shri Chandan Beena	411
52832	Digital Labour in Indian Agriculture: The Growing Gig Economy	414
52833	Seeds of Change: Unraveling the Story of Genetically Modified Organisms	417
52834	Plasma-Activated Water: Physico-chemical Characteristics, Production Techniques and Utilization	419
52835	Emerging Precision Farming Strategies for Resource-Efficient Agricultural Systems	422
52836	Climate Change Vulnerability and Adaptation in Kiwifruit Production Systems	425
52837	Agriculture at the Crossroads: Can India Turn its Oilseed Paradox into an Opportunity?	428
52838	Comparative Performance of Area, Production and Productivity of Major Crops in India and Telangana (2024–25)	430
52839	Role of Robotics in Dairy and Food Industry	433
52840	RNA Based Biopesticides in Plant Disease Management: An Emerging Approach	435
52841	*Bacillus*-Based Biocontrol: A Pathway to Sustainable Crop Protection	439
52842	Water Use Efficiency in Hydroponics vs Conventional Agriculture in Tamil Nadu	442
52843	Improved Varieties of Rice in Gujarat	444
52844	Integrating Trees into Farming Systems: Agroforestry as a Nature-Based Solution for Climate and Livelihood Resilience	446

The articles published in this magazine are based on personal view / opinion of the authors
Magazine does not ensure the genuinely of the facts mentioned in the articles
Authors are solely responsible for plagiarism present in the article

AGRICULTURE & FOOD: eNewsletter
ISSN: 2581-8317
www.agrifoodmagazine.co.in

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

CRISPR Genome Editing: A New Era in Vegetable Crop Improvement

Article ID: 72700

P. Agalya[1], A. Kingsly Raj[1], A. Ajay Raja[1]
[1]Ph.D Scholar, Department of Vegetable Science, TNAU, Coimbatore.

Abstract
Vegetable crops play a crucial role in human nutrition, yet their production is increasingly threatened by climate change, resource limitations, and biotic stresses. Conventional breeding approaches, although successful, are often time-consuming and constrained by limited genetic variability. In this context, CRISPR/Cas9 genome editing has emerged as a transformative technology for precise and efficient crop improvement. This article reviews the principles of CRISPR/Cas9 and highlights its applications in vegetable crops for enhancing tolerance to abiotic stresses such as drought, heat, cold, and salinity, as well as resistance to diseases and pests. The potential of CRISPR in developing herbicide-tolerant varieties, improving fruit ripening and shelf life, inducing parthenocarpy for seedless vegetables, and enhancing nutritional and quality traits is also discussed. Furthermore, key challenges related to off-target effects, delivery systems, regeneration efficiency, and regulatory frameworks are examined. Despite these limitations, advances in genome editing tools and evolving regulatory policies indicate a promising future for CRISPR-based vegetable improvement. The integration of CRISPR technology with conventional breeding and omics approaches holds significant potential for developing climate-resilient, high-quality, and sustainable vegetable crops to ensure future food and nutritional security.

Introduction
Vegetables are an essential part of the human diet, supplying vitamins, minerals, dietary fiber, and health-promoting bioactive compounds. As the global population continues to rise and climate change intensifies, vegetable production faces increasing challenges. Abiotic stresses such as drought, salinity, heat, and cold, along with biotic stresses caused by pests and diseases, significantly reduce yield and quality. Conventional plant breeding has contributed greatly to crop improvement, but it is often slow, labor-intensive, and limited by the availability of genetic variation.

In recent years, genome editing technologies have emerged as powerful tools to accelerate crop improvement. Among them, CRISPR/Cas9 has gained remarkable attention due to its simplicity, precision, and efficiency. This technology has opened new possibilities for developing improved vegetable varieties with enhanced yield, stress tolerance, nutritional quality, and consumer appeal.

What is CRISPR/Cas9?
CRISPR/Cas9 is a genome editing system originally discovered as part of the natural defense mechanism of certain bacteria and archaea. In nature, it helps microorganisms protect themselves from invading viruses. Scientists have adapted this system to edit genes in plants, animals, and microorganisms.

The CRISPR/Cas9 system mainly consists of two components: a guide RNA (gRNA) and the Cas9 enzyme. The guide RNA directs the Cas9 enzyme to a specific DNA sequence in the genome. Once the target site is reached, Cas9 creates a break in the DNA. The plant's own DNA repair machinery then repairs this break, leading to changes in the gene sequence. These changes can disable a gene, modify its function, or introduce precise alterations.

Unlike traditional genetic modification, CRISPR does not necessarily involve the insertion of foreign DNA. This makes genome-edited crops closer to naturally occurring mutants, improving their acceptance among regulators and consumers.

Why is CRISPR Important for Vegetable Crops?
Vegetable breeding traditionally relies on repeated crossing and selection, which can take many years to produce a new variety. In contrast, CRISPR enables precise changes in specific genes within a much shorter time. With the availability of complete genome sequences for many vegetable crops, researchers can now target genes responsible for important traits with high accuracy.

CRISPR technology has been successfully applied in several vegetables such as tomato, potato, eggplant, cucumber, cabbage, pumpkin, carrot, sweet potato, and squash. Although its application is still limited to a few crops due to challenges in plant regeneration and transformation, the potential is enormous.

Improving Tolerance to Abiotic Stresses
Environmental stresses are major constraints in vegetable production. CRISPR has been used to understand and improve stress tolerance mechanisms in vegetables.

For example, heat stress can damage plant cells and reduce fruit yield. In tomato, genome editing of genes involved in hormone signaling pathways has helped reduce oxidative damage under high temperatures. Similarly, genes related to drought tolerance have been targeted to improve antioxidant activity and protect plant tissues from stress-induced injury.

Cold stress tolerance has also been enhanced by editing genes that regulate cold-responsive pathways. In addition, CRISPR-based studies have helped improve tolerance to ultraviolet radiation and salinity by modifying genes involved in ion balance, reactive oxygen species regulation, and stress signaling.

By developing stress-resilient vegetable varieties, CRISPR can contribute significantly to climate-smart agriculture.

Enhancing Resistance to Diseases and Pests

Diseases caused by fungi, bacteria, viruses, and parasitic weeds result in major yield losses in vegetable crops. CRISPR technology offers a powerful approach to develop disease-resistant varieties by targeting susceptibility genes.

In tomato, deletion of specific genes has resulted in resistance to powdery mildew, downy mildew, bacterial speck disease, and gray mold. Similarly, cucumber plants edited using CRISPR have shown resistance to multiple viral diseases. Genome editing has also been used to protect vegetables from parasitic weeds by modifying genes involved in signaling compounds that trigger parasite germination.

These disease-resistant vegetables reduce dependence on chemical pesticides, leading to safer food and more sustainable farming systems.

Developing Herbicide-Resistant Vegetables

Weeds compete with vegetable crops for nutrients, water, and light, reducing yield and quality. CRISPR has been used to develop herbicide-tolerant vegetable varieties by introducing precise mutations in genes targeted by herbicides.

For instance, modifications in genes associated with amino acid biosynthesis have produced herbicide-resistant tomato, potato, and watermelon plants. Such crops allow effective weed management while minimizing crop damage. Importantly, many of these edited plants are free from foreign DNA, making them distinct from conventional genetically modified crops.

Controlling Fruit Ripening and Shelf Life

Fruit ripening is a complex process involving changes in color, texture, flavor, and nutritional composition. In vegetables like tomato, ripening determines shelf life and market value. CRISPR has been used to modify genes that regulate ethylene production, pigment synthesis, and DNA methylation, leading to delayed ripening.

By slowing down the ripening process, genome-edited vegetables can have extended shelf life, reduced post-harvest losses, and improved transportability. This is particularly important for reducing food waste in supply chains.

Producing Seedless Vegetables through Parthenocarpy

Seedless vegetables are often preferred by consumers for their better texture and convenience. Parthenocarpy refers to fruit development without fertilization. CRISPR has been successfully used to develop parthenocarpic tomato plants by editing genes involved in hormone signaling and flower development.

These seedless fruits are also more tolerant to adverse environmental conditions such as high temperatures, where pollination may be impaired. This trait can help stabilize yields under changing climatic conditions.

Improving Nutritional and Quality Traits

Consumer demand for high-quality, nutritious vegetables is increasing. CRISPR offers precise ways to enhance nutritional composition and sensory traits.

Genome editing has been used to increase beneficial compounds such as lycopene, anthocyanins, malate, and gamma-aminobutyric acid (GABA) in vegetables. Improvements in oil quality, starch composition, and fatty acid profiles have also been achieved in crops like sweet potato, rapeseed, and camelina.

Additionally, undesirable compounds can be reduced. For example, editing genes responsible for enzymatic browning has led to vegetables with reduced discoloration after cutting. In potato, toxic glycoalkaloids have been minimized through targeted gene editing, improving food safety.

Challenges in Applying CRISPR to Vegetables

Despite its promise, CRISPR technology faces several challenges in vegetable crops. One concern is the possibility of off-target mutations, where unintended regions of the genome are altered. Advances in guide RNA design and improved Cas9 variants are helping minimize this risk.

Another limitation is the low efficiency of precise DNA repair mechanisms, which restricts complex gene insertions. Delivering CRISPR components into plant cells also remains challenging, particularly for crops with poor regeneration capacity.

Genome instability and difficulty in linking edited genes to visible traits further complicate large-scale application. However, newer approaches such as base editing and CRISPR interference systems are addressing some of these issues by reducing DNA damage and improving precision.

Regulatory and Public Acceptance Issues

Regulation of genome-edited crops varies widely across countries. Some nations regulate them similarly to conventional crops if no foreign DNA is present, while others apply strict GMO regulations. India and China have recently taken steps to exempt certain genome-edited crops from extensive biosafety assessments, encouraging innovation.

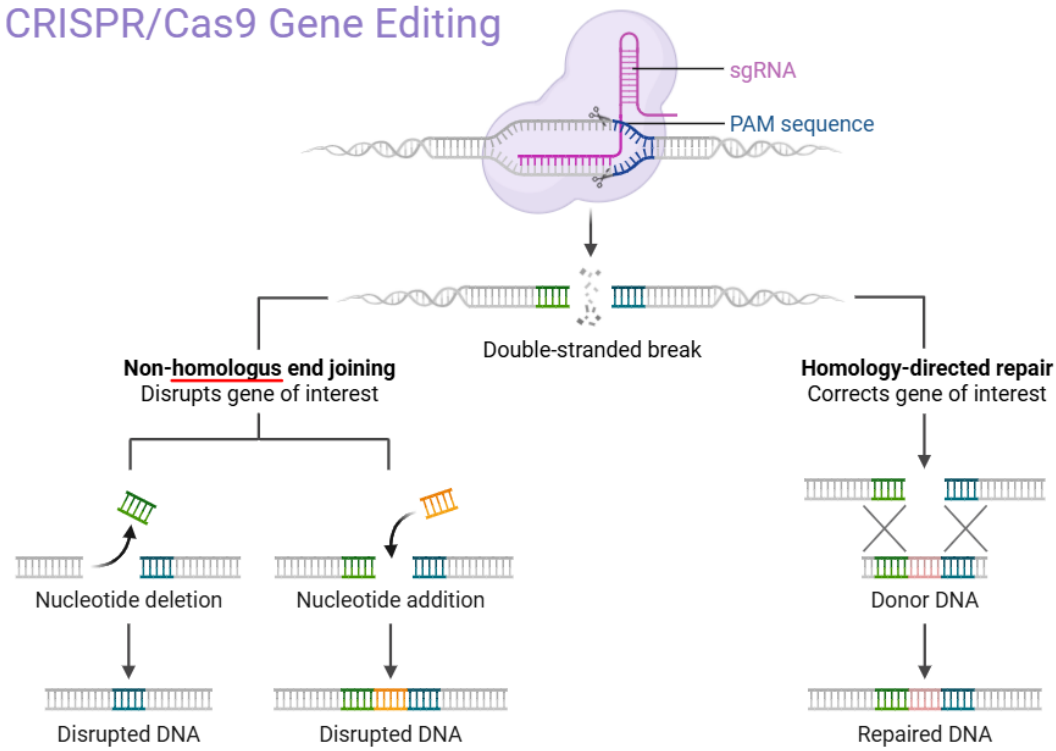
Public acceptance remains a key challenge. Although scientific evidence shows no adverse health effects from genome-edited foods, transparent communication and clear labelling are essential to build consumer trust.

Future Prospects

CRISPR/Cas9 technology represents a major breakthrough in vegetable breeding. By combining genome editing with traditional breeding and modern omics technologies, it is possible to develop vegetables that are more productive, nutritious, resilient, and environmentally sustainable. As technical challenges are gradually overcome and regulatory frameworks become clearer, genome-edited vegetables are likely to play an important role in ensuring food and nutritional security. The key question for the future is not whether these vegetables can be developed, but whether society is ready to accept and benefit from them.

Conclusion

CRISPR/Cas9 genome editing represents a significant breakthrough in vegetable crop improvement by enabling precise, rapid, and targeted modification of genes controlling yield, stress tolerance, disease resistance, and quality traits. As discussed in this review, its applications span the development of climate-resilient vegetables tolerant to abiotic stresses, resistant to pests and diseases, improved in shelf life, nutritional value, and consumer-desirable traits such as seedlessness, while also supporting sustainable agriculture through reduced chemical inputs. Although challenges related to off-target effects, delivery efficiency, regeneration, and regulatory uncertainty remain, continuous technological advancements and evolving policy frameworks are steadily addressing these limitations. Overall, the integration of CRISPR/Cas9 with conventional breeding and modern omics approaches holds immense promise for developing high-quality, resilient, and sustainable vegetable crops, thereby contributing meaningfully to future food and nutritional security.



Source: Biorender.com

References

1. Das, T., Anand, U., Pal, T., Mandal, S., Kumar, M., Radha, ... & Dey, A. (2023). Exploring the potential of CRISPR/Cas genome editing for vegetable crop improvement: an overview of challenges and approaches. *Biotechnology and Bioengineering*, *120*(5), 1215-1228.
2. Devi, R., Chauhan, S., & Dhillon, T. S. (2022). Genome editing for vegetable crop improvement: Challenges and future prospects. *Frontiers in Genetics*, *13*, 1037091.
3. Sood, A., Sharma, P., Sharma, A., Chaudhary, D. R., & Manisha. (2025). Genome editing in vegetable crops: a new era of sustainable agriculture. *Molecular Biology Reports*, *52*(1), 944.
4. Biorender.com.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Precision Horticulture and Digital Technologies in Vegetable Farming

Article ID: 72701

P. Agalya[1], A. Kingsly Raj[1], A. Ajay Raja[1]
[1]Ph.D Scholar, Department of Vegetable Science, TNAU, Coimbatore.

Abstract

Vegetable farming is increasingly challenged by rising production costs, climate variability, labour constraints, and the growing demand for high-quality produce. Precision horticulture, supported by digital technologies, has emerged as an effective solution to address these challenges by enabling data-driven, site-specific, and resource-efficient crop management. This article presents an overview of precision horticulture in vegetable farming, highlighting key digital tools such as soil and crop sensors, GPS and GIS mapping, drones and remote sensing, smart irrigation systems, mobile advisory platforms, artificial intelligence, and automation in protected cultivation. These technologies help optimize the use of water, nutrients, and plant protection measures, while enabling early detection of crop stress, pests, and diseases. The adoption of precision horticulture improves yield, quality, profitability, and environmental sustainability across a wide range of vegetable crops. Despite challenges related to cost, digital literacy, and infrastructure, rapid technological advancements and supportive policies are accelerating adoption. Overall, precision horticulture represents a transformative approach for building resilient, climate-smart, and economically viable vegetable production systems for the future.

Introduction

Vegetable farming is no longer just about soil, seeds, and seasons. In today's rapidly changing world, farmers face rising input costs, climate uncertainty, labour shortages, and increasing demand for high-quality produce. To meet these challenges, vegetable growers are turning toward precision horticulture and digital technologies—a modern approach that uses data, sensors, automation, and smart decision-making tools to manage crops more efficiently.

Precision horticulture focuses on *doing the right thing, at the right place, at the right time, and in the right amount*. When combined with digital tools such as mobile apps, sensors, drones, and artificial intelligence, it transforms traditional vegetable farming into a knowledge-driven, sustainable, and profitable enterprise.

This article explores the concept of precision horticulture, key digital technologies used in vegetable farming, their benefits, real-world applications, and future prospects.

What is Precision Horticulture?

Precision horticulture is a farming approach that recognizes field variability and manages crops according to the specific needs of plants rather than treating the entire field uniformly. Vegetables grown in the same plot may differ in nutrient needs, moisture levels, pest pressure, and growth stages. Precision techniques allow farmers to address these differences effectively.

In vegetable farming, precision horticulture involves:

a. Precise application of water, fertilizers, and pesticides
b. Continuous monitoring of soil and crop health
c. Data-based decision making instead of guesswork
d. Efficient use of resources to reduce waste and environmental impact

Digital technologies act as the *backbone* of precision horticulture by collecting, analyzing, and converting data into practical farm actions.

Why Precision and Digital Farming is Important for Vegetables?

Vegetable crops are high-value, input-intensive, and sensitive to management errors. Even small mistakes in irrigation, nutrition, or pest control can result in significant yield and quality losses.

Key challenges in conventional vegetable farming include:

a. Over- or under-irrigation leading to stress and diseases
b. Excess fertilizer use causing nutrient imbalance and pollution
c. Late detection of pests and diseases
d. Rising labour and production costs
e. Climate variability affecting crop growth and yield.

Precision horticulture addresses these challenges by offering timely, accurate, and crop-specific solutions, improving productivity while protecting natural resources.

Major Digital Technologies in Precision Vegetable Farming

1. Soil and Crop Sensors: Sensors are among the most important tools in precision horticulture. They continuously measure soil and plant parameters and provide real-time data.

Common sensors used in vegetable farming include:

a. Soil moisture sensors for irrigation scheduling
b. Soil nutrient sensors to guide fertilizer application
c. Temperature and humidity sensors for microclimate monitoring
d. Leaf wetness sensors for disease forecasting.

With sensor data, farmers can avoid unnecessary irrigation or fertilization and ensure optimal growing conditions for crops like tomato, chilli, cucumber, and leafy vegetables.

2. GPS and Geographic Information Systems (GIS): GPS and GIS technologies help in mapping field variability. By creating digital maps of soil fertility, moisture levels, and crop performance, farmers can manage each part of the field differently.

Applications in vegetables:

a. Variable rate fertilizer and water application
b. Mapping disease or pest hotspots
c. Yield mapping in commercial vegetable production
d. Planning crop layout and planting density.

These technologies are especially useful in large-scale vegetable farms and protected cultivation systems.

3. Remote Sensing and Drones: Remote sensing uses satellite images or drone-based cameras to assess crop health from above. Drones equipped with multispectral or thermal cameras can detect plant stress long before visible symptoms appear.

Benefits for vegetable farmers:

a. Early detection of nutrient deficiencies
b. Identification of water stress zones
c. Monitoring pest and disease spread
d. Assessing crop vigour and uniformity.

Drone technology is increasingly used in high-value vegetables like capsicum, onion, and tomato, where early intervention saves cost and yield.

4. Smart Irrigation Systems: Water is a critical input in vegetable production. Smart irrigation systems combine sensors, weather data, and automated controllers to deliver water precisely when and where it is needed.

Key features include:

a. Automated drip or sprinkler systems
b. Weather-based irrigation scheduling
c. Mobile app-controlled irrigation
d. Reduced water loss and energy consumption.

Smart irrigation not only conserves water but also improves nutrient uptake and reduces disease incidence caused by excess moisture.

5. Mobile Apps and Digital Advisory Platforms: Mobile technology has made precision horticulture accessible even to small and marginal farmers. Digital platforms provide real-time advisories directly to farmers' smartphones.

Common services include:

a. Weather forecasts and alerts
b. Crop stage-based fertilizer recommendations
c. Pest and disease identification through images
d. Market price information.

These apps bridge the gap between research, extension services, and farmers, empowering vegetable growers with actionable knowledge.

6. Artificial Intelligence (AI) and Machine Learning: AI is transforming vegetable farming by analyzing large datasets and providing predictive insights. Machine learning models can process data from sensors, images, and weather records to support decision-making.

Applications include:

a. Predicting pest and disease outbreaks
b. Optimizing irrigation and fertilizer schedules
c. Yield forecasting
d. Automated grading and sorting of vegetables.

AI-based tools help farmers move from reactive to proactive crop management.

7. Protected Cultivation and Automation: Precision horticulture plays a crucial role in greenhouses, polyhouses, and vertical farms, where environmental conditions must be tightly controlled.

Digital technologies help regulate:

a. Temperature and humidity
b. Light intensity and duration
c. Carbon dioxide levels
d. Nutrient delivery in hydroponics.

Automation reduces labour dependence and ensures consistent vegetable quality throughout the year.

Benefits of Precision Horticulture in Vegetable Farming

1. Higher Yield and Quality: Precise management leads to uniform growth, better fruit size, improved color, and enhanced nutritional quality.

2. Efficient Resource Use: Water, fertilizers, and pesticides are used only where needed, reducing input costs and environmental pollution.

3. Reduced Crop Losses: Early detection of stress, pests, and diseases minimizes damage and prevents large-scale crop failures.

4. Improved Profitability: Lower costs combined with higher yields and better market quality result in increased farm income.

5. Climate-Smart Farming: Precision horticulture helps farmers adapt to climate change by optimizing resource use and reducing vulnerability to weather extremes.

Precision Technologies in Different Vegetable Crops

1. Tomato and chilli: Smart fertigation, disease prediction models

2. Cucurbits: Precision irrigation, pollination management tools

3. Onion and garlic: Drone-based crop monitoring, yield forecasting

4. Leafy vegetables: Controlled environment farming and vertical systems

Each crop benefits uniquely based on its growth pattern and market demand.

Challenges in Adoption

Despite its advantages, precision horticulture faces some limitations:

1. High initial investment cost
2. Limited digital literacy among farmers
3. Need for technical support and training
4. Connectivity issues in rural areas.

However, increasing smartphone penetration, government support programs, and private sector innovation are rapidly overcoming these barriers.

Future Prospects

The future of vegetable farming lies in data-driven, intelligent, and sustainable systems. Emerging trends include:

1. Internet of Things (IoT)-based farm networks
2. Robotics for harvesting and weeding
3. Blockchain for traceability and food safety
4. Integration of precision farming with organic and natural farming

As technologies become more affordable and user-friendly, precision horticulture will play a vital role in ensuring food security and farmer prosperity.

Conclusion

Precision horticulture and digital technologies are reshaping vegetable farming from a traditional labor-intensive practice into a smart, efficient, and sustainable system. By using real-time data, advanced tools, and intelligent decision-making, vegetable growers can achieve higher productivity while conserving resources and protecting the environment.

In a world where every drop of water, gram of fertilizer, and square meter of land matters, precision horticulture offers a promising path forward—helping farmers grow more vegetables with less input and greater confidence.

References

1. Das, U., Pathak, P., Meena, M. K., & Mallikarjun, N. (2018). Precision farming a promising technology in horticulture: a review. *Int J Pure Appl Biosci*, *6*(1), 1596-1606.
2. Layden, I. A., & O'Halloran, J. (2020). Adoption of precision systems technology in vegetable production.
3. Boruah, T., Kalita, M., Hasnu, S., Das, K. S., Singh, R., & Nayik, G. A. (2024). Role of Digital Technologies in the Field of Horticultural Science and Technology. In *Novel Approach to Sustainable Temperate Horticulture* (pp. 116-148). CRC Press.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Biostimulants and Attractants for Enhancing Pollination in Vegetable Crops

Article ID: 72702

P. Agalya[1], A. Kingsly Raj[1], A. Ajay Raja[1]
[1]Ph.D Scholar, Department of Vegetable Science, TNAU, Coimbatore.

Abstract

Pollination is a critical biological process underpinning fruit and seed production in many vegetable crops, directly influencing yield, quality, and economic returns. However, declining pollinator populations, unfavorable weather conditions, and intensive farming practices often lead to inadequate pollination in vegetable fields. In this context, sustainable approaches that enhance both plant performance and pollinator activity are gaining importance. This article reviews the role of biostimulants and pollinator attractants as complementary tools for improving pollination efficiency in vegetable crops.

Biostimulants, derived from natural or biological sources, enhance plant physiological processes such as root development, flowering, stress tolerance, and nutrient use efficiency, thereby indirectly supporting pollination by producing healthier and more attractive flowers. Pollinator attractants, including sugar or jaggery solutions and floral scent compounds, directly increase pollinator visitation by appealing to insects' natural foraging cues.

When used together, these tools create a synergistic effect—healthy, well-flowering plants combined with increased pollinator activity—leading to improved fruit set, seed yield, and crop uniformity. The article highlights practical application strategies, safety considerations, and the importance of integrating these tools with pollinator-friendly farming practices. Overall, biostimulants and pollinator attractants offer environmentally responsible and farmer-friendly solutions to enhance pollination and productivity in vegetable cultivation.

Introduction

Vegetables are vital to human nutrition and global food security, yet many growers face challenges in achieving *optimal pollination*—a key step in setting fruit and seeds. Proper pollination not only increases yields but also improves quality, uniformity, and market value of vegetables. Two sustainable tools have gained attention in recent years for enhancing pollination success: biostimulants and pollinator attractants. These tools don't just boost growth or lure insects—they help create a farming ecosystem where plants and pollinators work together better, especially in vegetable fields where flowers may otherwise go under-visited by bees and other beneficial insects.

What are Biostimulants?

Biostimulants are a class of agricultural inputs that improve plant performance through *physiological stimulation*, not by supplying direct nutrition like a fertilizer, nor by killing pests like a pesticide. Instead, they trigger natural plant processes that *enhance growth, stress tolerance, nutrient use efficiency, flowering, root development, and overall yield potential*.

Key Characteristics

1. Composed of natural or biologically-derived substances: seaweed extracts, humic/fulvic acids, protein hydrolysates, beneficial microbes, amino acids, etc. PMC

2. Act on plant hormonal, metabolic, or microbial pathways. Frontiers

3. Not fertilizers—benefits come from *stimulating plant biology* rather than adding nutrients. Verdesian Life Sciences

How Biostimulants Work?

Biostimulants can improve:

1. Root growth and nutrient uptake: plants take up water and nutrients more efficiently, often leading to more vigorous plants.

2. Flower development: more robust flower initiation and longevity, enhancing opportunities for pollination.

3. Stress resilience: plants handle drought, heat, or salinity better, keeping flowers healthy and attractive.

4. Plant-microbe interactions: beneficial microbes can improve soil health and nutrient cycling, feeding plants over time.

All these benefits indirectly support pollination by helping plants produce more and better flowers that are attractive and receptive when pollinators visit.

What are Pollinator Attractants?

Pollinator attractants are substances or solutions applied specifically to *encourage pollinators*—especially bees—to visit crop flowers. Most vegetable crops rely on insect pollination, whether it's cucurbits like cucumbers and bottle gourds, alliums like onions, or brassicas like radish seeds.

How Attractants Work?

Attractants harness insects' natural preferences—sugar, scent, or pheromone cues—to increase the time pollinators spend on and near crop flowers. Common attractants include:

1. **Sugar solutions** (commonly ~10%)
2. **Jaggery (unrefined cane sugar) solutions**
3. **Honey or nectar analogs**
4. **Plant volatiles or essential oils** known to attract bees (e.g., geraniol, eugenol)

These can be sprayed near flowers during peak bloom to *enhance visitation rates* and thus pollination. Field studies have repeatedly shown that treated plots attract more bees than untreated ones.

Vegetable Pollination: Why it Matters?

Before delving into tools, it's helpful to appreciate *why pollination matters* in vegetable crops.

1. Fruit and seed set: Cross-pollinated crops like squash, cucumbers, onions, carrots, and many others depend on bees and insects to transfer pollen.

2. Yield increase: For seed production, honey bee pollination can *raise seed yields dramatically* in crops like radish and cabbage.

3. Quality and uniformity: Good pollination often means more uniform fruit size and better marketability.

However, pollination can be inadequate due to:

a. Low pollinator presence
b. Competition from nearby flowering weeds or crops
c. Adverse weather (rain, heat, wind)
d. Pesticide use that deters pollinators

This is where biostimulants and attractants can *tip the balance towards success*.

Biostimulants: Boosting Flowering and Crop Performance

Biostimulants may not directly lure bees—but they create conditions where plants *are more likely to produce flowers that pollinators want to visit*.

Effects on Vegetable Crops

Studies and grower experience indicate that biostimulants can:

1. Support bigger root systems and a healthier plant *architecture*.
2. Improve flowering intensity and duration, which increases opportunities for pollination.
3. Enhance nutritional quality, which may influence nectar and pollen rewards (especially floral scent and sugar content).

Practical Application Tips

1. Apply biostimulants at key growth stages: seedling stage, pre-flower, and early flowering.
2. Use foliar sprays to support quick uptake and physiological stimulation.
3. Combine with good soil management for best results.

By fostering healthier, more resilient plants that flower better, biostimulants indirectly elevate pollination success.

Attractants: Direct Tools to Enhance Pollination

While biostimulants set the stage, attractants bring in the actors—the bees and pollinators.

Common Attractants and their Impact

Research and field trials have shown that:

1. Jaggery or sugar solutions (≈10%) sprayed on flower canopies *significantly increase bee visitation* in vegetables such as cucumber and bottle gourd.
2. Attractants encourage bees to linger near crops, increasing pollination efficiency.

3. Indigenous attractants work well and are *affordable and accessible* for smallholders.

Additionally, commercial attractant products and bee-scent compounds can sometimes outperform simple sugar sprays and are used in some seed production systems.

How to Use Attractants?

1. Prepare solutions:

a. *Jaggery solution:* dissolve jaggery at about 10–15% (100–150 g per liter of water).
b. *Sugar solution:* about 10% sugar in water is effective.

2. Spray timing:

a. Apply in the *morning* when pollinators are most active.
b. Target early to full bloom stage—multiple sprays can be used during peak flowering.

3. Placement:

a. Focus sprays on flower canopies rather than leaves.
b. Avoid spraying during hottest or rainiest parts of the day.

Some farmers also use bee-attractant products based on pheromones or plant volatiles, though local efficacy can vary by crop and environment.

Combining Biostimulants & Attractants in Vegetable Farming

To maximize pollination success, many growers adopt an *integrated approach*:

Plant Health + Pollinator Attraction:

a. Biostimulants ensure healthy, productive plants with abundant flowers.
b. Attractants ensure pollinators find and visit those flowers frequently.

This synergy supports:

a. Higher fruit set and yield
b. Improved seed production in cross-pollinated vegetables
c. Better crop quality and consistency.

For example, in onion seed production (which depends heavily on insect pollination), using bee attractants has been shown to enhance both productivity and seed quality.

Best Practices and Considerations

Pollinator Safety First:

a. Avoid spraying pesticides during flowering; these can deter or harm pollinators.
b. Use attractants when bees are active and conditions are favorable.

Biodiversity and Habitat:

a. Plant flowering edges or strips with native nectar plants to sustain pollinators year-round.
b. Diversify crops and flowering periods to maintain pollinator populations.

Conclusion

Biostimulants and pollinator attractants offer a sustainable and practical approach to improving pollination in vegetable crops by addressing both plant health and pollinator activity. Biostimulants enhance flowering, stress tolerance, and overall crop vigor, while attractants directly increase pollinator visitation during critical flowering periods. When used together and supported by pollinator-friendly management practices, these tools can significantly improve fruit and seed set, yield, and quality, making them valuable components of integrated and environmentally responsible vegetable production systems.

References

1. Zariman, N. A., Omar, N. A., & Huda, A. N. (2022). Plant attractants and rewards for pollinators: their significant to successful crop pollination. *International Journal of Life Sciences and Biotechnology*, *5*(2), 270-293.
2. Melini, F., Melini, V., Luziatelli, F., Abou Jaoudé, R., Ficca, A. G., & Ruzzi, M. (2023). Effect of microbial plant biostimulants on fruit and vegetable quality: current research lines and future perspectives. *Frontiers in Plant Science*, *14*, 1251544.
3. Shubha, K., Mukherjee, A., Kumari, M., Tiwari, K., & Meena, V. S. (2017). Bio-stimulants: an approach towards the sustainable vegetable production. In *Agriculturally Important Microbes for Sustainable Agriculture: Volume I: Plant-soil-microbe nexus* (pp. 259-277). Singapore: Springer Singapore.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Valorization of Oilseed Meals into Value-Added Proteins: Processing Technologies, Functional Properties, and Sustainable Applications

Article ID: 72703

Amit Prakash[1], Dr. Preethi Ramachandran[1]

[1]Post Harvest Process and Food Engineering, College of Technology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India.

Abstract

The extraction of edible oils generates oilseed meals as by-products, which are a great yet still largely untapped source of plant proteins. These residues, which are rich in proteins, have been traditionally confined to applications in animal feed and fertilizers but nowadays, they are gradually becoming more and more recognized as possible sustainable protein sources for the food industry. The global protein demand is on the rise, and at the same time, environmental and economic issues related to animal protein production make it even more urgent to find ways to utilize oilseed meals. In the past, processing oilseed meals into protein concentrates, isolates, and hydrolysates with better nutritional value and functional performance has been made possible through technological innovations. These protein ingredients are characterized by a wide range of good properties, such as emulsification, foaming, water retention, and gel formation, thus they can be used in various food and industrial applications. This paper reviews the protein sources among oilseed meals and presents the different technological routes that lead to their transformation into value-added proteins. The systematic exploration of pretreatment, extraction, recovery, drying, emerging green technologies, functional and nutritional characteristics, sustainability considerations, and future opportunities has resulted in the highlighting of oilseed meals' valorization as a key strategy for the promotion of resource efficiency, waste reduction, and sustainable protein systems development.

Keywords: Oilseed meals; Protein valorization; Plant-based proteins; Protein extraction; Functional properties; Sustainable processing; Green technologies; Food applications; Circular bioeconomy.

Introduction

Proteins are important components of human nutrition and growth. They form the basis for our body tissues and support various physiological functions throughout life. Although many people believe animal-derived protein products are superior from a nutritional standpoint, the production of these products has many negative social economics and environmental impacts. As a result, there is an increasing trend toward using plant-based protein sources that are sustainable and healthy alternatives to animal-based protein sources. Oilseed meals represent an excellent opportunity to address this issue. Within the agricultural systems of many countries, the extraction of oil from oilseeds such as soybeans and rapeseed generates excess amounts of by-products referred to as oilseed meals. These oilseed meals are high in protein content and produced in large volumes all over the world, including soybeans and rapeseed. Unfortunately, the excessive amounts of antinutritional components, the difficulties associated with processing these meals and the poor taste of many oilseed meals have limited their use in human foods. However, new developments in food processing technologies and protein extraction methods have made the conversion of these by-products into high-value protein ingredients more possible than ever before. Utilisation of oilseed meals provides an opportunity to promote sustainability and reduce agro-industrial waste while increasing resource efficiency and supporting the concept of a circular economy. Because of the multifunctional properties of oilseed proteins, they can be used in a variety of food applications, including bakery products and meat alternatives, dietary supplements, and beverages, among others.

Oilseed Meals as Protein Sources

Oilseed meals are the solid leftovers after extracting oil through mechanical pressing or solvent methods. Depending on the seed type and how it is processed, oilseed meals usually contain 30 to 60% protein by dry weight. This makes them one of the most concentrated plant protein sources (Moure et al., 2006). Major oilseed meals include soybean, rapeseed (canola), sunflower, sesame, flaxseed, cottonseed, peanut, and palm kernel meals. The protein makeup of oilseed meals changes based on the plant and method of extraction. Soybean meal is often used as a standard for plant protein because it has a high protein level and a good balance of amino acids. Rapeseed and sunflower meals contain about 35 to 40% protein and have higher amounts of sulfur-containing amino acids than many other plant proteins (Kotecka-Majchrzak et al., 2020). Sesame and flaxseed meals are also recognized for their protein and mineral content, along with bioactive compounds (Abbas et al., 2020). From a nutrition standpoint, oilseed proteins offer essential amino acids, but some amino acids, like lysine or methionine, might be low depending on the source. You can overcome these limits by mixing in complementary proteins or using enzymatic modification. Besides their nutritional benefits, oilseed meals also have bioactive peptides and phenolic compounds that show antioxidant, antihypertensive, and health benefits (Singh et al., 2022). In the past, using oilseed meals for human food has been limited because of antinutritional factors like phytic

acid, tannins, glucosinolates, and enzyme inhibitors. Modern processing techniques, including controlled heat treatment, fermentation, and solvent washing, have effectively reduced these compounds and made protein more digestible and safer (Moure et al., 2006). Due to their abundance, low cost, and high protein content, oilseed meals are important raw materials for sustainable protein production and developing valuable food ingredients.



Major oilseed meals such as soybean, rapeseed (canola), sunflower, sesame, and flaxseed used as potential sources of plant proteins.
Adapted from Moure et al., 2006; Kotecka-Majchrzak et al., 2020.

Processing Technologies: Oilseed Meal to Proteins

The transition from oilseed meals to functional protein ingredients is an extensive and complex process made up of multiple operations each dedicated to providing greater purity, functionality, and stability of the resulting protein. Usually the operations consist of pretreatment, protein extraction, recovery, and drying. The selection of the processing parameters has a significant impact on both the quantity and quality of the final protein product (Moure et al., 2006). The aim of the protein processing is to open up the structural matrix of the oilseed meals, to dissolve the proteins, and to isolate them from the non-protein materials like fibre carbohydrates, and residual lipids. Traditional processing methods use chemical extraction under alkaline conditions, while the newer ones focus on less harsh and more eco-friendly technologies. The process conditions like pH, temperature, particle size, solvent type, and extraction time are all critical factors in determining the efficiency of the extraction. Depending on the processing method, oilseed meals may result in protein meals, protein concentrates, protein isolates, or protein hydrolysates. Protein concentrates typically have a protein content of 60-80%, while isolates contain over 90% protein and are the most suitable for food applications where high purity and neutral flavour are necessary. Protein hydrolysates are obtained by enzymatic treatment and are promoted for their higher digestibility and bioactive properties (Singh et al., 2022).

Advances in processing technologies have improved extraction efficiency, reduced energy consumption, and minimized environmental impact. As a result, oilseed protein processing has evolved from feed-oriented applications toward high-value food and industrial protein production systems.

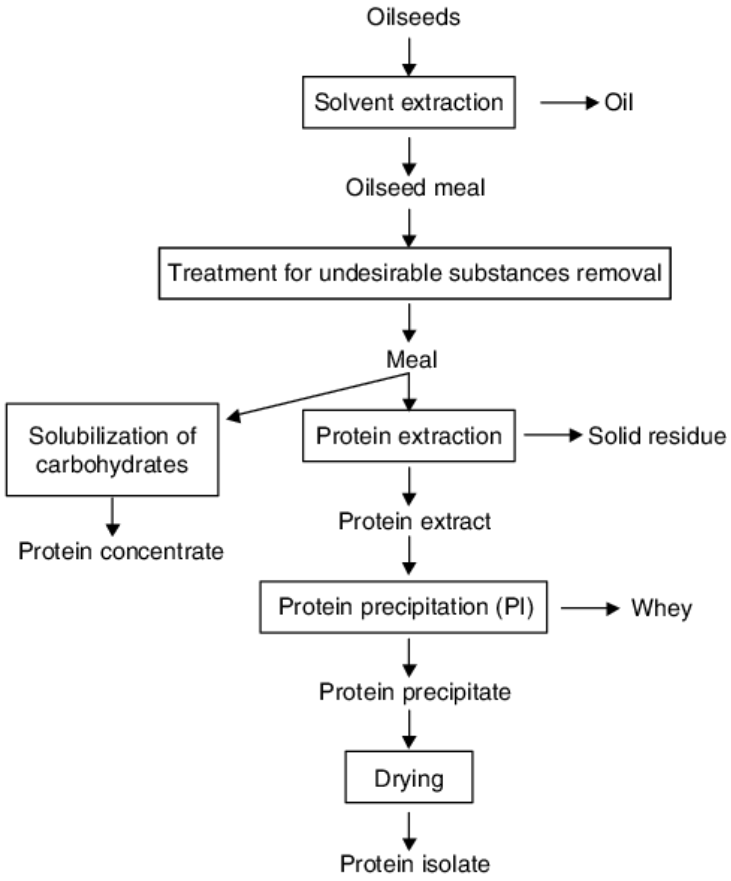
Pretreatment: Pretreatment is one of the most important steps in the process that increases the yield, quality, and efficiency of protein extraction. Among the various pretreatment methods used are dehulling, milling, solvent washing, heat treatment, fermentation, and enzymatic conditioning. Dehulling, for instance, diminishes the fibre content and thus increases the concentration of protein, while milling enhances the area for the solvent to penetrate (Moure et al., 2006). Solvent washing, especially aqueous ethanol, is a very effective way of removing substances such as phenolic compounds, pigments, and residual oil that might be harmful to the colour and flavour of the protein (Cisneros-Yupanqui et al., 2021). Besides, controlled thermal or biological pretreatments are the most common methods for eliminating the antinutritional factors and improving protein digestibility respectively.

Protein Extraction Methods: The most commonly used method for protein extraction is the combination of alkaline solubilization followed by isoelectric precipitation. In this technique, the proteins are made soluble at alkaline pH and then precipitated at their isoelectric point to produce a very high purity product (Abbas et al., 2020). Other methods of extraction are salt extraction, enzyme-assisted extraction, and membrane-based techniques. Enzymatic extraction boosts protein yield under gentle conditions while ultrafiltration provides selective concentration of proteins with very little denaturation (Singh et al., 2022).

Protein Recovery: Protein recovery is the process through which proteins that have been solubilized are segregated from the extraction medium. Isoelectric precipitation is the method that is still most frequently applied in recovery

processes, although it is simplicity and effectiveness are the main features. Membrane filtration methods which include ultrafiltration and diafiltration have become more common in their application for the improvement of protein quality and functionality (Moure et al., 2006). These methods are able to perform the simultaneous removal of salts and low-molecular-weight impurities while the protein structure is kept intact. The productivity of recovery is highly influenced by pH control, ionic strength, and temperature during processing.

Drying Techniques: The drying process reduces the activity of extracted proteins and makes them suitable for storage and commercial use. Among various drying techniques, spray drying has been the most common and preferred method for industrial purposes due to its ability to retain functional properties and being cost-effective at the same time. Freeze-drying yields proteins that are very soluble and have excellent structural integrity but the high energy requirement is a limitation (Sharma et al., 2010). The decision on the drying technique affects protein dispersion, life span and possible applications.



General processing flow diagram illustrating the conversion of oilseed meals into protein concentrates, protein isolates, and protein hydrolysates.
Adapted from Meyer, 1971; Rodrigues et al., 2012.

Emerging & Green Technologies

One of the key factors in the development of new and green technologies for oilseed protein extraction and processing has been the rising number of environmental concerns and sustainability objectives. Conventional solvent-based methods, despite being very effective, come with drawbacks such as high chemical usage, energy consumption, and significant environmental impact. Consequently, technologies that are less dependent on solvents and that involve less intensive processing are being increasingly studied as alternatives. One method that has been getting a lot of attention is enzyme-assisted extraction, which is considered a green method because it can significantly increase the yield of proteins when applied at mild conditions. Enzymes that work in tandem with cell wall degrading substances like cellulases, proteases, and hemicelluloses can release proteins and at the same time keep their nutritional quality intact (Moure et al., 2006). Another technology, ultrasound-assisted extraction, is able to significantly reduce the extraction time and solvent needed since it relies on cavitation effects for its operation. Among the new technologies, supercritical carbon dioxide extraction is considered to be one of the most effective techniques especially if used together with co-solvents. This process allows the selective removal of oils and active compounds and at the same time maintains protein integrity. Microwave-assisted and pulsed electric field techniques, like the ones previously mentioned, also increase the extraction efficiency albeit through somewhat different means i.e. altering cellular structures with minimum thermal damage (Kotecka-Majchrzak et al., 2020). The biorefinery concepts are termed as a holistic green approach, wherein the oilseed meals are fractionated into proteins, phenolics, fibres, and other value-added compounds. Such integrated

systems not only restore but also create new economic value while supporting the principles of a circular economy (Cisneros-Yupanqui et al., 2021). As a whole, the new green technologies are transforming oilseed protein valorization towards more sustainable practices.

Functional & Nutritional Properties

The functional and nutritional properties of oilseed proteins are the primary factor in deciding their food and industrial applications. Looking at the nutrition aspect, there are oilseed proteins that supply the necessary amino acids which are indispensable for human health. However, there may be some oilseed proteins that lack certain amino acids, mainly lysine or sulfer-containing amino acids; however, these drawbacks can be solved through protein blending, fortification, or enzymatic modification (Kotecka-Majchrzak et al., 2020). Oilseed proteins are usually well digested throughout the process of reducing antinutritional factors to adequate levels. Enzymatic hydrolysis also contributes to better digestion and the release of bioactive peptides with antioxidant, antihypertensive, and anti-inflammatory activities (Singh et al., 2022). These bioactivities give health benefits in addition to basic nutrition. Looking from a techno-functional point of view, oilseed proteins are very versatile as they have the different properties including water and oil absorption capacity, emulsification, foaming, viscosity and gelation. Water-holding capacity is one of the main factors that help to retain moisture in food products and oil-binding ability is responsible for flavour retention and mouthfeel enhancement. The emulsifying properties of oilseed proteins allow them to stabilize oil–water interfaces and hence they are included in sauces, dressings, and meat analogues as valuable ingredients (Moure et al., 2006). Foaming capacity and stability are the desirable qualities for bakery and confectionery applications, whereas gelation behaviour controls texture development in processed foods. These peculiarities are largely determined by the protein structure, molecular weight distribution, and processing conditions. Functional performance can be customized by thermal treatment, pH adjustment, and enzymatic modification.

Food & Industrial Applications

By virtue of their inherent nutritional value and functional versatility, oilseed proteins are gradually winning over the food sector where they are fairly and widely used. The bakery application of oilseed proteins is first of all. High protein content in the end product is a plus. In meat products as well as analogues, the oilseed proteins act as binders, fillers, and emulsifiers, which result in the improvement of texture and reduction of the cost of the formulations (Kotecka-Majchrzak et al., 2020). Dairy substitutes are not left behind and the oilseed proteins are present in the case of e.g. plant milk, yogurts, and cheese analogues. The emulsifying and stabilizing properties of the oils support the product's homogeneity and mouthfeel. The protein isolates and hydrolysates are very much used in the case of nutrition supplements, sports foods, and clinical nutrition as they represent the high-protein and high-digestibility stuff (Singh et al., 2022). The industrial side of things has also experienced the benefits drawn from oilseed proteins. The cosmetics industry is one of the places where they are widely used in skin and hair formulations for the moisturizing and film-forming properties. In the medical field, oilseed proteins are being tested as bioactive substances and controlled-release systems carriers. Also, for non-food uses like biodegradable films, adhesives, and packaging materials, oilseed proteins are under increasing research. Their renewability and biodegradability render them a favour replacement for petroleum-based polymers (Moure et al., 2006). The widening range of applications underlines the industrial importance of oilseed protein degradation.

Sustainability & Economic Aspects

The transformation of oilseed meals into protein ingredients brings along considerable sustainability and economic gains. The oilseed meal is produced in large amounts as the waste product of the edible oil processing industry and its proper use guarantees reduction in the disposal of waste along with greater resource efficiency for the whole process. The turning of these residues into high-value protein products is an act that supports the principles of circular economy as it is recycling of waste into inputs of value (Singh et al., 2022). Besides, the environmental footprints of plant proteins made of oilseed meals are generally much lower than those of animal protein in terms of greenhouse gas emissions, land use, and water consumption. Hence, oilseed proteins are considered as the most sustainable components of food systems (Kotecka-Majchrzak et al., 2020). In a money-wise view, oilseed protein valorization is giving oilseed processors and farmers the chance of getting more returns than before. The full-fledged biorefinery methods make it possible for the extraction of proteins, phenolics, fibre, and other bioactive compounds at the same time and hence, slide in the profits (Cisneros-Yupanqui et al., 2021). But still, the prices for processing, energy usage, and the size of the operations continue to be factors that need consideration. Investment in green technologies and process optimization is essential to improve cost-effectiveness and competitiveness. With increasing consumer demand for sustainable and plant-based foods, oilseed protein ingredients are well positioned to play a key role in future agri-food economies.

Challenges & Limitations

The potential of oilseed proteins for human consumption is still not fully realized and one of the main reasons is that these proteins face several challenges that limit their widespread use. One of these challenges is the presence of antinutritional factors like phytic acid, tannins, glucosinolates, and enzyme inhibitors, which can adversely affect the

digestibility of proteins and the bioavailability of minerals. Processing can help to some extent in reducing the levels of these compounds, but complete removal remains difficult (Moure et al., 2006). On the other hand, the bitterness, dark colour, and off-odour are some of the sensory attributes that keep consumers from accepting oilseed protein products. These problems are frequently linked to the presence of phenolic compounds and thermal degradation during the processing (Cisneros-Yupanqui et al., 2021). Besides, the inconsistency in the composition of raw materials owing to different cultivars, climate conditions, and history of processing makes it difficult to achieve standardization. The risk of allergic reaction is an issue that cannot be overlooked and that mainly concerns proteins obtained from soy, peanut, and sesame. A combination of correct labelling, control over processing, and allergen risk assessment is vital for the safe use of these products in food applications (Kotecka-Majchrzak et al., 2020). There are also technological challenges like trying to obtain the best possible protein yield without compromising on functional quality and at the same time reducing environmental impact. The larger scale production of new green technologies while at the same time maintaining their economic viability is a major challenge. All these issues must be tackled to the oilseed protein ingredients' commercial success.

Future Prospects

The future of the valorization of oilseed proteins is tied today to the above-mentioned processing and innovation of products and sustainability. The research into the washing out of the mildest methods and enzymatic modification is likely to result in proteins that are more functional and nutritious, and at the same time, cause less pollution (Singh et al., 2022). The genetic enhancement of oilseed crops with a focus on protein increase and reduction of harmful factors will surely be another area of research with great potential. The incorporation of oilseed proteins into new food products like meat, dairy alternatives, and personalized nutrition has already begun and will likely grow fast as the consumer trends change. Processing systems based on the biorefinery concept will be instrumental in not only extracting but also completely utilizing the whole oilseed meal thus giving it the maximum value. The developments in membrane technology, fermentation and protein engineering will still expand application areas even more (Moure et al., 2006). The backing from regulations, the awareness of consumers, and investments made by the industry will be the main factors for the large-scale uptake. With technological and scientific progress continuing, oilseed proteins will be at the center of the sustainable global protein supply chain.

Conclusion

Among the plant-based proteins oilseed meals are the most promising and among the least used sources, which have considerable potential in the food as well as in other industrial applications. The development of processing technologies has made it possible to turn such by-products into protein ingredients of higher nutritional quality and better functional performance. The integration of the emerging green technologies and biorefinery concepts further facilitates sustainability and economic viability. However, there are still some problems regarding antinutritional factors, sensory limitations, and processing costs, but ongoing research and innovation are continuously finding solutions to these problems. The utilization of oilseed meals results in less waste and higher efficiency of resource use and helps in the creation of sustainable protein systems. The demand for alternative proteins is growing steadily, and oilseed-derived proteins are expected to be the main suppliers of global nutrition and at the same time, the main support of environmental sustainability.

References

1. Cisneros-Yupanqui, M., Chalova, V. I., Kalaydzhiev, H. R., Mihaylova, D., Krastanov, A. I., & Lante, A. (2021). Preliminary characterisation of wastes generated from the rapeseed and sunflower protein isolation process and their valorisation in delaying oil oxidation. *Food and Bioprocess Technology*, *14*(10), 1962-1971. https://link.springer.com/article/10.1007/s11947-021-02695-y
2. Rodrigues, I. M., Coelho, J. F., & Carvalho, M. G. V. (2012). Isolation and valorisation of vegetable proteins from oilseed plants: Methods, limitations and potential. *Journal of Food Engineering*, *109*(3), 337-346. https://www.sciencedirect.com/science/article/abs/pii/S0260877411005772
3. Singh, R., Langyan, S., Sangwan, S., Rohtagi, B., Khandelwal, A., & Shrivastava, M. (2022). Protein for human consumption from oilseed cakes: a review. *Frontiers in Sustainable Food Systems*, *6*, 856401. http://frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2022.856401/full
4. Sibt-e-Abbas, M., Butt, M. S., Khan, M. R., Sultan, M. T., Saddique, M. S., & Shahid, M. (2020). Nutritional and functional characterization of defatted oilseed protein isolates. *Pakistan Journal of Agricultural Sciences*, *57*(1), 219-228. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=NUTRITIONAL+AND+FUNCTIONAL+CHARACTERIZATION+OF+DEFATTED+OILSEED+PROTEIN+ISOLATES&btnG=
5. Sharma, G. M., Su, M., Joshi, A. U., Roux, K. H., & Sathe, S. K. (2010). Functional properties of select edible oilseed proteins. *Journal of Agricultural and Food Chemistry*, *58*(9), 5457-5464. https://pubs.acs.org/doi/abs/10.1021/jf1002446

6. Kaushik, P., Dowling, K., McKnight, S., Barrow, C. J., Wang, B., & Adhikari, B. (2016). Preparation, characterization and functional properties of flax seed protein isolate. *Food chemistry*, *197*, 212-220. https://www.sciencedirect.com/science/article/abs/pii/S0308814615014582
7. Gao, D., Helikh, A. O., & Duan, Z. (2021). Functional properties of four kinds of oilseed protein isolates. *Journal of Chemistry and Technologies*, *29*(1), 155-163. http://chemistry.dnu.dp.ua/article/view/215020
8. Meyer, E. W. (1971). Oilseed protein concentrates and isolates. *Journal of the American Oil Chemists' Society*, *48*(9), 484-488. https://aocs.onlinelibrary.wiley.com/doi/abs/10.1007/BF02544666
9. Kotecka-Majchrzak, K., Sumara, A., Fornal, E., & Montowska, M. (2020). Oilseed proteins–Properties and application as a food ingredient. *Trends in Food Science & Technology*, *106*, 160-170. https://www.sciencedirect.com/science/article/abs/pii/S0924224420306270
10. Moure, A., Sineiro, J., Domínguez, H., & Parajó, J. C. (2006). Functionality of oilseed protein products: A review. *Food research international*, *39*(9), 945-963. https://www.sciencedirect.com/science/article/abs/pii/S0963996906000962
11. Jones, L. J., & Tung, M. A. (1983). Functional properties of modified oilseed protein concentrates and isolates. *Canadian Institute of Food Science and Technology Journal*, *16*(1), 57-62. https://www.sciencedirect.com/science/article/abs/pii/S0315546383720201

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Qualitative Assessment of Packaged Drinking Water in India: A Review

Article ID: 72704

Vinay Kumar Patel[1], Preethi Ramchandran[2]

[1]Department of Post-Harvest Process and Food Engineering, College of Technology, GBPUAT, Pantnagar, Uttarakhand, 263145.

[2]Department of Food Science and Technology, College of Agriculture, GBPUAT, Pantnagar, Uttarakhand, 263145.

Abstract

Packaged drinking water (PDW) represents one of the most rapidly expanding sectors of the water supply industry in India, driven largely by widespread concerns regarding the deterioration of municipal water quality and increasing groundwater contamination. Numerous studies have investigated the physico-chemical and microbiological quality of PDW marketed across different regions of India, including metropolitan areas such as Delhi, Kolkata, and other urban centres. These studies encompass a variety of products, including bottled water, sachet water, and bubble-top can water produced by both national and local manufacturers. The quality assessment of PDW has been based on key physical, chemical, and microbiological parameters, including pH, turbidity, total dissolved solids (TDS), total hardness (TH), major ions (calcium, magnesium, sodium, chloride, and fluoride), trace metals (iron, copper, nickel, lead, and arsenic), and microbial indicators such as total coliforms and *Escherichia coli*. The findings consistently demonstrate substantial variability in water quality among brands and packaging formats, with a considerable proportion of samples exceeding the permissible limits prescribed by the Bureau of Indian Standards (BIS). Several critical issues have been identified across the reviewed studies, notably the low mineral content observed in many PDW brands, deviations of pH from recommended ranges, elevated concentrations of certain trace metals, and microbial contamination, particularly in sachet water. These deficiencies raise concerns regarding the potential health implications of long-term consumption of inadequately mineralised or contaminated packaged water. Collectively, the evidence underscores the urgent need for strengthened regulatory oversight, routine quality surveillance, and stricter enforcement of existing standards to safeguard public health and ensure the consistent quality of packaged drinking water in India.

Introduction

Access to safe drinking water is fundamental to human health and recognized as a basic human right **(Gleick, 1993)**. Water comprises approximately 70% of the human body, with the brain containing 95% water, lungs 90%, and blood 82% **(Nazir et al., 2022)**. Despite water's abundance on Earth, covering 71% of the planet's surface, only 1% is accessible for human consumption **(Singla et al., 2014)**. In developing nations, including India, the quality of this limited freshwater resource has become a critical public health concern. India faces significant challenges in providing safe drinking water to its population of over 1.4 billion people. Groundwater contamination, industrial pollution, inadequate sanitation infrastructure, and climate change have compromised water quality in many regions **(Ray et al., 2016)**. Studies indicate that waterborne diseases account for 30–40% of all reported illnesses and deaths in Pakistan, with similar patterns observed in India **(Mohsin et al., 2019)**.

In response to declining municipal water quality and growing health consciousness, the packaged drinking water (PDW) industry has experienced exponential growth in India since the 1990s. The sector has evolved from virtually no activity before 1993 to making India one of the top 10 countries in bottled water consumption globally **(Rani et al., 2012)**. The global bottled water industry has become a multibillion-dollar enterprise, with consumers worldwide drinking approximately 480 billion plastic bottles annually **(Provasnek et al., 2018)**.

PDW is defined as water intended for human consumption that may contain naturally occurring or intentionally added minerals, and is sealed in containers of various compositions, forms, and capacities suitable for direct consumption without further treatment **(Bureau of Indian Standards, 2016)**. The Indian packaged water market includes bottled water (typically 500 mL to 20 L), sachet water (200–500 mL in polyethylene pouches), and bubble-top can water (200 mL to 1 L rigid containers).

The Bureau of Indian Standards (BIS) regulates PDW quality in India through two primary standards; IS 10500:2012 for drinking water and IS 14543:2016 for packaged drinking water **(BIS, 2012; BIS, 2016)**. These standards specify acceptable limits for physical, chemical, and microbiological parameters. However, enforcement remains inconsistent, particularly among smaller manufacturers and regional brands. This review synthesizes findings from multiple research studies conducted across India to provide a comprehensive assessment of PDW quality, identify prevalent quality issues, evaluate health implications, and recommend improvements to regulatory frameworks and industry practices.

This review analyses data available of the mentioned cities and concludes qualitative prospects with respect to their physio-chemical and microbial parameters.

Sampling of Water Sample

This review analysed data from peer-reviewed research studies examining PDW quality in various Indian cities, including Delhi, Kolkata, Vikarabad, and other regions **(Singla et al., 2014; Rao et al., 2016; Ray et al., 2016; Nazir et al., 2022)**. The studies collectively assessed 166 samples of packaged water, including 78 bottled water samples from national and local brands, 23 sachet water samples, 14 bubble-top can water samples, and 51 municipal tap water and public bore well samples for comparison **(Singla et al., 2014; Rao et al., 2016; Ray et al., 2016; Nazir et al., 2022)**. Samples were collected from retail outlets, markets, restaurants, and public locations across different geographical zones within each study area. All samples were transported under refrigerated conditions to maintain sample integrity and analysed within 7 days of collection.

Analytical Methods

Physico-chemical and microbiological analyses were conducted in accordance with the standard procedures recommended by the American Public Health Association **(APHA, 18th edition, 1992)**. The specific analytical parameters evaluated, along with the corresponding methods employed for water quality assessment, are detailed in Table 1. To ensure the reliability and accuracy of the results, rigorous quality assurance and quality control (QA/QC) protocols were followed. These included calibration of instruments using certified reference standards, analysis of procedural blanks, and performing all measurements in triplicate. Ultrapure reagents were used throughout the analysis, and all glassware and plasticware were thoroughly acid-washed and rinsed with deionized water prior to use.

Table 1. Analytical methods for water quality assessment **Source: Ray et al., (2016):*

Parameters	Analytical Methods
Ph	Digital pH meter
Turbidity	Nephelometric method (NTU)
Electrical Conductivity (EC)	Conductivity meter (μS/cm)
Total Dissolved Solids (TDS)	Gravimetric method (mg/L)
Total Hardness (TH), Calcium (Ca)	EDTA titration method
Total Alkalinity	HCl titration method
Magnesium (Mg)	Calculation from TH and Ca
Chloride (Cl)	Argentometric method
Fluoride (F)	Ion-selective electrode / SPADNS method
Nitrate (NO_3^-)	Spectrophotometric method
Sulphate (SO_4^{2-})	Turbidimetric method
Sodium (Na), Potassium (K)	Flame photometry
Trace metals (Fe, Cu, Ni, Pb, As, etc.)	ICP-AES / Atomic absorption spectroscopy
Total Coliforms, *E. coli*	Membrane filtration / MPN method

Results and Discussion

1. Physical Parameters:

a. pH: pH values across all PDW samples exhibited considerable variation, ranging from 5.13 to 9.46 across different studies. The mean pH for bottled water was 6.57 (range: 5.52–7.95), for sachet water 6.34–7.13, for bubble-top cans 7.2 (range: 7.0–7.5), and for bore well water 6.8 (range: 5.9–9.4) **(Thakur & Singh, 2024; Rao et al., 2016; Ray et al., 2016)**. Significantly, 41% of bottled PDW and 90% of bubble-top can PDW samples showed pH values below the acceptable limit of 6.5, indicating acidic conditions **(Ray et al., 2016)**. Only one bore well sample exceeded the upper limit (pH > 8.5). The acidic nature of many PDW brands is concerning, as pH below 6.5 can cause irritation to mucous membranes, eyes, and skin with long-term exposure, corrosion of distribution infrastructure, enhanced leaching of metals from pipes, containers and altered taste and reduced palatability. The observed low pH in PDW is primarily attributed to the removal of alkalinity and buffering minerals during reverse osmosis (RO) treatment, coupled with dissolution of atmospheric CO_2 forming carbonic acid **(Nazir et al., 2022; Thakur & Singh, 2024; Verma & Kushwaha, 2014; Kozisek, 2004)**. Several studies noted that pH values of Indian PDW matched those of bottled water from developed countries, suggesting this is a widespread characteristic of RO-treated bottled water **(Azoulay et al., 2001; Nazir et al., 2022; Thakur & Singh, 2024)**.

b. Turbidity: Turbidity measurements indicated that most PDW samples were crystal clear, with values ranging from 0.06 to 2.45 NTU for bottled and sachet water, well below the BIS limit of 1–2 NTU **(BIS, 2016)**. This demonstrates effective removal of suspended particles through filtration processes. However, six bore well water samples showed turbidity values as high as 10 NTU, exceeding acceptable limits and indicating inadequate treatment or contamination. Low turbidity is essential for both aesthetic acceptance and effective disinfection, as suspended particles can harbour microorganisms and protect them from disinfectants. The consistently low turbidity observed in commercial PDW indicates the efficiency of sand filtration, activated carbon filtration, and microfiltration processes used in treatment plants.

c. Electrical Conductivity and Total Dissolved Solids: Electrical conductivity (EC) ranged from 47 to 1299 µS/cm across PDW samples, with corresponding TDS values from 4.9 to 1012 mg/L **(Nazir et al., 2022)**. The mean TDS for different PDW types is listed in Table 2. While all PDW samples satisfied BIS and WHO standards for maximum TDS (500–600 mg/L), the remarkably low TDS values are concerning from a nutritional perspective. Approximately 78% of bottled PDW and 100% of bubble-top can samples contained TDS below 50 mg/L, classifying them as "oligomineral" or demineralized water **(Kozisek, 2004)**. The WHO recommends a minimum TDS of 100–300 mg/L for optimal health benefits. Research indicates that consumption of demineralized water with low TDS can lead to increased excessive production of urine (approximately 20% on average), decreased serum potassium concentrations, increased elimination of sodium, potassium, chloride, calcium, and magnesium ions, compromised mineral homeostasis, and potential increased cardiovascular disease risk.

Table 2. The mean TDS for different PDW sources- *Source: Ray *et al.*, (2016):

PDW types	TDS (mg/L)
Bottled water	38.26-101.1
Sachet water	24.68-73
Bubble-top cans	139.5
Municipal tap water	186-296

2. Major Ion Chemistry: The total hardness of drinking water is mainly influenced by calcium and magnesium content. Although no definitive health risks have been established, several studies indicate that moderately hard water may have protective effects against cardiovascular and respiratory diseases. Hard water can act as a supplementary source of essential minerals during cooking, whereas excessively soft or demineralized water may leach minerals from food, reducing its nutritional value **(Verma & Kushwaha, 2014)**.

Calcium present in drinking water contributes to bone strength, muscle function, and nerve transmission, while magnesium plays a critical role in enzymatic activity, energy metabolism, and cardiovascular health. Insufficient intake of these minerals has been associated with metabolic disorders, hypertension, and increased risk of cardiovascular diseases **(Kozisek, 2004)**. Potassium supports cellular function and blood pressure regulation, and its deficiency may result in muscle weakness and hypertension.

Sodium and chloride are essential electrolytes responsible for maintaining fluid balance and nerve function, though drinking water generally contributes only a minor proportion of daily requirements. Fluoride in drinking water is important for dental and skeletal health, and inadequate levels may increase susceptibility to dental caries **(WHO, 2022)**. Sulphate, nitrate, and phosphate are usually present at low concentrations and are not harmful at permissible levels; however, excessive sulphate may cause gastrointestinal discomfort, while elevated nitrate levels are linked to adverse health effects **(WHO, 2022)**.

Overall, the widespread consumption of highly softened or demineralized packaged drinking water may limit the intake of essential minerals, emphasizing the need for balanced mineral composition to support long-term human health. A summary of these findings is provided in Table 3.

Table 3. Major ion parameters across all water types-*Sources: Ray et al. (2016); Rahman et al. (2017); Roy et al. (2015):*

Parameter	Bottled Water	Sachet Water	Bubble-Top Cans	Municipal Tap Water	Standards/Guidelines
Total Hardness (mg/L as $CaCO_3$)	2-88 (Mean: 17.58-37.8)	6-22 (Mean: 13-21.2)	40-212 (Mean: 130.5)	132-196 (Mean: 162-184)	Acceptable: <300
Calcium (mg/L)	0.1-47.3 (Mean: 3.09-14.6)	1-30 (Mean: 14.25)	10-96 (Mean: 36.5)	-	WHO Min: 20; Optimal: 40-80
Magnesium (mg/L)	0-38 (Mean: 1.03-23.2)	2-17 (Mean: 2.22-8)	30-130 (Mean: 94)	-	WHO Min: 10
Sodium (mg/L)	1.7-71.2 (Mean: 12-19)	3.9-30.6 (Mean: 13.27)	4-33 (Mean: 12)	BIS Limit: 50 mg/L	-
Potassium (mg/L)	0.1-7.1	0.1-7.1	Trace	RDA: 3500 mg/day	-
Chloride (mg/L)	0.57-180	Similar range	0.57-180	Acceptable: 250 mg/L	-
Fluoride (mg/L)	0.02-0.95	0.02-0.70	-	-	Desirable:0.7
Sulphate (mg/L)	0.09-320	Similar range	-	-	Limit: 200-250
Nitrate (mg/L)	0.01-28.9	Similar range	-	-	BIS Limit: 45; WHO: 50

Phosphate (mg/L)	0.023-0.17	0.023-0.17	-	-	No guideline

3. Trace Metal Analysis: Iron is an essential micronutrient involved in oxygen transport, energy metabolism, and the prevention of anemia. Iron deficiency can result in fatigue, reduced cognitive performance, and delayed motor development, particularly among children and pregnant women. While elevated iron concentrations in drinking water are mainly associated with aesthetic concerns such as discoloration and unpleasant taste, drinking water contributes only marginally to the daily iron requirement. Consequently, dietary intake remains the primary source of iron for meeting nutritional needs **(WHO, 2022; ICMR, 2020)**.

Zinc plays a vital role in immune function, growth, wound healing, and sensory perception. Insufficient zinc intake increases vulnerability to infections and may impair physical growth and development. Drinking water generally provides a negligible contribution to zinc intake, with nutritional adequacy largely dependent on dietary sources. Elevated zinc concentrations in water may affect palatability but are rarely reported in treated bottled drinking water **(WHO, 2022)**.

Copper is required for hematopoiesis, bone development, iron metabolism, and normal neurological function. Copper deficiency can lead to anemia, skeletal abnormalities, and compromised immune responses. Although copper concentrations in drinking water are regulated to avoid toxicity, bottled water contributes minimally to daily copper intake, highlighting the importance of adequate dietary consumption **(Otten et al., 2006; WHO, 2022)**.

Boron occurs naturally in groundwater and is required in trace amounts for normal metabolic processes; however, excessive exposure may adversely affect the liver, kidneys, and nervous system. In contrast, toxic trace metals such as lead and arsenic in drinking water pose serious health risks, including nephrotoxicity, neurotoxicity, and carcinogenic effects **(Singh et al., 2011; WHO, 2022)**.

Other trace metals, including cadmium, chromium, manganese, lithium, cobalt, and strontium, were detected at very low concentrations and remained within international safety limits. Mercury was not detected in any of the samples. Overall, the results indicate that bottled drinking water is generally free from significant trace metal contamination. Nevertheless, continuous monitoring is necessary, particularly for potentially toxic elements such as nickel, lead, copper, and arsenic, to ensure long-term consumer safety **(BIS, 2012; WHO, 2022)**. On the basis of reviewed trace metals and their concentrations in different water sources are listed in Table 4.

Table 4. Trace metal concentrations in different water sources-**Sources: Ray et al. (2016); Rahman et al. (2017); Roy et al. (2015):*

Metal	Bottle Water	Sachet Water	Bubble-Top/Tap	Limits
Iron (mg/L)	ND-0.17	ND-0.17	Up to 0.17	BIS Limit: 0.3
Copper (mg/L)	0-0.002	0.0019-0.9545	-	BIS Limit: 0.05
Zinc (mg/L)	0.001-2.946	Similar	-	Acceptable: 3-5
Nickel (mg/L)	0.0227-0.0337	0.0289-0.0653	Tap: 0.0754	Limit: 0.02
Lead (mg/L)	<0.008-3.29	Up to 0.862	-	FDA: 0.005; BIS: 0.01
Arsenic (mg/L)	0.0005-0.009	0.001-0.01	Industrial GW: 0.04	Limit: 0.01

4. Microbiological Quality: Bacterial contamination was detected in sachet drinking water from several brands, indicating non-compliance with packaged drinking water standards that require the complete absence of total coliforms in potable water. The presence of total coliform bacteria reflects inadequate disinfection or fecal contamination and serves as an indicator of potential presence of pathogenic microorganisms, including bacteria, viruses, and parasites. Although *Escherichia coli* was not detected, the occurrence of total coliforms renders these sachet water samples microbiologically unfit for human consumption **(Ray et al., 2016)**.

The observed microbial contamination in sachet water can be attributed to manual filling operations, poor hygiene during handling and packaging, insufficient disinfection practices such as ineffective ozonation or ultraviolet treatment, and the use of contaminated raw water sources including bore wells and surface water. Additionally, compromised sealing and packaging integrity may allow post-processing contamination, further increasing microbial risk **(Ray et al., 2016)**.

In contrast, bottled drinking water produced by larger manufacturers showed no evidence of bacterial contamination, reflecting the effectiveness of automated production systems, strict hygienic controls, and multi-barrier treatment technologies involving filtration, ultraviolet disinfection, and ozonation **(Sunswell, 2023)**.

The absence of coliform bacteria in municipal tap water samples indicates effective treatment and chlorination at centralized water treatment facilities. However, the detection of microbial contamination in bore well water from rural locations highlights the susceptibility of groundwater to fecal pollution arising from inadequate sanitation practices, leaking sewer systems, and agricultural runoff, underscoring the need for regular monitoring and appropriate treatment of groundwater sources **(Rao et al., 2016)**. Table 5 shows the results of microbial contamination in different water sources.

Water Type	Total Coliforms	*E. coli*
Bottled water	Absent (0/78 samples)	Absent (0/78)
Sachet water	Present (4/23 samples)	Absent (0/23)
Bubble-top cans	Absent (0/14 samples)	Absent (0/14)
Municipal tap water	Absent (0/18 samples)	Absent (0/18)
Public bore wells	Present (4/35 samples)	Absent (0/35)

Table 5. Microbiological contamination in different water sources-*Sources: Ray et al. (2016); Rahman et al. (2017).*

Conclusion

This study demonstrates that packaged drinking water in India is generally safe with respect to microbiological quality and trace metal contamination, largely complying with BIS and WHO guidelines. However, extensive use of treatment processes such as reverse osmosis has resulted in water that is predominantly soft and low in essential minerals. While such water meets chemical safety standards, it contributes minimally to daily dietary requirements of calcium, magnesium, potassium, and fluoride, which may have implications for long-term nutritional balance. The analysis also indicates that sachet and small-scale packaged water units are more prone to quality inconsistencies, particularly regarding hygiene and microbial safety, compared to regulated bottled water brands. Although trace metals were mostly within permissible limits, occasional detections highlight the need for consistent quality control and monitoring. Overall, the findings emphasize that drinking water quality assessment should extend beyond microbial safety to include mineral composition and nutritional adequacy, ensuring that packaged drinking water is not only safe but also supportive of human health.

References

1. American Public Health Association. (1992). *Standard methods for the examination of water and wastewater* (18th ed.). American Public Health Association.
2. Azoulay, A., Garzon, P., & Eisenberg, M. J. (2001). Comparison of the mineral content of tap water and bottled waters. *Journal of General Internal Medicine, 16*(3), 168–175.
3. Bureau of Indian Standards. (2012). *Indian Standard IS 10500:2012: Drinking water—Specification* (2nd rev.). Bureau of Indian Standards.
4. Bureau of Indian Standards. (2016). *Indian Standard IS 14543:2016: Packaged drinking water (other than natural mineral water)—Specification* (2nd rev.). Bureau of Indian Standards.
5. Gleick, P. H. (1993). Water and conflict: Fresh water resources and international security. *International Security, 18*(1), 79–112.
6. Indian Council of Medical Research. (2020). *Nutrient requirements and recommended dietary allowances for Indians*. Indian Council of Medical Research.
7. Kozisek, F. (2004). Health risks from drinking demineralised water. In *Nutrients in drinking water* (pp. 148–163). World Health Organisation.
8. Mohsin, M., Safdar, S., Nasar-u-Minallah, M., Riaz, O., & Khan, A. A. (2019). Assessment of drinking water quality and its impact on residents' health in Bahawalpur city. *International Journal of Humanities and Social Science, 1*(2), 114–128.
9. Nazir, M. A., Yasar, A., Bashir, M. A., et al. (2022). Quality assessment of the non-carbonated bottled drinking water: Comparison of their treatment techniques. *International Journal of Environmental Analytical Chemistry, 102*(19), 8195–8206.
10. Otten, J. J., Pitzi Helwig, J., & Meyers, L. D. (2006). *Dietary reference intakes: The essential guide to nutrient requirements*. National Academies Press.
11. Provasnek, A. K., Schmid, E., & Steiner, G. (2018). Sustainable corporate entrepreneurship: Performance and strategies toward innovation. *Business Ethics Quarterly, 28*(4), 521–551.
12. Rahman, I. M., Barua, S., Barua, R., Mutsuddi, R., Alamgir, M., Islam, F., ... & Hasegawa, H. (2017). Quality assessment of the non-carbonated bottled drinking water marketed in Bangladesh and comparison with tap water. *Food control*, *73*, 1149-1158.
13. Rani, B., Maheshwari, R., & Prasad, M. (2012). Bottled water: A global market overview. *Bulletin of Environment, Pharmacology and Life Sciences, 1*(6), 1–4.
14. Rao, K. Y., Anjum, M. S., Reddy, P. P., Monica, M., Hameed, I. A., & Sagar, G. V. (2016). Physico-chemical and bacterial evaluation of public and packaged drinking water in Vikarabad, Telangana, India. *Journal of Clinical and Diagnostic Research, 10*(5), LC01–LC07.
15. Ray, S., Roy, P. K., & Majumder, A. (2016). Quality of packaged drinking water in Kolkata City, India and risk to public health. *Desalination and Water Treatment, 57*(55), 28734–28742.
16. Rubenowitz, E., Axelsson, G., & Rylander, R. (1996). Magnesium in drinking water and death from acute myocardial infarction. *American Journal of Epidemiology, 143*(5), 456–462.
17. Singh, R., Gautam, N., Mishra, A., & Gupta, R. (2011). Heavy metals and living systems: An overview. *Indian Journal of Pharmacology, 43*(3), 246–253.

18. Singla, A., Kundu, H., Basavaraj, P., Singh, S., Singh, K., & Jain, S. (2014). Physico-chemical and bacterial evaluation of packaged drinking water marketed in Delhi: Potential public health implications. *Journal of Clinical and Diagnostic Research, 8*(3), LC01–LC05.
19. Sunswell. (2023). Water treatment systems for bottling plants: RO, UV, and ozone. https://www.sunswell.com/.
20. Thakur, A., & Singh, J. (2024). Qualitative analysis of physico-chemical parameters of packaged drinking water commercially available in India. *Water Supply, 24*(7), 2285–2301.
21. Venkatesan, K. D., Balaji, M., & Victor, K. (2014). Microbiological analysis of packaged drinking water sold in Chennai. *International Journal of Medical Science and Public Health*, *3*(4), 472-476.
22. Verma, K. C., & Kushwaha, A. S. (2014). Demineralization of drinking water: Is it prudent? *Medical Journal Armed Forces India, 70*(4), 377–379.
23. World Health Organisation. (2022). *Guidelines for drinking-water quality* (5th ed.). World Health Organisation.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Zero Tillage Farming of Maize & its Importance

Article ID: 72705

Oddula Vamshi[1], K. Vinay Reddy[2], K. Susmitha[3], I. Sonika[4], G. Bhanuchander[5]

[1]Ph.D Scholar, Department of Agronomy, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana Agriculture University, Hyderabad.

[2]M.Sc. (Agronomy), Agricultural College, Jagtial, PJTAU, Hyderabad.

[3]M.Sc. (Agronomy), Agricultural College, Jagtial, PJTAU, Hyderabad.

[4]M.Sc. (Agronomy), Agricultural College, Jagtial, PJTAU, Hyderabad.

[5]Ph.D. Scholar, Department of Agronomy, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana Agriculture University, Hyderabad.

Abstract

Zero tillage (ZT), a core principle of conservation agriculture, involves direct seeding of crops into untilled soil while minimizing mechanical soil disturbance. In maize (*Zea mays* L.) based production systems, zero tillage has emerged as a sustainable alternative to conventional tillage, offering significant agronomic, environmental, and socio-economic advantages. These include improved soil structure, enhanced soil organic carbon sequestration, better moisture conservation, reduced production costs, and greater resilience to climate variability. However, the success of zero tillage maize systems is highly context-specific and depends on appropriate residue management, nutrient placement, crop rotation, and weed control strategies. This review critically synthesizes global and Indian research evidence on zero tillage maize systems, elucidates underlying mechanisms affecting crop performance and soil health, highlights benefits and constraints, and identifies future research and policy priorities for large-scale adoption.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops globally, serving as a staple food, feed, and industrial raw material. In India, maize cultivation has expanded rapidly due to its adaptability, high yield potential, and increasing demand from feed and processing industries. However, intensive conventional tillage practices involving repeated ploughing and soil inversion have resulted in soil degradation, loss of organic matter, increased erosion, and declining factor productivity. These challenges have necessitated the adoption of alternative crop establishment techniques such as zero tillage (Rusinamhodzi et. al., 2011).

Zero tillage farming represents a paradigm shift from soil manipulation to soil conservation. It is increasingly promoted as part of conservation agriculture, which integrates minimal soil disturbance, permanent soil cover, and crop diversification. In maize-based systems, particularly under rainfed and semi-arid conditions, zero tillage has shown promise in enhancing resource-use efficiency and sustainability (Pittelkow et. al., 2015).

Concept and Principles of Zero Tillage in Maize

Zero tillage refers to the practice of sowing maize seeds directly into undisturbed soil without prior land preparation, except for a narrow slit or furrow for seed placement. The soil surface is usually covered with residues of the previous crop or cover crops. The three fundamental principles underpinning zero tillage maize systems are:

1. Minimal mechanical soil disturbance.
2. Continuous soil cover through residue retention.
3. Crop rotation or diversification.

When these principles are applied collectively, they create a biologically active soil environment that supports improved nutrient cycling, water infiltration, and soil aggregation.

Effects of Zero Tillage on Soil Properties

1. Soil physical properties: Zero tillage generally improves soil aggregate stability and reduces erosion by protecting the soil surface from raindrop impact. Over time, the accumulation of organic residues enhances soil structure and macro porosity in the surface layers. However, soil bulk density may increase in the upper soil layer during the initial years of zero tillage adoption, particularly in fine-textured soils. This compaction is often transient and diminishes with biological activity and root penetration in long-term systems (Pittelkow et. al., 2015).

2. Soil organic carbon dynamics: Numerous long-term studies and meta-analyses have reported that zero tillage increases soil organic carbon concentration in the top 0–5 cm soil layer due to reduced oxidation of organic matter and continuous residue input. However, when carbon stocks are evaluated across the entire soil profile, gains are often

modest, indicating stratification rather than uniform sequestration. Nevertheless, surface carbon accumulation plays a critical role in improving soil fertility and microbial activity (Rusinamhodzi et. al., 2011).

3. Soil moisture conservation: Residue cover under zero tillage reduces evaporation losses and improves soil moisture retention, particularly during dry spells. Enhanced infiltration and reduced runoff further contribute to improved water availability for maize crops. These effects are especially beneficial in rainfed and moisture-stressed environments, where water use efficiency is a key determinant of productivity (Lal, 2015).

Influence on Maize Growth and Yield

1. Yield response: The effect of zero tillage on maize yield is variable and highly dependent on agro-climatic conditions, management practices, and duration of adoption. Meta-analytical evidence indicates that zero tillage combined with residue retention and crop rotation can increase maize yields in the long term, particularly in low-rainfall environments. Short-term yield reductions have been reported in some cases, often due to poor residue management, nutrient immobilization, or increased weed pressure during the transition phase.

2. Yield stability and climate resilience: Zero tillage systems generally exhibit greater yield stability across years compared to conventional tillage, owing to improved soil moisture buffering capacity and enhanced soil biological activity. This resilience is particularly important under climate variability, where erratic rainfall and temperature extremes increasingly threaten maize productivity.

Nutrient Management under Zero Tillage Maize

Nutrient stratification is a common feature of zero tillage systems, with higher concentrations of phosphorus and potassium in the surface soil layer. To address this, fertilizer placement strategies such as banding or deep placement are recommended. Nitrogen management is critical, as surface-applied nitrogen under residue cover may be susceptible to volatilization losses. Split applications and precision nutrient management practices improve nitrogen use efficiency in zero tillage maize systems (Lal, 2015).

Weed, Pest, and Disease Dynamics

Weed flora often shifts under zero tillage, with perennial and residue-tolerant species becoming more dominant. As a result, integrated weed management approaches combining crop rotation, residue management, timely herbicide application, and mechanical interventions are essential. Residue retention may also influence pest and disease dynamics by providing habitat for certain insects and pathogens, necessitating vigilant monitoring and integrated pest management strategies (Pittelkow et. al., 2015).

Environmental and Socio-Economic Importance

1. Environmental benefits: Zero tillage significantly reduces soil erosion, improves soil carbon storage, enhances water use efficiency, and lowers greenhouse gas emissions through reduced fuel consumption. These environmental benefits contribute to climate change mitigation and long-term ecosystem sustainability.

2. Economic advantages: From a socio-economic perspective, zero tillage reduces land preparation costs, labour requirements, and energy use. Several studies report higher net returns in maize-based zero tillage systems despite similar or slightly lower yields, primarily due to cost savings.

Adoption Constraints and Challenges

Despite its benefits, adoption of zero tillage maize faces constraints such as limited access to suitable planting equipment, increased reliance on herbicides, residue competition with livestock feeding, and knowledge gaps among farmers. Addressing these challenges requires institutional support, mechanization services, and targeted extension programs.

Indian Context and Future Prospects

In India, zero tillage has gained momentum in cereal-based systems, particularly in the Indo-Gangetic Plains. Its application in maize is expanding in rainfed and irrigated regions due to increasing labour costs and climate stress. Future research should focus on region-specific agronomic packages, long-term soil carbon assessment, and integration of zero tillage with precision agriculture tools (Pittelkow et. al., 2015).

Conclusion

Zero tillage farming represents a sustainable and climate-resilient approach to maize production. When implemented as part of a holistic conservation agriculture system, it enhances soil health, conserves natural resources, and improves farm profitability. However, its success depends on proper residue management, nutrient optimization, and integrated weed and pest control. Strategic research, policy support, and extension efforts are essential to realize the full potential of zero tillage maize systems, particularly in smallholder-dominated agricultural landscapes like India.

References

1. Rusinamhodzi, L., Corbeels, M., Nyamadzawo, G., Giller, K. E., & Scopel, E. (2011). A meta-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. *Agronomy for Sustainable Development*, 31(4), 657–673.
2. Pittelkow, C. M., Liang, X., Linquist, B. A., (2015). Productivity limits and potentials of the principles of conservation agriculture. *Nature*, 517, 365–368.
3. Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, 7(5), 5875–5895.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Microbial Dark Matter in *Alfisols*: Uncultivated Microbial Species and their Role in Zinc Solubilization

Article ID: 72706

Swosti Narayan Mohnaty[1], Dr. Samanyita Mohanty[2], Dr. Sweta Rath[3], Dr. Ashok Kumar Mahapatra[4]
[1]M.sc. (Ag.) Scholar, Dept. of Soil Science and Agricultural Chemistry, Faculty of agricultural sciences, Siksha 'O' Anusandhan, Odisha, India.
[2]Professor, Dept. of Soil Science and Agricultural Chemistry, Faculty of agricultural sciences, Siksha 'O' Anusandhan, Odisha, India.
[3]Assistant Professor, Department of Ag nomy, Faculty of agricultural sciences, Siksha 'O' Anusandhan Odisha, India.
[4]Professor, Department of Agronomy, Faculty of agricultural sciences, Siksha 'O' Anusandhan, Odisha.

Abstract
Alfisols are recognized as agricultural soils with medium fertility status and are usually zinc-deficient owing to the formation of zinc-insoluble compounds. Recently, the advent of high-throughput sequencing has revealed a huge variability of uncultivated microbes that have come to be known as 'microbial dark matter'. This group of microbes have specific roles with respect to nutrient cycling, micronutrient solubility as well as their availability. This article reviews the concept of microbial dark matter and discusses the emerging understanding of their possible contribution to zinc solubilization for maintaining soil fertility in a sustainable manner.

Introduction
Soil microbes have crucial role in nutrient cycling, soil quality and plant productivity. Classic approaches concentrated on microbes that were relatively easy to be cultured, representing only a tiny proportion of total microbes. However, using molecular approaches such as metagenomics and 16/18S ribosomal sequencing, thousands of novel microbes, also known as microbial dark matter, have been identified that are phylogenetic but are not cultured in laboratory. Even if they are not completely characterized metabolically, these microbes play a very important role concerning biogeochemistry of micronutrients within soil.

Zinc Deficiency in *Alfisols*
Alfisols, commonly found in tropical and subtropical climates, are recognized by moderate to high clay percentage, low to neutral pH, low organic matter content and significant level of Zn fixation into soil minerals (zinc oxide and zinc phosphate). Zinc deficiency has a major effect on agricultural productivity since the ion is an essential nutrient required for enzyme function and hormone actions.

Microbial Dark Matter
Microbial dark matter: It refers to microbes that have already been determined by means of DNA sequencing but are yet to be lab-cultivated. Bacterial and Archaea domains dominate the lineage ad they are metabolically active, occupy different microhabitats (e.g., rhizosphere, interior of aggregates) and are engaged in complex transformations of nutrients.

Mechanisms Involved in Solubilization of Zinc by Microorganisms
Research on microbial dark matter on zinc solubilization is sparse. However, the microbial mechanisms involved in the process of micronutrient solubilization has been well noted:

1. Organic Acid: The microbes have the ability to produce gluconic acid, citric acid, and oxalic acids. These acids act as chelating agents for zinc and reduce the pH of the area around the plant roots, thereby facilitating the zinc availability that were previously unavailable to the plants.

2. Proton Extrusion and Acid: Bacterial metabolism results in liberation of protons which makes the soil micro-environment acidic. This acidic nature increasing the solubility of zinc compounds.

3. Siderophore and Chelator Production: Siderophores are organic molecules produced by microbes. They have the ability to bind iron; however, they can still effectively bind zinc ions, thus improving its availability and mobility.

4. Microbial-Plant Interactions: Rhizospheric microbes, including uncultivated types, associate with plant exudates from roots, thereby increasing the solubility of nutrients in close proximity to roots.

Implications on Soil Fertility and Crop Production

The utilization of microbial dark matter in agriculture holds potential in the following areas:

1. Development of biofertilizers: Functional microbial consortia can be a sustainable approach to optimize Zn bioavailability.

2. Reduced use of chemical fertilizers: Natural biological nutrient solubilization is promoted thus reducing cost and environmental pollution.

Future Research Directions

Discovering the diversity of microbial dark matter will further enhance our knowledge of soil ecosystems and, in turn, allow strategies to maximize soil fertility in a more directed manner. The future research on microbial dark matter includes:

1. Application of metagenomic and meta-transcriptomic analysis to identify Zn-solubilizing genes within the uncultivated taxa.

2. Stable isotope probing to track Zn transformation pathways mediated by microbial dark matter.

3. Cultivation with the use of new growth media conditions to isolate uncultivated microbes.

Conclusion

Microbial dark matter refers to the hidden functional potential that exists in *Alfisols*. Even though they are non-cultivated, they are major components of microorganisms, which play a crucial role in influencing zinc bioavailability in the soil. Further new technologies and strategies are required to define their potential in promoting efficient agriculture.

References

1. Janssen, P. H. (2006). Identifying the dominant soil bacterial taxa in libraries of 16S rRNA genes. *Applied and Environmental Microbiology*, 72(3), 1719–1728.
2. Hug, L. A., Baker, B. J., Anantharaman, K., et al. (2016). A new view of the tree of life. *Nature Microbiology*, 1, 16048.
3. Alloway, B. J. (2008). Zinc in soils and crop nutrition. *International Zinc Association*, Brussels.
4. Rengel, Z. (2015). Availability of micronutrients in the rhizosphere. *Journal of Soil Science and Plant Nutrition*, 15(2), 397–409.
5. Sharma, S. K., Ramesh, A., Sharma, M. P., et al. (2013). Zinc solubilizing microbes for enhancing crop productivity. *Journal of Soil Science and Plant Nutrition*, 13(2), 325–342.
6. Fierer, N. (2017). Embracing the unknown: Disentangling the complexities of the soil microbiome. *Nature Reviews Microbiology*, 15, 579–590.
7. Gadd, G. M. (2010). Metals, minerals and microbes: Geomicrobiology and bioremediation. *Microbiology*, 156, 609–643.
8. Richardson, A. E., & Simpson, R. J. (2011). Soil microorganisms mediating phosphorus availability. *Plant Physiology*, 156, 989–996.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Climate-Smart Vegetables: Producing Nutritious Food under Changing Climatic Conditions

Article ID: 72707

P. Agalya[1], A. Ajay Raja[1], A. Kingsly Raj[1]
[1]Ph. D Scholar, Department of Vegetable Science, HC&RI, TNAU, Coimbatore, Tamil Nadu, India.

Abstract
Vegetable crops are essential for human nutrition and play a critical role in ensuring food and nutritional security worldwide. However, climate change poses significant challenges to vegetable production through rising temperatures, erratic rainfall, drought, salinity, flooding, and increased pressure from pests and diseases. The concept of climate-smart vegetables has emerged as an effective and sustainable approach to address these challenges. Climate-smart vegetables integrate stress-resilient genetic traits, efficient water and soil management, protected cultivation, sustainable pest and disease control, and modern digital technologies to enhance productivity, resilience, and nutritional quality under changing climatic conditions. This article highlights the vulnerability of vegetable crops to climate variability and discusses key strategies for developing and managing climate-smart vegetable systems, including breeding climate-resilient varieties, water-efficient production practices, soil health management, protected cultivation, nutrition-oriented improvement, and the use of digital innovations. The role of farmers and supportive policy frameworks in enabling the adoption of climate-smart vegetables is also emphasized. Overall, climate-smart vegetables represent a promising pathway for achieving sustainable vegetable production, strengthening climate resilience, and ensuring long-term food and nutritional security in the face of global climate change.

Introduction
Vegetables form a cornerstone of a healthy human diet by supplying vital vitamins, minerals, dietary fiber, and numerous bioactive compounds that promote overall well-being. They are especially important for nutritional security in developing nations, where deficiencies of essential micronutrients remain widespread. However, vegetable cultivation is becoming increasingly vulnerable due to climate change. Rising global temperatures, irregular rainfall patterns, extended dry spells, increasing soil salinity, flooding events, and the growing prevalence of pests and diseases are exerting severe pressure on vegetable production systems across the world. In response to these challenges, the concept of climate-smart vegetables has gained recognition as a sustainable and resilient approach to future food systems.

Understanding Climate-Smart Vegetables
Climate-smart vegetables encompass vegetable crops and cultivation practices that are designed to cope with climate variability while minimizing environmental impacts and sustaining or enhancing productivity and nutritional value. This concept is closely aligned with climate-smart agriculture, which aims to strengthen resilience to climatic stresses, reduce greenhouse gas emissions wherever feasible, and ensure long-term food and nutrition security.

Rather than relying on a single characteristic, climate-smart vegetables integrate multiple components, including improved genetic traits, stress-tolerant varieties, efficient use of natural resources, eco-friendly farming practices, and innovative technologies. Such vegetables are capable of withstanding extreme temperatures, limited water availability, saline conditions, and new pest pressures while continuing to deliver acceptable yields and quality.

How Climate Change Affects Vegetable Production?
Vegetable crops are highly sensitive to changes in climatic conditions. Compared with cereal crops, many vegetables possess shallow root systems, require frequent irrigation, and have narrow temperature ranges for optimal growth, flowering, and fruit development.

Elevated temperatures can interfere with pollen viability and fertilization, resulting in flower abortion and reduced fruit set in crops such as tomato, brinjal, and chilli. Heat stress also increases respiration rates, thereby lowering carbohydrate accumulation and productivity. Water stress caused by drought restricts nutrient absorption and leaf growth, whereas excessive rainfall and flooding encourage root diseases and nutrient losses. Salinity, particularly in coastal and irrigated areas, disrupts water uptake and ion balance, severely affecting vegetable growth.

Additionally, climate change influences the distribution and severity of insect pests and pathogens. Warmer climates allow many pests and diseases to spread into new regions, increasing yield losses and farmers' dependence on chemical control measures. These combined stresses make conventional vegetable varieties increasingly susceptible.

Breeding Climate-Resilient Vegetable Varieties

Genetic improvement is central to the development of climate-smart vegetables. Creating varieties that can tolerate environmental stresses offers one of the most effective long-term solutions for adapting vegetable production to climate change.

Plant breeders continue to rely on both traditional and advanced breeding strategies to enhance stress tolerance. Conventional approaches, including the selection of landraces and wild relatives, remain important sources of resilience. Many wild vegetable species have evolved under extreme conditions and naturally possess tolerance to drought, heat, salinity, and diseases.

Modern breeding tools such as molecular markers, marker-assisted selection, and genome editing have significantly accelerated varietal development. By identifying and manipulating genes linked to stress tolerance, breeders can develop vegetables that perform well under high temperatures, limited water availability, and increased disease pressure. Such climate-resilient varieties are already being developed in crops like tomato, cabbage, cauliflower, okra, cucurbits, and leafy vegetables.

Water-Efficient Vegetable Production Systems

Water scarcity represents one of the most serious consequences of climate change. Climate-smart vegetable production emphasizes maximizing output while minimizing water use.

Advanced irrigation methods such as drip systems and micro-sprinklers deliver water directly to plant roots, reducing evaporation losses and improving efficiency. The use of organic mulches or biodegradable films helps retain soil moisture, moderate soil temperature, and suppress weed growth. Raised beds and improved drainage systems protect crops from waterlogging during periods of intense rainfall.

Combining drought-tolerant varieties with precise irrigation scheduling based on crop growth stages further improves water productivity. Collectively, these strategies enable farmers to cope with uncertain rainfall patterns while conserving limited water resources.

Soil Management for Climate-Smart Vegetables

Soil health plays a vital role in building climate-resilient vegetable production systems. Climate-smart practices aim to enhance soil structure, organic matter content, and biological activity.

The application of compost, farmyard manure, and crop residues improves soil fertility and increases its capacity to retain water. The use of cover crops and green manures helps prevent soil erosion, enhances nutrient cycling, and suppresses weeds. Reduced or minimum tillage practices limit soil disturbance, conserve soil carbon, and contribute to climate change mitigation.

Improved soil conditions promote stronger root systems, better nutrient uptake, and greater tolerance to environmental stress, resulting in more stable vegetable yields under variable climatic conditions.

Protected Cultivation as a Climate Adaptation Strategy

Protected cultivation is an important component of climate-smart vegetable farming. Structures such as polyhouses, shade nets, and low tunnels create a favorable microenvironment that protects crops from extreme weather conditions.

Growing vegetables under protected structures allows better control over temperature, humidity, and light, thereby reducing stress and increasing productivity. Net houses limit insect infestation, reducing the need for chemical pesticides, while polyhouses enable off-season cultivation, ensuring consistent supply and higher economic returns for farmers.

As weather patterns become more unpredictable, protected cultivation offers an effective means of stabilizing vegetable production, particularly for high-value crops.

Sustainable Pest and Disease Management

Climate change has intensified pest and disease problems in vegetable crops. Climate-smart vegetable systems adopt integrated pest and disease management approaches that balance effectiveness with environmental sustainability.

The use of resistant varieties provides the first layer of protection. Crop rotation, intercropping, and habitat manipulation disrupt pest populations and reduce disease buildup. Biological control agents, including beneficial insects and microbial formulations, offer eco-friendly alternatives to chemical pesticides. When necessary, pesticides are applied judiciously based on monitoring and threshold levels.

Reducing chemical inputs not only lowers production costs but also safeguards biodiversity, improves food safety, and protects environmental health.

Nutrition-Oriented Climate-Smart Vegetables

Climate-smart vegetables focus not only on resilience and productivity but also on nutritional quality. Climate stress can negatively affect nutrient uptake and metabolic processes, leading to reduced nutritional value in vegetables. Therefore, enhancing nutritional traits is a major priority.

Through breeding and biotechnological interventions, vegetables with higher levels of vitamins, minerals, antioxidants, and functional compounds are being developed. Iron- and folate-rich leafy greens, lycopene-enriched tomatoes, and beta-carotene-rich carrots contribute to improved human nutrition.

Ensuring the consistent availability of nutrient-dense vegetables under adverse climatic conditions strengthens both food security and nutritional security.

Digital Innovations in Climate-Smart Vegetable Farming

Digital technologies are increasingly supporting climate-smart vegetable production. Tools such as weather prediction applications, soil moisture sensors, and decision-support platforms assist farmers in making timely and accurate management decisions. Precision farming technologies optimize the use of water, fertilizers, and pesticides, reducing waste and environmental impact.

Remote sensing and artificial intelligence enable early detection of crop stress and disease outbreaks, allowing rapid interventions. These technologies enhance farmers' capacity to adapt to climate variability and improve overall farm resilience.

Importance of Farmers and Policy Support

The success of climate-smart vegetables depends on effective participation by farmers and supportive policy environments. Farmers require access to climate-resilient seeds, technical knowledge, and extension services. Capacity-building initiatives such as training programs, demonstration fields, and peer learning are essential for widespread adoption.

Policy support is equally important. Investments in research, infrastructure, seed systems, and conservation of genetic resources are crucial. Integrating climate-smart vegetable production into national agricultural and climate adaptation policies will strengthen long-term food security.

Future Prospects

The future of climate-smart vegetables lies in the strategic integration of advanced breeding technologies, sustainable agronomic practices, and digital innovations to enhance resilience against climate variability. Rapid developments in genomics, marker-assisted selection, and genome editing are expected to accelerate the development of vegetable varieties with improved tolerance to multiple abiotic and biotic stresses, while the use of wild relatives and landraces will broaden the genetic base for adaptation. Increasing adoption of precision agriculture tools, sensor-based irrigation, remote sensing, and artificial intelligence–driven decision-support systems will enable efficient resource use and timely climate-responsive management. Expansion of affordable protected cultivation, coupled with nutrition-focused breeding, will support year-round production of high-quality, nutrient-rich vegetables. Strong policy support, investment in research and extension services, and capacity building of farmers will be critical for scaling climate-smart vegetable systems, making them a cornerstone of sustainable agriculture, food security, and climate resilience in the coming decades.

Conclusion

Climate-smart vegetables offer a practical and essential response to the combined challenges of climate change, population growth, and diminishing natural resources. By combining stress-tolerant varieties, efficient water and soil management, protected cultivation, eco-friendly pest control, and digital innovations, climate-smart vegetable systems provide a sustainable pathway to food and nutritional security. As climate-related risks intensify, investing in climate-smart vegetables is no longer optional but critical for building a resilient agricultural future and a healthier global population.

References

1. Canton, H. (2021). Food and agriculture organization of the United Nations—FAO. In *The Europa directory of international organizations 2021* (pp. 297-305). Routledge.
2. Kumar, P., Rouphael, Y., Cardarelli, M., & Colla, G. (2017). Vegetable grafting as a tool to improve drought resistance and water use efficiency. *Frontiers in plant science*, *8*, 1130.
3. Ray, D. K., Gerber, J. S., MacDonald, G. K., & West, P. C. (2015). Climate variation explains a third of global crop yield variability. *Nature communications*, *6*(1), 5989.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Adoption of Oil Extraction Machinery: A Pathway to Enhanced Farmers' Income

Article ID: 72708

Dr. Dinesh Rajak[1], Dr. Vishal Kumar[2], Dr. Devendra Kumar[3]
[1&2]Associate Professor and [3]Professor, Processing and Food Engineering, CAE&T, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar.

Introduction

In many developing regions, agriculture remains the backbone of rural economies. Among the various agricultural products, oilseeds such as sunflower, groundnut, sesame, mustard, and soybean serve not only as cash crops but also as essential ingredients in local diets. Traditionally, smallholder farmers have had limited access to modern processing tools, particularly oil extraction machinery. As a result, they have sold their raw produce at low prices, missing out on the added value that comes from oil processing.

The recent rise in the availability and adoption of oil extraction machinery is beginning to reshape this scenario. With improved access to technology, farmers are no longer just cultivators—they are becoming processors and entrepreneurs. This shift is not only enhancing productivity and profitability but is also fostering inclusive rural development. This article explores how the adoption of oil extraction machinery increases the economic benefits for farmers.

Economic Impact on Farmers

The direct economic benefit of oil extraction machinery lies in the value addition it enables. Traditionally, farmers sold raw oilseeds to local traders or mills at low prices. With access to machinery, they can now extract and sell the oil themselves—often at double or triple the price of raw seeds.

For example, a farmer who used to sell sunflower seeds for $0.40 per kg can now extract oil and sell it at $1.50 per liter, with byproducts such as oilseed cake also fetching a price in the market. This vertical integration not only increases revenue but also improves bargaining power.

Additionally, farmers save on transportation and processing costs by processing oil locally. These savings, combined with higher selling prices, significantly boost household income. In some regions, incomes have risen by 30-50% within the first two years of adopting such technology.

Employment and Entrepreneurship

Oil extraction machines create opportunities beyond the immediate benefit to the machine owner. The demand for skilled labor to operate and maintain machines introduces new employment prospects in rural areas. Young people, who might otherwise migrate to cities, find meaningful work within their communities.

Furthermore, entrepreneurial farmers have started offering oil extraction services to neighbors, creating micro-enterprises that benefit the wider community. Some cooperatives have established mini oil mills where members bring their harvests for processing, paying a nominal fee. This has proven especially beneficial in women-led cooperatives, where oil processing becomes a community-driven economic engine.

These enterprises often expand into packaging and branding of locally produced oil, capturing even more value from the supply chain and fostering rural industrialization.

Challenges and Solutions

Despite the clear benefits, the adoption of oil extraction machinery is not without challenges. High upfront costs remain a barrier for many smallholders. The lack of technical know-how and maintenance support can also limit sustained usage. Access to electricity or fuel in remote areas further complicates operations.

To overcome these barriers, governments and NGOs have launched initiatives such as subsidies, training programs, and microfinance schemes. Cooperative ownership models help spread the cost and risks. Some startups have introduced solar-powered oil extraction units, reducing dependence on unreliable electricity supply.

There is also a need for market linkage programs that connect rural oil producers to urban and international buyers, ensuring consistent demand and fair pricing. Policymakers and private players alike have a role to play in scaling these solutions.

Increased Income through Value Addition

The most immediate and visible impact of oil extraction machinery is the significant increase in farmers' income. By processing oilseeds themselves, farmers are able to add value to their produce. Instead of selling raw seeds at low

market prices, they can extract oil and sell it at a much higher price per unit. Additionally, the by-product—oil cake—is also marketable as livestock feed or organic fertilizer.

For example, a farmer producing 1,000 kg of groundnuts might previously earn $400 by selling to a middleman. However, with access to an oil press, the same farmer can extract around 400 liters of oil and 600 kg of oil cake, yielding $1,000 or more in total. This value-added income can significantly improve household livelihoods, allowing for better education, healthcare, and reinvestment in farming.

Local Employment and Rural Entrepreneurship

Oil extraction machinery does not just benefit the individual farmer. It also stimulates local employment and entrepreneurship. In many areas, farmers form cooperatives or small enterprises to jointly own and operate oil presses. These groups create jobs for machine operators, maintenance workers, packagers, and marketers.

Moreover, oil processing facilities often become centers for other rural businesses. Women's cooperatives, for instance, are increasingly taking on oil processing as a way to earn income and achieve financial independence. Some groups move beyond basic oil pressing to include packaging, branding, and direct sales at markets or through local stores.

This ripple effect helps to build a more diverse and resilient rural economy, reducing dependence on single crops or markets and curbing rural-to-urban migration by offering local opportunities.

Reduced Post-Harvest Loss and Better Market Access

Oil extraction machinery also helps reduce post-harvest losses. Oilseeds are perishable and can lose quality if not sold or processed quickly. By having local machinery available, farmers can process their harvest soon after collection, preserving quality and reducing spoilage.

Furthermore, oil is often easier to transport and store than raw seeds, and it can be marketed more flexibly. Farmers can sell oil locally, supply it to urban markets, or even export if quality standards are met. As more farmers gain experience in processing and marketing, they develop better market linkages and negotiating power, enabling them to capture a greater share of the value chain.

Barriers to Adoption and the Role of Support Systems

Despite its benefits, the widespread adoption of oil extraction machinery faces several challenges. High initial costs of machines, lack of technical knowledge, and limited access to maintenance services are common barriers. Moreover, farmers in remote areas may struggle with electricity access or transport logistics.

To address these challenges, governments, NGOs, and private sector actors have introduced various support mechanisms. These include:

Subsidies or Grants: Unlocking Access to Technology: The high upfront cost of oil extraction machinery is one of the most significant barriers for smallholder farmers. Most modern oil presses, even small-scale models, can be expensive—costing hundreds or even thousands of dollars. For farmers with limited capital and no access to affordable credit, this price tag often puts the technology out of reach. To overcome this challenge, subsidies and grants provided by governments, NGOs, and international development organizations play a crucial role. These financial incentives reduce the financial burden on farmers and encourage investment in machinery that can transform their income potential.

Types of Support Offered

1. Capital Cost Subsidies: Farmers receive a percentage of the machine's cost paid by the government or a donor agency. For example, a 50% subsidy on a $1,000 oil press would reduce the farmer's out-of-pocket expense to $500.

2. Matching Grants: Farmers are required to contribute a certain amount (e.g., 40–60%) while the grant covers the rest. This model promotes ownership and accountability.

3. Startup Grants for Cooperatives: Cooperatives and women's groups often receive bulk grants to purchase machinery, set up oil processing units, and even invest in packaging and marketing infrastructure.

4. Pilot and Demonstration Projects: In some regions, governments provide oil extraction machines for free to pilot communities to demonstrate the benefits. Successful pilots often lead to broader adoption and funding.

5. Integration with Rural Development Schemes: Machinery subsidies are often bundled with broader agricultural development initiatives—such as rural employment programs or women's empowerment schemes—making them more accessible.

Real-World Example

In India, under the National Mission on Oilseeds and Oil Palm (NMOOP), farmers are eligible for machinery subsidies of up to 50% for oil extraction equipment. Similar programs in African countries, like Kenya and Nigeria, offer support through agricultural innovation funds or public-private partnerships.

Impact

These subsidies reduce the financial risk for farmers and speed up the adoption process. Once machines are in place, the increased income from oil sales often allows farmers to repay any remaining loans quickly. Over time, the machinery pays for itself many times over, enabling sustainable rural development.

Training Programs on Machine Operation and Maintenance

The successful adoption of oil extraction machinery does not end with its purchase. Farmers must know how to operate the machines efficiently, maintain them properly, and troubleshoot common issues. Without adequate training, even subsidized or grant-funded equipment can fall into disrepair or remain unused. That's why training programs on machine operation and maintenance are essential components of any mechanization initiative.

Importance of Training

1. Improved Efficiency: Well-trained farmers can operate machines at optimal capacity, ensuring maximum oil yield and minimum wastage.

2. Longevity of Equipment: Regular maintenance extends the life of machines, protecting farmers' investments.

3. Safety Assurance: Machines involve moving parts and sometimes high temperatures. Training reduces the risk of injury.

4. Empowerment Through Knowledge: Technical training builds confidence, especially among women and youth, enabling them to take ownership of the machinery and even become local service providers or repair specialists.

What Training Typically Includes?

1. Basic Operation: Step-by-step instruction on how to set up, start, and shut down the oil press machine.

2. Maintenance Practices: Cleaning routines, lubrication, part replacement schedules, and how to detect early signs of wear.

3. Troubleshooting Common Problems: Identifying causes of low oil yield, machine overheating, or motor issues.

4. Storage and Spare Parts: Proper storage methods during the off-season and where/how to acquire spare parts.

5. Record Keeping: Training may also cover financial and operational record-keeping to help farmers manage their oil processing business.

Who Provides the Training?

1. Government Agricultural Departments: Often run extension programs or workshops as part of rural development missions.

2. NGOs and International Agencies: Organizations like FAO, GIZ, and USAID frequently partner with local groups to deliver hands-on technical training.

3. Machinery Suppliers: Reputable manufacturers and dealers often provide free or low-cost training as part of the purchase package.

4. Farmer Cooperatives and Peer Learning: In many areas, trained farmers train others, creating a local knowledge network.

Case Example

In Ethiopia, an NGO-led oilseed project provided both oil extraction equipment and intensive training to farmer groups. As a result, not only did the groups improve oil yield and income, but they also developed in-house capacity to repair and maintain their machines—reducing downtime and dependence on external technicians.

Mobile Processing Units That Travel Between Villages to Serve Multiple Communities

In remote or resource-constrained rural areas, owning or accessing oil extraction machinery remains a challenge for many small-scale farmers. Mobile processing units—vehicles or trailers equipped with oil extraction machines—offer a practical and innovative solution. These units travel between villages, providing on-site oil processing services to farmers who cannot afford or access fixed-location equipment.

What are Mobile Processing Units?

Mobile units are essentially miniature, self-contained oil mills mounted on trucks, vans, or trailers. They are equipped with:

1. Oil press machines (manual or motorized)
2. Basic filtration and storage systems

3. Power sources (diesel, petrol, or solar)
4. Trained operators or technicians

Farmers bring their oilseeds to a central location in the village where the mobile unit operates on designated days, either seasonally or regularly.

Benefits of Mobile Units

1. Low-Cost Access:
   a. Farmers pay a small fee per kilogram of oilseeds processed instead of investing in a machine.
   b. Cost-effective for farmers with small harvest volumes.

2. Bridging the Infrastructure Gap:
   a. Ideal for villages with no electricity or poor road access where permanent machinery setups are not feasible.
   b. Can serve multiple communities in a single region.

3. Reduced Post-Harvest Loss: On-site, timely processing prevents spoilage and preserves seed quality.

4. Empowering Marginalized Groups: Women's groups or youth cooperatives often manage or operate the units, generating employment.

5. Scalability and Flexibility:
   a. Service providers can adjust routes and coverage based on seasonal demand or crop cycles.
   b. Units can be upgraded with more features or expanded to new villages.

Implementation Models

1. Government or NGO-Owned Units: Operated as part of rural development programs, often subsidized to make services affordable.

2. Private Enterprise: Entrepreneurs or cooperatives invest in mobile units and charge service fees, creating a rural business model.

3. Public-Private Partnerships: Shared investment and operation between government agencies and local businesses.

Example in Practice

In Uganda, a rural development NGO introduced solar-powered mobile oil extraction units to communities growing sunflower and sesame. Within one year, oil yield increased, more than 200 farmers accessed services, and women's groups began selling bottled oil in local markets—without ever owning the machinery.

Conclusion

The adoption of oil extraction machinery is proving to be a game-changer for farmers involved in oilseed cultivation. By enabling value addition at the farm level, it enhances incomes, creates jobs, and empowers rural communities. Farmers are no longer merely suppliers of raw produce—they are becoming small-scale producers and entrepreneurs.

As technology becomes more affordable and accessible, and as support systems strengthen, more farmers are likely to adopt oil extraction machinery. This will not only improve individual livelihoods but also contribute to broader rural economic development and food security.

In conclusion, investing in oil extraction technology is a practical and effective way to uplift farming communities and ensure sustainable agricultural growth. The future of farming lies not just in growing crops, but in processing and adding value to them—and oil extraction machinery is a vital tool in this transformation.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Understanding the Ghani Method of Oil Extraction: How it Work, Its Benefits and Why it is Still Used

Article ID: 72709

Shivank Bhardwaj[1], Dr. Preethi Ramachandran[1]

[1]Post-Harvest Process and Food Engineering, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India.

Abstract

The Ghani method of oil extraction is a traditional oil extraction process which is used to produce edible oils in India. This method involves slow crushing of oil seed using mortar and pestle system, this creates minimal heat and absence of chemical free oil. Due to lower temperature and absence of chemical solvents the oil obtained through this process is considered as cold-pressed and retains its natural flavor, aroma and quality. Although Ghani method has lower oil recovery compared to modern mechanical expeller and solvent extraction method, it produces high quality oil. With increase in demand for natural, chemical-free oil, the Ghani method regain its importance. Modern improvements such as motor driven Ghani unit and better processing practices have enhanced its suitability for small scale farmers and rural enterprises. This article highlights the principle, working, advantages, limitations, market potential of the Ghani method of oil extraction

Keywords: Ghani method, Oil extraction, Cold-pressed oil, Traditional processing Sustainable agriculture, Edible oil.

Introduction

Edible Oils are essential component of human diet they provide energy, essential fatty acids and fat soluble vitamins. Over time oil extraction technologies evolving over time from traditional mechanical method to highly efficient solvent extraction processes. Among these Ghani method of oil extraction holds unique position due to its simplicity and ability to produce high quality of cold press oil. In India Ghani method has been used for centuries to extract oil. It is still important because it follows eco-friendly process, provide natural, chemical free edible oil, which are mostly preferred by consumers (Achaya 1994).

Historical Background of Ghani Method

Ghani method is also known as Kolhu or Chekku in different regions of India, it was originated as a village level technology for extracted oil from locally grown oil. At that time this system was powered by animals mainly bullocks, which rotates a pestle inside a mortar made of wood or stone. This method was the backbone of rural oil production before the introduction of mechanical expellers and solvent extraction plants. Historical data says that this method was widely adopted due to its low capital requirement, ease of operation and oil can be extracted locally in small units instead of large industries (Patel, 1947).

Principle of Oil Extraction in Ghani Method

Ghani method works on the principle of mechanical expression of oil by continuous crushing and pressing of oil seeds to extract oil. When oil seeds are placed under compressive and shear forces between rotating pestle and stationary mortar, the oil bearing cells rapture and release oil. Operation speed is slow so that heat does not generates during crushing. As a result, oil retains its natural biochemical properties and called as a cold-press oil, which have high nutritional and sensory quality (Kaviani &Tomovska, 2015).

Construction and Main Components of a Ghani

A traditional Ghani method consists of a mortar (Ghani pit), pestle, drive mechanism, oil outlet and oil cake discharge system. The mortar is usually cylindrical or cylindrical in shape made from hard stone (granite) or hard wood to withstand in continuous friction. The pestle inside mortar is connected to either animal power or an electric motor in modern systems. Oil expelled from oil seeds flows out through a small outlet, while the residual cake remains inside the pit. This simple construction of Ghani makes it easy to maintain and suitable for rural conditions (FAO, 1986).

Raw Materials and Seed Preparation

A variety of oilseeds can be processing using Ghani method, include groundnut, mustard, sesame, coconut, linseed and sunflower. Before oil extraction, seeds are cleaned to remove foreign materials like dust, stalk and debris. After cleaning oilseeds are drying to achieve optimum moisture content, which improves oil recovery and reduce wear of equipment. Proper seed preparation plays an important role in ensuring consistent oil quality and efficient operation of Ghani system (Singh et al., 2018).

Working Steps of Ghani Method

The Ghani oil extraction method involves several steps. Cleaning oilseeds are fed into mortar, where they crushed continuously by rotating pestle. As crushing continues oil starts oozing out and collected through the outlet. The process is carried out for longer duration compared to modern duration, allowing building slow pressure and make sure that oil temperature does not rise too high to preserve its natural quality. After most of the oil is extracted, the remaining oil cake is removed manually. The crude oil obtained is usually filtered to remove fine suspended particles before storage and consumption (FAO,1986).

Operating Conditions

Ghani method use gentle and low- temperature processing, which helps to preserve the natural quality, flavor and nutrients of oil. This mild operation is one of its major advantages because it avoids damage caused by excessive heat and harsh treatment. The rotational speed is kept low, so less heat is produce during friction, and the oil temperature usually kept below 45–50 °C, pressure is applied slowly instead of all at once, which helps to protect sensitive compounds from heat damage. Although the Extraction process takes more time but this slow and careful process kept oil quality better (Sharma & Jain, 2020).

Quality Characteristics of Ghani Extracted Oil

Oil extracted from Ghani method are known for their special aroma, natural colour and superior taste. The low temperature operation helps in preserving bio active compounds such as tocopherols, polyphenols and natural antioxidants. Studies shows that Ghani-extracted oils have lower fatty acid formation as compared to oil obtained through high-temperature processes. These quality attributes make Ghani oil attractive to health-conscious consumer and deeply valued in traditional medicine systems such as Ayurveda (Kumar et al., 2019).

Utilization of By-Products

The main by-product of Ghani oil is oil cake, which contains residual oil, proteins, minerals and fibres. Oi cake generally used as an animal feed and organic manure. In some cases, it also used as a soil conditioner to improve soil fertility. The effective utilization of by-products enhances economic viability of the Ghani system and supports sustainable agriculture practices (Patel, 1947).

Advantages and Limitations of Ghani Method

Ghani method have several advantages over modern extraction techniques. It produces chemical-free and cold-pressed oil with high nutritional value. The technology is environment-friendly, consumes less energy, supports rural employment. The simple design and low operational cost make it suitable for small-scale processors and village-level enterprises. Also Ghani method sold at high price in premium market due to their cold-press and high nutritional value. (Achaya, 1994).

However, Ghani methods have limitation also, oil recovery efficiency is lower compared to solvent extraction method. The process requires labour and tie hence it is not suitable for large scale production. Moreover, it is difficult to maintain same quality due to variability in operating conditions and raw materials (Singh et al., 2018).

Comparison with Modern Oil Extraction Methods

When compared with other methods Ghani method stands out in terms of quality rather than quantity. Mechanical expeller offers higher yield but generates heat, which effect oil quality. Solvent extraction method provide high oil recovery but it uses chemicals like hexane cause inflammation and toxic in nature, this process requires high temperature for solvent removal that can degrade heat sensitive nutrients and natural antioxidants. Oh the other hand Ghani Ghani method includes natural processing and minimal refining make it ideal for premium market rather than bulk production (Kaviani & Tomovska, 2015).

Application and Market Potential

Ghani-extracted oils are mainly used for edible purpose because of their natural flavour, aroma and high nutritional value. These oils are commonly used in cooking, pickles, food preparation where taste and purity are important. Due to low temperature processing and absence of chemical solvents, Ghani oils contains natural antioxidants and essential fatty acids, making them suitable for regular consumption (Kumar et al., 2019).

In addition of food use, Ghani oils are widely used in Ayurveda, traditional medicine and various industries, such as massage oils an herbal industry. Their unrefined and chemical-free nature makes them suitable for organic and health food sector. From market perspective Ghani oils comes under premium consumer segments, where increasing health awareness has created huge demands in domestic and export market (Achaya, 1994).

Conclusion

In conclusion Ghani method is an important traditional technique that focus on oil's natural processing, good nutritional value, environmental safety. Although it does not compete with today's modern processing method in large scale production, but with proper improvements and support, the Ghani method can continue to contribute sustainable agriculture and safe food processing (Achaya, 1994).

References

1. Achaya, K. T. (1994). *Indian Food: A Historical Companion*. Oxford University Press.
2. FAO. (1986). *Small-Scale Oil Extraction by Traditional Methods*. FAO Agricultural Services Bulletin.
3. Patel, J. P. (1947). *Oil Extraction with the Bullock Oil Press*.
4. Kaviani, M., & Tomovska, J. (2015). Comparison of oil extraction methods.
5. Singh, R., Sharma, P., & Verma, A. (2018). Traditional oil extraction technologies in India.
6. Kumar, N., et al. (2019). Nutritional quality of cold-pressed oils.
7. Sharma, S., & Jain, R. (2020). Advances in small-scale oil processing technologies.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Plant-Derived Melatonin for Insect Management: Principles and Mechanism

Article ID: 72710

Bristi Sinha Mahapatra[1], Kinjal Mondal[2]
[1]Department of Entomology, Maharana Pratap University of Agriculture and Technology, Udaipur-313001, Rajasthan.
[2]Department of Molecular Biology and Biotechnology, Maharana Pratap University of Agriculture and Technology, Udaipur-313001, Rajasthan.

Abstract
Plant-derived melatonin is increasingly recognized as a promising environmentally sustainable approach for insect pest control in contemporary agriculture. In addition to modulating plant growth and stress resilience, melatonin bolsters innate plant defence mechanisms, thereby indirectly inhibiting insect nutrition, movement, reproduction, and population proliferation. Evidence demonstrates its capacity to interfere with insect circadian rhythms and elevate mortality rates at threshold concentrations, thereby diminishing infestation pressure. As a biodegradable substance compatible with integrated pest management (IPM), melatonin provides an environmentally sustainable alternative to synthetic insecticides. Additional field validation and dose refinement are necessary to maximize its laboratory efficacy into effective crop protection applications in larger scale.

Keywords: Melatonin, insect, plant defence, circadian rhythms, IPM.

Introduction
Melatonin (N-acetyl-5methoxytryptamine) is generally known as a sleep regulator in humans. It has traditionally been regarded as an antioxidant in plants, controlling the pool of reactive oxygen and nitrogen species (**Ikram et al., 2024**). Its function in a variety of physiological processes, including growth, roots, photosynthesis, fruit maturity, and defense against biotic and abiotic stresses, has been extensively studied. Melatonin may reduce the harmful effects of abiotic stresses since it plays an important role in plants' capacity to endure stress. Melatonin is a harmless biomolecule to the environment, and because of its small size and high solubility in both lipids and water, it can enter cell compartments and play an important role as a modulatory agent (a biostimulator and plant growth regulator) that increases a plant's tolerance to both biotic and abiotic stress (**Khan et al., 2024**). Melatonin is anticipated to be a low-cost strategy for increasing plant resilience to abiotic and biotic stressors (**Mukherjee et al., 2024**). Melatonin acts as a natural plant regulator and biostimulator, promoting sustainable agriculture and reducing global food poverty. Tryptophan, like auxin, is an indoleamine that serves as the precursor of melatonin and is thought to have a function in growth and development control. It has a physiological effect on plants by encouraging seedling growth, producing primary, lateral, and adventitious roots, modifying the branching and growth cycles of leaves and stems, and avoiding leaf senescence by increasing photosynthesis, blooming, and seed production. Melatonin is a broad-spectrum biopesticide and stress protectant for sustainable agriculture because it disrupts circadian rhythms, affects feeding and diapause, acts as a powerful antioxidant to protect against stress and pesticides, alters immunity, and interferes with plant-insect interactions by increasing plant defence or decreasing feeding. Its processes influence insect behaviour and physiology by scavenging reactive oxygen species (ROS), regulating gene expression especially which are related to defence mechanisms, and interfering with hormone pathways.

Melatonin Biosynthesis in Plants
In plants, melatonin (N-acetyl-5-methoxytryptamine) is produced from shikimate-derived tryptophan through a highly versatile, multi-compartmental pathway that is closely linked with indole and redox metabolism, especially under stress conditions. The primary pathway involves the decarboxylation of tryptophan by tryptophan decarboxylase (TDC) to produce tryptamine, followed by hydroxylation within the endoplasmic reticulum by the cytochrome P450 enzyme tryptamine-5-hydroxylase (T5H) to generate serotonin. This serotonin is subsequently acetylated by serotonin N-acetyltransferase (SNAT)—the main rate-limiting and stress-responsive enzyme—primarily within chloroplasts, forming N-acetylserotonin (**Arnao and Hernández-Ruiz, 2015**). Finally, N-acetylserotonin is methylated to melatonin by N-acetylserotonin methyltransferase (ASMT) or the multifunctional enzyme caffeic acid O-methyltransferase (COMT) in the cytosol or plastids. Under challenging conditions, alternative serotonin-centric pathways play a vital role, maintaining continuous melatonin production through enzymatic redundancy. The chloroplast localization of SNAT supports the evolutionary hypothesis that plant melatonin serves as a primary antioxidant, buffering reactive oxygen species generated during photosynthesis (**Back et al., 2016; Ahammed et al., 2024**). Additionally, the transcriptional upregulation of TDC, SNAT, and ASMT/COMT under conditions of heat, salinity, drought, and metal stress enhances melatonin synthesis to stabilize redox homeostasis, preserve mitochondrial and chloroplastic integrity, and regulate nitrogen assimilation pathways (NR, GS/GOGAT). Furthermore, the shared tryptophan pool functions as a regulatory

nexus connecting melatonin biosynthesis with auxin metabolism and phenylpropanoid flux, positioning melatonin as a stress-induced indoleamine that integrates metabolic signalling, antioxidant defence, and growth regulation at both subcellular and whole-plant levels.

Antimicrobial and Insecticidal Properties of Melatonin

Recent studies revealed melatonin to function as a regulatory molecule in the rhizosphere, influencing microbial diversity, composition, and function, alongside its role as a versatile phytohormone. The administration of exogenous melatonin enhances rhizosphere conditions by increasing soil enzyme activity, improving nutrient cycling, fostering beneficial microbial communities, and reducing pathogenic fungus. Furthermore, it suppresses detrimental microorganisms that compromise rhizosphere stability and plant health.

The primary mechanisms of melatonin-induced biotic stress in plants include the upregulation of defence genes, cell wall thickening, reactive oxygen species scavenging, and enhanced nitric oxide production (**Chen et al., 2025**). Plants treated with melatonin have been shown to activate genes associated with enhanced ethylene and salicylic acid (SA) signalling. Plants treated with melatonin accumulate callose, cellulose, galactose, and xylose, resulting in cell wall thickening and the metabolic basis for disease resistance. The endogenous production of melatonin in host plants is activated by reactive oxygen species (ROS), and melatonin concurrently enhances the activation of defence-related genes.

Melatonin Minimizes Insect Attack to Plants: Mode of Action

Melatonin treatment mitigates biotic stress by synthesizing alkaloids and phenolic compounds, which possess insecticidal and antibacterial properties. Melatonin synthesis and regulation significantly influence several biological processes in insect pests, including circadian rhythms, feeding behaviours, reproduction, and responses to photoperiodism. Moreover, melatonin administration has been seen to reduce the bacterial population in the psyllid vector (*Diaphorina citri*) responsible for transmitting citrus greening disease. A range of proteins and enzymes, released in response to melatonin, directly deter or injure insects (Figure 1):

1. Antinutritive Enzymes: It makes polyphenol oxidases (PPOs) and proteinase inhibitors more active. When consumed, they impede the growth and development of insects by inhibiting their digestive enzymes and lowering the nutritional value of plant tissue.

2. Lignin Accumulation: Plant cell walls become more difficult to break down when lignin levels rise.

3. Secondary Metabolites: Melatonin can trigger the production of anthocyanins, flavonoids, and other potentially harmful or repulsive metabolites.

4. Direct Insect Effects: Melatonin also affects insects directly, controlling their eating habits and circadian cycles by regulating insect internal clocks, controlling photoperiod, diapause, and feeding patterns. Elevated concentrations within the plant could interfere with these functions, decreasing the insects' feeding activity.

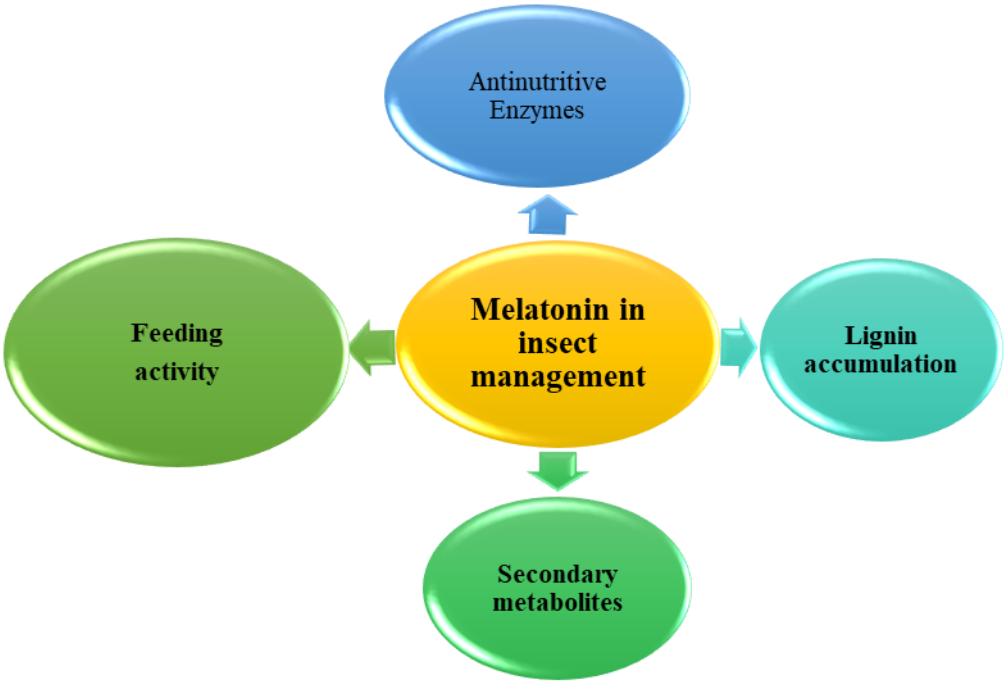


Figure 1: Melatonin restricts insect infestation by several modes

Case Studies

Gao and Hardie (1997) reported a clear concentration-dependent response of pea aphids to dietary melatonin delivered via an artificial diet, with low doses (4.3×10^{-7}–4.3×10^{-5} M) showing no statistically significant deviation from control pre-adult mortality (19.2–27.3%). However, exposure to a high melatonin concentration (2.2×10^{-4} M) caused a pronounced increase in pre-adult mortality (58.6%), indicating a threshold-level disruption of aphid developmental physiology and survival.

Shi et al. (2021) demonstrated root-applied melatonin (1×10^{8} pg ml^{-1}) in rice BPH (*Nilaparvata lugens*) significantly disrupted insect circadian rhythms and reproductive behaviour, resulting in reduced nighttime copulation (31.2% as compared to 68.7% in control) and progeny as well. Melatonin significantly decreased locomotor activity in macropterous and brachypterous males, as well as both daytime and nighttime activity in macropterous females, effects that were not detected with luzindole or combination treatments, showing that melatonin modulates host-insect interactions specifically.

Jan et al. (2025) demonstrated that exogenous melatonin (50–150 µM) provides dose-dependent early resistance to white-backed planthopper in rice by markedly improving seedling survival (up to 384% at 7 days post-infestation) and substantially reducing vector establishment (up to 93% decrease in insect density). The protective effect mainly postpones symptom development under continuous insect pressure, suggesting melatonin-mediated induction of host tolerance and partial antibiosis rather than complete resistance.

Conclusion

The extensive reliance on synthetic insecticides poses significant risks to agro-ecosystem health, soil quality, and food-chain safety, necessitating a shift toward integrated pest management (IPM)–based approaches. Plant-derived melatonin has emerged as a promising eco-friendly bioregulator that enhances plant innate defence responses and indirectly modulates insect behaviour, development, and fitness. Given the increasing demand to minimize chemical pesticide inputs, systematic research on melatonin–insect interactions, dose optimization, and field-level efficacy is essential to validate its practical utility. Collectively, current evidence supports melatonin as a viable component of sustainable and biologically driven insect pest management strategies.

References

1. Ahammed, G. J., Li, Z., Chen, J., Dong, Y., Qu, K., Guo, T., & Li, X. (2024). Reactive oxygen species signaling in melatonin-mediated plant stress response. *Plant Physiology and Biochemistry*, *207*, 108398.
2. Arnao, M.B., & Hernández-Ruiz, J. (2015). Functions of melatonin in plants: a review. *Journal of Pineal Research*, 59, 133–150.
3. Back, K., Tan, D.X., & Reiter, R.J. (2016). Melatonin biosynthesis in plants: multiple pathways catalyzed by SNAT and COMT. Journal of Pineal Research, 61, 328–339.
4. Chen, T., Xu, L., Yang, P., Tong, J., Liu, Y., Su, Y., & Sun, S. (2025). Plant melatonin: roles and regulatory mechanisms in plant growth, development, and responses to biotic and abiotic stresses. *Plant Signaling & Behavior*, *20*(1), 2585629.
5. Gao, N., & Hardie, J. (1997). Melatonin and the pea aphid, *Acyrthosiphon pisum*. *Journal of Insect Physiology*, *43*(7), 615-620.
6. Ikram, M., Mehran, M., ur Rehman, H., Ullah, S., Bakhsh, M. Z. M., Tahira, M., & El Sabagh, A. (2024). Mechanistic review of melatonin metabolism and signalling pathways in plants: Biosynthesis, regulation, and roles under abiotic stress. *Plant Stress*, *14*, 100685.
7. Jan, R., Asaf, S., Asif, S., Khan, Z., Lubna, Elsharkawy, E. R., & Kim, K. M. (2025). Exogenous Melatonin Modulates Rice Responses to Phloem-Feeding Insect Stress. *Plant, Cell & Environment*.
8. Khan, T. A., Hilal, B., Arnao, M. B., & Fariduddin, Q. (2024). Melatonin-mediated physio-biochemical, and ultrastructural modifications in tomato plants to foster drought stress tolerance. *Plant Growth Regulation*, *104*(3), 1605-1628.
9. Mukherjee, S., Roy, S., & Arnao, M. B. (2024). Nanovehicles for melatonin: a new journey for agriculture. *Trends in Plant Science*, *29*(2), 232-248.
10. Shi, L., Zhang, J., Qiu, L., Jiang, Z., Xie, Z., & Zhan, Z. (2021). Behavioral changes in the brown planthopper, *Nilaparvata lugens*, mediated by melatonin. *CABI Agriculture and Bioscience*, *2*(1), 16.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Red Bhendi: A Nutrient-Rich, High-Value Vegetable for Health and Income

Article ID: 72711

A. Ajay Raja[1], A. Kingsly Raj[1], and P. Agalya[1]
[1]Research scholar, Department of Vegetable Science, Horticultural College and Research Institute, TNAU, Coimbatore, Tamil Nadu, India - 641 003.

Abstract
Red bhendi or red okra (*Abelmoschus esculentus* L.) is an emerging vegetable crop gaining popularity due to its attractive reddish-purple pods, superior nutritional quality, and health-promoting properties. Unlike conventional green okra, red bhendi is rich in anthocyanins and other bioactive compounds that provide strong antioxidant, antidiabetic, cardioprotective, and immune-boosting effects. India, being the largest producer of okra in the world, has immense potential to promote red bhendi as a functional vegetable crop that supports nutritional security and farmer income. Recent varietal developments such as Pusa Lal Bhindi-1 have further strengthened its cultivation prospects through higher yield and disease tolerance. This article highlights the origin, nutritional and medicinal importance, phytochemical composition, cultivation practices, economic benefits, and future potential of red bhendi as a high-value vegetable crop.

Keywords: Red okra; Anthocyanins; Functional vegetable and Nutritional security.

Introduction
Vegetables play a vital role in human nutrition by supplying essential vitamins, minerals, dietary fibre, and protective phytochemicals. Among them, okra (*Abelmoschus esculentus* L.), popularly known as bhindi or lady's finger, is one of the most widely consumed vegetables in tropical and subtropical regions. India ranks first in okra production, contributing nearly 60–63% of the world's total output.

In recent years, red bhendi, an anthocyanin-rich form of okra, has attracted attention from consumers, farmers, nutritionists, and researchers. Its deep red to purple colour, pleasant taste, and enhanced health benefits distinguish it from green okra. With rising awareness about lifestyle diseases such as diabetes, obesity, cardiovascular disorders, and cancer, red bhendi is increasingly being recognized as a functional food.

Origin and Botanical Description
Okra belongs to the family Malvaceae and is believed to have originated in Ethiopia, from where it spread to Asia, Europe, and the Americas. Among vegetable crops, okra is unique in having the highest chromosome number (2n = 130), reflecting its wide genetic variability.

Red bhendi is a fast-growing, erect, annual herbaceous plant. The plants are characterized by reddish-purple stems, petioles, veins, and pods. Flowers are yellowish with purple pigmentation at the base of petals. The edible pods are tender, ribbed, and covered with fine hairs.

Why Red Bhendi is Special?
Red bhendi is unique for its vibrant pod colour, attributed to anthocyanins and phenolic compounds that are largely absent in green okra. These bioactive pigments enhance visual appeal while offering strong antioxidant and disease-preventive benefits by neutralizing free radicals and protecting cells from oxidative stress. Additionally, red bhendi is rich in mucilage, which aids in regulating blood sugar levels, improving digestion, and supporting gut health, making it both a functional and nutritionally superior vegetable.

Nutritional Composition of Red Bhendi
Red bhendi is a low-calorie vegetable rich in essential nutrients. The mineral and vitamin composition of red bhendi per 100 g of fresh pods is presented in Table 1. This impressive nutrient profile makes red bhendi suitable for children, adults, elderly people, and pregnant women.

Table 1. Nutritional profile of Red bhendi:

Nutrient	Content (per 100 g fresh pods)
Potassium	303 mg
Calcium	81 mg
Phosphorus	63 mg
Magnesium	57 mg
Iron	0.8 mg
Vitamin C	12.8–82.8 mg

Health and Medicinal Benefits of Red Bhendi

The major health benefits of red bhendi attributed to its rich nutrient and bioactive compound profile are summarized in Table 2.

Table 2. Medicinal value of Red bhendi:

Health Benefit	Key Role of Red Bhendi
Antidiabetic	Mucilage and soluble fibre slow glucose absorption and regulate blood sugar
Antioxidant	Polyphenols and flavonoids neutralize free radicals and delay ageing
Anticancer	Phenolics and flavonoids help inhibit tumour growth
Anti-obesity	Low calories and high fibre promote satiety and reduce fat accumulation
Antimicrobial	Bioactive compounds protect against pathogenic microorganisms
Immunity booster	Vitamins, antioxidants, and phytochemicals strengthen immune response
Cardiovascular health	Anthocyanins improve lipid profile and heart function
Eye health	Anthocyanins support vision and reduce eye disorders
Anaemia recovery	Iron content supports haemoglobin formation
Healthy pregnancy	Folate aids proper foetal brain and neural development

Cultivation Practices of Red Bhendi

Red bhendi is a warm-season vegetable crop and can be successfully cultivated using practices similar to green okra, with slight emphasis on timely harvesting to retain pod colour and tenderness.

Climate: Red bhendi thrives best in warm and humid climatic conditions. It requires a long growing season with temperatures ranging from 22–35°C. Seed germination does not occur below 18°C, and the crop is highly sensitive to frost. Therefore, cultivation should be avoided during periods of prolonged cold stress.

Soil: Although red bhendi can grow in a wide range of soils, well-drained sandy loam to loam soils rich in organic matter are ideal. The optimum soil pH ranges from 6.0 to 6.8. Waterlogged and heavy clay soils should be avoided as they adversely affect root growth and yield.

Land Preparation: The field should be ploughed 2–3 times to obtain a fine tilth. Well-decomposed farmyard manure (20-25 t/ha) should be incorporated during the final ploughing to improve soil fertility and moisture retention.

Improved Varieties:

Variety	Developing Institute	Pod Colour / Traits	Yield Potential	Disease Reaction / Special Features
CO 1	TNAU, Coimbatore	Pinkish-red pods	~12 t/ha	Susceptible to YVMV
Kashi Lalima	ICAR-IIVR, Varanasi	Reddish-purple pods; rich in anthocyanins	140-150 q/ha	Tolerant to YVMV and OLCV; notified in 2019
Pusa Lal Bhindi-1 (DOV-68)	ICAR-IARI, New Delhi	Reddish-purple pods; high anthocyanin (130 µg/g)	~15 t/ha	Moderately resistant to YVMV and ELCV; released in 2022



CO 1 Kashi Lalima Pusa Lal Bhindi-1

Fig. 1. Released red bhendi varieties from Indian Institutes

Seed Rate:

a. **Spring-summer season:** 12–15 kg/ha
b. **Kharif season:** 8–10 kg/ha

Seeds may be soaked in water for 8–10 hours before sowing to improve germination.

Time of Sowing: Red bhendi can be grown throughout the year in frost-free regions.

a. **Spring-summer:** February–March
b. **Kharif:** June–July

In high rainfall areas, sowing on raised beds is recommended to prevent water stagnation.

Spacing: Proper spacing for healthy growth is 45 cm (spring–summer) or 60 cm (kharif) between rows and 15–20 cm between plants.

Manure and Fertilizer Management: For optimal growth and yield, red bhendi requires 20 t/ha of FYM and a fertilizer dose of 100:60:80 kg/ha of N: P: K. Full doses of phosphorus and potassium along with one-third of nitrogen should be applied at sowing, while the remaining nitrogen is split and applied at 30, 45, and 60 days after sowing.

Irrigation: Red bhendi needs frequent, light irrigation every 5–7 days in summer and only as needed during the rainy season, while avoiding overwatering to prevent root rot and diseases.

Weed Management: Weeds compete with the crop during the early growth stages.

a. Pendimethalin @ 3.0 L/ha in 500 L water as pre-emergence herbicide.
b. 1–2 manual weeding at 20–30 days after sowing.

Earthing up after weeding helps improve plant stability.

Plant Protection: Bhendi faces major insect pests like jassids, whiteflies, shoot and fruit borer, and red spider mites that damage plants by sap-sucking, virus transmission, or fruit boring. Key diseases, Yellow Vein Mosaic Virus (YVMV) and Enation Leaf Curl Virus (ELCV), mainly spread by whiteflies, significantly reduce yield and fruit quality.

Management:

a. Use yellow sticky traps (20/ha)
b. Spray neem seed kernel extract (5%)
c. Apply recommended insecticides such as acetamiprid or spinosad at need-based intervals.

Harvesting: Tender pods should be harvested 5–6 days after flowering. Delayed harvesting results in fibrous pods, loss of colour, and reduced market value. Regular harvesting promotes continuous flowering and higher yield.

Yield:

a. Spring-summer: 120 q/ha
b. Kharif: 140–150 q/ha

Culinary Uses

Red bhendi is consumed in diverse forms, including as a fresh vegetable and in boiled, fried, or cooked preparations, and it is widely used in soups, stews, and curries, while young tender pods are also added to salads and the crop can be utilized in dried or processed products. Interestingly, although red bhendi often turns green upon cooking due to pigment changes, its nutritional quality remains largely unaffected.

Shelf Life and Storage

Red bhendi has a short shelf life at room temperature and should ideally be consumed on the same day of harvest. Delayed harvesting leads to rapid over-maturity and loss of colour and tenderness.

For better storage:

a. Optimum temperature: 12–13°C
b. Use ventilated packaging
c. Avoid chilling injury.

Proper storage helps maintain texture, colour, and nutritional quality.

Economic Importance and Market Potential

Red bhendi fetches **3-4 times higher market price** compared to green okra due to its novelty, health benefits, and consumer preference. It offers:

a. Higher profitability for farmers
b. Scope for export and processing industries
c. Opportunities in nutraceuticals and natural food colouring
d. Anthocyanin extracts from red bhendi can be used in jams, beverages, confectionery, and functional foods.

Conclusion

Red bhendi is more than just a colourful vegetable, it is a nutritional powerhouse and a high-value crop. With its rich content of anthocyanins, antioxidants, dietary fibre, and essential minerals, red bhendi contributes to better health, disease prevention, and improved quality of life. The availability of improved varieties like Pusa Lal Bhindi-1 and increasing consumer awareness make red bhendi a promising crop for sustainable agriculture, nutritional security, and enhanced farmer income. Promoting its cultivation and consumption can play a key role in addressing malnutrition and lifestyle-related health issues in India and beyond.

References

1. Khoo, H. E., Azlan, A., Tang, S. T., & Lim, S. M. (2017). Anthocyanidins and anthocyanins: Colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food & nutrition research*, *61*(1), 1361779.
2. Yadav, R. K., & Lata, S. Pusa Lal Bhindi-1: Anthocyanin Rich Okra. *Indian Horticulture*, *69*(2), 3-5.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Climate Resilience in Seemanchal, Bihar: Facing Uncertainty with Strength and Strategy

Article ID: 72712

Krishna D Karjigi[1], Nagarjun P[2]
[1]Assistant Professor-cum-Junior Scientist, Extension education, BAU Sabour, Bihar.
[2]Assistant Professor-cum-Junior Scientist, Agronomy, BAU Sabour, Bihar.

Introduction: Seemanchal at the Frontline of Climate Change

Seemanchal, comprising the districts of Kishanganj, Purnia, Katihar and Araria, represents one of the most climate-sensitive regions of Bihar. Traditionally known for its fertile alluvial soils, rice-based farming systems and diversified livelihood options, the region is now experiencing unprecedented climatic stress.



Fig.01- Seemanchal area in Bihar

Rising temperatures, erratic rainfall, recurring floods and prolonged dry spells are no longer occasional disturbances but have become defining features of the regional climate. These changes are significantly reshaping agricultural practices, water availability and the socio-economic stability of rural households. In this context, climate resilience refers to the capacity of communities, farming systems and institutions to absorb climatic shocks, adapt to variability and transform livelihoods to withstand future risks. For Seemanchal, climate resilience is not merely a policy objective—it has emerged as a pressing development imperative.

Changing Rainfall and Temperature Patterns

Recent climatic observations indicate increasing variability in Bihar's rainfall regime. During the 2024 monsoon season, the state recorded an overall rainfall deficit of nearly 23 percent, while early monsoon assessments in 2025 showed deficits approaching 50 percent in several districts. These deficits were spatially uneven and temporally erratic, with long dry spells followed by short episodes of intense rainfall—a pattern that has become increasingly common in Seemanchal.

Such erratic rainfall disrupts traditional sowing calendars, delays transplanting of paddy and adversely affects the germination of maize, pulses and oilseeds. Rising temperatures further intensify crop stress, particularly during critical growth stages. Prolonged heat waves during summer months reduce soil moisture and increase evapotranspiration losses, making rain-fed agriculture highly uncertain. Small and marginal farmers, who constitute the majority of cultivators in the region, are particularly vulnerable to these climatic shifts.

Floods amid Deficits: The Paradox of Extremes

Despite frequent rainfall deficits, Seemanchal continues to experience devastating floods. Rivers such as the Koshi, Mahananda and their tributaries frequently overflow due to heavy rainfall in upstream catchments, particularly in Nepal. As a result, large tracts of agricultural land are inundated almost every year, damaging standing crops, eroding fertile topsoil and disrupting transport, markets and essential services.

It is estimated that nearly three-fourths of North Bihar's population lives under recurring flood risk, with Seemanchal districts among the most affected. Repeated crop losses, displacement of households and damage to rural infrastructure impose severe economic and social costs, further weakening the adaptive capacity of already vulnerable communities. The coexistence of drought-like conditions and destructive floods within short time spans illustrates the growing extremity of climate behaviour in the region.

Agriculture and Rural Livelihoods Under Stress

Agriculture remains the backbone of Seemanchal's rural economy, yet climate variability has substantially increased production risks. Paddy yields fluctuate sharply due to delayed monsoons and waterlogging, while rabi crops such as wheat and lentil suffer from inadequate soil moisture and rising winter temperatures. Horticultural crops and vegetables, which play a crucial role in income diversification, are particularly sensitive to heat stress and irregular rainfall. Climate stress also affects allied livelihood activities. Livestock productivity declines during heat waves, disease incidence rises under humid conditions and seasonal migration increases as farming incomes become unreliable. These interconnected impacts demonstrate how climate change acts as a multiplier of existing socio-economic vulnerabilities in the region.

Case Study 1: Heat Stress and Crop Failure in Kishanganj

In several villages of Kishanganj district, farmers have reported severe crop losses due to prolonged heat stress and delayed rainfall. In Chikabadi Panchayat, smallholders cultivating jute, green gram and vegetables observed widespread wilting and premature crop failure despite limited irrigation efforts. Crops that would normally sustain until the onset of monsoon were destroyed by late May, resulting in significant income losses.

Such experiences highlight the growing impact of rising temperatures and shifting rainfall patterns on traditional cropping systems, particularly for farmers operating on small landholdings with limited access to irrigation.

Case Study 2: Flood-Resilient Paddy in Low-Lying Areas

In flood-prone pockets of Purnia and Katihar districts, farmers adopting submergence-tolerant paddy varieties have reported improved crop survival during short-duration flooding. These varieties can withstand submergence for up to two weeks, allowing farmers to recover yields even after flash floods. Although adoption remains limited, these experiences demonstrate the potential of climate-resilient technologies when supported by effective extension services.

Emerging Climate-Resilient Responses

Despite mounting challenges, adaptive responses are gradually gaining ground across Seemanchal. Farmers are increasingly adopting climate-resilient crop varieties capable of tolerating drought, heat stress and temporary submergence. Crop diversification with pulses, oilseeds and vegetables is helping reduce dependence on single crops and spread climatic risk.

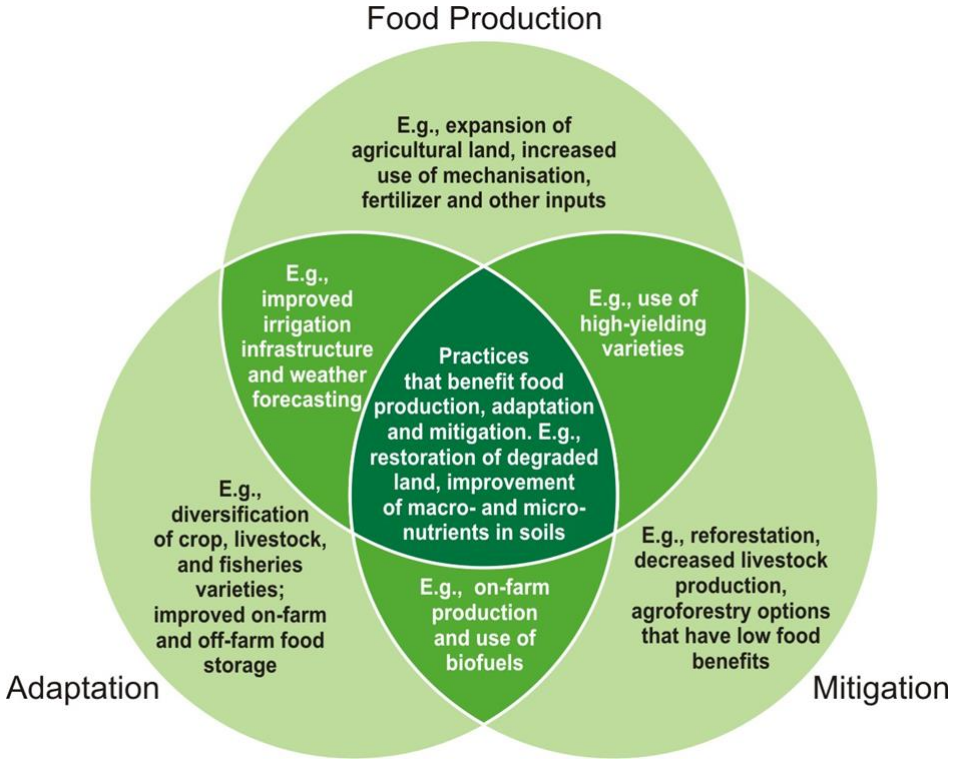


Fig.02- CRA focuses on improving productivity, resilience (adaptation) and mitigation

Water-saving technologies such as rainwater harvesting, micro-irrigation and improved field drainage are being promoted through government schemes and extension programs. Soil health management practices, including organic amendments, residue retention and conservation agriculture, are improving moisture retention and reducing land degradation.

Research institutions and extension agencies are also strengthening climate advisory services, providing weather-based agromet advisories that guide farmers on sowing, irrigation and crop protection decisions. These science-based interventions are crucial for shifting from reactive coping strategies to anticipatory climate risk management.

Policy Initiatives and Institutional Support

At the policy level, climate resilience has emerged as a core development priority in Bihar. State-level climate action plans and stakeholder consultations emphasize integrated management of land, water and agriculture, alongside disaster preparedness and livelihood diversification. Programs promoting climate-smart agriculture, water conservation and sustainable resource management are aligned with broader goals of food security and rural development.

However, effective resilience building in Seemanchal requires sustained investment, localized planning and strong institutional convergence. Interventions must be tailored to district-specific ecological conditions, farming systems and socio-economic realities. Strengthening last-mile extension delivery and ensuring timely access to climate information remain critical challenges.

The Road Ahead: Building Long-Term Resilience

Climate projections indicate that extreme weather events are likely to intensify in the coming decades. For Seemanchal, this underscores the urgency of moving beyond short-term relief toward long-term resilience-building. Strengthening early-warning systems, improving rural infrastructure, expanding crop insurance coverage and empowering local institutions are essential steps in this direction.

Equally important is community participation. Farmers' knowledge, collective action and adaptive innovations must be integrated with scientific research and policy frameworks. Climate resilience in Seemanchal will ultimately depend on how effectively people, institutions and ecosystems work together to navigate an increasingly uncertain climatic future.

References

1. Change.org. (2025). *Declare flood torn Seemanchal as disaster prone and mitigate the sufferings of the people*. https://www.change.org/p/ministry-of-home-affairs-declare-flood-torn-seemanchal-as-disaster-prone-and-mitigate-the-sufferings-of-the-people
2. Down To Earth. (2024). *Bihar faces double whammy of floods and droughts as climate change wreaks havoc*. https://www.downtoearth.org.in
3. Down To Earth. (2025). *Bihar faces high deficit rainfall, paddy farmers fear drought-like situation*. https://www.downtoearth.org.in
4. Main Media English. (2023). *IIT report indicates Seemanchal districts as highly susceptible to climate change*. https://english.mainmedia.in
5. Times of India. (2025). *Climate-resilient farming need of hour in Bihar*. https://timesofindia.indiatimes.com

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Developing a Nutrient Density Score for Upland Rice

Article ID: 72713

Sarmistha Das[1], Dr. Sweta Rath[2], Professor Ashok Ku. Mohapatra[3]
[1]M.Sc. (Ag) Scholar, Department of Soil Science & Agricultural Chemistry,
[2]Assistant Professor, Department of Agronomy,
[3]Professor, Department of Agronomy,
Faculty of Agricultural Sciences, Siksha 'O' Anusandhan (deemed to be University), Bhubaneswar, 751003, Odisha, India.

Abstract
Rice serves as the main staple food for people in India, contributing to more than 40% of their daily energy consumption. Although grains like rice provide a significant amount of energy, they tend to be low in essential micronutrients such as zinc (Zn) and iron (Fe) compared to other dietary sources. Upland rice varieties or rainfed crops exhibit genetic diversity and can be utilized to enhance the nutritional quality of these crops. This paper presents a novel method for establishing a Nutrient Density Score (NDS) specifically for upland rice.



Introduction
Rice plays a crucial role in ensuring food security in India, although it lacks essential nutrients. Therefore, as problems like malnutrition and nutrient shortages persist, it is important to focus on enhancing the nutritional content of staple foods. The Indian Council of Agricultural Research (ICAR) and state agricultural universities are working to create and promote biofortified rice varieties that are high in zinc, iron, and protein (ICAR-NRRI, 2024).

Upland Rice in India
Upland rice types are mainly cultivated in Odisha, Jharkhand, Chhattisgarh, and Northeast India, particularly in areas reliant on rainfall that face water shortages. These rice varieties grow in soils that are low in nutrients and experience inadequate fertilizer access, which impacts their yield. In this context, traditional landrace varieties of upland rice display specific nutritional properties, featuring increased fiber and nutrient levels (EPUBS ICAR, 2023).

Nutrient Composition of Indian Rice Germplasm
Numerous studies have indicated a significant range in the nutrient content of rice, such as: Protein: 6.7–13.1 g/100 g

Zinc: 12–28 mg/kg

Iron: 8–18 mg/kg

Conventional varieties such as Kalanamak, Chakhao, and Ragolu contain high levels of minerals and antioxidants (FAO, 2022).

What is Nutrient Density Score (NDS)?
The Nutrient Density Score (NDS) serves as a combined measure of the nutritional quality of food, considering the amounts of essential nutrients relative to the energy content per serving for every 100 grams of the edible portion. For upland rice, the focus of the Nutrient Density Score is on: Macronutrients: Protein

Micronutrients: Zinc and Iron

Fiber: advantageous for digestion and metabolic functions.

By allocating weights to each nutrient based on the significance of public health issues, particularly those related to deficiencies in Zinc and Iron, it becomes possible to rank various rice types.

Framework for Developing the NDS

Nutrient	Average value (per 100g)	Weight (%)	Contribution to NDS
Protein	8 g	30	2.4
Zinc	2 mg	35	0.7
Iron	1.5 mg	25	0.375
Fiber	3.5 g	10	0.35
Total NDS (example)	-	-	**3.83/5.0**

The scoring system enables the ranking of upland rice genotypes to identify the top performers for yield and nutritional value.

Laboratory and Field Procedures

Samples from various upland varieties are assessed for protein content using the Kjeldahl method and for micronutrients through ICP-AES. Factors including environmental differences, soil composition, and farming practices are considered, as they have been shown to influence the nutrient levels in the grain (Update Publishing, 2022).

Biofortification and Case Studies

India has introduced more than 25 biofortified rice varieties, such as DRR Dhan 45 (High Zinc), CR Dhan 310, and the enhanced Samba Mahsuri (Improved). Research has shown that these rice varieties can have up to 40% more zinc and 25% more protein compared to standard varieties, as verified by the ICAR-NRRI and DRR Hyderabad Programs (ICAR, 2022).

Advantages of a Nutrient Density Score (NDS)

1. Identification of Breeding Targets: Aids in pinpointing rice varieties that possess elevated nutritional qualities for integration into breeding initiatives.

2. Nutrition Policy and Guidance: Offers a measurable approach for nutrition policymakers to advocate for varieties that can help address micronutrient deficiencies.

3. Raising Consumer Awareness: Supports the extension service in conveying the nutritional advantages linked to specific types of upland rice.

Challenges

1. Interactions between genotype and environment result in variations in nutrient absorption.

2. Balancing yield and nutrient density remain a significant challenge.

3. There is an absence of uniform national datasets for profiling micronutrients.

A current initiative called the All India Coordinated Rice Improvement Project (AICRIP) is aimed at creating a strategy to address these challenges.

Conclusion

Creating a nutrient density score for upland rice within the Indian context requires a collaborative approach that spans multiple disciplines. It is essential for the design to guarantee accurate measurement of nutrients while factoring in their bioavailability and the impacts of processing methods. An efficient nutrient density score design will be crucial for the nutritional breeding of upland rice, contributing significantly to food security for the population in India.

References

1. ICAR-NRRI (2024). Enhancing Nutritional Security through Biofortified Rice Varieties in India. National Rice Research Institute (NRRI), Cuttack, India.https://www.icar-nrri.in/wp- content/uploads/2024/08/NRRI_Research-Bulletin-No-48.pdf
2. EPUBS ICAR (2023). Nutrient Management and Productivity of Upland Rice in Eastern India.
3. Indian Journal of Agricultural Sciences, ICAR Publication. https://epubs.icar.org.in/index.php/IJAgS/article/view/115141
4. FAO (2022). Nutrient Composition of Rice and Its Role in Human Nutrition. Food and Agriculture Organization of the United Nations https://www.fao.org/ag/humannutrition/25340- 068ed1cea3ee10795e47c89db15493d9e.pdf

5. ICAR (2022). Biofortified Varieties of India – Fourth Edition. Indian Council of Agricultural Research, New Delhi.https://icar.org.in/sites/default/files/2022-06/Biofortified-Varieties-4th- Edition.pdf
6. NAAS (2019). Biofortification Strategy for Nutritional Security. Strategy Paper No. 17. National Academy of Agricultural Sciences (NAAS), New Delhi. https://naas.org.in/spapers/Strategy%20Paper%20No.%2017.pdf
7. ScienceDirect (2023).
8. Biofortification and Nutrient Profiling in Indian Rice Germplasm. Current Research in Food Science. https://www.sciencedirect.com/science/article/pii/S266615432500688X.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Predicting Carbon Sequestration Potential Using Generative Models

Article ID: 72714

Jagnyaseni Behera[1], Dr. Antaryami Mishra[2], Dr. Sweta Rath[3], Dr. Ashok Kumar Mahapatra[4]

[1]M.sc. (Ag.) Scholar, Dept. of Soil Science and Agricultural Chemistry, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

[2]Professor, Dept. of Soil Science and Agricultural Chemistry, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

[3]Assistant Professor, Department of Agronomy, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

[4]Professor, Department of Agronomy, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

Abstract

Accurately assessing carbon sequestration potential is important for developing effective strategies for combating climate change in agriculture, power sectors, and geological storage. Traditional statistical and process-based models often fail to adequately capture the nonlinear relationships between climate, soil, crops, and subsurface factors. Latest developments in artificial intelligence, especially generative models create new pathways for resolving these challenges. This article focuses on the emerging importance of generative and hybrid AI models in estimating carbon sequestration capacity, focusing on carbon sequestrating agricultural practices, low-carbon intelligent systems, and the geological storage of CO_2. Combining generative models with sensor information, remote sensing technologies, and specialized knowledge allows for more flexible, scalable, and precise predictions of carbon absorption and storage behaviors.

Introduction

Carbon sequestration refers to the process of trapping and retaining carbon dioxide over extended periods in areas such as vegetation, soils, and geological formations. It is vital for reaching a carbon-neutral status and achieving net-zero emission objectives. Agricultural systems and engineered carbon capture and storage (CCS) technologies represent some of the most promising sequestration approaches; however, their success depends on accurately estimating sequestration potential across different environmental conditions and management practices.

Traditional prediction methods, including linear regression, empirical coefficients, and physics-based simulations, tend to be data-intensive, site-specific, and limited in their adaptability to dynamic systems. While artificial intelligence (AI), especially machine learning, has enhanced prediction accuracy, discriminative models alone face challenges related to data availability and generalization. Generative models offer a transformative approach by learning data distributions and creating synthetic, scenario-aware predictions, making them particularly suitable for forecasting carbon sequestration.

Potential for Carbon Retention in Agriculture

Agricultural systems have the ability to sequester carbon via plant growth and the buildup of carbon in the soil. AI-driven models, such as regression, gradient boosting, and XGBoost, enhance the forecasting of crop carbon sequestration by taking into account the variability in climate, soil, and yields. Generative AI can model potential future scenarios, aiding in the development of climate-resilient agriculture, carbon management, and sustainable land-use strategies.

Predictive Modelling Approaches for Carbon Storage Assessment

Generative AI models distinguish themselves from conventional predictive models by understanding the fundamental data distribution instead of establishing predetermined input-output correlations. This characteristic is especially beneficial in carbon sequestration research, where data is often limited, diverse, and uncertain.

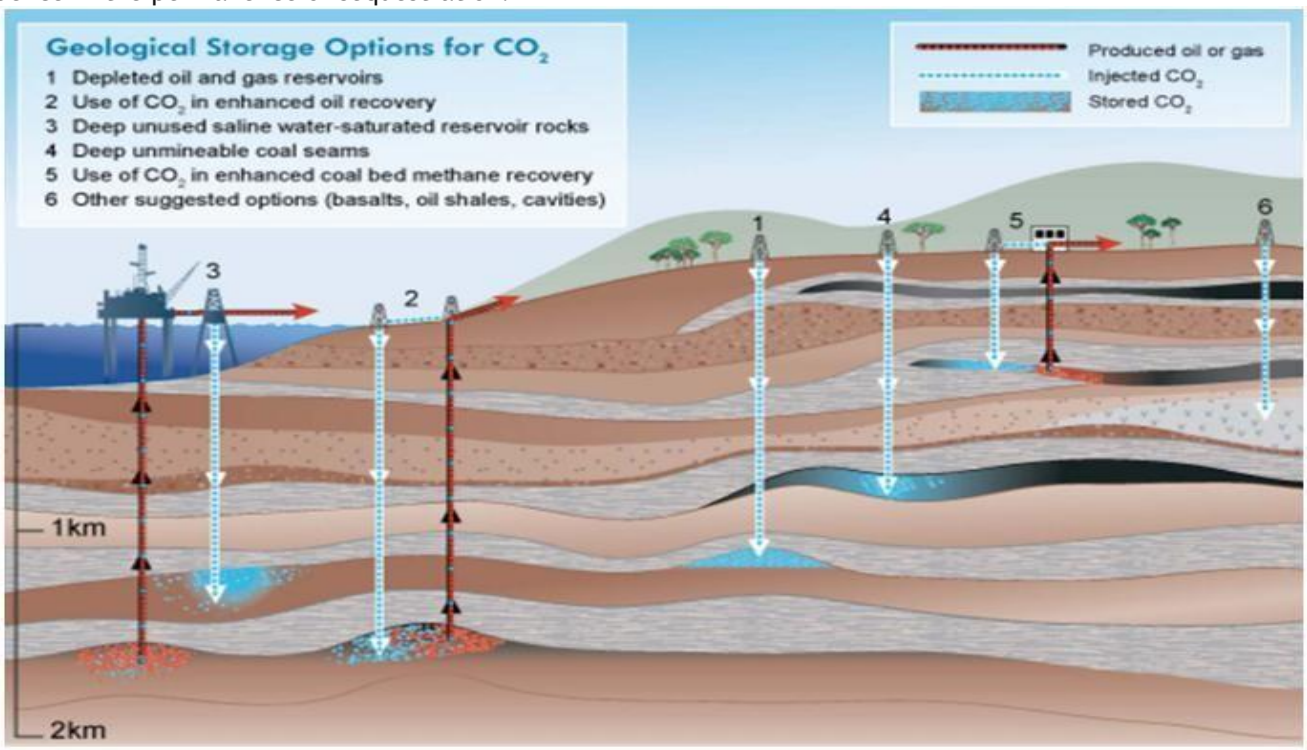
1. Generative Adversarial Networks (GANs): GANs are composed of a generator that creates synthetic data and a discriminator that assesses their authenticity. In the context of carbon sequestration, GANs can produce believable forecasts of future carbon uptake scenarios based on limited observational data. For instance, continuous conditional GANs have been applied to model CO_2 plume migration in geological storage, showcasing their ability to predict sequestration patterns in both space and time under different injection conditions.

2. Variational Autoencoders (VAEs): VAEs facilitate dimensionality reduction and predictions that account for uncertainty by compressing complex environmental data into probabilistic latent spaces. In studies of sequestration, VAEs enable the effective modeling of high-dimensional sensor and remote-sensing information, providing estimates of carbon stocks and anticipating future sequestration potential with measured uncertainty.

3. Diffusion and Large Language Model-Enabled Frameworks: Recent studies emphasize the capacity of diffusion models and frameworks powered by large language models (LLMs) to improve low-carbon systems. By incorporating retrieval-augmented generation (RAG) and specific domain knowledge, these models can dynamically create optimization strategies that reduce emissions and enhance carbon storage efficiency in sophisticated agricultural and energy networks.

4. Application to Geological Carbon Storage: In geological CCS systems, it is crucial to forecast the long-term stability and capacity of CO_2 storage reservoirs. AI-powered generative models are being increasingly employed to analyze seismic, electromagnetic, and distributed acoustic sensing data for tracking plumes and detecting leaks.

Advanced generative architectures, including GANs and neural operators, can efficiently simulate CO_2 migration patterns, providing a computationally efficient alternative to traditional physics-based reservoir simulations. These models facilitate real-time monitoring, early risk identification, and adaptive site management, thereby boosting confidence in the permanence of sequestration.



Types of geological storage options for CCS (adapted from Aminu et al. 2017

5. Advantages of Generative Models in Carbon Sequestration Studies: Generative AI offers numerous benefits compared to traditional approaches:

- **a. Scenario generation:** The capability to model potential future situations concerning climate, yield, and management.
- **b. Data augmentation:** Enhanced learning from datasets that are limited or incomplete.
- **c. Adaptability:** The ability to update dynamically without the need for complete model retraining.
- **d. Uncertainty handling:** Probabilistic predictions of sequestration results.

These advantages make generative models especially well-suited for long-term carbon accounting and policy-focused climate modeling.

Conclusion

Generative AI models signify a groundbreaking method for estimating carbon sequestration potential in both agricultural and geological contexts. By capturing complex, nonlinear behaviors and facilitating scenario-based forecasting, these models improve the dependability and scalability of sequestration evaluations. Their incorporation into carbon farming, CCS oversight, and low-carbon intelligent systems presents a significant pathway towards achieving climate mitigation objectives.

References

1. Senyk Ivan., Borysiak O., Semenenko Y., Pryshliak K., Petrukha N.,Pavlova O. (2025). Assessment of the potential and forecasting of carbon sequestration by agricultural crops using artificial intelligence. *The Second International*

Conference of Young Scientists on Artificial Intelligence for Sustainable Development. https://share.google/eSeHO1hGVTcmeP3r4

2. Aminaho, E. N., Aminu, N. I., & Aminaho, F. (2025). Artificial intelligence based solutions for monitoring CO_2 storage reservoirs: A review. *SSRN Electronic Journal*. April 2025. https://share.google/ud8yP3SLyYo8EU97I
3. Wen, J., Zhang, R., Niyato, D., Kang, J., Du, H., Zhang, Y., & Han, Z. (2024). Generative AI for low-carbon Artificial Intelligence of Things with large language models. *IEEE Communications Surveys & Tutorials, Early Access*, 1–35. https://share.google/TNsZSnsLI0XZxXjmd
4. Shen, C. (2018). A comprehensive review of deep learning research and its significance for professionals in water resources science. *Water Resources Research,* 54(11), 8558–8593.
5. Mo, S., Zabaras, N., Shi, X., & Wu, J. (2019). Deep autoregressive neural networks for addressing high-dimensional inverse challenges in the identification of groundwater contaminant sources. *Water Resources Research*, 55(5), 3857–3881.
6. Willard, J., Jia, X., Xu, S., Steinbach, M., & Kumar, V. (2022). A survey on the integration of physics-based modeling and machine learning. *ACM Computing Surveys*, 55(8), 1–34.
7. Rolnick, D., Donti, P. L., Kaack, L. H., Kochanski, K., Lacoste, A., Sankaran, K., …Bengio, Y. (2022). Addressing climate change through machine learning techniques. *ACM Computing Surveys*, 55(2), 1–96.
8. Zhang, Y., Li, X., Wang, J., & Luo, X. (2023). A review of machine learning applications and challenges in geological carbon sequestration. *Energy Reports*, 9, 4370–4387.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Designing a 3D Soil Temperature-Moisture Cube for Predicting Crop Yield Under Moisture Stress

Article ID: 72715

Tamanna Mohanty[1], Dr. Ipsita Pattanaik[2], Dr. Sweta Rath[3], Dr. Ashok Kumar Mahapatra[4]

[1]M.sc. (Ag.) Scholar, Dept. of Soil Science and Agricultural Chemistry, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

[2]Assistant Professor, Dept. of Soil Science and Agricultural Chemistry, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

[3]Assistant Professor, Department of Agronomy, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

[4]Professor, Department of Agronomy, Faculty of agricultural sciences, Siksha 'O' Anusandhan University, Odisha, India.

Abstract

Moisture stress is one of the main reasons for reduced crop yield, especially under changing climate conditions. Accurate prediction of crop yield under moisture stress conditions is critical for sustainable agriculture. Soil temperature and moisture plays a very important role in plant growth, root development, nutrient uptake, and ultimately crop performance. Traditional approaches often consider these variables separately or in two-dimensional frameworks, which may not capture complex interactions over space and time. This article presents the design and implementation of a 3D Soil Temperature–Moisture Cube — a spatio-temporal data structure that integrates soil temperature and moisture across depths and time to enhance predictive modeling of crop yield under moisture-stress environments.

Introduction

Agriculture today faces serious challenges due to irregular rainfall, rising temperatures and limited water availability. Moisture stress occurs when crops do not receive enough water during critical growth stages,which leads to poor crop growth and yield losses. Soil moisture determines how much water is available to plant roots, while soil temperature affects root activity, microbial processes, and nutrient uptake. Since both factors act together, studying them in an integrated way is necessary. A 3D soil temperature–moisture cube provides a clear picture of how soil conditions change with depth and time, making crop yield prediction more accurate.

Theoretical Background

1. Soil Moisture and Crop Yield: Soil moisture governs water availability to plant roots. Under drought conditions, reduced soil water limits transpiration and photosynthesis, leading to stunted growth and lower yield. Soil moisture dynamics vary by soil texture, organic matter content, irrigation regimes, and climatic conditions.

2. Soil Temperature Effects: Soil temperature affects seed germination, root elongation, microbial activity, and nutrient cycling. Warmer soils within optimal ranges improve plant metabolism, while extremes inhibit growth.

3. Spatio-Temporal Integration: Capturing both soil temperature and moisture over soil depth and time is essential. A 3D data cube allows representation of:

- **a. Depth (Z-axis):** Multiple soil layers (e.g., 0–10 cm, 10–30 cm, 30–60 cm),
- **b. Spatial Location (X-Y axes):** Field/grid coordinates,
- **c. Time (T):** Temporal changes (hourly/daily), forming a four-dimensionally indexed dataset.

Soil moisture directly controls plant water supply. When moisture levels are low, plants experience stress, which results in reduced photosynthesis and growth. Soil temperature influences seed germination, root growth, and biological activity in the soil. Very high or very low soil temperatures can slow down plant development. When moisture stress occurs along with unfavorable soil temperatures, crop yield losses become more severe. Therefore, understanding their combined effect is essential for effective crop management.

Design of the 3D Temperature-Moisture Cube

1. The cube is designed as a three-dimensional matrix:

Cube = f(Location (x,y), Depth (z), Time (t)) → [Temperature, Moisture]

2. Sensing and Data Acquisition: Finding the accurate sensing is critical:

- **a. Moisture Sensors:** Time-Domain Reflectometry (TDR) or Capacitance probes at multiple depths.
- **b. Temperature Sensors:** Thermocouples or digital temperature probes integrated co-located with moisture sensors.

c. **Spatial Grid:** Regular field grid (e.g., 10 × 10 m spacing) for high-resolution spatial data.
d. **Temporal Resolution:** Hourly or daily recording allows dynamic pattern capture.

3. **Data Preprocessing:** It requires Raw sensor data:
   a. **Calibration:** Adjust for soil type and sensor drift.
   b. **Noise Filtering:** Remove outliers using smoothing filters (e.g., moving average).
   c. **Interpolation:** For locations without sensors, we use spatial interpolation to complete the cube.

4. **Using the Cube for Crop Yield Prediction:** Important indicators like moisture stress level, heat accumulation, and rate of soil drying can be extracted from the cube. These indicators are then used in crop yield prediction models. Machine learning methods such as decision trees or neural networks can identify patterns between soil conditions and yield. Crop simulation models can also use cube data to better represent water and temperature stress effects on crops.

Advantages

1. It captures soil conditions at different depths where roots actually grow
2. It explains how moisture stress develops over time
3. It improves yield prediction accuracy
4. It supports timely irrigation and stress management decisions.

Challenges

1. It is costly and Requires high maintenance
2. Data Volume: Large datasets require efficient storage and computation.
3. Calibration Complexity: Soil heterogeneity affects sensor accuracy.

Conclusion

The 3D soil temperature–moisture cube represents a important role to integrate key soil physical parameters across depth, space, and time. When it is applied to predictive modeling of crop yield under moisture stress, it enhances accuracy, helps in decision support, and promotes resilience in farming systems. Continued developments in sensing technologies and analytics will further unlock its potential for precision agriculture.

References

1. Jones, H. G. (2004). Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology.
2. Robinson, D. A., et al. (2003). Soil Moisture Measurement for Ecological and Hydrological Watershed Scale Studies.
3. Hammer, G. L., et al. (2002). Crop Modelling and Decision Support.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Management of Major Insect Pests in Ginger

Article ID: 72716

Kunuru Sai Ganesh[1], Dr. G Vidya[2]
[1]M.Sc. Scholar, Department of Plantation, Spices, Medicinal and Aromatic Crops, PGIHS, SKLTGHU Mulugu (V&M), Siddipet (Dist), Telangana – 502279.
[2]Scientist (H). Turmeric Research Station SKLTGHU, Kammarpally, Nizamabad district.

Introduction

Turmeric *(Curcuma longa)* and ginger *(Zingiber officinale)* are important spice crops widely cultivated for their culinary, medicinal and commercial value. However, their productivity is often threatened by several insect pests that attack different growth stages, from early crop establishment to rhizome development. Among these, a few pests such as the rhizome scale, shoot borer and leaf roller cause major economic losses, while others like thrips, aphids, mites and root grubs are considered minor but can become serious under favorable conditions. Effective management of these pests is essential to ensure good crop health, high-quality rhizomes and sustainable yield.

Shoot Borer		
Scientific Name: *Conogethes punctiferalis* **Order:** Lepidoptera **Family:** Crambidae	**Symptoms:** The major symptoms of shoot borer in turmeric and ginger include small round boreholes on the pseudostem, often accompanied by visible frass. The central shoot begins to wither, leading to a typical dead-heart appearance. Leaves above the damaged portion turn yellow and wilt. Affected plants show stunted growth due to internal feeding by the larva. Severe infestation ultimately reduces rhizome size and overall yield.	**Management:** Regular field inspection and removal of infested shoots, along with the use of pheromone traps to suppress adult moths. Neem based sprays like NSKE 5% or neem oil 3% offer effective eco-friendly control. Biological control agents should be protected by avoiding excessive chemical use. In severe cases, chemicals such as chlorantraniliprole 18.5% SC, spinosad 45% SC or lambda-cyhalothrin 5% EC may be applied with proper safety guidelines.
Rhizome fly		
Scientific Name: *Mimegralla coeruleifrons* **Order:** Diptera **Family:** Micropezidae	**Symptoms:** Rhizome fly infestation include yellowing and wilting of leaves due to larval feeding on rhizomes. Small tunnels or galleries are seen inside the rhizomes, often filled with decayed tissue. Infested rhizomes may become soft, rotten and emit a foul odor. Seed rhizomes show poor sprouting and reduced growth. Severe infestation can lead to significant yield loss and poor-quality rhizomes.	**Management:** Rhizome fly includes selecting healthy, disease-free rhizomes for planting and treating them with insecticides or neem-based solutions. Seed rhizomes can be dipped in carbofuran 3G or chlorpyriphos 20 EC before planting. Field sanitation, deep ploughing, and removal of infested rhizomes help reduce larval populations. Crop rotation and proper drainage also minimize infestation. Biological options like entomopathogenic fungi (Beauveria bassiana) can be used for eco-friendly control.
Rhizome Scale		
Scientific Name: *Aspidiella hartii* **Order:** Hemiptera **Family:** Diaspididae	**Symptoms:** Infested rhizomes show small, circular, brown or black scale insects attached to the surface. Leaves may turn yellow and the plant shows stunted growth due to reduced nutrient uptake. The scales produce honeydew, sometimes leading to sooty mold on leaves and rhizomes. Infested rhizomes become hard, cracked and poorly developed. Severe infestations result in reduced	**Management:** Rhizome scale begins with the use of healthy, disease- and pest-free seed rhizomes. Seed treatment by dipping in hot water at 50°C for 30 minutes helps kill scale insects. Field sanitation, removal, and destruction of infested rhizomes reduce pest buildup. Soil drenching or foliar application of insecticides like chlorpyriphos 0.05% or quinalphos 0.05% is effective in

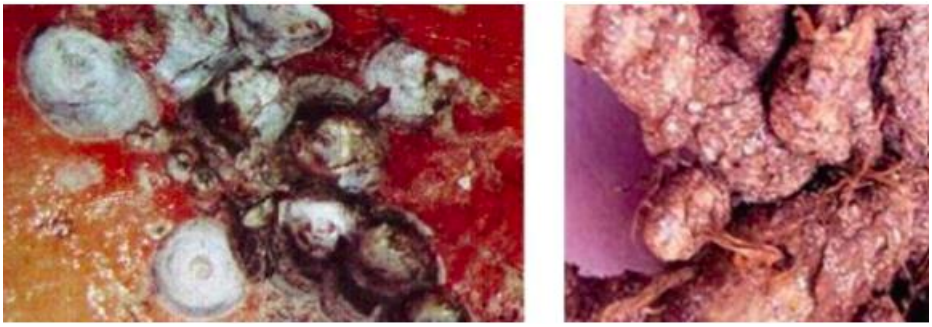
	rhizome size, low yield and poor-quality planting material.	severe infestations. Incorporating neem cake (1 ton/ha) into the soil also provides eco-friendly control and improves soil health.



Shoot Borer



Rhizome fly



Rhizome Scale

References

1. Gautam, J and Mainali, R. P (2016). Management of ginger rhizome fly (Calobata sp) and associated rhizome rot (Pythium sp.), *World Journal of Agricultural Research*. 4(4):128 131.
2. Thangjam, b and nair, n (2020). Insect pests of ginger and turmeric and their management. *Management of Insect Pests in Vegetable Crops: Concepts and Approaches. 43.*
3. Thakur, D and Münzbergová, Z (2022). Rhizome trait scaling relationships are modulated by growth conditions and are linked to plant fitness. *Annals of Botany*. 129(5): 529-540.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

New Approaches in Plant Disease Resistance with Special Reference to Genome Editing

Article ID: 72717

VD Babariya[1], PJ Davaria[2], VC Gadhiya[3], DS Kelaiya[4]

[1&2]Assistant Professor, College of Agriculture, Junagadh Agricultural University, Mota Bhandariya 365 610 (Gujarat).

[3]Associate Professor, College of Agriculture, Junagadh Agricultural University, Mota Bhandariya 365 610 (Gujarat).

[4]Professor and Head, Depoartment of Plant Pathology, College of Agriculture, Junagadh Agricultural University, Mota Bhandariya 365 610 (Gujarat).

Introduction

Since domestication of plants for human use begin, diseases have caused major yield losses (Agrios, 1997). One of the challenge faced by the breeders during the development of improved crop cultivars for agricultural use to incorporation of resistance to diseases. The incorporation of disease resistance genes into plants has been successfully achieved by using conventional breeding methods, which involve selection and evaluation of large progeny populations derived from crosses made between resistant and susceptible parents. With the beginning of the molecular era of plant biology in the early 1980's, a major area of research has been to identify, clone and characterize various genes involved in disease resistance. Many mechanisms, which plants have evolved to respond to pathogen infection, have been identified over the past 10 years and remarkable progress has been made to identify the genes that are involved in these responses and transfer into plant for disease resistance with Genetic engineering. The introduction or change of DNA, RNA, or proteins by human manipulation to effect a change in an organism's genome is known as Genetic engineering. The applications of GE especially for development of disease resistant crop cultivars through gene editing offers novel opportunities to control viral, bacterial and fungal pathogens, parasitic weeds and insect vectors of the plant pathogens.

Genome Editing for Disease Resistance

Yin and Qiu (2019) defined genome editing as a type of genetic engineering in which DNA is inserted, replaced or removed from genome using artificially engineered nucleases or "molecular scissors" in the genome of a living organism.

Application in Agriculture

1. Can be used to create high degree of genetic variability at precise locus in the genome of the crop plants.
2. Potential tool for multiplexed reverse and forward genetic study.
3. Developing biotic and abiotic resistant traits in crop plants.
4. Can be used to eradicate unwanted species like herbicide resistant weeds, insect pests.
5. Potential tool for improving polyploidy crops like potato and wheat.

Types of Designers Engineered Nucleases

1. Mega Nucleases/Homing: Baltes and Voytas (2015) described meganucleases were the first class of sequence-specific nucleases used in plants and they continue to be deployed to achieve complex genome modifications. The DNA binding site overlaps with those for DNA cleavage sites. The most widespread and best known meganucleases were the proteins in the LAGLIDADG family.

2. ZFNs (Zinc finger nucleases): Kim and Kim (2014) mentioned that a zinc finger nucleases (ZFN) had a modular structure that was composed of two domains: DNA-binding and DNA-cleavage domains derived from the *Fok*I restriction enzyme which targeted at that specific site on DNA and induced double stranded breaks that lead to both targeted mutagenesis and targeted gene replacement at remarkably high frequencies.

3. TALENs (Transcription Activator-Like Effector Nucleases): Mussolino and Cathomen (2012) described that Transcription activator like effectors (TALEs) are bacterial proteins that were injected into infected plant cells via a type III secretion system by pathogens of the genus *Xanthomonas*. These proteins were typically composed of N-terminal translocation domain, a central repeat domain that mediated binding to the DNA and a C-terminal transcriptional activation domain. In the cell, these factors recognize DNA targets in the host genome and activate the expression of genes necessary for pathogen multiplication and spread.

4. CRISPR-Cas9 (clustered regularly interspaced short palindromic repeats and CRISPR-associated protein 9): Belhaj *et al*. (2015) elaborated that the most rapidly emerging tool is a bacterial monomeric DNA endonuclease, known as Clustered Regularly Interspersed Short Palindromic Repeats CRISPR-associated protein 9 (Cas9) has two domain DNA-binding which contained Protospacer adjacent motif (PAM), single guide RNA (sgRNA) and DNA-cleavage domain which

had Cas-9 protein that can be targeted to a specific genomic sequence by an easily engineered 20 base pairs (bps) RNA guide sequence and cut at that specific site. CRISPR-Cas9 induced double-strand breaks which are subject to cellular DNA repair processes that lead to both targeted mutagenesis and targeted gene replacement at remarkably high frequencies.

Review of Research Work

Case study 1: Sera (2005) designed artificial zinc finger proteins targeting the replication origin of the *Beet severe curly top virus* (BSCTV) to confer plant resistance against BSCTV and reported that all of the transgenic *Arabidopsis* plants expressing the AZP showed phenotypes strongly resistant to virus infection and 84 per cent of the transgenic plants showed no symptom. Southern blot analysis demonstrated that BSCTV replication was completely suppressed in the transgenic plants.

Case study 2: Wang *et al*. (2016) revealed that rice blast resistance was enhanced through engineering a CRISPR/Cas9 targeting multiple sites within OsERF922 by using Cas9/Multi-target-sgRNAs (C-ERF922S1S2 and C-ERF922S1S2S3) to obtain plants harboring mutations at two or three sites. The results revealed that the number of blast lesions formed following pathogen infection was significantly decreased in all 6 mutant lines compared with wild-type plants at both the seedling and tillering stages.

Case study 3: Ortigosa *et al*. (2019) revealed that *SlJAZ2* is a major co-receptor of COR in stomatal guard cells which provide resistance to bacterial speck pathogen *Pseudomonas syringae* strains Pto DC3000. They edited *SlJAZ2* by using CRISPR/Cas9 to generate *SlJAZ2Δjas* and revealed that *SlJAZ2Δjas* mutant plants prevented stomatal reopening by COR and provided resistance to Pto DC3000. They also observed that water transpiration rate remained unaltered in *SlJAZ2Δjas* mutant plants.

Case study 4: Han *et al*. (2020) used a TALEN-based technique to edit its dominant allelic *TFIIAy5* for reduction of rice susceptibility against rice bacterial blight disease caused by *Xanthomonas oryzae pv. oryzae* (*Xoo*). They found that the knocked-out *TFIIAy5* can reduce the rice susceptibility significantly while, pathogen was able to overcome the resistance of *Xa21* gene, but not that of *xa5* gene and concluded that *TFIIAy5* is a major component involved in disease susceptibility.

Conclusion

In current molecular era, plant pathological events occurring during evaluation and host-pathogen interaction has explained significantly. Although development disease resistance plants has been successfully achieved by using conventional breeding methods. But it involves selection and evaluation of large progeny population for longer period of time to obtain resistance in the progenies.

The introduction of genome editing techniques in the recent past has made changes in time and labour intensive classical plant breeding as they are highly specific, rapid and cost effective. The emergence of ZFNs, TALENs and CRISPR-Cas like gene editing techniques has transformed the plant biology research as they have ability to generate highly specific and efficient mutations as well as provid molecular immunity against the phytopathogens like bacterial leaf blight of rice, bacterial speck of tomato, rice blast and beet severe curly top virus (BSCTV) diseases respectively.

Along with this the precise gene editing technology was successfully applied for functional genomics study, transcriptional regulation, disease and pest resistance and new trait development in model plants as well as cereals, vegetable and fruit crops.

References

1. Agrios, G.N. (1997). Plant pathology. 4th ed. Academic Press, New York.
2. Baltes, N. J. and Voytas, D. F. (2015). *Trends in biotechnology*, **33**(2): 120-131.
3. Belhaj, K., Chaparro-Garcia, A., Kamoun, S., Patron, N. J. and Nekrasov, V. (2015). *Current opinion in biotechnology*, **32**: 76-84.
4. Han, J., Xia, Z., Liu, P., Li, C., Wang, Y., Guo, L., Jiang, G. and Zhai, W. (2020). *Scientific Reports*, **10:** 2036.
5. Kim, H. and Kim, J. S. (2014). *Nature Reviews Genetics*, **15**(5): 321-324.
6. Mussolino, C. and Cathomen, T. (2012). *Current opinion in biotechnology*, **23**(5): 644-650.
7. Ortigosa, A., Gimenez-Ibanez, S., Leonhardt, N. and Solano, R. (2019). *Plant Biotechnology Journal*, **17:** 665–673.
8. Sera, T. (2005). *Journal of virology*, **79**(4): 2614–2619.
9. Wang, F., Wang, C., Liu, P., Lei, C., Hao, W. and Gao, Y. (2016). *PLoS One*, **11**: e0154027.
10. Yin, K. and Qiu, J. (2019). *Phil. Trans. R. Soc. B.*, **374**: 20180322.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Semiochemicals: A Tool for the Management of Pink Bollworm in Cotton

Article ID: 72718

PJ Davaria[1], VD Babariya[2], VC Gadhiya[3], DM Jethva[4]

[1&2]Assistant Professor, College of Agriculture, Junagadh Agricultural University, Mota Bhandariya 365 610 (Gujarat).

[3]Associate Professor, College of Agriculture, Junagadh Agricultural University, Mota Bhandariya 365 610 (Gujarat).

[4]Professor and Head, Depoartment of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh 362 001 (Gujarat).

Introduction

Cotton, 'the king of fibers' usually commercially referred as 'white gold' is a unique natural fiber producing most common fiber crop grown on six continents of the world.

The pink bollworm (PBW), *Pectinophora gossypiella* (Lepidoptera: Gelechidae) is a key pest of cotton accounting for yield losses to the level of 20-90 per cent and has recently emerged as a serious concern for cotton production in India. The insect has its origin from Indo-Pak region and is widely distributed throughout the world. The pink bollworm, hereafter referred as PBW, is a stenophagous insect species which has co-evolved with Malvaceous food plants like cotton, okra, deccan hemp and roselle. From various methods of non-chemical insect control, semiochemical is one of the effective tool in pest management and it fits well in IPM strategies.

Semiochemicals

Semiochemicals are signaling chemicals produced by an organism to send message. They elicit changes in the behaviour or physiology of the receiving organism. Insects use semiochemicals to locate mate, host, or food source, avoid competition, escape natural enemies, and overcome their hosts' natural defense systems. Used to communicate messages over relatively long distances compared with other insect means of communication such as touch. It has two types *viz.*, pheromones and allelochemicals. "Pheromones are exocrine secretions of insects, which are used for communication among different individuals of the same species" (Karlson and Butenandt, 1959).

Different Types of Pheromone

1. Based on changes in insects

- **a. Primer effect pheromones**: Foung in social insects. Eg. Honeybees, termites and ants.
- **b. Releaser effect pheromones**:
  - **i. Territorial pheromone**: Secreted by males of some species to attract female E.g. Males of bumblebees and carpenter bees
  - **ii. Aggregation pheromone**: Produce to bring both sexes together for feeding and reproduction. E.g. Cotton boll weevil and store weevil, pea and bean weevil
  - **iii. Alarm pheromone**: Produce to repeal and disperse other insects in the area. E.g. Ants, aphids and honeybees
  - **iv. Trail pheromone**: It produces a trail that laid individuals towards a source of food or refuge. E.g. Ants
  - **v. Epidiectic pheromone**: Female fruit flies produce this so other females should clutch elsewhere. E.g. Fruit flies
  - **vi. Sex pheromone**: A substance generally produced by male or female to attract for the purpose of mating.

2. Based on functional group:

- **a. Type 0:** It consists of short chain methylcarbinols and methylketones. E.g. Caddisflies.
- **b. Type 1:** C_{12}-C_{18} carbon chain with functional groups – Alcohols, Aldehyde and Acetate. Used in approximately 75% of moths. E.g. Lepidopteran moths.
- **c. Type 2:** Comprising poly unsaturated hydrocarbons and their epoxy derivates. C_{17}-C_{23} hydrocarbons and epoxides. Comprise about 15% of the moth pheromones. E.g. Geometridae, Arctiidae and Cockroach.

3. Based on number of component:

- **a. Monocomponent:** Only One chemical compound. E.g. Silkworm- Bombykol - (10*E*,12*Z*)-Hexadeca-10,12-dien-1-ol ($C_{16}H_{30}O$). *Lymantria dispar* – Disparlure 7,8-Epoxy-2-methyloctadecane ($C_{19}H_{38}O$).
- **b. Multicomponent:** More than one chemical compound. E.g. Ipsenol and ipsdienol in Bark beetle, Gossyplure ($C_{18}H_{32}O_2$) in pink bollworm and Blatellaquinone in Cockroach.

Monitoring

Helps to detect the pest population and the level of infestation. PBW moth activity was observed throughout the crop period from 31st standard week, being more pronounced during 44th to 50th standard week which ranged from 207.50 to 1440 moths/trap/week (Anon., 2016). Monitoring the pheromone traps indicated that the activity has been advanced to as early as August month. However, the peak activity of the pest was consistently high during the end of the season (Radhika and Reddy, 2006).

Mass Trapping

A large number of pheromone traps can be used to capture adult moths and thus reduce the number of males for mating. The traps can be impregnated with insecticides to kill insects falling in traps. The lowest population of PBW was recorded in the month of August and September at Khanewal and Khokhran, respectively. The highest number of moth catch recorded on second fortnight of September (10684/144traps/12ha) and October (1088/30traps/2.4ha) at Khanewal and Khokhran, respectively. (Attique *et al.*, 2000).

Mating Disruption

It is achieved by widespread application of synthetic pheromones over the treated crop. Slow-release pheromone formations permeate air with high level of pheromone so as to provide numerous discrete point sources so as to create false trail. Male moves in a zig-zag flight against the wind towards the source of the pheromone.

Factor Affecting the Effectiveness of Mating Disruption Technique (MDP)

Pheromone dispenser characteristics: The release pheromone into environment is governed by speed of permeation and evaporation (Anonymous, 2007).

Concentration of pheromone in field: Each pest requires different concentration and active substance for success mating disruption (Anonymous, 2007).

Features of the treated area: Size, shape and slope of field, tree size, level of infestation, dispenser application also affects on mating disruption (Anonymous, 2007).

Successful Studies for the Management of Pink Bollworm

Papa *et al.* (1998) reported that only one application of mating disrupt pheromone, used in a dosage of 250 dispenser/ha, reached 80% of control for pink bollworm. The release period of pheromone from dispenser, after the application, was 120 days.

Athanassiou *et al.*(2002) stated that in insecticide-treated field trap catches were notably high, regardless of the sprays application whereas, in the pheromone-treated field, captures were totally suppressed, from the day of dispensers' placement and on.

Patil *et al.* (2003) revealed that the Sirene treated block recorded 7.91% green boll infestation compared to 17.35% in the untreated block. Furthermore, there was a reduction in locule damage to the extent of 52.31%, with a 19.12% increase in seed cotton yield.

Lykouressis *et al.* (2005) stated that the number of male moths caught in pheromone traps was greatly reduced in treated compared to control fields. Mating disruption reached 99.1%, 96.8% and 93.2% in the fields T_1, T_2 and T_3, respectively.

Mohamed *et al.*(2016) recommended that by using only one application of pheromone dispenser during the flowering growth stage of the cotton plants is sufficient to maintain the moth catches and infestation % in green bolls at the lowest level.

Shrinivas *et al.* (2019) found SPLAT technology @500 g/acre as effective mating disruption tool for PBW management.

Meena *et al.* (2021) stated that moth catches were highly suppressed in the treated fields by installation of the dispensers @ 685 PB Rope L at 50 days after crop sowing. These Rope were sufficient to maintain the moth catches and percent green boll infestation at the lowest level as compared to untreated field.

Conclusion

Semiochemicals have the potential to play a role in insect pest suppression through a variety of management strategies. There is a good deal to be optimistic about the prospects for successful implementation of pheromones in management of pink bollworm through monitoring, mass trapping and mating disruption techniques. Careful studies of behavioural responses, dispersion and dispenser performance/longevity will help to inform the decision-making needed for choosing optimal trap deployment locations and trap density. The infestation due to PBW was observed throughout the crop period and thus, this pest can be managed by installing pheromone traps and application of Mating Disruption technologies in cotton field during this period.

References

1. Anonymous (2007). www.jenny.tfrec.wsu.edu/opm/displaySpecies.phppn=-80
2. Anonymous (2016). Annual Progress Report of Entomology, 12th PPSC of AGRESCO of Navsari Agricultural University, Navsari, 6th February, 2016.
3. Athanassiou, C. G., Buchelos, C, T., Kavallieratos, N. G. and Barbetaki, A. E. (2002). *IOBC wprs Bulletien*, **25:** 1-13.
4. Attique, M. R., Ahmad, M. M. and Ahmad, Z. (2000). *Pak. J. Biol. Sci.*, **3**(2): 309-312.
5. Karlson, P. and Butenandt, A. (1959). *Annu. Rev. Entomol*, **4**: 39-59.
6. Lykouressis, D, Perdikis, D., Samartzis, D., Fantinou, A. and Toutouzas, S. (2005). *Crop Protection*, **24**: 177-183.
7. Meena,R. S., Kumar, P., Meena, B. L. and Meena, B. S. (2021). *ASAG*, pp. 24-31.
8. Mohamed, H. O., Heneidy, A. H. E., Ali, A. E. G. and Awad, A. A. (2016). *Egypt. Acad. J. Biolog. Sci.*, **8**(2): 115 – 124.
9. Papa, G., Silva, R. B. and Almeida, F. J. (1998). *Beltwide cotton Conference*, **2**: 1022-1024.
10. Patil, S. B., Udikeri, S. S., Nadaf, A. M. and Khadi, B. M. (2003). Proceedings of the World Cotton Research Conference-3, pp. 1156-59.
11. Radhika, P. and Reddy, B. S. (2006). *Asian J. of Bio Sci.*,**1**(2): 68-69.
12. **Shrinivas, A. G., Hanchinal, S. G., Hurali, S. and Beldhadi, R. V. (2019). *J. Entomol. Zool. Studies*, 7(1): 1043-1048.**

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Artificial Intelligence in Indian Agriculture: Applications, Challenges and Future Prospects

Article ID: 72719

Sandip Saravadiya[1], Dharmishtha Rathod[2], Umang Patel[3]

[1]Assistant Professor (Contractual), Department of Agricultural Economics, College of Agriculture, NAU, Bharuch, Gujarat – 396450.

[2]M.Sc. Scholar, Agricultural Meteorological Cell, Department of Agricultural Engineering, NMCA, Navsari Agricultural University, Navsari, Gujarat – 396450

[3]Assistant Professor, Department of Agricultural Economics, College of Agriculture, SDAU, Tharad, Gujarat – 385506.

Abstract

Indian agriculture is at a critical juncture facing challenges such as climate change, fragmented landholdings, rising input costs, labour shortages and increasing food demand from a growing population. Artificial Intelligence (AI) supported by technologies like Machine Learning (ML), Deep Learning (DL), Internet of Things (IoT), drones and data analytics is emerging as a transformative force capable of addressing these constraints. This article synthesizes key concepts, applications, challenges and opportunities of AI in Indian agriculture, highlighting how AI-driven innovations can enhance productivity, sustainability and farmer livelihoods.

Introduction

Artificial Intelligence refers to the ability of machines and computer systems to perceive, analyze, learn and make decisions in a manner similar to human intelligence (Anand and Raj, 2019). Unlike traditional automated systems, AI continuously improves its performance by learning from data. In agriculture, AI applications range from weather forecasting and soil health assessment to precision farming, robotics and supply chain optimization. (Jain, 2020; Latent view analytics, 2022). Asia accommodates more than half of the global population but possesses only about one-fifth of the world's agricultural land, making food security a pressing concern (World economic forum, 2023). India being an agrarian economy, must adopt advanced technologies to ensure sustainable agricultural growth. AI offers immense potential to modernize Indian agriculture by enabling data-driven decision-making from "soil to shelf" (Anonymous, 2022).

Artificial Intelligence is a broad domain that encompasses several related fields. Machine Learning uses statistical techniques to learn patterns from data and build predictive models. Deep Learning a subset of ML, mimics the human brain through multilayered neural networks and is widely used in image recognition and natural language processing. (Jain, 2020). Data Science integrates mathematics, statistics and computing to extract insights from large datasets. Together, these domains form the technological backbone of AI-driven agriculture (Latent view analytics, 2022).

Current Scenario of Indian Agriculture

Indian agriculture contributes significantly to employment and rural livelihoods, yet it faces persistent structural and technological challenges. The level of farm mechanization in India is only about 40 to 45 per cent which is lower than that of many developed economies (IBEF, 2023). Small and fragmented landholdings, inadequate infrastructure, inefficient market linkages, climate variability and limited access to timely information constrain farm productivity (NASSCOM, 2022). At the same time, the sector is witnessing rapid digital transformation. The rise of agritech start-ups, increased investment flows and government initiatives focused on digital agriculture have created an enabling environment for AI adoption. India received nearly US$ 1 billion in agritech funding, positioning it among the top countries globally in this domain. (Maximize Market Research, 2023).

Need for Artificial Intelligence in Agriculture

The global food demand is projected to increase by 59 to 98 per cent between 2005 and 2050, driven by population growth and changing consumption patterns (World Economic Forum, 2023). Climate change is expected to adversely affect crop yields, making traditional farming practices insufficient to meet future needs. AI-based technologies can improve efficiency, reduce risks and promote climate-resilient agriculture (Anand and Raj, 2019). AI helps optimize the use of resources such as water, fertilizers and pesticides, thereby reducing costs and environmental impacts. It also enhances decision-making by providing real-time insights and predictive analytics, enabling farmers to respond proactively to weather extremes, pest outbreaks and market fluctuations (NASSCOM, 2022).

Applications of AI in Indian Agriculture

1. Weather Forecasting: Accurate weather forecasting is crucial for determining optimal sowing dates, irrigation scheduling, fertilizer application and harvesting. AI powered weather models analyze historical and real-time climate data to generate localized forecasts. This enables farmers to plan farm operations efficiently and minimize losses due to unpredictable weather conditions.

2. Soil and Crop Health Monitoring: Soil quality and nutrient status play a vital role in crop productivity. AI based applications using image recognition and machine learning can diagnose nutrient deficiencies, pest attacks and plant diseases through smartphone images. Such systems also recommend appropriate corrective measures, improving crop health and yield quality.

3. Drone-Based Crop Health Analysis: Drones equipped with advanced sensors and imaging technologies are used to monitor crop health, detect pest infestations and assess field variability. AI algorithms analyze aerial images to generate detailed health reports, supporting timely pest control and precision input application. Drone-based crop phenotyping also aids plant breeders in selecting climate resilient varieties.

4. Precision Farming and Predictive Analytics: Precision farming uses AI driven tools to provide site specific recommendations related to irrigation, crop rotation, nutrient management and harvesting schedules. Predictive analytics helps forecast yields, pest outbreaks and price trends, allowing farmers to make informed decisions and reduce uncertainty.

5. Agricultural Robotics: AI enabled robots are increasingly being developed for tasks such as weeding, spraying, harvesting and sorting. These robots improve operational efficiency, reduce dependency on manual labour and ensure timely farm operations. Robotic solutions are particularly useful in addressing labour shortages and rising wage costs.

6. AI-Based Pest Detection Systems: AI systems analyze satellite images and historical pest data to detect early signs of pest infestation. These systems can identify specific pests and send real-time alerts to farmers, enabling timely intervention and reducing crop losses while minimizing excessive pesticide use.

7. Hydroponics and Controlled Environment Agriculture: AI plays a significant role in hydroponics and vertical farming by automating nutrient delivery, climate control and water management. Sensor data collected from hydroponic systems is analyzed using AI algorithms to maintain optimal growing conditions, ensuring year-round production and efficient resource utilization.

8. Role of Private Players and Start-ups: Several Indian agritech start-ups have successfully integrated AI into their business models. Companies such as Ninjacart, DeHaat, Cropin, Agribolo, Reshamandi, Fasal and Aibono use AI for supply chain optimization, crop advisory services, demand forecasting and quality assessment. These platforms bridge information gaps, improve market access and enhance income stability for farmers. The agritech ecosystem in India has witnessed significant growth, with over 1,000 start-ups and increasing venture capital investments. Despite this progress, total agritech penetration remains low, indicating substantial scope for expansion.

Challenges in AI Adoption

The adoption of AI in Indian agriculture faces several challenges, including limited digital literacy among farmers, high initial investment costs, inadequate rural connectivity and data availability issues. Small and marginal farmers may find it difficult to access and adopt advanced technologies without institutional support. Addressing these challenges requires coordinated efforts from government, private sector and research institutions.

Government Initiatives

The Government of India has initiated several programs to promote digital and AI based agriculture, focusing on data-driven decision-making, smart farming and innovation ecosystems. Public–private partnerships and policy support play a crucial role in scaling AI solutions and ensuring inclusive benefits for farmers.

Conclusion

Artificial Intelligence is poised to play a transformative role in shaping the future of Indian agriculture. By enabling precision farming, improving resource efficiency, enhancing risk management and strengthening supply chains, AI can significantly contribute to sustainable agricultural development. Although challenges related to adoption and infrastructure persist, increasing investments, supportive policies and technological advancements indicate a promising future. Integrating AI into Indian agriculture is not merely an option but a necessity to ensure food security, farmer prosperity and environmental sustainability in the coming decades.

References

1. Anand A. and Raj A., (2019). Artificial intelligence in agriculture: Opportunities and challenges. *Agricultural Economics Research Review*. 32(2):135-144.

2. Anonymous., (2022). Redefining agriculture through artificial intelligence: Predicting the unpredictable. PwC India. https://www.pwc.in/assets/pdfs/grid/agriculture/redefining-agriculture-through-artificial-intelligence.pdf
3. India Brand Equity Foundation (IBEF)., (2023). Indian agriculture and allied sectors overview. IBEF, Government of India. https://www.ibef.org/
4. Jain P., (2020). Artificial intelligence in agriculture: Using modern-day AI to solve traditional farming problems. *Analytics Vidhya*. https://www.analyticsvidhya.com/blog/2020/11/artificial-intelligence-in-agriculture-using-modern-day-ai-to-solve-traditional-farming-problems/
5. Latent View Analytics., (2022). Artificial intelligence in agriculture. *Latent View Analytics*. https://www.latentview.com/blog/artificial-intelligence-in-agriculture/
6. Maximize Market Research Pvt Ltd., (2023). Artificial intelligence in agriculture market: Global analysis and forecast. *Maximize market research. https://www.maximizemarketresearch.com/market-report/artificial-intelligence-in-agriculture-market/25885/*
7. NASSCOM., (2022). Artificial intelligence and data analytics in Indian agriculture. NASSCOM Report. https://nasscom.in/
8. World Economic Forum., (2023). Why artificial intelligence is key to Asia's farming future. *World Economic Forum*. https://www.weforum.org/stories/2023/05/artificial-intelligence-sustainable-farming-asia/

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Seaweed – The Ocean's Gift to Farming

Article ID: 72720

B Chinna Gopi[1], A Uma Maheswari[2]
[1,2]Thirdl year BSc. (Hons.) Agri students, Department of Vignan Institute of Agriculture and Technology, Vignan's University, Guntur, Tenali Road, Vadlamudi-522213 (Andhra Pradesh).

Abstract
Seaweed, often called the "ocean's gift to farming," is rich in nutrients, minerals, vitamins, amino acids, and plant growth hormones that enhance soil fertility, plant growth, yield, and stress resistance. It is widely used in agriculture as a biofertilizer, biostimulant, soil conditioner, foliar spray, seed treatment, and a key input in organic and climate-resilient farming. Globally, countries like China, Indonesia, Japan, Korea, and the Philippines lead in seaweed cultivation, while India, particularly Andhra Pradesh, is promoting it through government support and coastal livelihood opportunities. Despite challenges like limited infrastructure, seasonal constraints, low awareness, and policy gaps, improved technology, training, financial aid, and strong policies can unlock seaweed's potential to boost productivity, sustainability, and rural livelihoods.

Introduction
Agriculture faces challenges like declining soil fertility, climate change, rising costs, and environmental harm from chemical inputs, prompting the need for sustainable alternatives. **Seaweed-based bio-stimulants**, derived from marine macroalgae, have emerged as a promising natural solution, providing essential nutrients, growth-promoting substances, vitamins, amino acids, and bioactive compounds. Unlike chemical fertilizers, seaweed extracts enhance plant metabolism, root development, nutrient uptake, growth, flowering, fruiting, and yield, while improving tolerance to drought, salinity, and temperature stress. Additionally, they enrich soil organic matter, boost microbial activity, and improve soil structure, supporting long-term soil health. With increasing demand for sustainable and organic farming, seaweed serves as an eco-friendly input that reduces chemical dependence and promotes resilient, environmentally safe agriculture.

Nutrient Composition of Seaweed
Seaweed is a rich source of **macro- and micro-nutrients, vitamins, amino acids, natural hormones, polysaccharides, and bioactive compounds** that support plant growth, soil health, and stress tolerance.

1. Macro-nutrients: nitrogen (leaf growth, chlorophyll), phosphorus (roots, flowering), potassium (water balance, disease resistance, fruit quality).

2. Micro-nutrients: zinc, iron, manganese, copper—essential for enzymes, photosynthesis, protein synthesis, and overall plant health.

3. Natural hormones: auxins (root growth), cytokinins (shoot growth, delayed leaf aging), gibberellins (stem elongation, fruiting).

Benefits of Seaweed in Farming
Seaweed-based bio-stimulants offer multiple agronomic, physiological, and environmental benefits, making them valuable for sustainable agriculture. They **enhance root development, nutrient uptake, and overall plant growth** through natural hormones like auxins and cytokinins. Seaweed improves **flowering, fruit set, yield, and crop quality while boosting stress tolerance against drought, salinity, heat, frost, and pests. It also enhances soil health by increasing organic matter, microbial activity, water-holding capacity, and soil structure. Being eco-friendly, biodegradable, and non-toxic, seaweed reduces dependence on chemical fertilizers and supports organic farming. Overall, it promotes healthy plants, higher productivity, improved crop quality, and sustainable, environmentally responsible farming.**

Applications of Seaweed in Agriculture
Seaweed and its bio-stimulants are versatile inputs used across **field crops, horticultural crops, plantation crops, and organic farming systems**. They improve **seed germination, seedling growth, nutrient uptake, stress tolerance, flowering, fruiting, and yield**. Seaweed products are applied as **seed treatments, foliar sprays, soil amendments, or through drip irrigation**, and are available in liquid, powder, or granular forms.



Global Scenario of Seaweed in Agriculture

Global seaweed production has expanded rapidly, reaching about **35.8 million tonnes in 2019**, with nearly **97% produced through aquaculture**. This growth—almost a **1,000-fold increase since 1950**—reflects rising global demand for seaweed, especially in agriculture as bio-stimulants, organic fertilizers, and soil conditioners. **Asia dominates production (97%)**, led by **China (56%)**, followed by Indonesia and other East Asian countries. The global seaweed and extract market is growing strongly, valued at **USD 16.5 billion in 2023** and projected to exceed **USD 30 billion by the early 2030s**, driven by sustainable farming, environmental benefits, and diversified applications in agriculture, livestock nutrition, and climate-smart solutions.

National Scenario of Seaweed in India

India is an emerging seaweed-producing nation, producing about **72,385 tonnes in 2023**, yet contributing **less than 1% of global production** despite having a long coastline of over 8,000 km. Seaweed farming mainly involves species like **kappaphycus** and **gracilaria**, supporting coastal livelihoods and offering strong scope for agricultural uses such as bio-stimulants and organic inputs. The indian seaweed industry is currently valued at around **₹200 crore**, with projections of growth up to **₹3,277 crore** in the next decade, and farmer earnings reaching **₹13.28 lakh per hectare**. Strong policy support under **pmmsy**, research by **icar-cmfri and csir-csmcri**, and an estimated **9.7 million tonnes production potential** highlight india's vast untapped capacity for future expansion.



Constraints of Seaweed Use in Agriculture

1. Damage risk due to storms, cyclones, and seasonal variations.
2. Lack of processing facilities and quality standards.
3. High initial investment and unstable market prices..
4. Limited awareness and technical knowledge among farmers.
5. Inadequate training, extension support, and skilled manpower.

Strategies to Overcome Constraints

1. **Expand cultivation areas:** identify suitable coastal zones and promote scientific seaweed farming.
2. **Strengthen infrastructure:** establish drying, processing, and extraction units near cultivation sites.
3. **Financial support:** provide subsidies, credit facilities, and assured buy-back systems.
4. **Capacity building:** train farmers, shgs, and coastal communities through extension programs.
5. **Standardization:** develop quality standards and recommended application protocols.
6. **Research & innovation:** improve high-yield varieties and develop stress-tolerant cultivation methods.
7. **Environmental regulation:** monitor ecological impact and control invasive species.
8. **Policy support:** simplify licensing, introduce supportive policies, and promote public–private partnerships.

Conclusion

Seaweed-based bio-stimulants represent a sustainable and eco-friendly solution to many challenges faced by modern agriculture. Rich in nutrients, natural growth hormones, and bioactive compounds, seaweed improves crop growth, yield, stress tolerance, and soil health while reducing dependence on chemical fertilizers. Global expansion and strong market growth highlight its increasing importance, and in india, vast coastal resources, supportive government policies, and high income potential for farmers indicate significant future prospects. With improved infrastructure, farmer awareness, research, and policy support, seaweed can play a crucial role in promoting resilient agriculture, enhancing farmer livelihoods, and ensuring environmentally sustainable food production.

References

1. Abobatta, w. F. (2024). *Seaweed extract as a tool for sustainable agriculture*. Joj horticulture & arboriculture, 4(2), 555634.
2. Begum, m., bordoloi, b. C., singha, d. D., & ojha, n. J. (2018). *Role of seaweed extract on growth, yield and quality of some agricultural crops: a review*. Agricultural reviews, 39(4), 321–326.
3. Nath, s. R. M., & ramsubhag, a. (2021). *Biostimulant properties of seaweed extracts in plants: implications towards sustainable crop production*. Plants, 10(3), 531. Mdpi.
4. Rani, v. S., & reddy, a. M. (2024). *Effect of seaweed extract on growth, yield and quality in different field crops: a review*. International journal of research in agronomy, 7(3), 76–79.
5. Supriya, i., singh, m., rakesh kumar, saxena, a., chetan babu, r. T., & meena, r. K. (2023). *Seaweed as bio-stimulant for advancing crop sustainability: a review*. Journal of indian fisheries association, 50(4).
6. Thaimei, t., bokado, k., & bera, b. B. (2024). *Seaweed extract for sustainable rice production-a review*. International journal of plant & soil science, 36(7), 147–160.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Agrometeorological Approaches for Climate-Smart and Climate-Resilient Agriculture: Current Advances, Challenges and Future Directions

Article ID: 72721

Dharmishtha S. Rathod[1], Sandip N. Saravadiya[2]

[1]PG Scholar, Agricultural Meteorological Cell, Dept. of Agricultural Engineering, N. M. College of Agriculture, Navsari Agricultural University, Navsari – 396 450.

[2]PG Scholar, Dept. of Agricultural Economics, N. M. College of Agriculture, Navsari Agricultural University, Navsari – 396 450.

Abstract

Agricultural systems across the world are increasingly exposed to climatic uncertainties arising from rising temperatures, irregular precipitation patterns and frequent extreme weather events. These changes have intensified risks to crop productivity, stability and sustainability, particularly in climate-sensitive regions. Climate-smart and climate-resilient agriculture focuses on enhancing adaptive capacity, improving resource-use efficiency and minimizing climate-related risks. Agricultural meteorology provides a critical scientific framework for understanding atmospheric influences on crop growth and translating weather and climate information into practical farm-level decisions. This review synthesizes recent developments in agrometeorological approaches supporting climate-smart agriculture, including the use of weather parameters, agrometeorological indices, crop simulation models, remote sensing techniques and advisory services. Emphasis is placed on the role of agrometeorology in reducing vulnerability to droughts, heat stress and other weather extremes through early warning systems and adaptive management practices. Strengthening the integration of agrometeorological knowledge with climate-smart agricultural planning is essential for ensuring resilient and sustainable food production under changing climatic conditions.

Keywords: Agricultural meteorology; Climate-smart agriculture; Climate resilience; Crop–weather interaction; Weather-based advisories; Climate variability.

Introduction

Agriculture remains one of the most climate-dependent sectors, with crop growth and productivity closely regulated by atmospheric conditions throughout the growing season. Agriculture is highly sensitive to weather and climate variability, making it one of the most vulnerable sectors to climate change. In recent decades, rising mean temperatures, altered rainfall patterns and an increased frequency of extreme weather events such as droughts, floods and heat waves have adversely affected crop growth, phenology and yield stability across different agro-ecological regions (IPCC, 2014; Lobell and Gourdji, 2012).

These climatic stresses pose a serious threat to food security, particularly in developing countries where agriculture is predominantly rainfed and resource constrained. Climate-smart agriculture (CSA) has emerged as a strategic framework to address the challenges posed by climate change by simultaneously enhancing agricultural productivity, strengthening adaptation and resilience to climate variability and reducing greenhouse gas emissions where feasible (FAO, 2013). The successful implementation of CSA largely depends on an improved understanding of crop–weather interactions and the ability to translate climate information into actionable farm-level decisions.

Agricultural meteorology, which focuses on the study of interactions between meteorological factors and agricultural production systems, provides a scientific basis for climate-smart and climate-resilient agriculture (Hatfield *et al.*, 2011). Weather parameters such as temperature, rainfall, solar radiation, humidity and wind play a critical role in regulating crop physiological processes, soil moisture dynamics and pest and disease incidence. Agrometeorological analyses enable the assessment of climate risks and support the development of weather-based management strategies including optimized sowing windows, irrigation scheduling and contingency crop planning (Aggarwal *et al.*, 2010).

Advances in agrometeorological tools such as weather forecasting, agrometeorological indices, crop simulation models and remote sensing have significantly enhanced the capacity to monitor climate variability and assess its impacts on agricultural systems (Challinor *et al.*, 2014). Furthermore, agrometeorological advisory services have proven effective in minimizing weather-related risks and improving farm productivity by delivering timely and location-specific weather-based advisories to farmers (Venkataraman and Krishnan, 2019). In this context, the present review synthesizes current knowledge on agrometeorological approaches for climate-smart and climate-resilient agriculture, highlighting recent advances, challenges and future directions.

Therefore, this review consolidates existing knowledge on agrometeorological approaches for climate-smart and climate-resilient agriculture, emphasizing their applications, constraints and future potential in addressing climate-induced challenges.

Review Objectives

The objectives of this review are:

1. To examine the role of agricultural meteorology in climate-smart and climate-resilient agriculture.
2. To review agrometeorological tools, indices and weather-based adaptation strategies used in crop production.
3. To identify challenges, research gaps and future opportunities in agrometeorological applications.

Climate Change and Agricultural Production Systems

Climate change has altered temperature regimes, rainfall distribution and frequency of extreme events, directly influencing crop growth and productivity. Increased temperature accelerates crop phenology, shortens growth duration and affects grain filling, while rainfall variability leads to moisture stress and yield instability. Rainfed agriculture is particularly vulnerable, emphasizing the need for climate-responsive agrometeorological interventions.

Applications of Seaweed in Agriculture

Seaweed and its bio-stimulants are versatile inputs used across **field crops, horticultural crops, plantation crops, and organic farming systems**. They improve **seed germination, seedling growth, nutrient uptake, stress tolerance, flowering, fruiting, and yield**. Seaweed products are applied as **seed treatments, foliar sprays, soil amendments, or through drip irrigation**, and are available in liquid, powder, or granular forms.

Agrometeorological Parameters Influencing Climate Resilience

Key agrometeorological parameters such as temperature, rainfall, solar radiation, evapotranspiration and soil moisture play critical roles in determining crop performance. Thermal regimes influence crop development stages, while rainfall and soil moisture availability determine water stress and yield outcomes. Understanding these parameters is essential for developing climate-resilient cropping systems.

Agrometeorological Tools and Indices

Agrometeorological indices such as growing degree days (GDD), heliothermal units and drought indices are widely used to quantify crop–weather relationships. Crop simulation models help assess climate impacts and evaluate adaptation strategies. Remote sensing and GIS tools provide spatially explicit information on crop conditions, moisture stress and weather variability, enhancing decision-making under climate uncertainty.

Weather-Based Adaptation Strategies

Weather-based adaptation strategies include adjustment of sowing windows, efficient irrigation scheduling, selection of climate-resilient varieties and microclimate modification practices. These interventions reduce exposure to climate risks and improve resource-use efficiency, contributing to sustainable crop production.

Agrometeorological Advisory Services

Agrometeorological advisory services integrate weather forecasts with crop management recommendations to support farmers' decisions. Short- and medium-range forecasts delivered through ICT platforms have significantly reduced weather-related risks and improved productivity, especially in smallholder farming systems.

Table 1. Commonly used agrometeorological indices and their applications in climate resilience:

Index	Description	Application in climate-smart agriculture
Growing Degree Days (GDD)	Accumulated heat units during crop growth	Prediction of phenological stages and harvest time
Heliothermal Units (HTU)	Combination of temperature and sunshine hours	Assessment of crop growth efficiency
Moisture Index	Ratio of rainfall to evapotranspiration	Drought monitoring and crop suitability analysis
Standardized Precipitation Index (SPI)	Statistical measure of rainfall anomaly	Early detection of meteorological drought
Heat Stress Index	Indicator of extreme temperature exposure	Evaluation of heat stress risk in crops

Table 2. Agrometeorological tools supporting climate-smart agriculture:

Tool	Purpose	Contribution to climate resilience
Weather forecasting systems	Short- and medium-range prediction	Reduces weather-related production risks

Crop simulation models	Simulation of crop response to climate	Testing adaptation strategies before field application
Remote sensing	Monitoring crop condition and stress	Large-scale assessment of climate impacts
GIS-based analysis	Spatial mapping of climate variables	Regional planning and vulnerability assessment
Agrometeorological advisory services	Weather-based farm advisories	Enhances adaptive decision-making by farmers

Integration with Climate-Smart Agriculture

Agrometeorology supports all three pillars of climate-smart agriculture—productivity, adaptation and mitigation. Weather-based resource management improves efficiency, while climate information aids long-term planning for sustainable and low-carbon agriculture.

Challenges and Research Gaps

Major challenges include limited availability of high-resolution weather data, uncertainties in climate projections, low adoption of technologies and inadequate extension support. Bridging these gaps requires interdisciplinary research, improved data infrastructure and capacity building.

Future Directions

Emerging technologies such as artificial intelligence, machine learning and precision agriculture offer new opportunities for agrometeorological applications. Integrating digital platforms with real-time weather data can enhance the effectiveness of climate-smart agricultural practices.

Conclusion

Agricultural meteorology plays a crucial role in advancing climate-smart and climate-resilient agriculture by providing weather-based insights essential for managing climate variability and extremes. The integration of agrometeorological parameters, indices, crop models and advisory services enables farmers to optimize resource use, reduce production risks and enhance adaptive capacity under changing climatic conditions. Weather-based adaptation strategies such as optimized sowing windows, efficient irrigation scheduling and stress-tolerant crop selection contribute significantly to sustainable crop production.

Despite substantial progress, challenges related to data availability, model accuracy, technology adoption and institutional support continue to limit the full potential of agrometeorological applications. Addressing these constraints through improved observational networks, advanced modeling techniques and farmer-centric advisory systems is essential. Future advancements in digital agriculture, artificial intelligence and precision farming are expected to further strengthen the role of agricultural meteorology in climate-smart agriculture. A holistic and integrated agrometeorological approach will be indispensable for ensuring food security, sustainability and resilience in the face of ongoing climate change.

References

1. Aggarwal, P. K., Singh, A. K., Mukesh, S., & Rani, S. (2010). Climate change and Indian agriculture: Impacts, adaptation and mitigation. *Indian Journal of Agricultural Sciences, 80*(1), 3–17.
2. Challinor, A. J., Watson, J., Lobell, D. B., Howden, S. M., Smith, D. R., & Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change, 4*(4), 287–291. https://doi.org/10.1038/nclimate2153
3. Food and Agriculture Organization of the United Nations. (2013). *Climate-smart agriculture sourcebook*. FAO.
4. Hatfield, J. L., Boote, K. J., Kimball, B. A., Ziska, L. H., Izaurralde, R. C., Ort, D., Thomson, A. M., & Wolfe, D. (2011). Climate impacts on agriculture: Implications for crop production. *Agronomy Journal, 103*(2), 351–370. https://doi.org/10.2134/agronj2010.0303
5. Intergovernmental Panel on Climate Change. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability*. Cambridge University Press.
6. Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiology, 160*(4), 1686–1697. https://doi.org/10.1104/pp.112.208298
7. Venkataraman, R., & Krishnan, P. (2019). Agrometeorological advisory services in India: Relevance and impact. *Mausam, 70*(2), 241–252.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Article on Soilless Cultivation of Vegetable Crops

Article ID: 72722

M. Tulasi Achary[1], Dr. Vijay Bahadur[2]

[1]M.Sc. Research Scholar, Department of Horticulture SHUATS, Naini Agriculture University, Prayagraj-211007.

[2]Professor and Head of Department, Department of Horticulture SHUATS, Naini Agriculture University Prayagraj-211007.

Introduction

Soil is usually the most available growing medium for all kinds of plants. Almost all crops are produced either directly or indirectly in open field soil. Existing level of biotic and abiotic stress in soil severely affect agriculture and horticulture crops. On the other side, shrinking of agricultural urbanization and industrialization. Due to a rapid increase in world population, soil based cultivation facing many challenges. Major challenge is the reduction in per capita land available for soil-based farming. This leads to other agricultural and environmental issues. Need to develop advanced technologies and techniques

Traditional soil-based agriculture, the foundation of global food production for millennia, is facing unprecedented challenges due to rapid urbanization, shrinking arable land, water scarcity, and the prevalence of soil-borne pests and diseases. In response to these pressures, soilless cultivation, a method of growing plants using nutrient-rich water solutions or inert growing media instead of soil, has emerged as a viable and sustainable alternative. This approach offers significant advantages, including higher crop yields, faster growth rates, drastically reduced water consumption (up to 90% less than soil-based methods), and the ability to produce fresh, high-quality vegetables year-round in controlled environments, regardless of local soil or climate conditions. This paper will provide an overview of the technical principles, primary systems (such as Nutrient Film Technique and Deep Water Culture), and specific requirements for the successful soilless cultivation of various vegetable crops.

Soil-Less Cultivation

Definition - "Soil less vegetable cultivation can be defined as "any method of growing vegetable crops without the use of soil as a rooting medium, in which the nutrients absorbed by the roots are supplied through the Irrigation water"

1. Soil less agriculture -new promising method for improving cultivation of different vegetable crops.
2. Can run places like; deserts, balconies, roof of the buildings, various greenhouses and land suitable for cultivation.

History of Soilless Cultivation

1. W. J. S. Duglas during 1946 started hydroponics in India and established a laboratory in Kalimpong area, West Bengal.
2. But commercial hydroponic farms began to emerge in 1960s.
3. Duglas also wrote a book on Hydroponics "The Bengal System".
4. In India, crops such as potato, tomato, green bean, carrot, cucumber, etc., were successfully grown by soilless culture.

Present Day Status of Soilless Cultivation

1. In recent decades, NASA has done extensive hydroponic research for its Controlled Ecological Life Support System (CELSS).
2. In 2017, Canada had hundreds of acres of large-scale commercial hydroponic greenhouses, producing tomatoes, peppers and cucumbers.
3. In the U.S. there are likely more than 100 hydroponic operations that are certified as organic.

Work Done by CPRI

Aeroponic technology for potato seed production at ICAR-Central Potato Research Institute, Shimla.

1. Since 2011, the aeroponics system has been commercialised several companies by CPRI.
2. Currently CPRI produces 3,186.82 tonnes seed of 25 varieties,
3. 70 percent is through conventional net house and field system and 30 percent through high tech and tissue culture-based system.
4. The institute has generated revenue of Rs one crore as licensing fee by commercialization of this technology to 14 firms from different states such as Uttar Pradesh, West Bengal, Punjab and Haryana.

5. Each firm was licensed to produce 10 lakh mini tuber by aeroponic system.

Work Done by IIHR

1. ICAR-Indian Institute of Horticulture Research (IIHR), Bengaluru has developed a variant of hydroponics, "Cocoponics" or the soilless production of vegetables, using cocopeat as a substrate, which has been found to be comparatively more successful in many vegetable crops.

2. The institute has developed a liquid nutrient formulation (Arka Sasya Poshak Ras) for soilless cultivation of different vegetables under open as well as in protected conditions.

3. More than 3,000 urban dwellers, cocopeat producers and hydroponic startups were trained for hydroponic farming at ICAR-IIHR during the last three years through various capacity-building programmes & trainings.

Reasons to Follow Soil-Less Farming

To overcome abiotic stress conditions such as

a. Salinity
b. Drought
c. Rocky and sandy soil
d. Insufficient nutrient availability.

To overcome biotic stress conditions such as:

a. Pest
b. Diseases
c. Shrinkage of farming lands
d. Industrialization
e. Urbanization.

Types of Soilless Cultivation

There are two types of soilless vegetable cultivation system (closed soilless vegetable cultivation and open soilless vegetable cultivation). In brief both the types are discussed in below:

1. Open cultivation System:

a. In this method, diluted nutrients are utilized for every irrigation pattern.
b. The plants uptake nutrient solutions which are usually delivered by dripping system.
c. Adequate amount of nutrients are synchronized in the root zone.

2. Closed cultivation System:

a. In closed soilless vegetable cultivation frameworks, the dissolved nutrient solution are recycled and are observed and balanced in like manner.
b. Diluted concentrations of nutrients are marked and balanced for reuse.
c. Difficult to maintain the calibration of nutrients in a hydroponic system as the dissolved supplements must be tested in a regular time interval to obtain better results.

3. Open cultivation System-

a. Root Dipping Techniques
b. Hanging Bag technique
c. Trench method.

4. Close cultivation System-

a. Hydroponics Technique
b. Aeroponics Technique
c. Aquaponics Technique
d. Bioponics Techniques.

5. Hydroponics Technique:

a. In this system, vegetables are growing without soil. Simply, it is defined as growing of vegetables in water.
b. Plants need vitamins and minerals that soil can provide for them with light, H_2O, Co_2 and O_2 for proper crop growth and development.
c. Inert medium like; rocks or coco coir fibre, peat moss, vermiculite, etc. are used as a growing medium and they are feed a solution containing macro and micro-nutrients.
d. Almost all vegetables can be grown successfully trough hydroponically. It is world widely used by farmers and growers because of various advantages.

Types of Hydroponics Technique

1. Wick system
2. Water culture or deep-water culture
3. Nutrient film technique (NFT)
4. Ebb and flow systems.

Case Study 1

Productivity, Quality and Economics of Tomato (*Lycopersicon esculentum*) Cultivation in Aggregate Hydroponics
Asha Joseph and 1. Muthuchamy
Coimbatore Region of Tamil Nadu
Indian Journal of Science and Technology, Vol 7(8), 1078-1086.

Material and methods: Three different hydroponic systems, i.e., tray, trough & pot and three different media combinations, i.e., cocopeat+gravel+silex stone, cocopeat+pebble+silex stone & cocopeat+perlite+silex stone, constituted the factors of the treatments.

Result:

a. Maximum yield (4.9 kg/plant), highest productivity & highest (benefit cost) B/C ratio (4.52) was observed in cocopeat+gravel+silex stone treatment.
b. This treatment can be adopted for commercial production of tomato.

Aeroponics Technique-

a. The aeroponics system is one of the most advanced type hydroponics system.
b. In this technique, the supplement solution is sprayed to create a fine mist around the root system inside the chamber.
c. Mostly leafy vegetables like lettuce, spinach, etc. are grown.
d. The leading countries in aeroponic technique China and USA.

Aqua agriculture (Aquaponics) Technique-

a. In these techniques' aquatic animals such as snails, fish, crayfish or prawns is grown in tanks with combination of hydroponics in which plants are grown in water in a symbiotic environment.
b. Water from the fish tank is pumped to the plants.
c. Bacteria convert ammonia and nitrite to nitrate.
d. Plants absorb the nutrient rich water.
e. Filtered water is returned to the fish tank, clean.
f. The leading countries in aquaponics are Israel, India. China and Africa.

Bioponics Technique-

a. A bioponics system is a soilless method of growing plants that uses organic matter instead of chemical fertilizers.
b. It works by creating a nutrient-rich liquid through the decomposition of organic materials like food waste, plant matter, or animal hair by microorganisms, which then provide nutrients for the plants.
c. It is similar to hydroponics but relies on biological activity for nutrients rather than manufactured chemicals.

Raising Seedlings of Vegetable Crops using portrays: Combination of 3 ingredients like coco peat, vermiculite and perlite used as medium for raising the nursery. These ingredients are mixed in 3:1:1 ratio before filling in the required containers. Media contains coarse textured peal which provides better drainage and aeration, therefore, promotes better root development of transplants.

Why Soil less Pro-trays Seedlings?

a. Proper germination
b. Provides independent area for each seed to germinate
c. Reduce mortality rate
d. Maintain uniform and healthy growth of seedlings
e. Easy to handle and store
f. Reliable and economical in transportation.

Growing Medium & Its Types: There are different types of growing medium and they are as follows:

a. Coco coir: This medium has excellent moisture holding ability and inert characteristics. It is made from a brown husk of coconut shell.
b. Hydroton: It is most versatile growing mediums in soilless crop production. It easy to absorb water and other nutrient solution, easy in exchange of Oxygen with roots.
c. Perlite: It is inert material having light weight inexpensive growing media. It is porous and has good water retention properties so keeps plants more open to air.

d. Vermiculite: It is natural mineral having lightweight which is used as growing media in soilless cultivation. It is rot resistant growing medium.
e. Peat Moss: Peat moss is made from sphagnum moss that is decomposed in peat bogs over thousands of years.It can holds moisture several times its weight in and releases slowly to the plants roots as required amount.
f. Sawdust: It is made from wood, produced by sawing. It is 100% natural, eco – friendly and easily available soilless growing medium.
g. Rockwool: It is inorganic material soilless growing media which is made into matted fiber It is more expensive than other medium and different from other insulating materials.
h. Coarse Sand: It is used in soilless mixes. It doesn't retain water; however, it improves drainage and aeration.
i. Pea Gravel: It is a small piece of stone having size of the size of a pea about 1*8 inch – 3*8 inch.

Case Study 2

Effect of different soilless growing media and fertigation levels on sweet pepper production under protected conditions
Saurabh
Dr.Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan
(Thesis 2013)

Materials and methods:

a. 15 different combinations were used comprising five growing media
b. Three fertigation levels of 150 kg NPK/ha, 200 kg NPK/ha and 250 kg NPK/ha followed through water soluble fertilizer.

Result: Vermicompost+sand (2:1) Azotobacter+Phosphate Solublizing Bacteria with 250 kg NPK/ha of fertigation developed superior quality of capsicum with increased yield.

Soil less Cultivation of major Vegetable Crops:

Vegetables: Tomato, Chilli, Brinjal, Green Bean, Beet, Winged Beans, Bell Pepper, Cauliflower, Cucumber, Melons, Radish, Onion.
Leafy Vegetables: Lettuce, Water Spinach/Kang Kong, Spinach, Coriander.

Significance of soilless vegetable cultivation:

a. Early nursery raising and easy management.
b. Production of healthy vegetable seedlings (Free from biotic and abiotic stresses).
c. Protect from adverse weather conditions.
d. Off season and year round production.
e. Higher productivity and uniform quality.
f. Management of insect-pests, diseases and weeds is easier.

Limitations of soilless vegetable cultivation:

a. Cost initial investment on hydroponics system is high.
b. Hydroponic production is management, capital & labour intensive.
c. A high level of expertise is required.
d. Daily attention is necessary.
e. Specially formulated, soluble nutrients must always be used.
f. Pests and diseases remain a big risk.
g. Some water borne diseases can spread rapidly in recirculation system.

Way to forward:

a. More and more research work should be done on the subject.
b. Government should take more interest to encourage the produce investing in these types of cultivations.
c. Various types of funding should be made available for promoting establishment of soilless cultivation by Government on large scale:
d. Educational seminars on the topic should be arranged throughout the country to educate more and more farmer so as to increase the soilless type of cultivation.

Conclusion

Soilless vegetable farming may not seem significant at current situation but it has huge potential in the coming generation. It has many pros and cons however, with the gradual decline of fertile land around the world due to advent unmanaged human civilization it becomes necessary to search new alternate technologies and techniques for mass production of vegetable to feed the entire rapidly growing population of the world. If, the advanced new technologies and techniques are applied and inspect properly it will open a doorway to produce different vegetable crops in outer space. Hence, it can be the next-generation vegetable cultivation science.

References

1. P. P. Jagtap, S. R. Bhakar, S. S. Lakhawat 2, P. K. Singh, M. Kothari, Present status and future prospective of hydroponics technique: hope and hype for future welfare, Journal of Postharvest Technology 2022, 10(3): 65-77 www.inhl.in
2. Hydroponics Market Size, Share & Trends Analysis Report By Type, By Crop Type (Tomatoes, Lettuce, Peppers, Cucumbers, Herbs, and Others), By Crop Area, By Region, And Segment Forecasts, 2024-2030
3. Amrita Sengupta and Hirak Banerjee "Soil-less culture in modern agriculture" World Journal of Science and Technology 2012, 2(7):103-108 ISSN: 2231-2587
4. Asher CJ. Limiting external concentrations of trace elements for plant growth: Use of flowing solution culture techniques. Journal of Plant Nutri, 1981, 163-180.
5. http://en.wikipedia.org/wiki/File:Hydroponics_vs_agricultural.jpg
6. http://www.iica.int/Esp/organizacion/DORI/Caribe/Publicaciones%20Region%20Caribe/webHome%20Hydroponics.pdf
7. Islam A, Edwards D, Asher C. pH optima for crop growth. Plant Soil, 1980, 339-357.
8. Jenner G, Starkey N. Nutrient film technique: Practicalities of cadmium. Plant Soil, 1980, 333-342.
9. Jones JB, Wolf N, Milla HA. Plant Analysis Handbook. Micro-Macro Publishing, Inc. Athens, GA, 1991.
10. Maharana L, Koul DN. The emergence of Hydroponics. Yojana (June), 2011, 39-40.
11. Rietveld WJ. A versatile apparatus for static solution systems. Hort. Sci. 1982, 583-585.
12. Rousos PA, Harrison HC. A labor-saving nutrient screening procedure using large-batch solution culture. Hort. Sci, 1986, 319-320.
13. Singh S, Singh BS. Hydroponics – A technique for cultivation of vegetables and medicinal plants. In. Proceedings of 4th Global conference on - Horticulture for Food, Nutrition and Livelihood Options, Bhubaneshwar, Odisha, India, 2012, 220p.
14. Rakocy JE, Masser MP, Losordo TM. Recirculating aquaculture tank production systems: Aquaponics -integrating fish and plant culture. SRAC publication -southern regional aquaculture center, 2006, 16p.
15. Beibel JP. Hydroponics -The Science of Growing Crops without Soil. Florida Department of Agric. Bull. 1960, 180p.
16. Diver S. Aquaponics - Integration of Hydroponics with Aquaculture. Amy Smith, Production. A Publication of AITRA - National Sustainable Agriculture Information Service, 2006. Retrieved from: www. attra.ncat.org.
17. Goddek S, Delaide B, Mankasingh U, Ragnarsdottir KV, Jijakli H, Thorarinsdottir R. Challenges of sustainable and commercial aquaponics. Sustainability (Switzerland), 2015, 4199-4224p.
18. Andre fussy and Jutta papenbrock "An overview of soll and soilless cultivation techniques - chances.challenges and the neglected question of sustainability" 2022.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Trace the Truth: Food Traceability - The Silent Shield Defeating India's Food Adulteration Crisis

Article ID: 72723

Chandra Kumar[1], Prof. Hulas Pathak[1]
[1]Ph.D. Research scholar, Professor and Head of Department, Department of agribusiness and rural management, IGKV, Raipur.

Introduction

Food adulteration is today considered one of the largest threats to food safety and is responsible for a wide range of health problems. Each year, millions of consumers are affected by these practices. From adding detergents to cooking oil or diluting milk with water or using chemicals to ripen fruit; or spraying vegetables with pesticides, food adulteration is a major threat to our health. Traceability is an innovative technology that provides complete transparency, real-time tracking from the farm to your dinner table and full accountability for food scams. Traceability technologies will help prevent the spread of food fraud until scientific testing and feral animal regulations become established. The use of blockchain technology, QR codes, IoT sensors, and AI applications in the traceability process allows rapid recalls of food items, allows consumers to purchase authentic products at premium prices, and restores consumers' trust in their food products. Whether it's protecting the farmer's income, preventing losses from rejected items, or supporting regulatory agency compliance, traceability technology is essential to building a future of safer food systems with no scams.

Exposing Food Adulteration: The Unseen Saboteur

Food adulteration, which involves purposefully spiking, substituting, or depriving foods of their safety, nutrition, and purity, undermines trust. It is widespread in India: processed snacks loaded with prohibited preservatives, fruits force-ripened with toxins, milk diluted with chemicals, and spices laced with phony dyes.

Why it Flourishes?

This crisis is fueled by profit over purity:

1. Desperate sellers are tempted by price chaos.
2. The offenders are concealed by broken chains.
3. Inadequate enforcement allows offenders to get away with it.
4. Farmers, traders, and buyers are blinded by information blackouts.

While consumers blindly gamble on origins and quality, smallholders must contend with harsh margins.

The Reality of Food Adulteration in India

In the Indian context, food adulteration is more than a hypothesis but at other times, data on enforcement may have emphasized the extent of the problem. Madhya Pradesh has shown one in thirty samples did not comply with the level of quality, indicating shortcomings in regulation exist at all levels. Indore authorities seized over 1,300 kgs of adulterated fennel and poppy seeds from an illegal warehouse, showing how contaminated foods make their way through the cracks in the local market. Monitoring through regulation alone has its weaknesses has been highlighted through such events. Prevention on a larger scale, especially in a de-centralized food chain like the Indian market, through monitoring and strict follow-through, which traceability systems accomplish, becomes the need of the hour.

Food Traceability: What is it?

Food traceability involves tracking back to where the food originated, and everything that went into making it. This process continues through each step of its journey from farm to table, including the initial point of production, storage, processing, distribution and finally delivery to the consumer. Currently there are various digital technologies, standardised data formats and unique identification codes being used to create accurate and verifiable records of food product histories and effectively prevent any tampering.

How Food Traceability Serves as a Watchful Eye?

Food traceability uses four clever mechanisms that operate in the background to prevent adulteration without requiring laboratory testing or immediate penalties. Food traceability allows for accountability in all players from farmers through to retailers. Each party has an electronic identity which cannot be hidden or concealed and thus they cannot hide or conceal bad practices. In addition to being accountable, all players provide accurate origin, input and handling data, thereby providing transparency which allows regulators and buyers to easily identify counterfeit products. Additionally,

recall systems allow for only the defective products to be recalled, thus, allowing the product to continue to be sold with less financial harm and fewer health risks when compared to going through an entire shutdown process.

Initiative Taken by Indian Authorities Towards Effective Traceability System

Gs1 standard barcodes are becoming common place. Gs1 India is a non-profit organization with various Government Departments in India that support barcoding standards including the Ministry of Commerce & Industry (MoC), Bureau of Indian Standards (BIS), Confederation of Indian Industries (CII), Federation of Chamber of Commerce & Industry of India (FICCI), Indian Institute of Packaging (IIP), International Marketing Corporation (IMC) and the SPICE Board. To provide safe, secure and sustainable food supply chains globally for consumers, they have established best practices that include the Unique and Universal identification of food products, the Capture of Data, the Transparency of Sharing Information regarding the location, manufacturers or suppliers to achieve seamless products.

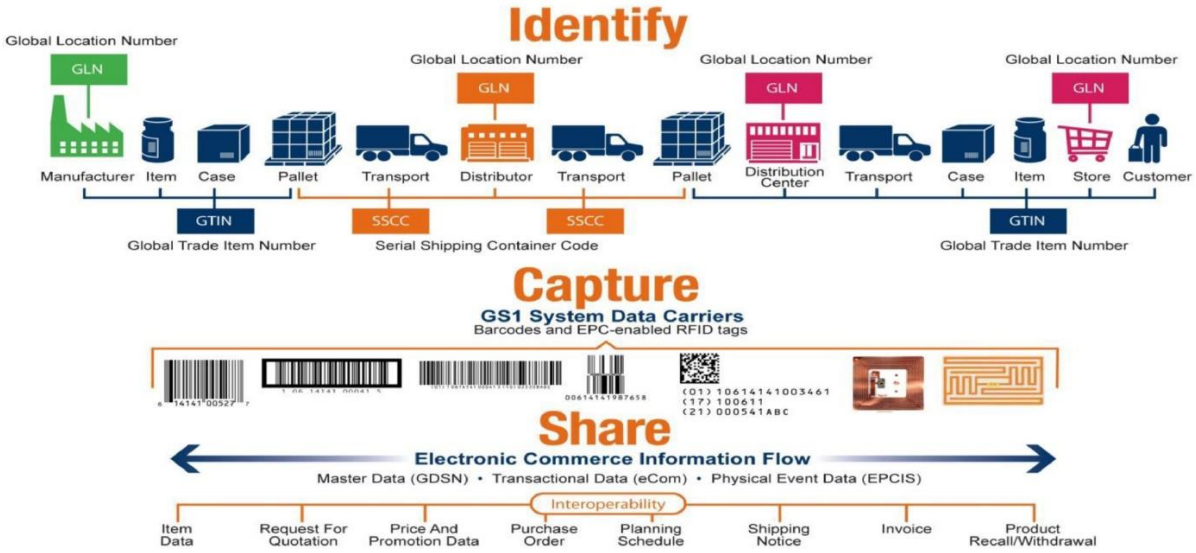


Fig 1: GS1 System Architecture

The following are examples of traceability systems that play a significant role in increasing the safety of food, preventing adulteration and increasing the level of confidence among exporters:

1. Grapenet: The first web-based traceability system specifically developed for the export of fresh table grapes to the EU.

2. Hortinet: An integrated system used for the traceability of a wide range of horticultural products, such as, pomegranates, vegetables, bananas and other types of fruit. o Furthermore, Hortinet allows for the registration of farms, the taking of samples, the testing and certification of exported products to the EU.

3. Tracenet: A traceability system created specifically for organic products to comply with the National Programme of Organic Production (NPOP).

4. Basmati.net: A traceability system for exported basmati rice, focused on ensuring the authenticity of the rice, compliance with geographic indication (GI), and supply chain management, to prevent the risk of adulteration. Collectively, these traceability systems enhance the overall safety of food, reduce the risk of food adulteration and increase the level of trust among exporters - much like Grapenet's (Grapenet's Silent Guard) role.

Traceability's Powerhouse Benefits: From Profits to Pride

Food Traceability has significant economic and strategic advantages that enhance both profit and pride in the agricultural sector. Many countries importing agricultural products mandate traceability; therefore, India's Agri-export commodities such as Basmati rice, grapes, peanuts, spices, and marine products must be traceable. Traceability serves to empower farmers through certification, and this assists farmers in realizing higher prices for their certified products. Traceability also assists in creating trust and confidence on the part of consumers, sustainability in terms of traceable organic, residue-free, and fair-trade farming practices and this is because traceable food products are currently associated with food safety, food ethics, and food security. Despite challenges in implementing traceability in India, it has the potential to provide enormous benefits to farmers by boosting transparency, market value, and competitiveness.

Challenges to Implementing Traceability

An Indian agricultural supply chain characterized by significant fragmentation, smallholder farming dominated, and the presence of digital infrastructure and digital literacy in rural areas at a limited level with high initial technology costs and problems of accuracy and verification of traceability data. To break through these barriers, measures such as

creating an inclusive system, building public-private partnerships, training farmers, and having a constantly supported policy environment are necessary.

Future Outlook: From Traceability to Trustability

Tracing food is just about tracking the journey each product takes from the farm to the retailer. As technology continues to advance, it is anticipated that more will be incorporated into future systems to create a food trustability ecosystem by incorporating the use of AI, prediction analytics and real-time sensors to create early warning systems that will detect potential issues of adulteration. Traceability offers multiple points for innovation - for students and researchers it provides multiple disciplines for learning, for farmers, traceability enables better pricing and greater recognition of their quality and for policymakers' traceability provides tools for creating a preventative framework for governance. Ultimately, for consumers, traceability creates a level of sustainable based confidence in their daily food choices.

Conclusion

The traceability of food is key to establishing a safe and sustainable food system in India, with the ultimate goal of providing consumers with transparent and reliable information about where their food comes from. The use of technology (blockchain, Internet, IoT, QR codes, and AI) enables consumers to trace their food origins. Traceable food system in India, the government can establish trust in the food supply system and keep food free from adulteration. India has developed several systems to support accountability in the food supply chain. These include Grapenet, Hortinet, Tracenet, and Basmati.net. These systems improve digital accountability which can lead export ability of India, maintain the integrity of its products, and meet international food safety standards. While there are still challenges to be addressed i.e., fragmented supply chains, lack of digital literacy, and high costs of technology continued investment in infrastructures, training farmers, and establishing public/private partnerships will ultimately help strengthen the implementation of food traceability. By building a transparent food system, traceability not only protects consumers, but it also allows farmers to receive premium prices for their products, while providing society with a foundation for safe and ethical food production.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Recent Trends Organic Farming in Vegetable Crops for Sustainable Production

Article ID: 72724

Ashitamitra[1], Prof (Dr). Vijay Bahadur[2]
[1]M. Sc. Research Scholar; Department Horticulture (Vegetable Science), Shuats.
[2]Proffessor, Department of Horticulture (Vegetable Science), Shuats, Pryagraj-211007.

Organic farming is an agricultural system that avoids synthetic fertilizers, pesticides, and genetically modified organisms (GMOs), relying instead on natural processes and materials to grow crops and raise livestock. This holistic approach focuses on building healthy soil through practices like crop rotation, using compost, and incorporating nitrogen-fixing cover crops, while also prioritizing environmental protection and higher animal welfare standards.

Need of Organic Farming

With the increase in population our compulsion would be not only to stabilize agricultural production but to increase it further in sustainable manner. The scientists have realized that the 'Green Revolution' with high input use has reached a plateau and is now sustained with diminishing return of falling dividends. The obvious choice for that would be more relevant in the present era when these agrochemicals which are produced from fossil fuel and are not renewable and are diminishing in availability.

The Four Principles of Organic Agriculture

Principle of health: Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. This principle points out that the health of individuals and communities cannot be separated from the health of ecosystems - healthy soils produce healthy crops that foster the health of animals and people.

Principle of ecology: Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. This principle roots organic agriculture within living ecological systems. It states that production is to be based on ecological processes, and recycling.

Principle of fairness: Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings.

Principle of care: Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. Organic agriculture is a living and dynamic system that responds to internal and external demands and conditions.

Components of Organic Farming

1. Crop Rotation: It is the method of growing several types of crops in the same area, according to different season in a sequential way. Here land is fixed but crop is rotated year after year according to their demand of nutrients and water. It helps to check the erosion, improves soil fertility and stabilizes income.

2. Green Manuring: Green Manuring is a process cultivating the plants and crops and which are uprooted and ploughed into soil to make them decomposed and act as organic matter and make source of nutrients for the soil to increase its quality. e.g. juncea, cowpea and other leguminous crops.

3. Composting: Compost is highly rich in nutrients and works as organic material. It is commonly used for manuring in crops. It can be made by decomposing farm waste, vegetables waste, food waste and crop residues onto a certain temperature and humidity for a certain period under controlled conditions.

4. Mulching: It is a process of covering the soil by any type of crop residues or plant material. It checks evaporation from soil surface, provides more favourable conditions for the best growth of the plant and after decomposition works as organic matter in soil.

5. Bio-fertilizers: There are some living micro-organisms, which provide nutrients to plants when applied to the seeds, plant surface or soil. They colonize on the plant's parts, roots and promotes plant growth by increasing the supply or availability of primary nutrients to the plants. e.g., Azolla, Blue Green algae etc.

6. Biological Pest control: It is a method in which micro-organisms are used to control diseases without use of chemical. Some beneficial insects are useful to control harmful insect by parasitizing on various stages of harmful insects or feeds direct to the insects.

7. Weed Management: Weed is the unwanted, unsown and undesirable plant that grows on field and competes with crops for space, nutrients, water and sunlight. Organic farming focuses on reducing the population of weeds by living organisms but not to using chemical herbicides for preventing and not removing them completely.

8. Vermicompost: - Vermicompost is the product of composting processes using various species of earthworms especially red earthworms, to create mixture of decomposed vegetation or food wastes. Earthworms are called "Farmer's Friend". Earthworms help to improve soil conditions by maintaining soil texture and structure with good aeration.

9. Soil Management: Soil is the soul of organic farming. It is well known fact that after taking one crop, the soil of farm loses most of its nutrients and its fertility becomes down. So, it is necessary for management of soil by manuring or other practices after harvesting of crops.

10 Livestock production: Organic farming proposed to keep domestic animals use to increase the sustainability of the farm. Livestock plays a vital role in organic farming. The products of the animals like dung (act as Organic material and having many nutrients), urine (rich source of nitrogen) are useful for making compost manure.

Types Of Organic Farming

1. Pure Organic Farming: Pure organic farming strictly adheres to using only naturally derived inputs and completely avoids all artificial or synthetic chemicals. Synthetic fertilizers, pesticides, herbicides, and genetically modified organisms (GMOs) are completely prohibited.

Types of Pure Organic Manure:

a. Organic Manure- Farmyard manure refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. On an average well decomposed farmyard manure contains 0.5 per cent N, 0.2 per cent P2O5and .0.5 per cent K2O.

b. Green Manure- Green manuring can be defined as a practice of ploughing or turning into the soil undecomposed green plant tissues for improving physical structure as well as soil fertility. Green manuring, wherever feasible, is the principal supplementary means of adding organic matter to the soil. Eg- Cowpea, Sunhemp, Indigo etc.

c. Neem Oil - Neem oil is a natural pesticide and fungicide for organic farming, derived from the neem tree's seeds. It is a biodegradable and broad-spectrum insecticide that works by disrupting pest life cycles, repelling insects, and acting as a fungicide against diseases like powdery mildew and root rot.

d. Bone Meal - Bone meal is a valuable organic fertilizer for organic farming, primarily providing slow-release phosphorus and calcium to promote strong root development, flowering, and fruiting. It also contains other essential nutrients, improves soil structure, and helps balance soil acidity.

e. Oil Cakes -Many oil cakes such as the castor, neem, madhuca, karanja, linseed, rape seed and cotton seed which are non-edible oil cakes may serve as useful organic manure as these contain high amounts of plant nutrients.

f. Vermicompost - Vermicompost is a nutrient-rich, organic fertilizer produced by earthworms breaking down organic matter, and it is widely used in organic farming to improve soil quality and plant health. In organic farming, it enhances soil structure, water retention, and aeration, while supplying essential nutrients, growth-promoting substances, and beneficial microbes. This leads to improved plant growth, yield, and resilience to pests and diseases.

2. Integrated Organic Farming: Integrated organic farming is a more holistic approach that combines various natural farming methods to create a self-sustaining, cyclical, and zero-waste system. It aims to meet both ecological requirements and economic demands.

Types Of Integrated Organic Farming:

a. Permaculture - Permaculture is an ecological design system that adopts the practices of organic farming but goes beyond them to create self-sustaining, integrated human habitats. It emphasizes a holistic, systems-thinking approach to ensure the long-term sustainability of the land and its people, often focusing on food self-sufficiency and minimal waste.

b. Agroforestry - Agroforestry enhances organic farming by integrating trees with crops to improve soil health, boost biodiversity, and increase system resilience and productivity. This synergistic approach reduces reliance on synthetic inputs by creating a more sustainable and stable agroecosystem, while also providing environmental benefits like carbon sequestration and better water management.

c. Mushroom And Crop Integration - Mushroom and crop integration for organic farming uses agricultural waste to grow mushrooms, which are then integrated with traditional crops, creating a sustainable system that reduces waste, improves soil health, and increases farmer income. The process enhances soil fertility, suppresses diseases, and reduces the need for chemical inputs, leading to a more resilient and eco-friendly farming system.

d. Aquaculture - Aquaponics is a sustainable and organic farming method that integrates aquaculture (raising fish) and hydroponics (growing plants in water). The system works by using fish waste, which is converted into nitrates by beneficial bacteria, to fertilize the plants. The plants then purify the water for the fish, creating a symbiotic, closed-loop system that uses up to 90% less water than traditional farming and eliminates the need for chemical fertilizers and pesticides.

e. Biosensing - Biosensing in organic farming uses devices to monitor plant health and soil conditions, detecting issues like nutrient deficiencies, diseases, and pests early to enable targeted, sustainable management. These

technologies, often incorporating nanomaterials, provide real-time data for farmers to make informed decisions, reducing the need for broad-spectrum chemical pesticides and fertilizers.

f. Zero Budget Natural Farming- Zero Budget Natural Farming (ZNBF) means raising crops without using any fertilizers and pesticides or any other external materials. The word Zero Budget refers to the zero cost of production of all crops.

Types of Zero Budget Natural Farming

1. Panchakavya - Panchagavya, an organic product has the potential to play the role of promoting growth and providing immunity in plant system. Panchagavya consists of nine products viz. cow dung, cow urine, milk, curd, jaggery, ghee, banana, Tender coconut and water.

2. Brijamruta - Bijamruta is a low-cost liquid organic formulation which is prepared by using locally available ingredients which are readily available on the farm like cow dung, and cow urine. It protects plants from seed- borne diseases during initial stages of germination and establishment stage results in to good yield.

3. Jeevamruta - Jeevamruta is a natural soil fertilizer and a crop growth enhancer. It is a bio-fertilizer rich in microorganisms that help improve the soil fertility and the productivity of the crop. Jeevamrut is a low-budget preparation that enriches the soil, helps to grow microorganisms, and improves the mineralization of the soil. Jeevamrut is prepared from native cow urine, dung, jaggery, and horse gram.

4. Mulching - Mulching is the process of covering the topsoil with plant material such as leaves, grass, twigs, crop residues, straw etc. A mulch cover enhances the activity of soil organisms such as earthworms.

5. Soil Aeration - Soil aeration is the process of improving soil structure to allow for better air, water, and nutrient exchange with the atmosphere, and it is crucial in organic farming to support plant and microbial health.

a. Precision Agriculture- Precision agriculture is a farming technique that utilises cutting-edge technologies like GPS, Internet of Things, and artificial intelligence to optimise organic farming's productivity and efficiency. By offering in-depth insights into field variability, drones and satellite imagery enable targeted interventions and cut down on resource waste.

b. Automation and Robotics- Organic farming is undergoing a revolution thanks to automation and robotics, which precisely and reliably carry out labor-intensive operations. Robotic weed eaters, autonomous tractors, and harvesting robots minimise soil compaction and need less physical labour.

c. In-Vessel Composting - In-vessel composting is an enclosed, highly controlled method ideal for organic farming due to its rapid process, efficient pathogen destruction, minimal odor/pest issues, and production of high-quality, nutrient-rich compost.

d. Biocontrol and Biostimulants Sustainable substitutes for chemical pesticides are provided by biocontrol agents such microbial inoculants and beneficial insects. Seaweed extracts and humic acids are examples of bio-stimulants that increase plant resilience and growth by improving nutrient uptake and stress tolerance.

e. Rice-Duck Farming- Rice-duck farming is an organic system that integrates raising ducks with growing rice, providing natural pest and weed control, soil fertilization, and enhanced soil quality. Ducks eat pests, trample weeds, and their droppings provide nutrients, while their movement in the paddy improves soil aeration and nutrient absorption.

f. Livestock Integration - Organic livestock farming offers numerous benefits for the environment, animal welfare, and human health. By avoiding the use of synthetic pesticides, hormones, and antibiotics, organic farmers promote a more natural and sustainable approach to animal husbandry.

Organic Certification Process

1. Receipt of application form: the farmer intending to get his farm organically certified must apply to the organic certification board. The documents required for applying are duplicate of application form, Pan card, Annual cropping pattern, Field map, General details of the farm, Soil and water analysis report, Chitta (land documents), a written annual production plan must be submitted, detailing everything from seed to sale.

2. Scrutiny and registration of application: the application received along with the others farm or field details are verified by the inspector if it meets the requirements then the application is forwarded for the registration. For the registration the farmer must pay a prescribed amount. Once the farm is registered it must be strictly maintained under the organic conditions only.

3. Inspection and evaluation of the farms and documents: annual on-farm inspections are required, with a physical tour, examination of records, and an oral interview is done. Record keeping written, day-to-day farming and marketing records maintained and will be checked, the farmers must have covered all activities like biodiversity conservation and buffer zone.

4. Sampling of soil, water and plant products if necessary: if the certification officers doubt that the grower has done a malpractice then he has all the right to collect the soil, water and plant sample. Analysis of plant and soil sample will

be done and if the results indicate the presence of any chemicals or toxic substance then their certificate will be taken back.

5. Issue of certificate to eligible organic farms: if the grower has maintained his farm purely under organic condition, then a certificate will be given to him assuring others that he is an organic grower.

Registration can be Done by

1. Individual farmers: The farmer willing to register a field under organic must be a legal owner of the land and there no limit of area for certification.

2. Group: All the members of the group must be within the revenue district and no restriction on the area for certification but numbers of farmers with more than 10 ac of land should be less than 50 per cent of total area of group.

3. Corporate bodies: Group of farmers can come together and register as a corporate body. They can produce organically, process and sell but there should be an office setup to monitor the activities.

Agencies for Certification

Sl. No	Certifying agency	Place	Year of Establishment
1	Bureau Veritas (India) Pvt. Limited	Mumbai, Maharashtra	Dec 19, 2001
2	ECOCERT India Pvt. Ltd.	Haryana, India	April 4, 2008
3	IMO Control Pvt. Ltd.	Bangalore, Karnataka	1948
4	INDOCERT	Ernakulam, Kerala	2001
5	Lacon Quality Certification Pvt. Ltd.	Thiruvalla, Kerala	Jan 4, 2005
6	OneCert International Private Limited	Jaipur, Rajasthan	Oct 4, 2014
7	Uttarakhand State Organic Certification Agency (USOCA)	Dehradun, Uttarakhand	March 14, 2001
8	Indian Society for Certification Organic Products (ISCOP)	Coimbatore,Tamil Nadu	Jan 6, 2003
9	TQ Cert Services Private Limited	Secunderabad, Telangana	Feb 2003
10	Chhattisgarh Certification Society, India (CGCERT)	Raipur, Chattisgarh	Sept 18, 2003
11.	Argencert	Argentina	1991
12.	California Certified Organic Farmers (CCOF)	California	1973
13.	International Federation of Organic Agriculture Movements (IFOAM)	Germany	1972
14.	Agricultural and Processed Food Product Export Development Authority	New Delhi	Feb 13, 1986

Status of Organic Farming in India

India's economy is based primarily on agriculture, which also provides a substantial amount of employment and GDP to the nation. More than half of the nation's workforce is employed in this industry, which has long served as the primary means of subsistence. India's unique topography, climate, and soil conditions have led to a reputation for its wide range of agricultural approaches. Crops such as rice, wheat, legumes, and cotton are among the most widely produced in the nation. The government began to encourage organic agricultural practices by holding programs, offering training, and adopting various schemes after recognizing the impact of using chemical fertilizers on the land. Madhya Pradesh is the leading state in terms of land used for organic agriculture. Rajasthan, Gujarat, and Maharashtra are next. Sikkim State is regarded as the first in India to embrace 100% organic farming.

1st Organic State of India

Sikkim is the first organic state in the world. All of its farmland is certified organic. At the same time, Sikkim's approach reaches beyond organic production and has proven truly transformational for the states and its citizens. In 2003, Sikkim officially adopted a resolution to switch to organic farming. The policy implemented a 'phase-out' of chemical fertilizers and pesticides and soon achieved a total ban on the sale and use chemical pesticides in the state. The same year, Sikkim also stopped all imports of chemical fertilizers. Since then, the farmers of the state have been using organic manure. In 2010, the State Government launched the ***'Sikkim Organic Mission'***. The Sikkim Organic Mission was launched to fast-track its journey towards achieving the 100% organic tag. The Mission helped by providing seeds and manure and training farmers inorganic methods. Besides proving transformational for public health and environment in the region, organic

farming is also attracting a large number of tourists to the state who throng to see its lush, green farms, pure and organic agro products, and meals made out of fresh produce. Between 2015 and 2017, the number of tourists in Sikkim went up by 50%.

Benefits of Organic Farming

Environmental benefits:

a. Reduces pollution: By avoiding synthetic pesticides and fertilizers, organic farming keeps air, water, and soil cleaner. Chemical runoff is significantly reduced, protecting waterways and marine life.

b. Improves soil health: Practices like composting and crop rotation increase soil fertility, improve structure, boost water retention, and reduce erosion and degradation.

c. Boosts biodiversity: Organic farms support a greater diversity of plant and animal life, including beneficial insects like pollinators, because they avoid synthetic chemicals.

d. Mitigates climate change: Organic farming systems use less energy and release fewer greenhouse gas emissions compared to conventional farming.

Health and nutritional benefits:

a. Lower pesticide residues: Organic produce has lower levels of synthetic pesticide residues.

b. Potentially higher nutrients: Some studies suggest that organic crops can have higher concentrations of antioxidants and certain nutrients.

c. No GMOs, additives, or preservatives: Organic standards prohibit the use of genetically modified organisms, as well as most synthetic additives and preservatives.

d. Healthier working conditions: Organic farms create a safer, non-toxic working environment for farmworkers.

Economic and social benefits:

a. Supports local economies: Organic farming can create jobs and support local food systems.

b. Premium prices: Organic products often command higher prices, which can improve farmer income.

c. Long-term sustainability: By focusing on soil health and resource conservation, it provides a more resilient and sustainable model for future food production.

Limitations of Organic Farming

1. Lower yields: Organic farming often produces lower crop yields per hectare compared to conventional farming, particularly during the first few years of conversion.

2. Vulnerability to pests: Without synthetic pesticides, organic farms are more susceptible to pests and diseases, requiring more labor-intensive management practices.

3. Higher production costs: Organic farming typically requires more labor for tasks like weeding, crop rotation, and pest control, which increases overall costs.

4. Certification costs: Obtaining and maintaining organic certification can be expensive and time-consuming, which can be a significant financial burden for farmers.

5. Knowledge and skills: Organic farming requires a deep understanding of soil systems, ecology, and other factors, and a lack of this knowledge can lead to crop failure.

Conclusion

Organic farming is a sustainable approach to agriculture that benefits the environment and human health by improving soil quality, increasing biodiversity, and reducing pollution. While it faces challenges like lower yields and higher labor intensity, its long-term advantages, including the production of healthier food and its growing market appeal, make it a crucial path towards a sustainable food future. Organic agriculture is a living and dynamic system that responds to internal and external demands and conditions. Practitioners of organic agriculture can enhance efficiency and increase productivity, but this should not be at the risk of jeopardizing health and well-being. Consequently, new technologies need to be assessed and existing methods reviewed. To advance organic agriculture and reach its full potential in the twenty-first century, cooperation and ongoing research will be crucial. With ever increasing population having huge requirements of vegetables and availability of organic resources, pure organic farming is not possible in India; rather some specific area can be diverted to organic farming for providing of high-quality vegetable crops to consumer.

References

1. Nair, P. K. R. (1993). An introduction to agroforestry. Springer.
2. Bongiovanni, R., & Lowenberg-Deboer, J. (2004). Precision agriculture and sustainability.
3. Lal, R. (2015). Restoring soil quality to mitigate soil degradation. Sustainability, 7(5), 5875-5895. 9. Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change.
4. Gomiero, T., Pimentel, D., & Paoletti, M. G. (2011). Environmental impact of different agricultural management practices: conventional vs. organic agriculture.

5. Kozai, T. (2013). Plant factory: An indoor vertical farming system for efficient quality food production
6. Parmentier, S. (2014). Scaling-up agroecological approaches: What, why and how? Oxfam-Solidarity.
7. Crowder, D. W., & Reganold, J. P. (2015). Financial competitiveness of organic agriculture on a global scale.
8. Hattam, C., Vetter, S., & Morison, J. (2016). Regulatory frameworks for organic agriculture. International Journal of Agricultural Sustainability.
9. Koch, H., Tischer, M., & Schmid, J. (2018). Biocontrol and biostimulants in organic farming. Journal of Applied Microbiology
10. Sahota, A. (2019). The global market for organic food & drink. In The World of Organic Agriculture. Statistics and Emerging Trends 2019
11. Duckett, M. (2020). Agricultural robotics: The future of farming. Automation in Agriculture.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Host Plants of Muga – The Green Gold Behind Golden Silk

Article ID: 72725

Anil Kumar S T[1], Suraksha Chanotra[2], Dharavath Saicharan[3]
[1]Scientist-B, Central Silk Board, P3 Unit, Narayanpur, Lakhimpur, Assam.
[2]Scientist-B, Central Silk Board, P3 Unit, Kowabil, Kokrajhar, Assam.
[3]Scientist-B, Central Silk Board, SSPC, Kaliabari, Boko, Assam.

Introduction

Muga silkworm is a polyphagous insect and feeds on a wide range of host plants (Borpuzari *et al.*, 2020). Muga silk, often called the **"Golden Silk of Assam"**, is one of the finest natural silks in the world. Known for its natural golden shine, durability, and cultural significance, it has been an integral part of Assamese heritage for centuries. But behind every shimmering thread of Muga lies another treasure — the **green host plants** that feed the silkworms. These trees and shrubs are the lifeline of Muga culture and are often referred to as the **"Green Gold of Assam."** These food plants are naturally abundant in north-eastern India both in plains of Brahmaputra basin and in eastern Himalayan ranges. The food plants are found in warm and humid conditions with high rainfall and acidic soils (Singh and Maheshwari 2003). The Muga food plants are also classified into primary and secondary host plants.

Primary Host Plants

1. Som (*Persea bombycina*), Family: Lauraceae:

Som is the **principal and primary host plant** of the Muga silkworm (Tikader *et al.*, 2013). Its tender, nutritious leaves ensure healthy growth of the larvae and yield superior quality cocoons. Farmers prefer Som because silkworms reared on its leaves produce stronger, shinier silk. Som plantations are carefully maintained, often like orchards, since they directly determine the quality and quantity of Muga silk.



Som (*Persea bombycina*)

2. Soalu (*Litsea polyantha*), Family: Lauraceae:

Soalu is also the **primary host plant** of the Muga silkworm silkworm (Tikader *et al.*, 2013). It is widely grown in both homestead plantations and forested areas. In certain seasons, Soalu leaves are considered better than Som because of their availability and tolerance to weather conditions. Together with Som, Soalu forms the backbone of commercial Muga rearing.



Soalu (*Litsea polyantha*)

Secondary Host Plants

While Som and Soalu dominate, the Muga silkworm can also feed on several other plants. These are often used during leaf scarcity or in specific regions:

1. **Dighloti** (*Litsea salicifolia*)
2. **Mejankari** (*Litsea citrata*)
3. **Bihlongoni** (*Litsea sebifera*)
4. **Pipli** (*Litsea monopetala*)
5. **Dhekia** (*Litsea cubeba*)

These secondary hosts ensure that Muga rearing continues even in adverse conditions, though silk quality may be slightly affected compared to Som and Soalu.

Why they are Called Green Gold?

1. These host plants are the foundation of Muga silk, without these plants, Muga silkworms cannot survive.

2. Just as the silkworm transforms the green leaves into shimmering golden threads, farmers transform plantations into sustainable livelihoods of thousands of farmers.

3. These trees enrich biodiversity, prevent soil erosion, and support a healthy ecosystem

4. Just as Muga silk is woven into Assamese traditions, the host plants are seen as protectors of heritage.

Like veins carrying life, these green plantations fuel the golden threads that drape Assamese identity.

Conservation and Challenges

Today, the availability of healthy host plants is one of the biggest challenges for Muga silk culture. Rapid urbanization, deforestation, and shifting agricultural practices are reducing natural plantations. Farmers also face problems like:

1. Leaf diseases and pests

2. Poor soil fertility affecting plant growth

3. Seasonal scarcity of tender leaves

To address this, government agencies and research institutes are encouraging **systematic plantation of Som and Soalu**, scientific pruning methods, and integrated pest management. Community-based plantation drives are also helping to preserve this Green Gold.

The Future of Golden Silk Depends on Green Gold

The journey of Muga silk begins not in the rearing house but in the green plantations of Som and Soalu. Protecting and expanding these host plants means ensuring the future of Assam's pride—Muga silk. For every golden thread that shines in a traditional Mekhela Chador, there are countless green leaves that made it possible. Truly, the **Green Gold of Assam is the silent partner behind the Golden Silk.**

References

1. Borpuzari, P., Das, M. R., Hussain, H., & Rahman, A. (2020). Performance of muga silkworm on different host plants under different rearing seasons with respect of rearing performance and chemical constituents. *Journal of Entomology and Zoology Studies*, *8*(2), 1254-1258.
2. Singh, R. N., & Maheshwari, M. (2003). Conservation and utilisation of sericigenous insects in northeast region of India. *Sericologia*, *43*(1), 1-28.
3. Tikader, A., Vijayan, K., & Saratchandra, B. (2013). Improvement of host plants of Muga silkworm (Antheraea assamensis) for higher productivity and better adaptation-A Review. *Plant Knowledge Journal*, *2*(2), 83-88.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Dragon Fruit: The Exotic Superfruit

Article ID: 72726

Dr. Sarika J. Donga[1], Dr. Ila L. Pithiya[1]
[1]Assistant Professor, Polytechnic in Horticulture, JAU, Junagadh -362001.

Introduction

Dragon fruit is the Wondrous Fruit of the 21st Century and is set to ring in a revolution in the Indian Horticulture Scenario. Its plant is attractive due to its exotic appearance. It was initially used as ornamental plant and latter due to its health benefits and market value emerged as a new fruit crop. Owing to its rich nutrient contents and antioxidant properties, it is emerging as a super fruit worldwide. Belongs to the family Cactaceae, basically, it is perennial semi epiphytic climbing cactus vine. It is tolerant to abiotic stresses and resistant to pests and diseases. It has many advantages including low water and nutrient requirements, relatively less requirement of resources for establishing the orchard and maintenance; multiple harvest of fruit in a year; potential to sustain high yield up to 20 years; high benefit to cost ratio; and high nutraceuticals and functional properties (e.g. rich in antioxidants and fibres). All these qualities are attracting the growers worldwide to establish and expand dragon fruit farming, provide opportunity for global export and encourage for high quality produce to meet the market demand. Dragon fruit is also known as Kamalam, Red Pitahaya.

Dragon fruit has great potential as a new crop for Mediterranean growers due to the requirement of little water and well adaption to high temperatures. There are different types of dragon fruit like most Hylocereus species have red-purple pigmented skin, while the pulp color ranges from white (in *H. undatus*) to red and purple (in *H. polyrhizus* and *H. costaricensis*).

Dragon fruit is an excellent source of vitamin C and therefore are abundant with minerals, particularly calcium supplement as well as phosphorus. Also, it is a good source of natural pigments in food processing, due to their high content of betalains. Pitahaya is considered a promising crop to be grown commercially in dry regions. This species is found to have high water-use efficiency. One of the pitahaya mechanisms to secure water requirement is developing aerial roots from the sides of the stem to collect water from the surroundings. Pitaya fruit has red or pink thornless skins, while its juicy flesh can range from white to magenta. The skin is covered with bracts or scales. The fruit has a very attractive colour and a fluffy pulp with a black edible seed embedded in the pulp with huge nutrient properties. Dragon fruits consist of phytoalbumins, which may have anti-oxidant qualities which help to stop the development of cancer cells. Dragon fruit also reported to have health benefits including prevention of memory losses, control of blood glucose level in diabetic patients, prevention of oxidation, aiding in healing of wounds etc.

Dragon Fruit Production in India

Gujarat, Karnataka and Maharashtra are the leading producers contributing about 70% of India's dragon fruit production the water-scarce areas of Kutch in Gujarat, Northern Karnataka, and Western Maharashtra are major dragon fruit growing regions of the country. Overall, southern and western states are contributing a major share to the production of dragon fruit since they have been growing dragon fruit for the last 5-8 years. For example, more than 600 farmers from Karnataka alone have taken up dragon fruit cultivation in the last five years after seeing the performance of the fruit. In Karnataka, the area under dragon fruit cultivation was about 8-10 ha during 2012, amplified to about 500 ha in 2020 and it is likely to reach around 5000 ha in the next five years. Presently over 200 farmers in Gujarat's Kutch are cultivating this fruit in approx. 800 ha of land.

Cultivation Practices for Dragon Fruit Cultivation

Soil requirement: Dragon fruit could be grown in a wide range of soils, but the soil should be well drained as water logging for long period hampers its growth and favours rotting of stems. The sandy loam soil, rich in organic matter is good for its commercial cultivation. The soil pH of 5.5-6.5 is optimum. It is very shallow rooted crop; mostly roots are confined up to 40 cm, therefore, depth of soil may not be problem for cultivation. It prefers slightly acidic soil and can tolerate some salts in soil.

Climatic requirements: Being originated from tropical rainforest regions, cultivation of dragon fruit is commercially good in areas with sufficient rainfall. But over time, this fruit crop has been acclimatized well in dry climates with low rainfall also. About 500-1500 mm of rainfall with proper distribution is good for its growth. Excess water leads to the abscission of flowers and young fruits. 20-30 °C temperature is optimum for the cultivation. It can be cultivated up to altitude of 1700 m above mean sea level. Evaluation studies on dragon fruit in relevance to adaptability and production aspects was under taken Coorg, Karnataka. Dragon fruit plant prefers a dry tropical climate with an average temperature of 20-29 °C, but can withstand temperatures of 38-40 °C and as low as 0 °C for short periods. The plants will be damaged at temperatures above 40 °C, cause yellowing of the stem. Heavy rain fall areas are not suitable for the crop, as excessive rain causes flower drop and fruit drop.

Land preparation: Before planting land should be given 2 to 3 deep ploughing. The field is weed free and it is better to have a fence around the field to protect from any predators. Dig the pit and fixed pole then add manures and fertilizers around pole before planting. Plantation of plantlets around the pole in four direction. Prepare the beds of 45-50 cm high and 3 meter broad but it may be various according to rainfall conditions. Full sunlight open area is very suitable for planting. Number of poles depends on the spacing. Poles should have 12 cm in diameter and 2 meter long. These poles should at least 1.4 to 1.5 meter high from ground level.

Propagation: The dragon fruit can be propagated by sexual (by seed) as well as asexual (by cuttings and tissue culture) means. The seed propagated plants are not true to type and possess longer juvenile period. The best and fastest way of multiplying the dragon fruit is by cuttings. 15-30 m long and slant cut stem are used for planting. The cutting should be prepared one-two days prior to planting. Pile up cuttings 1-2 days prior to potting. Mature stem is more resistant to insect and snail damage. Should be collect early in the morning. Can be obtain through the year. Preferable to collect cutting after fruiting season of mother plant. IBA encourage quick rooting formation (10-15 instead of 40-50 days). Dry cow dung, top soil and sand (1:1:2).

Easiest and cheapest method. Start fruiting 1-2 year after planting. True to type plant. Develop root system within 3 to 4 months. Though seed propagation method is very simple but seeds are not true to type due to cross pollination.

Planting: Rainy season with the onset of monsoon (June to August), is the best time for planting but it can be planted in other seasons too with the provision of irrigation. It is a semi epiphytic vine plant; therefore support system needs to be erected before planting. Around the pole, 2-4 plants should be planted in pits of (0.5 x 0.5 x 0.5 m) which are filled with top soil along with FYM and other fertilizers. After planting of cuttings, regular watering in basin prepared around plants is required to ensure satisfactory rooting. Planting can be done at 2.5 × 2 m, 3 × 1.5 m, 3 × 3 m, and 4 × 3 m etc. Therefore, as per the situations planting can be done at above spacing. This result was showed that the higher planting density until 1,815 trellis plants/ha was not affected the average fruit weight of red pitaya.

Manure and fertilizer: There are different fertilizers doses are observed in different countries. Generally 1 to 2 year old plants should be given 10 to 15 kg of FYM and for >3 year old is should be given 20 kg FYM. It can be grown organically without applying chemical fertilizers and pesticide. These organic fruits have more demands in the market. Oil cakes, beneficial micro-organisms and organic manures performed very well in dragon fruit. In India, ICAR-NIASM, Pune (MS) has recommended dose for dragon fruit grown in rocky degraded lands in which for first two years, 500 g urea and 500 g P and 300 g K is applied to each pole per year in four splits at three months interval. After two years each pole/year should be fertilized with 800 g N, 900 g P and 550 g K, which should be well distributed in six splits=

Irrigation requirement: It is having high water use efficiency and low water requirement compare to C3 and C4 crops. It develops aerial roots from the sides of the stem to collect water from the surroundings and for anchorage. It requires only 10 % of the water required by most of other fruit crops such as pear, citrus, peach, etc. 120 to 150 mm of irrigation/year is recommended to meet its water requirement. Dragon fruit is very shallow rooted crop, its water requirement and frequency of irrigation is higher than other cacti. Small quantity of irrigation at shorter interval is more effective to ensure proper growth and higher fruit yields. Flowering and fruit enlargement stages are the critical stages. Micro-irrigation is recommended to avoid uneven and excess watering that can result in flowers and early fruit drop.

Flowering & Fruiting: Hermaphrodite nature of flowers. Flowering in flushes and it depend on the species and age of plant. The blooming of is affected by temperature and light intensity. There are self- compatible and self-incompatible varieties. Pitaya is pollinated by moths, flies and bees in the evening and hand pollination can enhance fruit set and size. The flowers start with on small spiral button type attract structures at the stem margins. These develop to flower buds in 10-15 days. The beautiful hermaphrodite nature flowers length (25-30 cm), white inside and greenish yellow with purple dyes on the outside. They are scented and only blooming at night and last one only night. Flower production generally takes place during May-August and fruit harvest 30-40 days after fruits set. Quality of the fruit does vary between varieties, but harvest time has a much greater effect on quality than varietal differences. There are self-compatible and self- incompatible varieties. There is considerable variation in fruit size and shape between the varieties.

Training and Pruning: Plants are fast-growing vines and produce thick dense of branches during the initial stage. The lateral buds and branches should be pruned to grow towards stands. Once vines reach up to the top of the stands the branches are then allowed to grow. The removal of tip of the main stem is done to allow growth of new shoots to grow laterally and climb at the ring to form an umbrella like structure of vines. The post-harvest pruning encourages the growth of

new young shoots that will bear flowers the following year. The well grown vine may produce 30 to 50 branches in one year and may be more than 100 branches in-four years. Plant is a climbing cactus with segmented stem. They have aerial roots used to attach themselves to supports. It has a life span of 15-20 years and weight of one plant may be goes up to 100kg.

'T' stands: 'T' shape structure of the stand. Plant planted between the two poles. Initial investment is high, around 6-6.5 lack/acre. After 4th year become clouded and chances of insect pest attack. Not prefer by the farmers.

Continuous pyramid stands: Continues type Stands are made of G.I. pipe and G.I. angles can also be used. This pyramid shape with a length of 10-15 meter. More number of plants may be planted. Provided adequate aeration to avoid disease and pests. Plant may be planted at 2-3 feet distance both the sides of the structure. The distance between two structures maybe 5-6 m.

Harvesting: The harvesting time mostly falls between July-November, which comes in 6-7 flushes. During initial fruit development period, the outer skin of immature fruit looks bright green in colour and gradually turns 85% pick as the ripening progress. The dragon fruit is matured 30- 35 days after flowering. Simply move the fruit in clock wise direction and twisting the fruit cause less or no injury to the fruits. An additional advantage of the crop is that depending upon the market demand, there is a scope for adjusting the harvesting time. For local market, fruit can be harvested three to four days after the skin colour changes from green to red/pink colour, while for far markets/export purpose it can be harvested a day after colour change.

Yield: It is a fast-return perennial fruit crop. In well-managed orchards, the flowering may start from 2nd year onwards and potential yield can be realized in 2nd or 4th year. The average yield can be 10 to 12 tonnes/ha. But in well managed commercial orchards the yield of 16-27 tonnes/ha can be possible from 3rd year onwards under favorable climatic and properly managed conditions Average weight of fruit is 300 800 g.

Processing and value addition: Dragon fruit pulp and juice with a solution containing 1.5 percent pectin, 55% sugar and 0.9 percent citric acid solution improved the colour as well as other organoleptic characteristics of dragon fruit jam and jelly. In the case of dragon fruit RTS beverage 14 percent pulp, 12 percent sugar and 0.9% were found to be most suitable. The prepared product was found to be organoleptically acceptable. Prepared products can be stored for a period of more than three months at ambient storage conditions without microbial spoilage or any considerable loss in quality. The fruit pulp is used to make juice, wine, jam, jelly, candy, syrup and preserve. Peel has utilization for the extraction of natural food colorant as well as a source of pectin. Seeds are mainly utilized to extract the oil from it which contains about 50% essential fatty acids. Also, the seeds have application as an ingredient in many food products such as syrup, ice cream, sherbet, candy, yoghurt and pastries.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Water Management in Agriculture

Article ID: 72727

Ms. Monu Kanwar[1]
[1]M.Sc. Research Scholar, CCAS-MPUAT UDAIPUR.

Abstract

The increasing demand for freshwater, driven by growing global populations and rising drought conditions in agricultural regions, has made water use efficiency in irrigated agriculture crucial. Irrigated agriculture is often wasteful, limiting water access for other sectors. Smart irrigation systems, incorporating wireless technologies, monitoring tools, and advanced control strategies, offer significant potential for improving water efficiency. This paper reviews the latest smart irrigation and monitoring methods for optimal irrigation scheduling. It finds that closed-loop control strategies are more efficient than open-loop systems, which fail to address uncertainties. Combining soil, plant, and weather-based monitoring with model predictive control can further enhance water use efficiency. This review offers guidance to researchers and farmers in selecting the best irrigation strategies for open field systems. The increasing demand for freshwater, driven by growing global populations and rising drought conditions in agricultural regions, has made water use efficiency in irrigated agriculture crucial. Irrigated agriculture is often wasteful, limiting water access for other sectors. Smart irrigation systems, incorporating wireless technologies, monitoring tools, and advanced control strategies, offer significant potential for improving water efficiency. This paper reviews the latest smart irrigation and monitoring methods for optimal irrigation scheduling. It finds that closed-loop control strategies are more efficient than open-loop systems, which fail to address uncertainties. Combining soil, plant, and weather-based monitoring with model predictive control can further enhance water use efficiency. This review offers guidance to researchers and farmers in selecting the best irrigation strategies for open field systems.

Introduction

Agriculture plays a crucial role in the global economy, contributing significantly to GDP and ensuring food security. However, it is also the largest consumer of freshwater, accounting for 70% of global water use to irrigate 25% of cropland. With climate change and population growth intensifying pressure on water resources, the demand for both food and water will continue to rise. The FAO projects a 50% increase in irrigated food production by 2050, which will require a 10% rise in agricultural water use, provided water productivity improves. As land for agriculture remains limited, efficient use of water and land is essential to meet the needs of a growing population. Improving water use efficiency (WUE) is critical, with WUE defined as the ratio of irrigation water requirements to actual water withdrawal, and it can be applied at various scales, from individual plants to national levels. Researchers have focused on improving WUE, particularly as water scarcity varies globally due to climate change. As competition for water increases, precision agricultural technologies have become essential in enhancing WUE (FAO, 2020a; Hatfield and Dold, 2019; Evans and Sadler, 2008).

Precision agriculture integrates technologies like sensors, information systems, and advanced machinery to optimize production and conserve resources. Smart irrigation, a key component of precision agriculture, enables the efficient application of water by accounting for variations in soil moisture, weather conditions, and plant needs. Unlike conventional irrigation systems, which apply water without considering the spatial and temporal variations in soil and weather, smart irrigation ensures that water is applied at the right time, in the right amounts, and at the right location. This approach helps prevent over-irrigation, *which leads to issues* like fertilizer leaching and water runoff, while also avoiding under-irrigation, which can stress plants and reduce crop yields. By adopting these modern irrigation and monitoring strategies, water use efficiency can be significantly improved, contributing to sustainable agricultural practices (Pierce, 2010; Singh *et al.*, 2019; Vories *et al.*, 2021).

Challenges in Agriculture Water Management

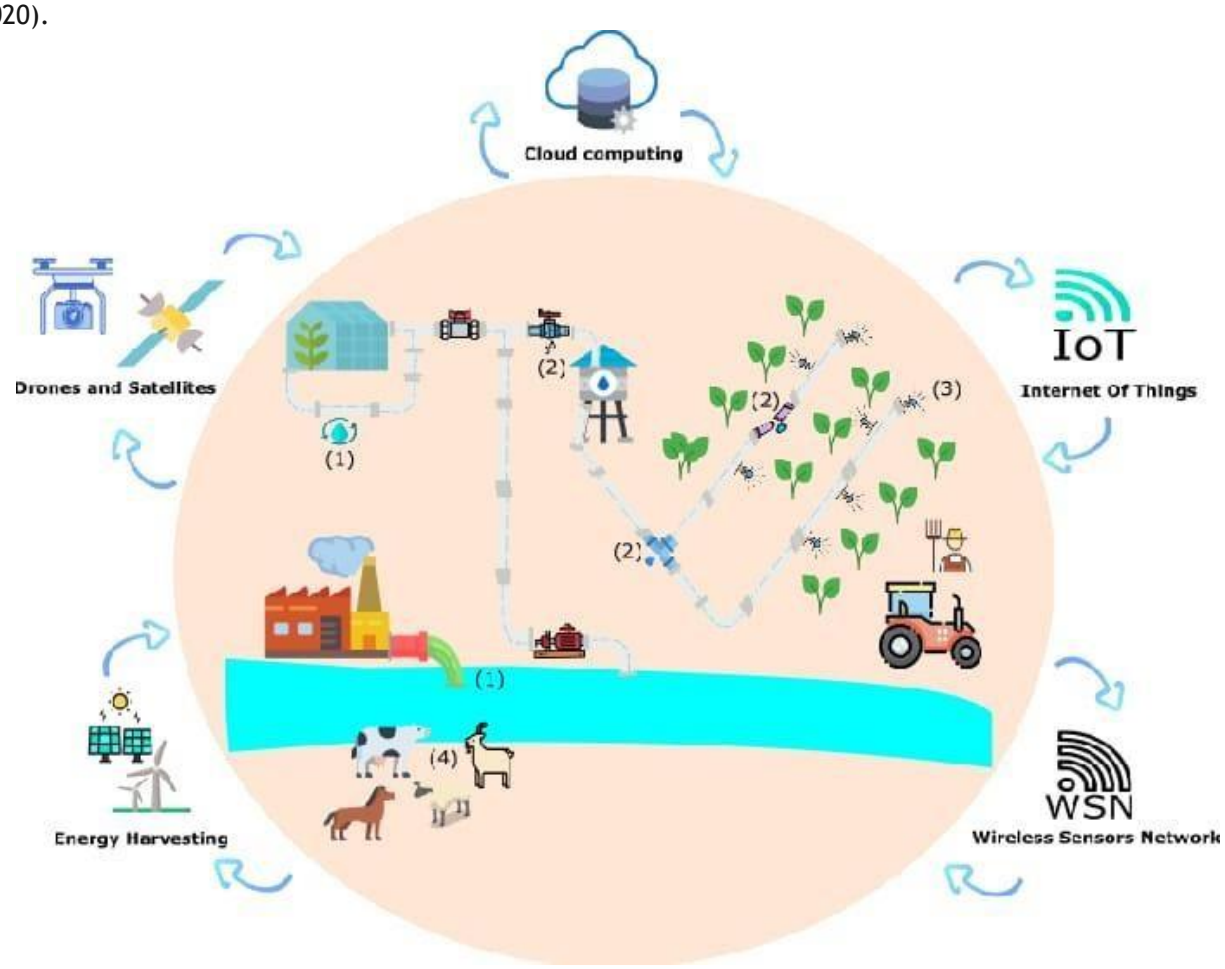
1. Water Reuse And Water Pollution Monitoring: Human and industrial activities often introduce contaminants into water bodies, leading to ecosystem degradation and affecting agricultural crops. Contaminated water can cause health risks, as untreated wastewater contains harmful pathogens and chemicals. While naturally occurring bacteria help maintain soil fertility and water quality, their growth can be hindered by environmental factors. Technological solutions, including wastewater treatment plants and real-time monitoring systems using IoT and sensors, offer ways to manage water pollution, though challenges remain in ensuring the safety and accessibility of treated water for agriculture.(Saad et al.,2020)

2. Water Pipeline Monitoring: Water distribution networks, particularly underground ones, require continuous monitoring to prevent leaks and ensure efficient water distribution for crops. Factors like aging pipes, overpressure, and equipment malfunctions contribute to water leaks, which can reduce agricultural productivity. Real-time monitoring

systems are essential for detecting leaks and maintaining infrastructure. These systems offer effective solutions for managing water distribution and preventing crop yield loss. .(Saad et al.,2020)

3.Water Irrigation: Water irrigation is the controlled application of water to crops to support growth in areas with insufficient rainfall. It helps maintain optimal moisture levels in the soil, ensuring healthy crop development. Various irrigation methods, such as drip, sprinkler, and surface irrigation, are used depending on the needs of the crops. Efficient irrigation systems are crucial for maximizing agricultural productivity and conserving water resources. .(Saad et al.,2020)

4. Drinking Water For Livestock: Drinking water for livestock is essential for their health, growth, and productivity. Adequate water intake supports digestion, temperature regulation, and overall well-being. Water should be clean, accessible, and available in sufficient quantities to meet the needs of different types of animals. Proper water management ensures that livestock remain hydrated and perform optimally in various environmental conditions. .(Saad et al.,2020).



Traditional Agricultural Water Management Techniques

Traditional agricultural water management techniques have been used for centuries, especially in areas where water resources are scarce or irregular. These techniques were often developed in harmony with the environment, using local knowledge and natural systems. Below are some examples of traditional techniques:

1. Terracing (Erosion Control): Used widely in mountainous regions, terracing involves creating stepped levels on slopes to prevent soil erosion and conserve water. This technique has been used in places like the Andes, Southeast Asia, and Sub-Saharan Africa (Grove, 1990).

2. Rainwater Harvesting: This method collects and stores rainwater for agricultural use. It involves the use of ponds, cisterns, or traditional reservoirs, and is common in regions with seasonal rainfall. In India, the traditional "kunds" or step wells are examples of this technique (Goyal et al., 2018).

3. Water Lifting Devices: Traditional water-lifting devices such as the Persian wheel (sakia) or the shaduf have been used in many parts of the world to lift water from rivers or wells for irrigation purposes (Smith, 1993).

4. Flood Irrigation: In regions like Mesopotamia, ancient civilizations used flood irrigation techniques, where the fields were flooded with water from nearby rivers or canals. While inefficient by modern standards, it supported early civilizations' agriculture (Parker, 2004).

5. Canals and Water Distribution Systems: The use of canals for water distribution dates back to ancient civilizations, such as the Egyptians and the Indus Valley. These systems were designed to divert water from rivers to irrigate crops over large areas (Choudhury, 2001).

6. Swales and Ditches: Swales, small ditches or channels used to slow the flow of water and direct it to crops, are found in many agricultural traditions. They were particularly important in semi-arid regions to optimize water use (Perkins, 2004).

Modern Agricultural Water Management Techniques

Modern agricultural water management techniques focus on increasing water use efficiency, conserving water resources, and enhancing crop productivity through advanced technologies and practices. Some of the key techniques are:

1. Drip Irrigation: This technique involves delivering water directly to the roots of plants through a network of tubes, pipes, and emitters. It is one of the most water-efficient methods of irrigation and is used widely in arid regions (Keller & Khamis, 2001).

2. Sprinkler Irrigation: Sprinkler systems spray water over crops in a manner similar to natural rainfall. This method is commonly used for large-scale agriculture and is highly effective for uniform water distribution (Pereira et al., 2002).

3. Center Pivot Irrigation: This method uses rotating sprinklers mounted on wheeled towers, allowing for the efficient and uniform irrigation of circular areas. It is particularly common in large-scale farms in the U.S. and Australia (Foster, 2011).

4. Soil Moisture Sensors: These devices monitor soil moisture levels in real-time, allowing farmers to apply water only when necessary. This precision irrigation technique helps conserve water and prevent over-irrigation (Evans & Sadler, 2008).

5. Rainwater Harvesting: Although a traditional practice, modern methods of rainwater harvesting involve advanced storage systems and filtration techniques to collect and store rainwater for irrigation. It is a sustainable solution for regions experiencing water scarcity (Singh et al., 2017).

6. Water Recycling and Reuse: Recycled water from domestic or industrial sources can be treated and used for agricultural irrigation, reducing the demand for freshwater resources. This technique is increasingly used in water-scarce regions (Tchobanoglous et al., 2003).

7. Hydroponics and Aquaponics: These soilless farming techniques use water to nourish plants while controlling the nutrients and water distribution. Hydroponics and aquaponics offer high yields in less water-intensive systems, making them suitable for urban farming (Graber & Junge, 2009).

8. Surface Irrigation with Land Levelling: Land levelling techniques improve the uniformity of surface irrigation, reducing water wastage and increasing irrigation efficiency. This method has seen adoption in countries like India and China (Yadav & Srinivas, 2006).

Innovations in Agriculture Water Management

Recent innovations in agricultural water management include precision irrigation systems that optimize water use through sensors and data analytics (Mulla, 2013). Drones and satellite imagery provide real-time monitoring of crop health, improving irrigation efficiency (Zhang et al., 2016). Hydroponics and vertical farming reduce water consumption by up to 90% compared to traditional methods (Resh, 2012). Additionally, AI-driven systems predict water needs and automate irrigation schedules (McKinsey, 2020).

Policies in Agriculture Water Management

Policies in agricultural water management aim to promote sustainable use of water resources while addressing challenges such as water scarcity, climate change, and population growth. Key policies include:

1. Water Pricing and Economic Incentives: Many countries implement policies that promote efficient water use through pricing mechanisms or subsidies for water-saving technologies (Oweis & Hachum, 2006). These policies encourage farmers to adopt waterefficient irrigation methods.

2. Integrated Water Resources Management (IWRM): IWRM policies, such as those in India and South Africa, advocate for a holistic approach to water management, considering social, economic, and environmental factors (Schreiner & Hassan, 2007).

3. Water Rights and Allocation: Clear policies on water rights and allocation ensure equitable distribution of water resources. The allocation often prioritizes drinking water and agriculture in water-scarce regions (Rogers et al., 2006).

4. Government Support for Technological Adoption: Many countries provide incentives for farmers to adopt water-saving technologies like drip irrigation, including subsidies or technical support (Foster et al., 2011).

5. Climate Change Adaptation Policies: Policies addressing the impact of climate change on water availability emphasize the need for resilient agricultural practices and infrastructure investments, such as improved irrigation systems (Howden et al., 2007).

Conclusion

In conclusion, as global water scarcity continues to escalate due to climate change and population growth, efficient water use in agriculture becomes more crucial. Traditional methods alone are no longer sufficient to address the growing demand for water in farming. Modern techniques, such as smart irrigation systems, precision agriculture, and innovations like rainwater harvesting and water recycling, offer promising solutions for improving water efficiency. The integration of advanced technologies, including sensors and drones, allows for real-time monitoring and precise irrigation, reducing wastage and ensuring crops receive optimal water. Policies promoting sustainable water management and technological adoption are essential to ensuring that agricultural practices can meet future demands for both food and water.

References

1. Erion Bwambale, Felix K Abagale, Geophrey K Anornu *Agricultural Water Management* 260, 107324, 2022
2. SAAD,A, BENYAMINA,A., & GAMATIÉ,A., 2020.*Water Management In Agriculture :A Survey On Current Challenges And Technological solution*
3. Evans, R.G., & Sadler, E.J. (2008*). Methodologies for Determining Irrigation Water Requirements. Journal of Irrigation and Drainage Engineering*, 134 **3**: 319-326.
4. Foster, T. (2011). *The Development and Effectiveness of Center Pivot Irrigation Systems. Irrigation Science, 29* ***5****: 305-312.*
5. Foster, T., et al. (2011*). Agricultural Water Management: Policies for Improved Efficiency. FAO Water Report No. 36.*
6. Graber, A., & Junge, R. (2009). *Aquaponic Systems: A Review of the Technologies. Journal of Sustainable Agriculture*, 33 **1**: 122-140.
7. Howden, M., et al. (2007*). Adapting Agriculture to Climate Change: A Policy Framework. Environmental Science & Policy*, 10 **4**: 313-321.
8. Keller, J., & Khamis, K. (2001). *Drip Irrigation: Theory and Practice. FAO Irrigation and Drainage Paper No. 60.*
9. McKinsey & Company. (2020). *Artificial Intelligence in agriculture: Transforming farming through data-driven technology.*
10. Mulla, D. J. (2013). *Twenty-five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. Biosystems Engineering*, 114 **4**: 358-371.
11. Oweis, T.Y., & Hachum, A.Y. (2006). *Water Harvesting for Improved Agriculture: An Overview of Policies and Practices.* International Water Management Institute.
12. Pereira, L.S., Oweis, T.Y., & Zairi, A. (2002). *Irrigation Management under Water Scarcity. Agricultural Water Management*, 57 **3**: 175-206.
13. Resh, H. M. (2012). *Hydroponic food production: A definitive guidebook for the advanced home gardener and the commercial hydroponic grower* (7th ed.). CRC Press.
14. Rogers, P., et al. (2006). *Water Governance and Water Resources Management: A Policy Framework. World Bank.*
15. Schreiner, B., & Hassan, R. (2007). *Integrated Water Resources Management in South Africa: A Policy Overview. Water SA*, 33 **3**: 385-392.
16. Singh, R., Gupta, A., & Kumar, P. (2017). Rainwater Harvesting: A Key to Sustainable Water Management in Agriculture. *International Journal of Water Resources and Environmental Engineering*, 9 **4**: 66-78.
17. Tchobanoglous, G., Burton, F.L., & Stensel, H.D. (2003). *Water Quality: Characteristics, Modeling, Modification.* McGraw-Hill.
18. Yadav, S., & Srinivas, K. (2006). *Improved Surface Irrigation Methods for Efficient Water Use. Irrigation Systems*, 30 **2**: 85-91.
19. Zhang, Y., et al. (2016). *Application of remote sensing and drones in precision agriculture. Computers and Electronics in Agriculture*, 123, 35-49.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Biotechnological Aspects of Crop Improvement in Vegetable Crops

Article ID: 72728

Swagatika Patra[1], Vijay Bahadur[2], Lalita Lal[3]

[1]M.Sc. Research Scholar, Department of Horticulture SHUATS, Naini Agriculture University, Prayagraj-211007.

[2]Professor and Head of Department, Department of Horticulture SHUATS, Naini Agriculture University Prayagraj-211007.

[3]Teaching Associate (PhD), Department of Horticulture SHUATS, Naini Agriculture University Prayagraj-211007.

Introduction

Biotechnology is an interdisciplinary field applied in areas like medicine, food, environment, and energy. In agriculture, it enables the development of low-cost, disease-free, and high-yield crops through techniques such as genetic engineering, and molecular markers. It helps overcome limitations of traditional breeding like cross barriers and genetic drag. Advances in molecular biology (e.g., DNA sequencing, cloning, in-vitro mutagenesis) and microbial applications (biofertilizers, biocontrol agents) have transformed vegetable production. Overall, biotechnology has revolutionized horticultural science by enhancing quality, productivity, and sustainability in vegetable crops.

Scope of Vegetable Improvement through Biotechnological Approaches

1. Genetic improvement of vegetable crops through biotechnological approach in India is at its embryonic stage.

2. Every year researchers all around the world through international collaborations, finding the complete genome of various vegetable crops and that can lead to the initiation of systematic and complete selection of genomes through MAS.

3. The abundance of genes and molecular markers responsible for economically important traits like yield, quality, and tolerance to biotic and abiotic factors will help us to make our breeding programs more robust.

Need for Biotechnological Approaches for Vegetable Improvement

1. Elimination of unreliable phenotypic evaluation
2. No linkage drags
3. Production of true types
4. Overcome distant hybridization barriers
5. No species/ genus gene transfer barrier
6. Eliminates long term field trials
7. 100% Achievement of gene transfer
8. Shorten breeding cycle.

Biotechnology for Vegetable Improvement

This can be done in 3 types:

1. **Genetic Engineering:** Transgenics or GM Crops
2. **Molecular Markers:**
    a. Genetic diversity studies
    b. Molecular mapping
    c. Marker Assisted Selection
    d. Construction of genetic maps
3. **Tissue Culture:**
    a. Anther culture
    b. Micro Propagation
    c. Embryo Culture
    d. Meristem Culture.

Molecular Markers

1. MAS refers to the use of DNA markers that are tightly- linked to target loci as a substitute for or to assist phenotypic screening.

2. Marker- assisted selection (MAS) provided a potential for increasing selection efficiency by allowing for earlier selection and reducing plant population size used during selection.

Application of MAS

1. MA evaluation of breeding material
2. Cultivar identity/ assessment of purity
3. Identification of genomic regions under selection
4. Marker assisted backcrossing
5. Marker assisted pyramiding
6. Early generation marker assisted selection
7. Combined marker assisted selection.

Marker - Applications in Tomato Breeding and Potato Breeding

Breeding Strategy	Breeding objective	Type of marker	References
Marker- assisted backcrossing (MABC) to introgress single resistance genes	Introgress Fusarium wilt resistance	Gene linked PCR markers	El Mohtar *et al.*, 2007
Pyramiding	Resistance to Tomato Yellow Leaf Curl Virus (TYLCV), *Fusarium oxysporum*, Verticillium wilt	DNA Markers	Atamain *et al.*, 2009
MAS for introgression of TYLCV resistance (Ty-1/ Ty-3)	Develop TYLCV resistant cultivars	SNPs/ SCAR markers for Ty-1/ Ty-3	Verlaan *et al.*, 2013
Marker- assisted early generation selection for root- knot nematode	Select nematode resistant lines without bioassay	SNP Markers	Devran *et al.*, 2016

Breeding Strategy	Breeding objective	Type of marker	References
MAS	Extreme resistance to Potato virus Y	SCAR	Cernak *et al.*, 2008
MAS	Tuber quality traits (starch content, sweetening)	SNPs, SSRs	Schreiber *et al.*, 2014
MAS	Potato Virus Y resistance	PCR marker	Fulladolsa *et al.*, 2015

Marker-Assisted Selection (MAS) is a powerful breeding tool for improving complex traits like disease resistance, fruit quality, shelf-life, and pigment expression in horticultural crops. **Patel *et al.*, (2025)**

The review focuses on tomato, papaya, and marigold as examples:

a. Tomato: Advanced MAS pipelines with successful gene pyramiding (e.g., Ty-2, Ty-3, Ph-3, I2 for resistance).
b. Papaya: Used for early sex type and PRSV resistance selection despite limited genomic resources.
c. Marigold: MAS is still developing; promising progress in SSR, AFLP, and RAPD marker development.
i. The paper compares different marker systems, crop-specific applications, and challenges in MAS.
ii. Emphasizes the need for robust, widely applicable markers to enhance practical MAS deployment in horticultural breeding.

Genome Sequencing

1. To develop millions of novel markers, as well as the identification of agronomically important genes(Edward & Batley 2010)

2. Enabled the development of high- density genetic maps.

3. The sequence data obtained will help to identify the genes determining different traits.

These data enable the unraveling of the regulatory mechanisms behind different traits and help to elucidate the complete pathway.

Completion of mitochondrial genome sequence of Onion (*Allium cepa* L.) containing the CMS-S male sterile cytoplasm and identification of an independent event of ccmF$_N$ gene split. Kim *et al.*, (2016)

a. First report of complete mitochondrial genome sequence containing CMS-S cytoplasm.
b. Cox1 gene was identified as part of the chimeric orf725 gene, which is a candidate gene responsible for inducing CMS.
c. For future it will help in better understanding of CMS system and its transfer to other genotypes.

Limitations of Genome Sequencing

1. Large genome size
2. Polyploidy exhibited by many vegetable crop species impedes the sequencing and further analysis
3. A high percentage of repeat elements is also a major hurdle in genome assembly
4. Another challenge is that the functions of many genes identified by genome sequencing remain unknown and the genetic control of the majority of agronomic traits has yet to be determined

Future Directions of Genome Sequencing

Systematic mining and utilisation of these data would help to develop varieties with higher yield and tolerance to biotic as well as abiotic stresses and would boost up the economy of tropical countries like India.

Tissue Culture

Anther Culture: Anther culture is a plant biotechnology technique that produces haploid plants by culturing immature pollen grains from anthers in a laboratory setting. This process bypasses sexual reproduction, allowing scientists to quickly develop homozygous, uniform plant lines for breeding programs. It is also used to produce doubled haploid plants, which are fertile and genetically pure.

Guidelines in Anther Culture:

a. Donor plant selection, Floral bud collection
b. Pollen development stage determination
    i. Acetocaramine
    ii. DAPI Staining
c. Pre treatment
d. Surface sterilizatior
e. Anther placement onto the medium
f. Morphogenic development plant recovery
g. Characterization of regenerates
h. Chromosome doubling.

Double Haploids in Vegetables: Haploids (Hs) are sporophytic plants with gametophytic chromosome number

a. A. In vivo
b. Gynogenesis
c. Ovule androgenesis
d. Genome elimination by distant hybridisation
e. Semigamy
f. Irradiation effect
g. B. In vitro
h. Anther culture
i. Ovary culture.

Application for Double Haploids:

a. Development of homozygous inbred line and cultivars.
b. Used in the fixation step during gene pyramiding in order to get the ideotype.
c. Double haploid in combination with molecular marker accelerate back crossing.
d. Construction of genetic maps or Gene tagging / locating genes.
e. QTL analysis is facilitated by using DH mapping populations and enable accurate phenotyping.

Haploid induction in Vegetable crops:

Crop	Method	Achievement	Reference
Onion	Gynogenesis	In short-day tropical Indian Onion cultivars: haploids, spontaneous diploids and tetraploids obtained	Khar *et al.*, 2018
Cucumber	Pollination with γ-irradiated pollen followed by embryo rescue	Haploid embryos in gynoecious/ parthenocarpic genotypes	Prakash*et al.*, 2024
Musk melon	Pollination with γ-irradiated pollen	Induction rate upto; 14- 33%	X *et al.*, 2023
Tomato	Anther culture	Haploid rates about; 0.5- 3.7%	Sengui- Simarro *et al.*, 2023

Embryo Rescue

In vitro techniques whose purpose is to promote the development of an immature or weak embryo into a viable plant.

Applications:

1. Distant hybridization.
2. Used to recover maternal haploids that have developed as a result of chromosome elimination following interspecific hybridization.

Wide Hybridization and Embryo-Rescue for Crop Improvement in *Solanum*. Kharkongar *et al.*, (2013).

Effect of age of hybrid embryos on development, when cultured on MS medium.

Sl. No.	Age of Embryo (days after pollination)	Growth response
1	15	Excision of embryos was difficult due to small size. Few embryos germinated.
2	25	Embryos showed best growth. Large number of healthy plantlets were rescued at this stage.
3	35	Ony a few embryos could be excised. Most seeds had shriveled and only a few seeds were present in a fruit.

3. MS medium**: 1mg/l GA3 + 0.1 mg/ l NAA and 0.5 mg/ l BAP** was most effective for germination of immature putative hybrid embryos.

4. The confirmation of hybridity of embryo rescued plants from the interspecific crosses done with RAPD analysis.

Somatic Hybridisation

Somatic hybridization (SH) via protoplast fusion is an important tool for the production of interspecific and intergeneric hybrids.

Steps:

a. Isolation
b. Fusion of protoplast
c. Regeneration of the post-fusion mixture.

Detection of somatic hybrids among the regenerated shoots.

Applications:

a. The technique provides an efficient mean of gene transfer from one species to another so as to break the crossing barriers.
b. Integration of parental nuclear and cytoplasmic genomes.
c. Generates novel germplasm for elite breeding of conventional crosses and promotes crop improvement in existing cultivars.

Somatic Hybridization: An effective tool for crop improvement. Singh *et al.*, (2025)

a. Somatic hybridization is a technique involving the fusion of isolated protoplasts (plant cells without cell walls) from somatic cells to create hybrid plants.
b. It bypasses sexual reproduction, allowing the combination of genomes from different species or genera.
c. This process enables the merging of nuclear, mitochondrial, and plastid genomes, creating novel genetic combinations such as **symmetric hybrids, asymmetric hybrids, and cybrids.**
d. Despite its advantages in overcoming sexual incompatibility and facilitating gene transfer, genomic incompatibility remains a limitation.
e. The technique was pioneered by Cocking (1960) for protoplast isolation and later used by Carlson et al. (1972) for producing the first somatic hybrid in tobacco.
f. The essential steps include protoplast isolation, fusion, culture, selection, and verification.

Micropropagation

1. Micropropagation in tissue culture is a technique of rapidly multiplying plants under sterile (aseptic) and controlled laboratory conditions using small pieces of plant tissue (called explants) such as shoot tips, nodal segments, or meristems.

2. It allows for mass production of genetically identical (clonal) plants in a relatively short time, independent of seasonal or environmental constraints.

Micropropagation is the in vitro (in glass) method of vegetative propagation where small parts of a plant (explants) are cultured on a nutrient medium containing plant growth regulator to produce multiple identical plants.

Key aspects of micropropagation:

a. Genetic identity: The plants produced are clones of the parent plant, meaning they are genetically identical.

b. Asexual reproduction: It relies on asexual reproduction through vegetative parts, as opposed to sexual reproduction from seeds.
c. Sterile environment: The entire process is carried out under controlled and sterile conditions to prevent contamination.
d. Rapid multiplication: It allows for the quick production of many plants from a single source, making it highly efficient.

Micropropagation of Major Tuber Crops: A Review. Sivakumar *et al*., (2025)

a. Tuber crops like potato, cassava, sweet potato, yam, and taro are vital for global food security and rural livelihoods.
b. Conventional propagation faces challenges, making micropropagation a key biotechnological method for producing disease-free, genetically uniform plants quickly and in large numbers.
c. This review compares micropropagation methods in major tuber crops, analyzing explant types, media, and growth regulators.
d. Most studies use Murashige and Skoog (MS) medium, with nodal segments or shoot tips as explants, and hormone combinations of BAP with NAA or IAA for regeneration.
e. The study emphasizes optimizing hormones and explant selection to enhance in vitro propagation for sustainable crop production and improvement.

Meristem Culture

1. Meristem culture is a plant tissue culture technique used to produce virus-free plants by culturing the meristematic cells from the growing tips of shoots or roots.

2. These cells are undifferentiated and divide rapidly, which often prevents viruses from multiplying and infecting them.

3. This method is used for virus elimination, rapid clonal propagation, and preserving endangered species, and involves isolating the meristem, sterilizing it, and growing it on a nutrient-rich medium to regenerate a whole plantlet.

Key aspects of meristem culture:

Purpose: The primary goal is to obtain disease-free plants, as meristematic tissue is often free of viruses and pathogens. It is also used for rapid cloning and maintaining genetic uniformity.
Procedure:

i. **Explant isolation:** A meristematic tissue, typically a shoot tip with a few leaf primordia, is carefully excised from a healthy parent plant.
ii. **Sterilization:** The explant is surface-sterilized to eliminate any contaminants.
iii. **In vitro culture:** The sterilized meristem is placed on a suitable nutrient medium in a controlled environment, where it develops into a plantlet.
iv. **Regeneration and acclimatization:** The plantlet is then transferred to different media to encourage shoot and root development.
v. Once it is large enough, it is gradually acclimatized to normal environmental conditions before being transferred to soil.

Use of Tissue Culture Techniques for Producing Virus Free Plant un Garlic and their Identification through Real-Time PCR. Taskin *et al*., (2013):

a. Comparison of meristem culture technique with shoot tip culture technique for obtaining virus-free plant.
b. Plants propagated via meristem culture, could not detect any virus.
c. OYDV (onion yellow dwarf virus) and LYSV (leek yellow stripe virus) viruses were detected in plants obtained via shoot tip culture.

Conclusion

1. Cultivated vegetables have narrow genetic base so in order to broaden their genetic base wide hybridization following in-vitro and biotechnological approaches should be use to generate genetic stocks with useful traits retrieved from wild relatives which could be employed for breeding desirable varieties/hybrids.

2. The genome sequencing will support crop improvement efforts and help identify additional candidate genes.

3. Recent gene editing technology like CRISPER CAS 9 can prove as a great replacement of transgenic crops.

References

1. Ananya Kaunar, Ankita Pati, Bibhudutta Pattnaik, RuchiBhuyan and Dattatreya Kar. 2021. Biotechnological Approaches for Enhancing the Production of Vegetables- An Updated Overview. *Universal Journal of Agricultural Research*. 9(6): 221-234
2. T. A. Patel, D. D. Champaneri and A. I. Patel. 2025. Marker- Assisted Selection In Horticulture: A Comparative Review Across Vegetables, Fruits and Flower Crops. *International Journal of Plant & Soil Science*. 37(10): 186-193

3. Bongju Kim, Kyunghee Kim, Tae-Jin Yang and Sunggil Kim.2016. Completion of mitochondrial genome sequence of Onion (*Allium cepa* L.) containing the CMS-S male sterile cytoplasm and identification of an independent event of ccmFn gene split. *Curr Genet*. 62:873-885
4. Herbert P. Kharkongar, V.K. Khanna, W. Tyagi, M. Rai and N. T. Meetal. 2013. Wide Hybridization and Embryo Rescue for Crop Improvement in *Solanum*. *Kharkongar et al., Agrotechnol*. S11-004
5. Swapnil, Digvijay Singh, Jenny Priya Ekka and PriyankaKumari. 2021. Somatic Hybridization: An effective tool for crop improvement. *Food and Scientific Reports*. ISSN 2582-5437
6. Hindawi Publishing Corporation. 2013.Use of Tissue Culture Techniques for Producing Virus- Free Plant in Garlic and Their Identification through Real- Time PCR. *The Scientific World Journal*. 781-282
7. Hari Har Ram.1998. Vegetable Breeding- Principles and Practices. Kalyani Publishers.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Technological Applications of Reverse Osmosis in the Dairy Industry: Principles, Process Optimization, and Industrial Relevance

Article ID: 72729

Nilesh Vadhiya[1], Neha Sahu[1], Ajit Munjal[1], Vidhi Patel[1]
[1]Research and Development Centre, Novasol Ingredients Pvt. Ltd. (Formerly known as Gujarat Enterprise), Ahmedabad, Gujarat 380-009.

Abstract
Reverse osmosis (RO) has become a key pressure-driven membrane technology in the dairy sector, largely because it enables the concentration of liquid dairy streams without exposing products to heat-related nutrient losses or compositional changes. In comparison with conventional evaporation, RO offers substantial advantages, including lower energy requirements, reduced transportation costs, and a smaller environmental footprint. This review provides a critical overview of the fundamental principles of RO, commonly used membrane materials and configurations, and the major operating parameters that govern process performance. Applications of RO across a wide range of dairy systems—including liquid milk, concentrated and dried milk products, fermented dairy foods, traditional Indian dairy products, cheese, ice cream, whey processing, and water recovery—are systematically discussed. Particular attention is given to energy efficiency, retention of product quality, membrane fouling behavior, and economic considerations. Recent developments in membrane materials and module design are highlighted, along with emerging opportunities for the valorization of dairy by-streams and the reuse of process water. Overall, the review underscores the role of RO as a cornerstone technology in advancing sustainable and resource-efficient dairy processing.

Keywords: Reverse osmosis; dairy processing; membrane technology; energy efficiency; whey utilization; sustainable food engineering.

Introduction
Membrane separation technologies now play a central role in modern dairy processing, driven by growing demands for improved energy efficiency, preservation of product quality, and enhanced environmental sustainability. Pressure-driven membrane processes—including microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO)—are widely applied for the fractionation, concentration, and purification of dairy streams. Among these techniques, RO is unique in its ability to retain even low-molecular-weight solutes (typically <150 Da), allowing for extensive water removal while maintaining the original compositional balance of milk constituents.

The industrial adoption of RO has expanded rapidly for the concentration of milk, whey, buttermilk, and various condensate streams, particularly in situations where thermal processing is either economically inefficient or detrimental to nutritional quality. Beyond process efficiency, the use of RO supports broader sustainability objectives by reducing overall energy consumption, lowering greenhouse gas emissions, and enabling the effective valorization of dairy by-products that might otherwise be underutilized.

Historical Development of Reverse Osmosis
The development of modern reverse osmosis technology can be traced back to the late 1950s, when Sourirajan and Loeb made a pivotal breakthrough by identifying asymmetric membrane structures formed through the controlled heat treatment of cellulose acetate membranes. This asymmetric architecture combined a thin, dense selective layer with a porous support, resulting in membranes capable of operating under high pressures (approximately 75 bar) while achieving high salt rejection efficiencies (around 99% for NaCl). Their findings laid the foundation for the first industrial RO systems and continue to influence the design principles of contemporary thin-film composite membranes used across food and water treatment applications.

Principle of Reverse Osmosis
Solvent transport across semi-permeable membranes is governed by osmotic pressure (π), which can be described by the Van't Hoff equation:

$$\pi = nRT$$

where n represents the molar concentration (mol·L^{-1}), R is the universal gas constant, and T is the absolute temperature (K).

In reverse osmosis, an external pressure greater than the osmotic pressure difference across the membrane is applied, thereby reversing the natural direction of osmotic flow. Under these conditions, water molecules permeate through a dense, essentially non-porous membrane, while dissolved solutes are largely retained. This pressure-driven mechanism

allows for efficient concentration of liquid streams without phase change, offering clear advantages over thermal evaporation in terms of energy use and product quality preservation.

RO Membrane Materials and Configurations

1. Membrane Materials: RO membrane development has progressed through three generations:

a. First generation: Cellulose acetate (CA), cellulose triacetate (CTA)

b. Second generation: Polyamide (PA), polyimide (PI), polybenzimidazole (PBI), thin-film composite (TFC) membranes

c. Third generation: Ceramic membranes (TiO_2, ZrO_2)

Second-generation TFC polyamide membranes dominate dairy applications due to their superior flux, salt rejection, and chemical stability.

2. Module Configurations: RO membranes are commercially available in tubular, plate-and-frame, hollow fiber, and spiral-wound modules, with spiral-wound configurations being most prevalent due to their compactness and cost efficiency.

Critical Operating Parameters

RO performance is influenced by feed composition, osmotic pressure, operating pressure, temperature, pH, viscosity, total solids, and membrane characteristics. In dairy systems, lactose and soluble salts contribute predominantly to osmotic pressure, thereby limiting achievable concentration.

Temperature increases reduce viscosity and enhance flux; however, membrane thermal tolerance typically restricts operation below 55 °C. Concentration polarization and fouling remain major operational challenges and are mitigated through cross-flow operation, turbulent flow regimes, and optimized cleaning-in-place (CIP) protocols.

Applications for RO in Dairy Processing

1. Liquid Milk Concentration: RO enables on-site concentration of raw milk at chilling centers, reducing transportation and refrigeration costs. Studies demonstrate that two-fold concentrated buffalo milk can be stored at 4 °C for up to 48 h without quality deterioration, and subsequent dilution yields products indistinguishable from fresh milk in sensory evaluation. Economic analyses indicate payback periods as short as 10 months for RO installations.

2. Concentrated and Dried Milk: RO pre-concentration prior to evaporation significantly reduces energy consumption. For skim milk, combined RO–evaporation systems require nearly 70% less energy than evaporation alone. Additionally, RO minimizes Maillard browning and protein denaturation, producing whiter skim milk powders with extended shelf life.

3. Fermented Dairy Products: RO-concentrated milk enhances texture, yield, and shelf life of fermented products such as yoghurt, dahi, and koumiss. Improved total solids and protein content contribute to stronger gel networks, while reduced post-acidification prolongs refrigerated stability.

4. Traditional Dairy Products: RO has been successfully integrated into the manufacture of khoa, rabri, and chakka, achieving substantial energy savings and yield improvements. For instance, khoa production using RO-concentrated milk consumes nearly seven times less energy than conventional open-pan boiling.

5. Cheese Manufacturing: RO retentates improve cheese yield, reduce starter and rennet requirements, and enhance fat recovery. Optimized casein-to-fat ratios and controlled volume reduction are critical for maintaining desired cheese quality attributes.

6. Ice Cream Manufacture: RO retentates serve as efficient milk solids-not-fat (MSNF) sources, improving melting resistance and reducing stabilizer requirements due to enhanced water-binding capacity of proteins.

7. Whey Processing and By-product Valorization: RO facilitates economical whey concentration, significantly lowering energy demand and waste disposal costs. Combined NF–RO systems enable recovery of lactose and proteins while reducing chemical oxygen demand (COD) by over 90%.

8. Water and Solid Recovery: RO treatment of condensates and dairy effluents allows recovery of high-quality water suitable for cleaning, heating, and even potable applications when combined with polishing steps.

Challenges, Sustainability, and Future Perspectives

Despite its advantages, RO adoption is constrained by fouling, membrane replacement costs, and sensitivity to cleaning chemicals. Future research should focus on:

1. Fouling-resistant and chlorine-tolerant membranes
2. High-flux, low-pressure membrane modules
3. Hybrid RO–NF–UF systems for selective fractionation
4. Integration with circular economy frameworks.

RO holds strong potential for enhancing sustainability, reducing carbon footprint, and valorizing dairy by-streams in both industrialized and developing dairy sectors.

Conclusions

Reverse osmosis represents a mature, energy-efficient, and versatile technology for dairy processing. Its ability to concentrate dairy streams without compromising nutritional and sensory quality positions it as a key enabler of sustainable dairy manufacturing. Continued advancements in membrane materials and system design are expected to further expand its industrial applicability and economic viability.

Selected References

1. Ananya Kaunar, Ankita Pati, Bibhudutta Pattnaik, RuchiBhuyan and Dattatreya Kar. 2021. Biotechnological Approaches for Enhancing the Production of Vegetables- An Updated Overview. *Universal Journal of Agricultural Research*. 9(6): 221-234
2. T. A. Patel, D. D. Champaneri and A. I. Patel. 2025. Marker- Assisted Selection In Horticulture: A Comparative Review Across Vegetables, Fruits and Flower Crops. *International Journal of Plant & Soil Science*. 37(10): 186-193
3. Bongju Kim, Kyunghee Kim, Tae-Jin Yang and Sunggil Kim.2016. Completion of mitochondrial genome sequence of Onion (*Allium cepa* L.) containing the CMS-S male sterile cytoplasm and identification of an independent event of ccmFn gene split. *Curr Genet*. 62:873-885
4. Herbert P. Kharkongar, V.K. Khanna, W. Tyagi, M. Rai and N. T. Meetal. 2013. Wide Hybridization and Embryo Rescue for Crop Improvement in *Solanum*. *Kharkongar et al., Agrotechnol*. S11-004
5. Swapnil, Digvijay Singh, Jenny Priya Ekka and PriyankaKumari. 2021. Somatic Hybridization: An effective tool for crop improvement. *Food and Scientific Reports*. ISSN 2582-5437
6. Hindawi Publishing Corporation. 2013.Use of Tissue Culture Techniques for Producing Virus- Free Plant in Garlic and Their Identification through Real- Time PCR. *The Scientific World Journal*. 781-282
7. Hari Har Ram.1998. Vegetable Breeding- Principles and Practices. Kalyani Publishers.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Advances in Post-Harvest Management strategies of Vegetable Diseases

Article ID: 72730

Dr. M. Madhavi[1], Dr. G. S Madhu Bindu[2], Dr. V. Swarnalatha[1], Dr. K. Kavitha[1]
[1]Agricultural College, Palem, Professor Jayashankar Telangana Agricultural University, Hyderabad.
[2]Agricultural College, Jagtial, Professor Jayashankar Telangana Agricultural University, Hyderabad.

Introduction

Vegetables are highly perishable commodities and are prone to rapid deterioration due to post-harvest diseases. These diseases, primarily caused by fungi and bacteria, develop during harvesting, handling, storage, transportation, and marketing. Traditional post-harvest disease management relies heavily on chemical fungicides; however, concerns regarding pesticide residues, environmental safety, and pathogen resistance have driven research toward safer and more sustainable alternatives. Recent advances in post-harvest disease management emphasize integrated, residue-free, and technology-driven approaches aimed at minimizing losses while maintaining quality and food safety.

Advanced Temperature and Atmosphere Management

Temperature regulation remains one of the most effective strategies in controlling post-harvest diseases. Advances in rapid pre-cooling methods such as forced-air cooling, hydrocooling, and vacuum cooling significantly reduce microbial growth by slowing down physiological and metabolic activities in vegetables. Controlled atmosphere (CA) and modified atmosphere packaging (MAP) technologies, which regulate oxygen and carbon dioxide concentrations, have been refined to suppress pathogen development while extending shelf life.

The integration of smart storage systems with sensors enables real-time monitoring of temperature, humidity, and gas composition. These systems allow early detection of unfavourable storage conditions, thereby preventing disease outbreaks and reducing post-harvest losses.

Non-Chemical Physical Treatments

Recent years have witnessed increased adoption of non-chemical physical treatments as alternatives to fungicides. Ultraviolet (UV-C) irradiation has shown effectiveness in reducing surface-borne fungal and bacterial pathogens by damaging their cellular DNA. Similarly, ozone treatment is increasingly used as a sanitizing agent in storage and packing facilities due to its strong antimicrobial activity and rapid degradation into non-toxic byproducts.

Heat-based treatments such as hot water dipping and vapor heat treatment have also been optimized for vegetables to eliminate surface infections without adversely affecting quality. These physical methods are particularly important for residue-free post-harvest disease management.

Advances in Biological Control

Biological control has emerged as a major advancement in post-harvest disease management. Beneficial microorganisms such as *Bacillus*, *Pseudomonas*, and *Trichoderma* species suppress pathogens through competition, antibiosis, and induction of host resistance. Recent improvements in formulation technology have enhanced the shelf life, stability, and efficacy of these biocontrol agents under post-harvest conditions.

The use of microbial consortia instead of single antagonists has shown improved disease suppression across a broad range of vegetable crops. Integration of biocontrol agents with mild physical treatments has further improved their effectiveness, indicating a synergistic approach in disease management.

Natural Compounds and Edible Coatings

Considerable progress has been made in the use of plant-based compounds and edible coatings for post-harvest disease control. Natural antimicrobials such as essential oils, plant extracts, and chitosan have demonstrated inhibitory effects against major post-harvest pathogens. Chitosan-based edible coatings form semi-permeable barriers that reduce moisture loss, delay senescence, and inhibit microbial invasion.

Recent advancements include enrichment of edible coatings with natural antifungal compounds, enhancing their protective ability while maintaining consumer acceptability. These approaches offer environmentally safe alternatives to synthetic chemicals.

Nanotechnology and Smart Packaging

Nanotechnology represents a significant breakthrough in post-harvest disease management. Nano-formulations of antimicrobial agents improve delivery efficiency and reduce the required dosage. Nano-coatings provide uniform coverage on vegetable surfaces, enhancing protection against pathogen colonization.

Smart packaging systems incorporating antimicrobial nanoparticles or spoilage indicators are emerging as innovative tools for disease suppression and quality monitoring. These technologies not only inhibit microbial growth but also provide real-time information on produce freshness.

Molecular and Diagnostic Advances

Advances in molecular diagnostics have improved early detection of post-harvest pathogens. Rapid diagnostic tools such as PCR-based assays and biosensors enable identification of pathogens before symptom expression. Early detection allows timely intervention, reducing disease spread during storage and transport. Improved understanding of host–pathogen interactions through molecular studies has also contributed to the development of targeted disease management strategies.

Conclusions

Advances in post-harvest management of vegetable diseases have significantly shifted from chemical-dependent approaches to integrated, sustainable, and technology-based strategies. Innovations in temperature management, physical treatments, biological control, natural compounds, nanotechnology, and molecular diagnostics have enhanced disease control while ensuring food safety. Adoption of these advanced approaches within an integrated post-harvest management framework is essential for reducing losses, improving quality, and meeting the increasing demand for safe and high-quality vegetables.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Implementing A Circular Economy: Mitigating Waste and Carbon Footprints

Article ID: 72731

M. Medha[1], Boniga Uday Mohan Raj[1]
[1]Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, India.

Summary
The circular economy replaces the traditional “take, make, dispose” model by promoting core principles of reducing, reusing, recycling, and regenerating resources in production and consumption. Reducing waste and minimizing the carbon footprint are essential for protecting the planet and ensuring a sustainable future. The article underscores the benefits, challenges, and practical steps involved in moving towards a circular economy, demonstrating how it provides a sustainable solution to address multiple environmental challenges.

Introduction
The circular economy is the substitute for traditional "take, make, dispose" model of production and consumption. Instead of using fresh resources to manufacture new products, and later discarding them, the circular economy emphasizes on using already available resources. It focuses on designing products that can be reused, repaired, refurbished, or recycled, thereby reducing waste and minimizing the need for new materials. The goal of circular economy is to ensure continuous reuse of resources, to create a self-sustainable resource system.

Cutting down on waste and lowering carbon footprint is indispensable for a healthier planet and a more sustainable future. By combating climate change we can slow down the rate of temperature rise, which in turn helps in preventing other natural calamities. Lesser waste regeneration means fewer resources are extracted, helping us preserve the nature and biodiversity for future generations. As waste ends up in landfills it contaminates soil, water and air. By reducing waste, toxic chemicals and pollutants that contaminate our environment, are eliminated leading to clean air and water. Production of new goods requires significant amounts of energy. By recycling, reusing, and reducing waste, we can lower energy-intensive processes. Reducing waste can lead to reap economic benefits for both businesses and consumers but cutting down production cost for businesses and saves money for consumer instead of purchasing. As it also reduces emissions into atmosphere cleaner environments are maintained thereby promoting healthier communities.

The intention of this article is to explore how adopting a circular economy can play vital role in reducing waste and lowering carbon footprints. By transitioning from a linear model of production and consumption to a circular approach, we can mitigate the environmental impact of our day to day activities, preserve natural resources. The article will showcase the benefits, challenges, and practical steps involved in transitioning to a circular economy, by proving how it offers a sustainable solution to address various environmental issues.

Reducing, reusing, recycling, and regenerating are the key principles of the circular economy. Reducing means utilization of fewer resources in the first place. By using fewer resources in products, we reduce waste and the energy in producing them. Reusing means using the product again, it instead of discarding after single use. It enhances the lifespan of the product thereby reducing the need for need product. Recycling refers to repurposing used materials to create new products, thus turning it into a valuable resource. Regenerating is not merely about reducing damage; it focuses on revitalizing and enhancing ecosystems and natural systems that are frequently harmed by conventional production methods. Altogether, these principles integrate to create a system where waste reduction is minimal, resources are utilized efficiently and nature is well protected, helping us build a more sustainable future(Yaduvanshi et al.,*2016)*.

Benefits of Implementing Circular Economy Model
Reducing waste, lowering carbon footprints, and preserving resources offer several environmental benefits. By minimizing waste, we reduce the amount of trash that ends up in landfills and pollutants that contaminate natural ecosystems, thereby, preventing toxic substances from leaching into the environment. Cutting down carbon emissions, on the other hand, helps to mitigate the effects of climate change by alleviating the greenhouse gases that retain heat in the atmosphere, leading to a stable planet. Additionally, conserving resources like water, minerals, and fossil fuels by preventing over-exploitation by present generations helps in retaining biodiversity and maintaining ecological balance. Collectively, these actions contribute to a greener and more sustainable planet for future generations.

Implementing circular economy model offers several economic benefits like efficiency, cost savings, and innovation. It also generates employment in fields like recycling, repair, and sustainable design, fostering economic growth while transitioning towards more environment friendly practices(Rajayya et al.,2025) In addition to the above, the circular model promotes innovation in designing products and business models, developing new markets and driving competitiveness. By transitioning to circular economy, companies not only improve their financial performance but also contribute to a more robust, resource-efficient economy.

Challenges in Implementing Circular Economy Model

There are several challenges posed by adopting circular economy model. There is a pressing need for significantly updating infrastructure and technology to facilitate recycling, repair, and reuse on a large scale. Many existing systems are developed for a linear model, making it difficult to shift to circular practices without revamping supply chains and production processes. Altering consumer behavior is another hurdle, as it requires a change in mindset towards appreciating durability, repair ability, and sustainability over short-term convenience and disposability. Moreover, governments and policymakers need to create supportive regulations and incentives, which can be challenging and slow to implement. Navigating these barriers requires collaboration among industries, innovation, and a long-term commitment to environment friendly practices.

There are many organizations, entities promoting circular economy practices. Few of them are **IKEA** is adopting a circular model by crafting furniture recycling services, modular designs for easier repair and repurposing, and investing in circular supply chains to produce more sustainable products from the start. Loop (by TerraCycle) is a global platform offering products in reusable packaging, with brands like Nestlé, Unilever, and Procter & Gamble partnering to reduce packaging waste through durable, refillable containers. Café Coffee Day, a well-known coffee chain in India, collaborates with recycling agencies to convert used coffee grounds into organic compost, reducing waste and supporting a circular economy in the food and beverage industry. Meanwhile, Recykal, a digital platform in Mumbai, connects businesses, waste generators, and recycling agencies to enhance waste segregation, recycling, and circular practices for management of waste in urban areas.

Individuals can make a significant difference in the fighting against climate change by incorporating few conscious actions like, adopting sustainable consumption habits, using energy-efficient appliances like LED bulbs, using public transport for commute and EV vehicles instead of petrol and diesel vehicles, conserving more water, eat more plant-based foods and avoiding meat. Recycle and compost the biodegradable substances, staying informed about environmental issues and share information and knowledge with friends and family to create a ripple effect. Supporting for policies and leaders who advocate environmental sustainability, clean energy solutions, and climate change at local, national, and global levels.

Conclusion

The circular economy model reduces waste generation by promoting reuse, recycling, and environmentally conscious design, minimizing the need for new materials. As a result, it lowers carbon footprints by minimizing emissions from production, transportation, and waste management processes. The transition to a circular economy requires joint action from businesses, governments, and individuals working together to build a sustainable future. Businesses must innovate with environment friendly designs and optimize resource use, while governments play a pivotal role in setting policies, regulations, and incentives that foster sustainability. When all sectors collaborate and work together, the impact can be transformative, reducing waste, reducing carbon emissions, and preserving resources for future generations. By welcoming this transformation, we can build a stronger, sustainable world, where environmental protection and economic growth go hand in hand. The potential for a brighter and sustainable future is within grasp—let's act now!

References

1. Mohanty, R., and Patil, B. (2024). Establishing a circular economy framework in the agro-waste to ethanol-based supply chain in Karnataka, India. *Frontiers in Sustainability, 5*. https://doi.org/10.3389/frsus.2024.1232611 (frontiersin.org)
2. Rajayya, A., Nair, R., and Karthiayani, V. P. (2025). India's transition to a circular economy towards fulfilling Agenda 2030: A critical review. *Sustainability, 17*(6), 2667. https://doi.org/10.3390/su17062667 (mdpi.com)
3. Gaura, J., Pandey, I., and Hungund, S. (2021). Adoption of circular economy: Data-driven strategies based on empirical evidence from Indian consumers. *Journal of Strategic Marketing, 32*(7), 823-841. https://doi.org/10.1080/0965254X.2021.1989014 (tandfonline.com)
4. Yaduvanshi, N. R., Myana, R., and Krishnamurthy, S. (2016). Circular economy for sustainable development in India. *Indian Journal of Science and Technology, 9*(46), 1–9. https://doi.org/10.17485/ijst/2016/v9i46/107325 (indjst.org)
5. Singh, S. P., Sajnani, M., and Arora, G. K. (2023). Circular economy of tourism in Delhi. *Prabandhan: Indian Journal of Management, 16*(12). https://doi.org/10.17010/pijom/2023/v16i12/173246 (indianjournalofmanagement.com)

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Generating Diversified Income through Oil Palm-Based Intercropping and Border Crops

Article ID: 72732

Kunuru Sai Ganesh[1], Majjiga Sreenivas[2]
[1]M.Sc. Scholar, Department of Plantation, Spices, Medicinal and Aromatic Crops, PGIHS, SKLTGHU Mulugu (V&M), Siddipet (Dist), Telangana – 502279.
[2]Scientist and Head Horticultural Research Station Aswaraopet SKLTGHU Telangana-507301.

Introduction

Oil palm as the main crop integrated with high-value intercrops and border plantations for efficient land use and diversified income. Teak, Sandalwood, Casuarina and Mulberry are used as border or intercrop species, providing long-term timber, fuelwood and sericulture income. The systems combine short-term, medium-term and long-term revenue streams, with Oil Palm yielding steady FFB from 4 years. They emphasize sustainable management practices, including proper spacing, pruning and separate fertilization. Overall, these intercropping strategies are economically profitable and ecologically sustainable.

Oil Palm with Teak Border Plantation

1. The system has oil palm as the main crop with teak planted along the borders.
2. The total plot size is 50 m × 80 m (0.4 ha or 1 acre).
3. Oil palm spacing: 9 × 9 × 9 m triangular, with 57 plants in the plot.
4. Teak spacing: 3 × 3 m along the border, totaling 85 plants.
5. Establishment cost (Year-1): approximately ₹54,000.
6. Oil palm costs ₹41,250 to establish; teak border planting costs ₹12,900.
7. Annual maintenance (Year-2 onwards): around ₹25,000.
8. Oil palm begins yielding from Year-4, producing 6–7 tonnes FFB/year.
9. Annual gross income from oil palm is ₹72,000–84,000, with a net income of ~₹53,000/year.
10. Teak harvest after 18–20 years gives a lump-sum income of ₹10–15 lakh.
11. Maintain at least 3 m distance between teak and oil palm; apply fertilizers separately.
12. Regular teak pruning is necessary to prevent shading and root competition.

Note: Estimated value after 15-20 years from Teak.

The Main Crop is Oil Palm, with Sandalwood and Casuarina Planted as Host/Intercrop Plants

1. Total number of Sandalwood trees planted: 80 trees.
2. Each Sandalwood tree is expected to produce 15 kg of heartwood after 20 years.
3. Total heartwood from 80 trees: 80 × 15 = 1,200 kg.
4. Current market price of 1 kg heartwood: Rs. 6,000/-.
5. Value of heartwood per tree: 15 × 6,000 = Rs. 90,000/-.
6. Total value from 80 trees: 1,200 × 6,000 = Rs. 72,00,000/- (72 lakh).
7. Casuarina is used as a fast-growing support/host plant, providing timber or fuelwood income earlier than Sandalwood.
8. Oil Palm will produce FFB starting from Year 4, giving annual income during the immature phase of Sandalwood.
9. The combined system ensures income diversification:
10. Short-term: Oil Palm + Casuarina
11. Long-term: Sandalwood heartwood
12. Establishment and maintenance costs include seedlings, planting, irrigation, and periodic management of all three crops.

Profit calculation:

13. Total heartwood value: Rs. 72 lakh
14. Less establishment & maintenance costs (approx. Rs. 10–15 lakh)

15. Net long-term profit: ~Rs. 57–62 lakh after 20 years.

Benefits of this model:

16. Efficient land use
17. Diversified income
18. Timber, fuelwood and high-value heartwood production
19. Soil improvement and wind protection
20. Oil Palm provides steady income in the short term, while Sandalwood gives high-value income in the long term.
21. Overall, this intercropping system is economically profitable and ecologically sustainable.

Note: Estimated value after 20 years from Sandalwood.

Oil Palm with Mulberry as Border and Intercrop

1. Main crop: Oil Palm, 50 plants per acre.
2. Intercrop: Mulberry planted between two oil palm plants in 3 rows.
3. Mulberry spacing:
    a. Row-to-row: 60 cm
    b. Plant-to-plant: 90 cm
4. Border planting: Mulberry planted along borders, 2.4 meters from edges.
5. Number of rows at border: 4 rows per side.
6. Border Mulberry spacing: 60 × 90 cm (same as intercrop).
7. This layout maximizes land use while keeping Oil Palm as the main crop.
8. Mulberry acts as a high-value intercrop, giving income before oil palm matures.
9. Borders of Mulberry also serve as windbreaks and soil protection.
10. Suitable for sericulture (silk production) and short-term revenue.
11. Requires proper irrigation and fertilizer management for both Oil Palm and Mulberry.
12. Overall, this system provides short-term income from Mulberry and long-term yield from Oil Palm.

Oil Palm with Mulberry Intercrop and Casuarina Border

1. Main crop: Oil Palm, 50 plants per acre, harvesting starts from 4th year.
2. Oil Palm yield: 8–10 tons FFB per acre per year.
3. Income from Oil Palm: Rs. 1.2–1.5 lakh per acre per year; total Rs. 30–37 lakh over 25 years.
4. Intercrop: Mulberry grown for the initial 3 years between oil palms.
5. Mulberry planting: 3,630 plants per acre.
6. Silkworm rearing: 675 DFLs in 5 crops per year (135 DFLs per crop).
7. Cocoon yield: 540 kg per acre per year.
8. Income from Mulberry cocoon: Rs. 1.56 lakh per acre per year; total Rs. 4.68 lakh in 3 years.
9. BordMer crop: Casuarina, planted along 3 rows at the border, 1,500 plants per acre.
10. Casuarina yield: 75 tons per acre at 2.5 years; 600 tons per acre over 8 harvests in 25 years.
11.. Income from Casuarina: Rs. 2.25 lakh per acre every 3 years; total Rs. 18 lakh in 25 years.
12. Combined system benefits: Short-term income from Mulberry, medium-term from Casuarina, and long-term from Oil Palm.
13. Total profit over 25 years (approx.):
    a. Oil Palm: Rs. 30–37 lakh
    b. Mulberry: Rs. 4.68 lakh
    c. Casuarina: Rs. 18 lakh
    d. Grand total: Rs. 52.68–59.68 lakh per acre.
14. Advantages:
    a. Efficient land use
    b. Risk diversification
    c. Continuous income streams

d. Soil conservation and wind protection from Casuarina.

Conclusion

Oil Palm intercropped with species like Teak, Sandalwood, Casuarina and Mulberry provides a sustainable and profitable land-use model. These systems ensure short-term income from Mulberry and Casuarina, medium-term returns from Oil Palm and long-term high-value timber or heartwood from Teak and Sandalwood. Proper management of spacing, pruning and fertilization enhances crop productivity while protecting the soil and microclimate. Overall, these integrated models offer efficient land utilization, income diversification and ecological benefits, making them ideal for sustainable agriculture and agroforestry.

References

1. Sitorus, R and Zasari, M (2023). Identification and Economic Contribution of Intercrops to the Income of Oil Palm Farmers on Bangka Island. *Equity Jurnal Ekonomi*.11(1): pp.18-25.
2. Khasanah, N., van Noordwijk, M., Slingerland, M., Sofiyudin, M., Stomph, D., Migeon, A.F and Hairiah, K (2020). Oil palm agroforestry can achieve economic and environmental gains as indicated by multifunctional land equivalent ratios. *Frontiers in Sustainable Food Systems*.3:p.12.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Remote Sensing-Based Vegetation Indices for Monitoring Crop Stress and Damage

Article ID: 72733

Dr. Srasvan Kumar G[1], Mrs. Swathi Yadav Kattula[2]
[1]School of Agricultural Sciences, Malla Reddy University, Hyderabad, India.
[2]College of Agriculture, SR University, Hasanparthy, Warangal.

Introduction

The increasing pressure on global food systems due to population growth, climate variability, land degradation, and limited natural resources necessitates efficient and sustainable agricultural management. Timely and accurate information on crop condition, stress, and damage is critical for decision-making at farm, regional, and national levels. Conventional field-based methods for crop monitoring are often labor-intensive, time-consuming, and limited in spatial coverage. In contrast, remote sensing provides a synoptic, repeatable, and non-destructive means of observing crops across large areas.

Vegetation indices (VIs) are mathematical combinations of spectral reflectance values measured in different wavelength bands. They enhance the vegetation signal while minimizing noise caused by soil background, illumination differences, and atmospheric effects. Since the pioneering development of the Normalized Difference Vegetation Index (NDVI), hundreds of vegetation indices have been proposed, each designed to capture specific aspects of plant biophysical or biochemical properties. These indices have been widely applied to assess crop growth, stress, damage due to pests and diseases, and yield potential. This article aims to present an in-depth account of vegetation indices commonly used in remote sensing for predicting crop stress, damage, and condition, with particular emphasis on their relevance to agricultural applications.

Spectral Basis of Vegetation Indices

Green vegetation exhibits a characteristic spectral reflectance pattern. Chlorophyll pigments strongly absorb radiation in the blue (450–500 nm) and red (620–680 nm) regions for photosynthesis, while reflectance is relatively high in the green region (around 550 nm), giving plants their green appearance. In the near-infrared (NIR: 700–1300 nm) region, reflectance is high due to multiple scattering within the leaf mesophyll structure. In the shortwave infrared (SWIR: 1300–2500 nm) region, reflectance is influenced by leaf water content, lignin, and cellulose. Crop stress—whether caused by water deficit, nutrient deficiency, temperature extremes, pests, or diseases—alters leaf pigments, cellular structure, and water content. These changes modify spectral reflectance, which can be detected and quantified using vegetation indices. Most VIs exploit contrasts between red and NIR reflectance, while others incorporate green, red-edge, or SWIR bands to improve sensitivity to specific stress factors.

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is the most widely used vegetation index in remote sensing. It is defined as:

$$NDVI = (\rho NIR - \rho Red) / (\rho NIR + \rho Red)$$

where ρNIR and ρRed are reflectance values in the near-infrared and red bands, respectively.

NDVI serves as a proxy for green biomass, leaf area index (LAI), and photosynthetic activity. Higher NDVI values indicate healthy, dense vegetation, while lower values correspond to sparse, stressed, or damaged crops. NDVI time-series analysis is commonly used to monitor crop phenology, growth stages, and seasonal dynamics.

Crop stress due to drought, nutrient deficiency, pest infestation, or disease often results in reduced chlorophyll content and canopy cover, leading to lower NDVI values. Sudden drops in NDVI can indicate acute damage caused by hailstorms, floods, or severe pest outbreaks.

Limitations: Despite its simplicity and robustness, NDVI has limitations, including saturation at high biomass levels, sensitivity to soil background in sparse vegetation, and reduced sensitivity to early stress conditions.

Enhanced Vegetation Index (EVI)

The Enhanced Vegetation Index (EVI) was developed to improve sensitivity in high biomass regions and reduce atmospheric and soil background effects. It is expressed as:

$$EVI = G \times (\rho NIR - \rho Red) / (\rho NIR + C1\rho Red - C2\rho Blue + L)$$

where G is a gain factor, C1 and C2 are aerosol resistance coefficients, L is the canopy background adjustment, and ρBlue is blue band reflectance.

EVI is particularly useful in dense crop canopies such as rice, sugarcane, and maize, where NDVI tends to saturate. It provides improved discrimination of canopy structure and vigor, making it suitable for monitoring crop condition under optimal and stressed conditions.

Soil-Adjusted Vegetation Index (SAVI)

Soil-Adjusted Vegetation Index (SAVI) was designed to minimize the influence of soil reflectance in areas with sparse vegetation cover:

$$SAVI = (\rho NIR - \rho Red) / (\rho NIR + \rho Red + L) \times (1 + L)$$

where L is a soil brightness correction factor, commonly set to 0.5.

SAVI is especially effective during early crop growth stages when vegetation cover is low, and soil background significantly affects spectral response. It improves stress detection in rainfed and dryland agriculture.

Red-Edge-Based Vegetation Indices

Normalized Difference Red Edge Index (NDRE): NDRE uses the red-edge band (around 700–740 nm) instead of the red band:

$$NDRE = (\rho NIR - \rho RedEdge) / (\rho NIR + \rho RedEdge)$$

NDRE is more sensitive to chlorophyll content in moderate to dense canopies and is effective for detecting nitrogen stress before visible symptoms appear.

Red-edge indices are widely used in precision agriculture for fertilizer management, variable-rate nitrogen application, and early stress diagnosis.

Green-Based Indices

Green Chlorophyll Index (GCI): The Green Chlorophyll Index is defined as:

$$GCI = (\rho NIR / \rho Green) - 1$$

It is strongly correlated with leaf chlorophyll concentration and nitrogen status.

GCI is useful for detecting nutrient deficiencies and monitoring crop vigor, particularly in cereals and oilseed crops.

Physiological and Stress-Specific Indices

1. Photochemical Reflectance Index (PRI): PRI is related to changes in xanthophyll cycle pigments and photosynthetic light-use efficiency:

$$PRI = (\rho 531 - \rho 570) / (\rho 531 + \rho 570)$$

It is sensitive to short-term physiological stress caused by water deficit, heat stress, and excess light.

2. Water Stress Indices: Indices incorporating SWIR bands, such as the Normalized Difference Water Index (NDWI) and Moisture Stress Index (MSI), are used to assess plant water status and drought stress.

Vegetation Indices for Pest and Disease Damage Assessment

Pest infestation and disease infection often result in defoliation, chlorosis, necrosis, and canopy structural changes. These symptoms alter spectral reflectance, leading to detectable changes in vegetation indices. NDVI, NDRE, and GCI have been widely used to map pest damage intensity and disease severity. Time-series analysis helps distinguish between gradual stress progression and sudden damage events.

Conclusion

Vegetation indices derived from remote sensing data provide valuable insights into crop stress, damage, and overall condition. Indices such as NDVI, EVI, SAVI, NDRE, GCI, and stress-specific indices have proven effective in diverse agro-ecological conditions.

While no single index can capture all aspects of crop health, the combined use of multiple indices, supported by ground observations and advanced analytics, offers a robust framework for crop monitoring. As remote sensing technology continues to evolve, vegetation indices will remain central to precision agriculture and sustainable crop management.

References

1. Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1974). Monitoring vegetation systems in the Great Plains with ERTS.
2. Huete, A. R. (1988). A soil-adjusted vegetation index (SAVI).
3. Gitelson, A. A., & Merzlyak, M. N. (1997). Remote estimation of chlorophyll content in higher plant leaves.

4. Jensen, J. R. (2015). Introductory Digital Image Processing: A Remote Sensing Perspective.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Cities of Waste and Oceans of Plastics

Article ID: 72734

Selva Dhikeesh M[1]
[1]Agricultural Engineering and Research Institute, Tamil Nadu Agricultural University, India.

Abstract
Improper solid waste management has emerged as a critical environmental challenge worldwide, creating a direct and alarming connection between urban streets and marine ecosystems. Rapid urbanisation, population growth, and changing consumption patterns have resulted in an unprecedented increase in waste generation, while waste management systems in many regions remain inadequate and inefficient. As a result, large quantities of solid waste—particularly plastics—are mismanaged and eventually transported from land-based sources into rivers, seas, and oceans. Natural processes such as rainfall runoff, wind action, and river flow act as pathways, enabling waste to travel long distances from its point of origin. This article explores the sources and pathways of poorly managed solid waste, its impacts on terrestrial and marine ecosystems, and the associated risks to human health and economic activities. It also highlights the urgent need for sustainable waste management practices, policy interventions, and public participation to prevent environmental degradation and protect the planet for future generations.

Keywords: Solid waste management, Marine pollution, Plastic waste, Micro plastics, Environmental sustainability, urban pollution

Introduction
Solid waste management is one of the most pressing environmental issues faced by modern society. Rapid urbanisation, industrial growth, and population expansion have led to a sharp rise in the quantity and diversity of waste generated across cities and towns. Municipal solid waste now includes biodegradable materials, plastics, metals, glass, electronic waste, and hazardous substances, making its management increasingly complex. Unfortunately, waste management systems in many regions have failed to keep pace with this growth, resulting in widespread improper disposal practices.

What appears to be a local problem—littered streets, overflowing bins, or open dumping—often has consequences far beyond the immediate surroundings. Waste discarded irresponsibly on land can travel through natural and artificial pathways, eventually contaminating rivers, seas, and oceans. This land-to-sea connection highlights the interconnected nature of environmental systems and demonstrates how poor waste management contributes directly to global marine pollution. Among all waste types, plastics are of particular concern due to their durability, widespread use, and resistance to degradation.

Sources of Poor Waste Management
Poor waste management arises from a combination of infrastructural, institutional, and behavioural factors. Inadequate waste collection services remain a major issue, particularly in rapidly growing urban areas and informal settlements. When waste collection is irregular or unavailable, residents resort to dumping waste in open spaces, drains, and nearby water bodies. Lack of segregation at the source further complicates waste handling, reducing opportunities for recycling and safe treatment.

Increasing consumption of single-use products and disposable packaging has significantly increased the volume of non-biodegradable waste. Weak enforcement of environmental regulations limited public awareness, and insufficient accountability also contribute to careless disposal practices. Industrial and commercial establishments sometimes dispose of waste illegally to reduce costs, further aggravating environmental pollution. These factors collectively result in large quantities of waste being released into natural ecosystems.

Pathways of Waste from Streets to Seas
Once waste is improperly disposed of, it can be easily transported into aquatic environments. Rainfall plays a crucial role in mobilising waste accumulated on streets, open grounds, and dumpsites. Surface runoff carries waste into storm water drains and sewage channels, many of which discharge directly into rivers without adequate treatment. Rivers then act as major transport pathways, carrying waste from inland regions to coastal and marine environments.

Wind also contributes to waste movement by blowing lightweight materials such as plastic bags, wrappers, and packaging into water bodies. In coastal areas, direct dumping of municipal waste, tourism-related litter, and fishing debris accelerates marine pollution. Poorly managed landfills located near coastlines are particularly vulnerable during storms and flooding events. These interconnected pathways demonstrate how waste generated far inland can ultimately reach the seas.

Impacts on Marine Ecosystems

Marine ecosystems are among the most severely affected by poor waste management. Plastic debris poses serious threats to marine organisms, which often ingest it after mistaking it for food. Ingestion can cause internal injuries, blockages, reduced feeding efficiency, and death. Entanglement in discarded fishing gear and plastic waste further increases mortality among marine species.

Over time, plastic waste breaks down into micro plastics, which persist in the marine environment and are consumed by plankton and small fish. These microplastics accumulate along the food chain, posing risks to larger predators and humans. Coral reefs are also affected, as waste accumulation damages coral structures, reduces light availability, and introduces harmful microorganisms. The degradation of marine ecosystems threatens biodiversity, fisheries productivity, and ocean health.

Impacts on Terrestrial Ecosystems

On land, improper waste management degrades soil quality and alters natural drainage systems. Blocked drains increase the risk of urban flooding, particularly during heavy rainfall. Open dumpsites create favourable conditions for insects, rodents, and other disease vectors, increasing public health risks. Leachate from unmanaged landfills contaminates soil and groundwater with toxic substances, affecting agriculture and drinking water sources. Natural habitats are also disrupted by waste accumulation, leading to habitat loss and reduced biodiversity. These impacts weaken ecosystem services such as water purification, soil fertility, and climate regulation, ultimately affecting human well-being.

Implications for Human Health

Poor waste management poses serious risks to human health. Open dumping and burning of waste release toxic gases, particulate matter, and harmful chemicals into the atmosphere, contributing to respiratory illnesses, cardiovascular diseases, and other health problems. Communities living near dumpsites are particularly vulnerable to these effects. Contaminated water bodies facilitate the spread of waterborne diseases such as cholera, dysentery, and typhoid. The presence of micro plastics and hazardous substances in seafood raises concerns about long-term health impacts. Informal waste handlers and sanitation workers face additional risks due to direct exposure to hazardous waste materials.

Economic Consequences of Poor Waste Management

The economic impacts of waste mismanagement are substantial. Polluted beaches and waterways reduce tourism revenue and negatively affect local economies. Fisheries suffer from declining fish stocks and contaminated waters, threatening livelihoods in coastal communities. Governments incur high costs for waste cleanup, healthcare, flood damage repair, and environmental restoration, placing a significant burden on public finances. Investing in effective waste management systems can reduce these costs while creating employment opportunities in recycling, waste processing, and environmental services.

Mitigation Measures and Sustainable Solutions

Addressing pollution from streets to seas requires an integrated and sustainable approach to solid waste management. Waste segregation at source, recycling, composting, and reduction of single-use plastics are essential measures. Strengthening waste collection and treatment infrastructure, enforcing environmental regulations, and promoting extended producer responsibility can significantly reduce waste leakage into natural systems. Public awareness campaigns, community participation, and environmental education are critical for encouraging responsible waste disposal behaviour.

Conclusion

The journey of waste from streets to seas highlights the far-reaching consequences of poor solid waste management. Waste discarded irresponsibly on land ultimately contaminates rivers and oceans, threatening ecosystems, human health, and economic sustainability. Addressing this issue requires collective responsibility from individuals, communities, industries, and governments. By adopting sustainable waste management practices and strengthening policy frameworks, it is possible to prevent environmental pollution and ensure a cleaner, healthier planet for future generations.

References

1. United Nations Environment Programme(UNEP).(2021). From Pollution to Solution A Global Assessment of Marine Litter and Plastic Pollution. UNEP, Nairobi.
2. World Bank.(2018). What a Waste 2.0 A Global Snapshot of Solid Waste Management to 2050. World Bank Publications, Washington, DC.
3. Jambeck, J. R., et al.(2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768 – 771.
4. Central Pollution Control Board(CPCB).(2022). Status of External Solid Waste Management in India. Government of India, New Delhi.

5. United Nations Environment Programme(UNEP).(2023). turning off the Tap How the World Can End Plastic Pollution. UNEP, Nairobi.
6. National Geographic.(2020). the plastic pollution extremity. National Geographic Magazine.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

The Growing Threat of Light Pollution in Modern Cities

Article ID: 72735

Neelakandan R[1]
[1]Agricultural Engineering and Research Institute, Tamil Nadu Agricultural University, India.

Abstract
Light pollution has emerged as a significant yet often overlooked form of environmental degradation associated with rapid urbanisation, technological advancement, and increased dependence on artificial lighting. Excessive and poorly designed outdoor lighting alters natural night-time darkness, leading to adverse impacts on ecosystems, human health, energy consumption, and astronomical observations. Recent studies indicate that night sky brightness is increasing at an alarming rate, primarily due to the widespread adoption of high-intensity LED lighting and unregulated urban illumination. This article examines the extent, causes, and consequences of light pollution, with particular emphasis on its ecological, economic, and health-related implications. The study also discusses mitigation strategies and policy interventions aimed at promoting sustainable and responsible lighting practices.

Keywords: Light pollution, Artificial lighting, Night sky brightness, Circadian rhythm, Biodiversity, Energy efficiency.

Introduction
Artificial light has become an indispensable component of modern civilisation, supporting economic activity, public safety, and urban development. However, the unchecked proliferation of artificial lighting has given rise to light pollution, defined as excessive, misdirected, or unnecessary artificial illumination that disrupts natural darkness. Unlike other forms of pollution, light pollution is intangible and often perceived as harmless, leading to limited public awareness and policy attention. With expanding cities, illuminated highways, advertising hoardings, commercial complexes, and round-the-clock economic activity, night-time environments have undergone drastic transformation. In many urban areas, natural darkness has nearly disappeared, fundamentally altering ecological processes and human biological rhythms. Understanding the implications of light pollution is critical, as its effects extend beyond aesthetics to encompass biodiversity loss, public health risks, and economic inefficiencies.

Extent and Growth of Light Pollution
Recent scientific research has revealed that the global night sky is brightening at a rate of approximately 10 percent per year, a figure significantly higher than earlier satellite-based estimates. This rapid increase is largely attributed to the growing use of light-emitting diode (LED) technology, which emits blue-rich light that scatters efficiently in the atmosphere and intensifies skyglow. Satellite sensors often underestimate this increase due to limitations in detecting certain wavelengths, whereas ground-based observations provide a clearer picture of escalating brightness.

As a result, a substantial proportion of the global population can no longer observe natural celestial features such as the Milky Way. This loss of dark skies not only diminishes cultural and scientific engagement with astronomy but also serves as a visible indicator of broader environmental imbalance.

Ecological Impacts of Light Pollution
1. Light pollution exerts profound effects on ecosystems by disrupting the natural light–dark cycles that govern biological processes. Many animal species rely on darkness for navigation, reproduction, and feeding. Migratory birds, for instance, use stars for orientation during long-distance travel. Artificial lighting disorients these birds, increasing the risk of collisions with illuminated buildings and infrastructure, leading to large-scale mortality events.

2. Nocturnal insects are particularly vulnerable, as they are attracted to artificial light sources where they face exhaustion, predation, or death. The decline in insect populations has cascading effects on ecosystems, as insects play a crucial role in pollination and serve as a primary food source for many species. Plants are also affected, as artificial light alters flowering cycles and seasonal cues, disrupting plant–pollinator interactions and reducing ecosystem stability.

Impact on Human Health and Well-Being
1. Human physiology is closely regulated by circadian rhythms that respond to natural patterns of light and darkness. Exposure to artificial light at night suppresses melatonin production, a hormone essential for sleep regulation and overall health. Prolonged disruption of circadian rhythms has been linked to sleep disorders, stress, metabolic imbalances, and increased risk of cardiovascular diseases.

2. Urban populations, shift workers, and individuals living in highly illuminated environments face heightened exposure to artificial night lighting. The growing prevalence of sleep-related health issues highlights the need to recognise light pollution as a public health concern rather than merely an environmental nuisance.

Economic and Energy Implications

1. From an economic perspective, light pollution represents significant energy wastage. A substantial proportion of outdoor lighting illuminates unoccupied spaces or is directed upward rather than toward intended areas. This inefficiency results in unnecessary electricity consumption, increased public expenditure, and higher greenhouse gas emissions due to reliance on fossil-fuel-based power generation.

2. While LED technology was initially promoted for its energy efficiency, reduced costs have led to over-installation of lighting systems, a phenomenon known as the rebound effect. Consequently, overall light output has increased rather than decreased, undermining potential energy savings.

Mitigation Strategies and Policy Interventions

1. Light pollution is unique among environmental problems in that it can be mitigated rapidly and cost-effectively. The adoption of shielded lighting fixtures that direct light downward, the use of warmer colour temperatures, and the installation of motion sensors and timers can significantly reduce unnecessary illumination. Urban planning policies that incorporate dark-sky principles have proven effective in balancing safety, functionality, and environmental protection.

2. Several cities worldwide have implemented dark-sky-compliant lighting regulations, particularly in ecologically sensitive areas. Public awareness campaigns and institutional guidelines are essential to encourage responsible lighting practices at both individual and community levels.

Conclusion

Light pollution is an emerging environmental challenge with far-reaching consequences for ecosystems, human health, energy consumption, and cultural heritage. The rapid brightening of night skies reflects unsustainable patterns of development and resource use. While artificial light remains essential for modern life, its application must be carefully managed to minimise ecological and social harm. A balanced approach combining technological innovation, policy regulation, and public awareness is necessary to restore natural darkness and promote sustainable coexistence between human activity and the night-time environment.

References

1. International Dark-Sky Association (IDA). (2023). Global trends in light pollution and urban night sky brightness. IDA Research Reports, Tucson, USA.
2. Finshots. (2025). The scourge of light pollution: How artificial lighting is reshaping our nights. Finshots Daily Archive, India.
3. The Times of India. (2024). Rising light pollution levels in Indian cities raise environmental concerns. National Edition, India.
4. Ministry of Environment, Forest and Climate Change (MoEFCC). (2023). Urban environmental challenges and light pollution management. Government of India Publication, New Delhi.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Market Dynamics Behind India's Rising Egg Prices

Article ID: 72736

Sivasuriyan S[1]
[1]Agricultural Engineering and Research Institute, Tamil Nadu Agricultural University, India.

Abstract
Eggs are among the most affordable and nutritionally dense sources of animal protein in India, contributing significantly to household food security. In recent months, however, egg prices have increased sharply across the country, with unprecedented farm-gate prices observed in Namakkal district of Tamil Nadu, India's largest egg production and export hub. This article analyses the underlying market dynamics driving the rise in egg prices, with emphasis on the role of the National Egg Coordination Committee (NECC) in price discovery, supply-side disruptions caused by feed quality issues, seasonal demand fluctuations, rising input costs, and export market pressures. The study highlights how coordinated pricing mechanisms and structural constraints in the poultry sector amplify price volatility during periods of supply-demand imbalance.

Keywords: Egg prices, Poultry sector, NECC, Namakkal, Feed cost, Seasonal demand, Exports.

Introduction
The poultry sector occupies a vital position in India's agri-food system, contributing significantly to food security, rural livelihoods, and nutritional outcomes. Eggs are widely consumed across income groups due to their relatively low cost, high biological value protein, and ease of distribution. According to industry estimates, Namakkal district in Tamil Nadu is popularly known as the 'Egg Bowl of India', produces nearly six crore eggs per day and serves as a major supply centre for domestic markets as well as exports to the Middle East and neighbouring regions.

In 2025, farm-gate egg prices in Namakkal crossed ₹6 per egg for the first time, representing a marked deviation from historical price bands. This surge has generated concern among consumers and renewed debate on market efficiency, cost structures, and price transmission within the poultry value chain. Understanding egg price behaviour requires a holistic examination of India's unique price discovery mechanism, evolving demand patterns, supply-side constraints, and rising production costs.

Role of the National Egg Coordination Committee (NECC)
Unlike many agricultural commodities, eggs in India are not governed by government-administered minimum support prices. Instead, price discovery is coordinated through the National Egg Coordination Committee (NECC), a farmer-led institution established in 1982 to protect poultry farmers from distress pricing and market manipulation by intermediaries. NECC functions through zonal committees located in major poultry-producing regions such as Namakkal, Hyderabad, Pune, and Delhi. These committees meet daily to assess prevailing market conditions, including egg supply, consumption trends, input costs such as feed, labour, electricity, and veterinary services, as well as regional demand signals.

Based on these assessments, NECC announces a daily benchmark or declared rate, which serves as the reference price for wholesale and retail transactions. Although NECC prices are advisory in nature, they effectively act as market-clearing prices due to widespread acceptance among more than 25,000 poultry farmers and traders across the country. This coordinated pricing framework provides a degree of stability but also ensures that supply-demand shocks are rapidly transmitted into prices.

Factors Driving the Recent Price Surge in Namakkal
1. Decline in Production Due to Feed Quality Issues: One of the key drivers of the recent price escalation has been a decline in egg production linked to feed quality deterioration. Unseasonal and continuous rainfall in parts of Tamil Nadu adversely affected maize—the primary component of poultry feed—leading to high moisture content and fungal contamination. Poor feed quality reduced feed conversion efficiency affected bird health, and lowered laying rates. Industry sources estimate that egg output in Namakkal declined by nearly 7–10 percent during this period, significantly tightening supply.

2. Seasonal Increase in Demand: Egg demand in India exhibits strong seasonal variation, with consumption rising during winter months due to dietary preferences and perceptions of eggs as a 'warming' food. Additionally, bakeries, hotels, and food processing units increase egg procurement ahead of festive seasons such as Christmas and New Year. The coincidence of peak seasonal demand with reduced production intensified upward pressure on prices.

3. Export Pull from International Markets: Namakkal's strategic proximity to ports such as Thoothukudi and Kochi enhances its role as a major egg export hub. Rising demand from Middle Eastern markets, coupled with improved logistics

and faster turnaround times, led to a diversion of local supply toward export orders. This export pull reduced domestic availability and further supported higher prices in the local market.

Implications for Consumers and Farmers

1. Impact on Consumers: The rise in farm-gate prices has translated into higher retail egg prices across urban centres. In cities such as Bengaluru, retail prices reportedly reached ₹7–₹8 per egg during peak winter demand. Although retail prices vary depending on transportation costs, intermediaries' margins, and local supply conditions, NECC's declared rates strongly influence consumer prices throughout the supply chain.

2. Impact on Poultry Farmers: Despite higher nominal prices, poultry farmers continue to operate under narrow profit margins. Feed accounts for nearly 60–70 percent of total production costs, and the cost of producing a single egg is estimated to range between ₹4.5 and ₹4.75. Rising maize prices, labour shortages, energy costs, and veterinary expenses significantly constrain net profitability, even during periods of elevated prices.

Measures for Price Stabilisation

1. Managing Feed Price Volatility: Indian poultry farmers currently lack formal risk management instruments such as futures contracts or structured hedging mechanisms for feed ingredients. Policy interventions including feed price stabilisation funds, strategic maize reserves, or temporary input subsidies during periods of extreme volatility could help reduce cost uncertainty and smooth price cycles.

2. Strengthening Disease Management Strategies: India's prevailing 'detect and cull' policy during avian influenza outbreaks often results in abrupt reductions in flock size and egg supply. A gradual transition toward preventive vaccination strategies, supported by robust biosecurity protocols and surveillance systems, could reduce sudden supply shocks and improve long-term market stability.

Conclusion

The recent escalation in egg prices in India, particularly in Namakkal, reflects a complex interaction of coordinated price discovery through NECC, supply disruptions arising from feed quality issues, seasonal demand growth, rising input costs, and export market pressures. While higher prices provide temporary relief to farmers, persistent structural vulnerabilities in feed supply chains and disease management continue to pose challenges. A balanced policy approach that complements market-based coordination with targeted institutional support is essential to ensure long-term price stability and affordability for consumers.

References

1. National Egg Coordination Committee (NECC). (2023). Egg price trends and market reports. NECC Poultry Price Board, New Delhi.
2. Finshots. (2025). Understanding the economics behind India's egg prices: Why Namakkal touched ₹6 per egg. Finshots Daily Archive, India.
3. The Times of India. (2025). NECC price remains at ₹6.10 per egg in Namakkal; likely to rise further in December. Coimbatore Edition, Tamil Nadu.
4. Tamil Nadu Poultry Farmers Federation. (2025). Feed cost fluctuations, maize quality issues, and poultry production challenges in 2025. Industry White Paper, Namakkal, Tamil Nadu.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Processing and Development of Value-Added Products of Vegetable

Article ID: 72737

Arun Patel[1], Vijay Bahadur[2]
[1]M.Sc. Horticulture (Vegetable Science), SHUATS, Prayagraj, U.P.
[2]Professor, Department of Horticulture, SHUATS, Prayagraj, U.P.

Introduction

India ranks as the world's second-largest producer of fruits and vegetables. The role of vegetables in addressing issues of food and nutritional security is now widely recognized. However, more than one-third of the total vegetable production is lost during different stages of handling—from harvesting to final consumption. Because vegetables are highly perishable and have a short shelf life, they need to be sold quickly or converted into various value-added products. Therefore, processing and value addition play a vital role in the post-harvest management of fruits and vegetables.

These processes help minimize post-harvest losses and wastage, control market gluts, ensure better nutritional availability, utilize surplus produce efficiently, and provide fair returns to both farmers and processors. Due to changing consumer preferences, evolving market trends, and the expansion of supermarkets, the demand for value-added products has increased significantly. As a result, ready-to-use and pre-packed vegetables are becoming more common and popular among consumers.

Potential for Fruit and Vegetable Processing

1. There is considerable potential to harvest and utilize many underexploited minor fruits. Although several of these fruits are nutritious, they are not always safe or palatable when consumed raw. However, through appropriate processing, they can be converted into high-quality products. This allows the processing industry to utilize its capacity more efficiently and productively.

2. With rising living standards and increasing participation of women in the workforce, food habits are changing, leading to a growing demand for processed fruits and vegetables. Fast foods, ready-to-eat items and convenience foods have now become essential components of modern lifestyles. Easily available fruit and vegetable products can greatly support working women by offering nutritious, affordable food options even during the off-season, saving their time and effort. Moreover, due to the influence of electronic media, processed fruit and vegetable consumption is becoming common even in rural areas.

3. Fruit and vegetable processing generates a large amount of solid waste. Proper use of this waste and byproducts can either increase overall profits or reduce processing costs. It is estimated that produce worth more than 3000 crore is lost every year due to inadequate post-harvest processing facilities. Minimizing these losses would not only raise the income of growers but also strengthen the nation's food supply system.

4. India is the world's largest producer of fruits and vegetables, accounting for approximately 10% of global fruit production and 13% of global vegetable production.

Keywords: Processing, Value addition, Vegetables.

Introduction

Scenario Of Vegetable Production and Processing: Vegetables form an essential part of a balanced daily diet. They are known as protective foods because they supply abundant vitamins, minerals and phyto-nutrients. Their role in improving food and nutritional security is now clearly recognized. Regular consumption of vegetables is associated with improved digestive health, better eyesight and a reduced risk of cardiovascular diseases, strokes, diabetes and various types of cancer.

India, after China, stands as the second-largest producer of fruits and vegetables globally. However, due to their highly perishable nature, a significant portion of these commodities is lost after harvesting. Nearly one-third of the produce is wasted during different stages of handling—from the field to the consumer. Therefore, processing and value addition have become vital aspects of the horticulture sector. These practices help minimize post-harvest losses, control market surpluses, ensure nutritional availability, utilize excess produce effectively and provide fair economic returns to both farmers and processors.

Potential for Fruit and Vegetable Processing

1. There is considerable potential to make use of many underutilized minor fruits. Although these fruits are nutritious, some of them are not suitable for raw consumption; however, they can be processed into high-quality products. This allows the processing industry to operate more efficiently and expand its production capacity.

2. With rising living standards and more women participating in the workforce, consumer food preferences are shifting, leading to increasing demand for processed fruits and vegetables. Ready-made, fast and convenience foods have become an integral part of modern life. Easily available fruit- and vegetable-based products can greatly support working women by offering nutritious, affordable options throughout the off-season, saving both time and effort. The growing influence of electronic media has also encouraged people in rural areas to consume processed food products.

3. Large quantities of solid waste are generated during the processing of fruits and vegetables. Proper utilization of this waste and its byproducts can help enhance overall profit margins or reduce processing costs per unit. It is estimated that producers worth more than ₹3000 crores are lost every year due to inadequate post-harvest processing facilities. Reducing these losses would increase farmers' incomes and help strengthen the nation's overall food availability.

4. India stands as the world's leading producer of fruits and vegetables, contributing roughly 10% of global fruit production and 13% of global vegetable production.

Export Market of Different Value-Added Vegetable Products

Sr. No	PRODUCTS	COUNTRIES
1.	Dried and preserved vegetables	Sri Lanka, USA, UAE, Germany, France, Netherlands
2.	Pickle and chutney from vegetables and fruits	UK, USA, UAE, Germany, Canada, Netherlands, Saudi Arabia
3.	Other processed fruits and vegetables	USA, Netherlands, UK, UAE, Indonesia, Philippines

Value Added Vegetable Products

1. Potato:

a. Chips:

i. For potato chips, fresh potatoes with a high dry matter content are preferred; these chips can also be made into potato flour. The browning interaction between sugars and other ingredients, primarily amino acids, produces the chip's colour.

ii. High-sugared potato chips turn brown or black when fried and the same thing happens to boiled and peeled potatoes. The production of chips is determined by the specific gravity/dry weight of the potatoes.

b. French Fries:

i. The process begins by thoroughly washing fully matured potatoes and removing any small, damaged, misshapen or discoloured portions. After this, the potatoes are peeled and sliced into rectangular strips. These strips are then blanched in hot water at a temperature of 70–90 °C for about five minutes. Once blanching is completed, the excess water is drained off and the pieces are transferred for frying. After frying, the product is defatted by allowing it to pass over a vibrating screen to remove extra oil. Finally, the fried pieces are allowed to cool to room temperature and then sealed in airtight containers.

ii. Kufri Chipsonna-3 is a suitable cultivar for making potato French fries.

c. Dehydrated Products: (Potato flour, Granules and Flakes): When the dry matter content is higher, less energy is required to eliminate the relatively small amount of moisture present in the raw material, resulting in a greater yield of the final product. Preserved potatoes generally contain less moisture but higher amounts of sugars and proteins compared to fresh ones. Fresh potatoes are commonly used for producing potato flour to minimize the problem of browning (Pedreschi).

d. **Canned Potatoes:**

i. Potatoes with lower dry matter content are preferred when a firm texture is required, such as for curries or canning purposes. They may be canned either whole or in slices, either on their own or mixed with other vegetables. These canned potatoes generally maintain very good texture, flavor and firmness.

ii. Important frozen potato products such as potato patties, potato puffs and potato cakes are prepared using mashed potatoes mixed with baking soda and various other ingredients.

2. Tomato:

a. Sauce/Ketchup:

i. Tomato sauce and ketchup are made from strained tomato pulp or juice combined with spices, salt, sugar, vinegar and sometimes onion and garlic paste. These products are semi-solid forms of processed tomatoes

ii. Sauces can be sieved and have a smoother consistency. At least 12% tomato solids and 25% total solids are present in the sauce.

iii. A thick tomato sauce with additional spices is known as ketchup.

b. Puree & Paste:

i. Tomato puree is a processed food typically made from concentrated tomato juice, either with or without peel, seeds, or salt. For medium tomato puree, the juice concentration shouldn't be less than 9 % and for heavy tomato puree, it shouldn't be less than 12 % solids. Tomato paste, which includes at least 25 % tomato solids, may be made by further concentrating tomato liquid. Concentrated tomato paste is tomato paste that has been further concentrated to include 33 % or more solids.

ii. In order to make tomato puree or paste, you must first extract the tomato juice from ripe fruits, stain it and then cook it until it reaches the desired consistency (12–14 °Brix for puree and up to 44 °Brix for paste). Next, you must pour the hot juice into sterilised bottles or cans, seal them and then pasteurise them in boiling water for 20 minutes before letting them cool completely and storing them somewhere cool and dry.

c. Chutney:

Option 1 (Simple & Clear): Chutney is made using chopped ginger, onion, and garlic along with spices, salt, sugar, and vinegar or sodium benzoate as preservatives.

Option 2 (More polished): Chutney is prepared from chopped ginger, onion, and garlic mixed with spices, salt, sugar, and vinegar or sodium benzoate as preservatives.

Option 3 (More formal): Chutney is formulated using chopped ginger, onion, and garlic, combined with spices, salt, sugar, and preserved with vinegar or sodium benzoate.

3. Garden Pea:

Dehydrated Pea, Frozen Pea & Canned Pea:

i. Dehydrated peas are becoming more and more popular as a result of their longer shelf life, better flavour and ease of handling and transportation. Similar to fresh peas, the drying method ought to effectively preserve the colour, texture, flavour, taste and nutritional content of the produce.

ii. Fluidized bed drying is gaining importance for pea drying.

iii. For freezing, small, dark-green peas with seeds are recommended. Using polythene sheets that are resistant to low temperatures and impermeable to water vapour, fresh peas are frozen at a temperature of 18°C.

iv. Tender, large-sized pods with delicious, assertive seeds are chosen for canning. Cultivars with wrinkled and smooth seeds are suitable for canning. However, due to their skin's propensity to turn bronze in the course of processing or storage, cultivars grown from freezing are not suitable for canning.

4. Cabbage:

Sauerkraut:

Option 1 (Simple & Clear): Sauerkraut is extremely popular in many European countries and the USA. It refers to fermented, acidic cabbage. It is a pure and healthy product with a distinct flavour, produced by fully fermenting shredded cabbage with 2–3% salt. Good-quality sauerkraut contains about 1.5% lactic acid and 0.5–2.5% salt.

Option 2 (More Polished): Sauerkraut enjoys great popularity in several European nations and the USA. It is essentially acidic, fermented cabbage. This pure and healthy product is prepared by completely fermenting finely shredded cabbage with 2–3% salt. High-quality sauerkraut typically contains around 1.5% lactic acid and 0.5–2.5% salt.

Option 3 (Formal / Academic): Sauerkraut is widely consumed in many European countries and the USA. It is an acidic, fermented cabbage product known for its purity and distinctive flavour. It is produced by fermenting shredded cabbage with 2–3% salt. Good-quality sauerkraut contains approximately 1.5% lactic acid and 0.5–2.5% salt.

5. Cauliflower:

Dehydrated & Frozen Cauliflower:

i. Several food products, including instant soup, contain dehydrated cauliflower as a key ingredient.

ii. Freshly cut florets (2.5 cm thick) are cleaned, blanched in boiling water for 5 minutes at 95 °C, cooled by fast freezing at 40 °C, then dipped in 0.05 % KMS solution for 5 minutes to prevent browning, packed in plastic bags and stored at 18 °C. To prevent dehydration during storage, the packaging material must be moisture-proof and durable at low temperatures.

6. Carrot:

a. Shred: After reconstitution, dried shreds are used in halwa, instant mixes, or noodle mixtures.

b. Powder:

i. Carrots may be preserved quite effectively by dehydration and powder production. The two main pretreatments used to prepare carrot powder are blanching and boiling.

ii. More beta-carotene and total dietary fibre in carrot powder made by boiling the carrots.

iii. Washing, cutting into 22 cm pieces, cooking for 10 minutes, mashing, allowing to cool at room temperature, drying for 18 hours at 50 °C and then grinding into powder.

7. Wax/Ash Gourd:

a. Candy/ Petha:

i. A rectangular or cylindrical transparent soft candy produced from ash gourd is known as "Agra petha."
ii. Indians love this sweet dish because of its exquisite flavour and beneficial therapeutic qualities

b. Pickles: Pieces that have been soaked are drained and utilised to make pickles.

Option 1 (Simple & Clear): Sweet potatoes can be used to make pickles by cutting them into 1 cm cubes and soaking the pieces in 1% acetic acid for one hour.

Option 2 (More Polished): Sweet potato pickles are prepared by cutting the tubers into 1 cm cubes and soaking them in a 1% acetic acid solution for an hour.

Option 3 (Formal / Academic): Pickles can be prepared from sweet potatoes by dicing them into 1 cm cubes and immersing the pieces in a 1% acetic acid solution for one hour.

Dehydrated Leafy Vegetables

It has the tremendous potential to be utilised all year round, even in the off-season, for the preparation of many types of mixed vegetables following rehydration.

1. It has the potential to develop into a significant product since it is affordable, simple to prepare and packed with nutrients that are vital to good health.

2. In the area of food technology, drying leafy vegetables and making them usable for the future opens up new horizons.

3. Currently, India exports a sizable number of value-added goods made from vegetables and spices, generating a sizable sum of foreign cash.

4. In addition to this, items are becoming more significant in the internal market as customer preferences and market behaviour have changed.

References

1. Arslan, M.; Xiaobo, Z.; Shi, J.; Rakha, A.; Hu, X.; Zareef, M. and Basheer, S. (2018). Oil uptake by potato chips or French fries: A review. Eur J Lipid Sci Technol, 120(10).
2. Burrier, S. (2000). Preparing and canning fermented foods and pickled vegetables: Featuring new, research-based recommendations for safer and better quality food at home. Post Harvest Management and Technology of Fruits and Vegetables 278.
3. Chang, K. H.; Cho, K. H. and Kang, M. K. (2012). Optimization of the preparation conditions and quality characteristics of sweet pumpkin-doenjang sauce. Korean J. Food Preserv., 19(4): 492- 500.
4. Chauhan, A. (2014). Preparation and sensory evaluation of value added products incorporated with dried cauliflower green leaves. J. Nutr. Ecol. Food Res., 2(1): 29-31.
5. Datta, S.; Chatterjee, R. and Jana, J. C. (2015). Value addition in vegetable crops. In Value Addition of Horticultural Crops: Recent Trends and Future Directions (pp. 43-57).
6. Simonyan, K. J. and Evwierhoma, E. T. (2019). Utilization of cassava wastes for value added products: An overview. Int. J. Eng. Sci., 3(1): 31-39.
7. Garayo, J. and Moreira, R. (2002). Vacuum frying of potato chips. J. Food Eng., 55(2): 181-191.
8. Griffin, M.; Sobal, J. and Lyson, T. A. (2009). An analysis of a community food waste stream. Agric. Human Values, 26(1): 67-81.
9. Khurdiya, D. S. (2003). Promoting export of value-added products of horticultural produce. Indian Horticulture (India).,27(2):68-81
10. Nawirska, A. and Uklańska, C. (2008). Waste products from fruit and vegetable processing as potential sources for food enrichment in dietary fibre. Acta Sci. Pol. Technol. Aliment., 7(2): 35-42.
11. Omoare, A. M.; Fakoya, E. O.; Fapojuwo, O. E. and Oyediran, W. O. (2014). Awareness of value addition of sweet potato (Ipomoea batatas (L.) LAM) in Osun State, Nigeria. Int. J. Agric. Eng., 8(1):71-78

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Pre & Post Harvest Handling of Vegetables

Article ID: 72738

Shrishti Gupta[1], Vijay Bahadur[2]
[1]M.Sc. Research scholar, Department of Horticulture, SHUATS, Naini Agricultural institute, Prayagraj.
[2]Professor and Head, Department of Horticulture, SHUATS, Naini Agricultural institute, Prayagraj.

Introduction

Horticulture is the major pillar of our nation's economy, with nearly 60-65% of people involved in this sector either directly or indirectly. It also contributes substantially to India's export income. However, due to improper post-harvest handling, nearly 20-40% of horticultural produce is lost in the country, causing considerable economic damage.

The term pre- and post-harvest handling refers to all the practices carried out to maintain the quality and extend the shelf life of vegetables—from the growing stage until they reach consumers. Pre-harvest activities mainly focus on the proper management of soil, irrigation, and nutrients, while post-harvest operations include timely harvesting, appropriate harvesting techniques, cooling, grading, washing, packaging, storage, and transportation to reduce spoilage, physical damage, and overall quality loss.

General Principles of Post-Harvest Management

1. Fruits and vegetables remain biologically active even after they are removed from the plant, and they continue to respire like living organisms.

2. Once harvested, fruits and vegetables depend on their stored nutrients to generate the energy required for respiration and metabolism, which gradually leads to their deterioration.

3. The speed at which they respire differs among crops and is affected by many internal and external factors, including variety, maturity stage at harvest, temperature, and relative humidity.

4. Ongoing respiration and metabolic activities after harvest cause noticeable changes in the produce, such as alterations in texture, color, flavors, taste, and appearance, along with moisture loss through water vapour.

5. If proper care is not taken during handling, these changes can progress rapidly, making the produce unacceptable or less desirable to consumers and buyers.

6. Therefore, careful post-harvest handling and management of fresh fruits and vegetables is essential to reduce spoilage and decay and to extend the shelf life of the produce.

Pre-Harvest Handling

1. Genetics and crop selection: Select crop varieties that possess strong quality traits and natural resistance to diseases.

2. Site and field management: Maintain suitable soil health, structure, and drainage to support proper crop growth.

3. Nutrient management: Use appropriate fertilizers to promote healthy development and prevent nutrient-related disorders.

4. Irrigation management: Provide uniform and adequate water to avoid plant stress, which can negatively influence final produce quality.

5. Pest and disease control: Adopt integrated pest management (IPM) methods to reduce pest injury and disease infections that may affect the crop during storage or after harvest.

Causes of Post-Harvest Losses

Horticultural crops supply people with nutritious, health-promoting foods and also serve as an important source of income for farmers. Without proper handling, produce that is rich in nutrients and market value can deteriorate or decay within a short period—sometimes even within hours.

Group	Examples	Main Causes of Post-Harvest Losses & Quality Decline
Root vegetables	Carrot, Beet, Onion, Garlic, Potato, Sweet potato	• Mechanical damage • Poor curing practices • Sprouting or rooting • Moisture loss • Decay • Chilling sensitivity

Leafy vegetables	Lettuce, Chard, Spinach, Cabbage, Green onion	• Water loss leading to wilting • Yellowing due to loss of chlorophyll • Mechanical injuries • High respiration rate
Flower vegetables	Artichoke, Broccoli, Cauliflower	• Physical damage • Yellowing and colour changes • Floret drop (abscission)
Immature-fruit vegetables	Cucumber, Squash, Eggplant, Pepper, Okra, Snap beans	• Harvesting at over-mature stage • Moisture loss • Bruising and other mechanical injuries • Chilling injury • Decay
Mature-fruit vegetables & fruits	Tomato, Melon	• Bruising • Over-ripening and softening after harvest

Table: Causes of post-harvest losses

Harvesting Method

There are two methods of harvesting. They are (a) Hand harvesting and (b) Mechanical harvesting.

1. Hand Harvesting: Hand picking has been practiced in horticultural crops since ancient times, and many crops are still harvested manually today. In India, hand harvesting continues to dominate because of limited mechanization, small and fragmented landholdings, and the wide variety of crops cultivated by small farmers. This method is preferred for fresh-market crops and for situations where harvesting must be done frequently or quickly, such as during rapid ripening. Hand harvesting is also essential for delicate commodities and soft vegetables that are easily damaged by machines.

2. Mechanical Harvesting: In areas where labour costs are high, mechanical harvesters are widely used, especially for crops destined for processing. Since machines can cause injury to produce and may accelerate spoilage, they are mainly used for hardy, low-value crops grown on the ground, such as potatoes and onions. The major benefits of mechanized harvesting are its speed and the lower cost per unit of harvested produce. However, due to the possibility of mechanical damage, it is suitable only for crops that can be harvested at one time rather than in multiple pickings.

Post-Harvest Handling

Fruits and vegetables remain biologically active after they are harvested, and because their food reserves are limited, they continue to respire using these stored materials. As respiration progresses, many quality attributes—including flavour, colour, taste, texture, and overall appearance—begin to change. If the produce is not handled carefully, these changes can make it unacceptable for consumers. Post-harvest technology comes into action the moment fruits and vegetables are detached from the plant, and all operations performed afterward fall under the category of fresh-produce handling.

Post-harvest technology integrates both biological characteristics of the crop and environmental conditions to maintain or enhance product quality. It includes immediate steps after harvest such as cooling, washing, grading, and packaging. The deterioration process begins the instant produce is pulled from the soil or cut from the parent plant, and the treatment it receives afterward determines its quality—whether it is destined for the fresh market or for processing.

Precooling

Precooling, or the rapid cooling of produce immediately after harvest, is essential for most fruits and vegetables. At temperatures around 32°C, freshly harvested commodities can lose a significant amount of quality within just an hour. Besides removing field heat, precooling also minimizes bruise damage caused by vibrations during transport. The cooling needs of a crop depend on factors such as the temperature at harvest, the maturity stage, and the nature of the commodity.

Precooling is considered one of the most crucial steps in preserving the quality of perishable produce in the post-harvest chain. It refers to the rapid removal of field heat from newly harvested crops to slow metabolic activity and delay deterioration before transport or storage. Temperature is one of the most influential factors affecting the postharvest life of fruits and vegetables. Therefore, maintaining market quality requires not only cooling but cooling as early and as rapidly as possible after harvest.

Method of Precooling: There are seven principal methods of pre-cooling fresh produce:

a. Room cooling.
b. Forced-air cooling.

c. Hydro cooling.
d. Ice cooling.
e. Vacuum cooling.
f. Cryogenic cooling.
g. Evaporative cooling.

Washing, Cleaning and Trimming

Basic postharvest steps such as cleaning, washing, and trimming help make produce look fresher and more appealing for market sale. The preparation process for fresh markets usually begins with loading the harvested produce onto packinghouse lines. This unloading, or "dumping," can be done either dry or in water. In both methods, it is important to use drop-cushioning systems to reduce damage and maintain a steady flow of produce.

Washing:

a. Washing of fruits and vegetables is done to remove adhering dirt, stains, insects, Molds and sometimes spray residues.
b. Washing not only help in cleaning and making the vegetables/fruits fresh and also improves appearance, it also helps in extending the shelf life of the produce.
c. Washing is done manually under tap water or in a wash tank using soft muslin cloth.
d. Produce should be thoroughly washed with clean water (preferably with 100 - 150 ppm hypochlorite/chlorine) or soap or calcium hydroxide. Most efficient detergent used is sodium metabisulphate.
e. After washing they are then wiped with dry muslin cloth or air-dried to remove excess surface moisture. Under automated systems, the produce passes under a spray washer on a moving conveyor roller.

Trimming: It refers to the removal, trimming, or cutting of unwanted leaves, stems, stalks, roots, or any non-edible and unmarketable parts of the produce. This process enhances the appearance of vegetables and makes them more suitable for sale. Trimming is commonly carried out in vegetables and flowers to eliminate damaged, discoloured, rotten, or insect-affected portions—as seen in crops like cabbage, cauliflower, spinach, lettuce, rose, chrysanthemum, gladiolus, and tuberose. In grapes, trimming of bunches helps remove undersized, immature, dried, split, or otherwise damaged berries.

This step improves the visual appeal of the produce, reduces water loss, and slows down deterioration. Additionally, trimming limits the spread of diseases, simplifies packaging and handling, and prevents damaged pieces from harming other produce.

Sorting, Grading and Sizing

Sorting is carried out manually to eliminate fruits that are not suitable for sale or storage because of insect damage, disease infection, or mechanical injury. The remaining produce is then divided into different grades based on factors such as surface colour, shape, and visible defects. Three market grades—Extra Fancy, Fancy, and Standard—while a fourth grade, known as "culls," is set aside for processing.

Once sorting and grading are completed, the produce may also be sized either manually or with the help of machines. Mechanical sizers generally operate on two principles: **weight or diameter**.

Grading: Produce is classified into different grades based on characteristics such as surface colour, shape, size, weight, firmness, maturity, cleanliness, and freedom from insect injury, disease, mechanical damage, or foreign matter. For example, potatoes may be divided into four grades: **Extra Fancy, Fancy, Standard**, and **Cull** (used mainly for processing). Grading can be carried out either manually or with machines. The process involves separating the produce into categories according to size or weight to ensure uniformity and quality.

Systems of Grading: Static and Dynamic:

1. Static systems: These are common in tender and/or high value crops. Here the product is placed on an inspection table where sorters remove units which do not meet the requirements for the grade or quality category.

2. The dynamic system: Here product moves along a belt in front of the sorters who remove units with defects. Main flow is the highest quality grade. Often second and third grade quality units are removed and placed onto other belts. It is much more efficient in terms of volume sorted per unit of time. However, personnel should be well trained. This is because every unit remains only a few seconds in the worker's area of vision. e.g., Onion grading There are two types of common mistakes: removing good quality units from the main flow and more frequently, not removing produce of doubtful quality.

Curing

Curing is an important postharvest operation used to minimize moisture loss during storage in hardy vegetables such as onions, garlic, sweet potato, and other tropical root crops. The curing techniques for root and tuber vegetables differ

from those used for bulb crops like onion and garlic. In root and tuber crops, curing promotes the formation of a protective periderm over cut, bruised, or peeled areas, allowing wounds to heal.
For bulb crops such as onion and garlic, curing is done mainly to dry the neck region and the outer layers. After harvest, bulbs are typically kept in the field or under shade for several days until the tops, outer scales, and roots have completely dried.

Waxing: Fruits and vegetables have a natural waxy layer on the whole surface (excluding underground ones). This is partly removed by washing. Waxing is especially important if tiny injuries and scratches on the surface of the fruit or vegetable are present and these can be sealed by wax.

Packaging

Packaging of vegetables serves primarily to group the produce into convenient units for easier handling and to safeguard it from damage. An effective package should protect the commodity from physical injury, physiological changes, and pathogen-related spoilage during storage, transportation, and marketing. With changing consumer expectations for convenience, attractive presentation, product information, and branding, packaging has become an increasingly important component of the horticultural supply chain.

Benefits of Packaging

1. Packaging serves as an efficient handling unit
2. It serves as a convenient storage unit
3. Packaging protects quality and reduces waste
4. Provides service and sales motivation
5. Reduces cost of transport and marketing.

Types of Packaging Materials

1. Traditional Packaging: Bamboo baskets / Wooden crates, Gunny bags / Jute sacks

2. Modern Packaging: Corrugated Fibreboard Boxes (CFB Boxes), Plastic Crates, Plastic Bags (LDPE/HDPE films, Clamshell Trays, Net Bags / Mesh Bags

3. Advanced Packaging Technologies:

- **a. Modified Atmosphere Packaging (MAP)**
  - i. Controls O_2 and CO_2 levels inside package.
  - ii. Extends shelf life.
  - iii. Used for: **lettuce, broccoli, tomatoes, capsicum, fresh-cut vegetables**.
- **b. Controlled Atmosphere Packaging (CAP)**
  - i. Uses active gas flushing for long-term storage.
  - ii. Used in export shipments.
- **c. Vacuum Packaging:**
  - i. Removes air → delays microbial growth.
  - ii. Used for **processed or minimally processed vegetables**.

Case Study on

Modified atmosphere packaging for vegetable crops using high-water-vapor-permeable films. Nehemia Aharoni, Victor Rodov, Elazar Fallik, Uzi Afek, Daniel Chalupowicz, Zion Aharon, Dalia Maurer, and Janeta Orenstein

Packing yellowing-susceptible herbs such as coriander, dill, chervil, parsley, watercress, chives, and others in nonperforated PE bags resulted in the development of a modified atmosphere capable of retarding yellowing and decay. Elevated concentrations of CO2 inhibited the senescence-inducing effect of accumulated ethylene in the package, especially when combined with a decreased level of O_2.

In this experiment they found that CO_2 concentrations of 5 to 9% (in air) effectively retarded yellowing of coriander stored at 7.5°C for 14 days. However, extending storage duration by an additional 4 days resulted in dark spots on the leaves due to CO_2 injury.

Storage: "Various storage techniques—such as ground storage, ambient storage, refrigerated storage, air-cooled storage, zero-energy storage, modified atmosphere storage, hypobaric storage, and controlled atmosphere storage—are employed for fruits and vegetables depending on the nature of the commodity and the intended storage duration."

Traditional / Low-Cost Storage Technologies

1. In Situ/On Site/Natural or Field Storage: In situ storage refers to delaying the harvest until the crop is needed and is commonly used for root, tuber, and rhizome crops. In this method, crops are left in the soil until they are ready for market. Examples include roots like carrots, sweet potato, and cassava; tubers like potato; and rhizomes like ginger.

2. Bulk Storage of Dried Bulb Crops: Onions, garlic, and dried produce are best stored under low humidity. Onions and garlic may sprout if kept at intermediate temperatures. Pungent onions, having higher soluble solids, have a longer storage life than mild or sweet onions, which are usually stored for no more than one month.

3. Cellars/ Root cellars: Another example of a traditional storage system is the cellar. Ideally, cellars should be dark, cool, and damp. They are usually located in a basement, walled-off area, or garage, with sufficient space and windows to allow proper ventilation.

Improved/ Modern Storage Methods/ High-Cost Storage Technologies

Various advanced and innovative packaging and storage technologies have been developed and commercialized for fruits and vegetables. These include refrigerated storage, controlled atmosphere storage (CAS), modified atmosphere packaging (MAP), and hypobaric storage. Some of the improved storage methods for horticultural crops are described below:

1. Cold storage:

a. Respiration **and Temperature:** The respiratory rate of a product is directly related to the storage temperature. Lowering the temperature slows respiration, reduces biochemical reactions, and extends the product's shelf life.

b. Cold Storage in the Supply Chain: Cold storage is the central component of the cold chain for fresh produce, ensuring quality from harvest to consumer.

c. Cold Storage Design: Cold storage spaces are maintained using non-toxic refrigerants, with walls insulated by effective materials like polyurethane foam (PUF) to minimize heat loss.

2. CAS:

a. Extended shelf life: The storage life of many fruits and vegetables can be significantly extended, sometimes doubled, by delaying the ripening process.

b. Improved quality: It helps preserve firmness, acidity, sugars, and vitamin C, and slows chlorophyll breakdown.

c. Reduced spoilage: It decreases microbial action and can prevent certain storage disorders.

Case Study on

Modern Methods for Prediction of Vegetable Storability.

Sándor Istella

In the experiment used different vegetables (Tomato, Onion, carrot, radish) in order to be able to study the range of applicability of the methods. Because of the detection of the cultivation technology effects and the applicability of the method the cultivation of the specimens used for the examination was conducted under different conditions.

Paprika, beetroot, onion, carrot was stored in Acoustic method.

The acoustic method gives relevant information about the overall stiffness of the sample (onion, tomato). According to new research this method can be applied for measuring the stiffness changes of elongated vegetables (carrot, cucumber, iceberg radish) as well in the case of mainly homogeneous samples.

After the evaluation and the analysis of the experiment concluded that each vegetable species tested (paprika, carrot, red beet and onion) was suitable for the quality monitoring with the dynamic measurements. The acoustic stiffness method can be applied to each of the vegetables tested for the detection of varietal differences, for the examination of the varietal effect on storability and for the monitoring of firmness diminishment during storage.

Maturity Index for Vegetables

The principles dictating at which stage of maturity a vegetable should be harvested are crucial to its subsequent storage and marketable life and quality.

Post-harvest distinguishes three stages in the life span of vegetables: **maturation**, **ripening**, & **senescence**.

Conclusion

Huge number of crops are being produced annually, but most is lost at various stages of handling due to pre-harvest and postharvest factors affecting quality and shelf life of harvested produce. Every unit of produce preserved converts to added unit available for productive utilization and food security. The use of any postharvest method or handling practices can only maintain quality. Understanding and controlling the various roles of pre-harvest factors like fertilizer application, pruning, maturity stage, cultivar selection, and irrigation can play major role in improving quality of harvested produce and prolonging their shelf life after harvest. Using best postharvest handling practices or factors such as optimum temperature, right relative humidity, right gases in storage and the best physical handling procedures to maintain the quality after harvest is also critical. Postharvest factors alone cannot maintain quality but the pre-harvest factors during production are also important. Until both factors are managed properly, quality loss will still be a major challenge in maintaining quality and prolonging shelf life of harvested produce.

References

1. Post-harvest Technology of Horticultural Crops by Sharon Pastor Simson Martha C. Straus
2. Post-Harvest Management of Horticultural Crops By: JILEN M. MAYANI Assistant Professor (PHT), Department of Post-Harvest Technology, Aspee College of Horticulture and Forestry, Navsari Agricultural University, NAVSARI-396450 (Gujarat)
3. Post-Harvest Management in Guava by Hemant Saini*1 and Sushma2 1 Department of Horticulture, CCS HAU, Hisar; 2 Department of Seed Science and Technology, CCS HAU, Hisar
4. Peleg, K. 1985. Produce Handling, Packaging and Distribution. The AVI Publishing Co., Westport, Conn, 20-53.
5. Segre, A. 1998. Global horticultural impact: Fruits and vegetables in developing countries. World Conference on Horticultural Research, Rome, Italy, June 17-20.
6. FAG. 1997. "Guidelines for Small-Scale Fruit and Vegetable Processors". FAG. Agricultural Service Bulletin 127. Rome.
7. Ryall, A.L. and Pentzer, W.T. 1982. Handling, Transportation and Storage of Fruits and Vegetables. The AVI Publishing Company, INC. Westport, CT. 2: 98-143.
8. Wills, R.B.H., W.B. McGlasson, D. Grahdm, T.H. Lee, and E.G. Hall. 1989. Post-harvest: An Introduction to the Physiology and Handling of Fruits and Vegetables. Van Nostrand Reinhold, New York.
9. Sloan, A.E., Labuza, T.P. 1975. "Investigating alternative humectants for use in foods". Food Product Development 9(7), 75-88.
10. Hauther,W. & Worth, M., 2008. Zapped! Irradiation and the Death of Food, Food & Water Watch Press, Washington, DC.
11. Mitchell, F.G., Guillon, R., R.A. Parsons. 1972. Commercial Cooling of Fntits and Vegetables. U.c. Extension Manual 43, University of California, Division of Agricultural Sciences, Oakland, California 94608.
12. Shephard, Sue. Pickled, Potted, and Canned: How the Art and Science of Food Preserving Changed the World.
13. Zachariassen KE, Kristiansen E. 2000. "Ice nucleation and antinucleation in nature".Cryobiology 41 (4): 257-279.
14. Hauther,W. & Worth, M., 2008. Zapped! Irradiation and the Death of Food, Food & Water Watch Press, Washington, DC.
15. Leistner, L. 1992. "Food preservation by combined methods". Food Research International. 25, 151 158.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Carbon Credits: How can Farmers Monetize through Group Approach?

Article ID: 72739

Dr. Shweta B. Karadipatil[1]
[1]Assistant Professor, International Institute of Management Studies, Pune.

Abstract

India's emerging carbon credit ecosystem presents a transformative opportunity for farmers, particularly when approached through collective institutional mechanisms such as Farmer Producer Organizations (FPOs). With agriculture intrinsically linked to soil carbon dynamics, regenerative practices can simultaneously restore soil health and generate tradable carbon assets. This article synthesizes recent policy developments, scientific evidence, and pilot initiatives to examine how Indian farmers can monetize soil carbon sequestration through group-based approaches. This paper analysis highlights various enabling policies, regenerative practices, monetization pathways, institutional roles, and practical challenges, positioning carbon credits as both an economic incentive and a climate resilience strategy.

Keywords: Carbon credits, Soil carbon sequestration, Regenerative agriculture, Farmer Producer Organizations, Voluntary carbon market, India

Introduction

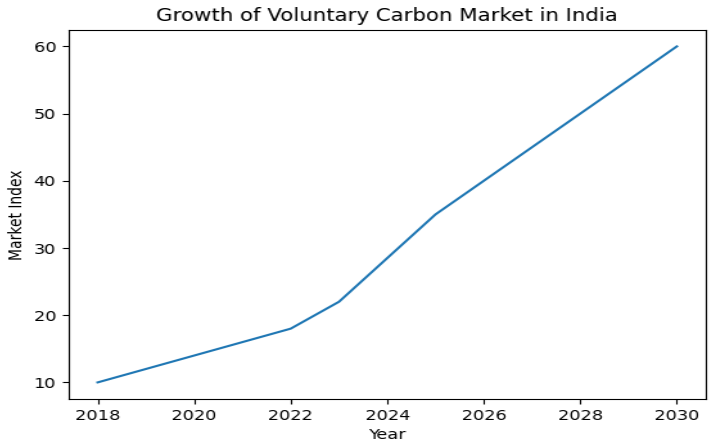
The passage of the Energy Conservation (Amendment) Act, 2022 marked a significant milestone in the India's climate policy architecture by formally establishing the foundation for a domestic carbon market. This Act introduced the Carbon Credit Trading Scheme (CCTS), positioning India to align climate mitigation with economic incentives to farmers. While initial focus has largely been on energy and industrial sectors, agriculture, employing nearly 55% of India's population stands to gain substantially from this evolving framework.

According to projections by McKinsey, global demand for carbon credits is expected to increase nearly 15 fold by 2030, driven by corporate net-zero commitments. Agriculture's centrality arises from its dependence on soil and water resources, both of which are severely impacted by climate change, land degradation, rising input costs, and market volatility. Empirical studies indicate that nearly 30% of India's land area is degraded, with agricultural land accounting for almost half of this degradation. Soil organic matter, of which carbon constitutes nearly 50%, serves as a reliable indicator of soil health. However, decades of intensive chemical fertilizer and pesticide use following the Green Revolution have led to significant depletion of soil carbon stocks. Restoring soil carbon through regenerative practices thus emerges as a dual-benefit strategy enhancing productivity while enabling climate finance access.

Evolution of India's Carbon Market

1. Key Initiatives and Milestones:

2010-2022: Emergence of the Voluntary Carbon Market (VCM), with India contributing nearly 17% of global voluntary credits, primarily through forestry-based projects led by institutions such as TERI and WRI.
2020 onwards: Introduction of pilot initiatives including Gujarat's cap-and-trade model and corporate internal carbon pricing (e.g., Mahindra Group).
2023: Operationalization of CCTS with voluntary participation.
2026 (expected): Phased introduction of compliance markets for industrial sectors.



(Source: Horizon, Outlook Magazine prediction 2025)
Figure 1. Growth trajectory of India's voluntary carbon credit market (2018-2030)

2. How can farmers practice to restore soil health: Farmers can use techniques that increase biomass and reduce the loss of carbon from soil. Some old methods which were used before green revolution are now called as regenerative agriculture practices. Some of such practices are as below:

a. Cover cropping to keep the land covered at all times
b. Residue mulching and recycling the soil's biowaste into the soil
c. Organic or Farm yard Manure, compost, and usage of biofertilizers replacing the conventional chemical NPK fertilizers
d. Regular crop rotations and intercropping with appropriate local varieties
e. Reducing flood irrigation using either drip or sprinkler.

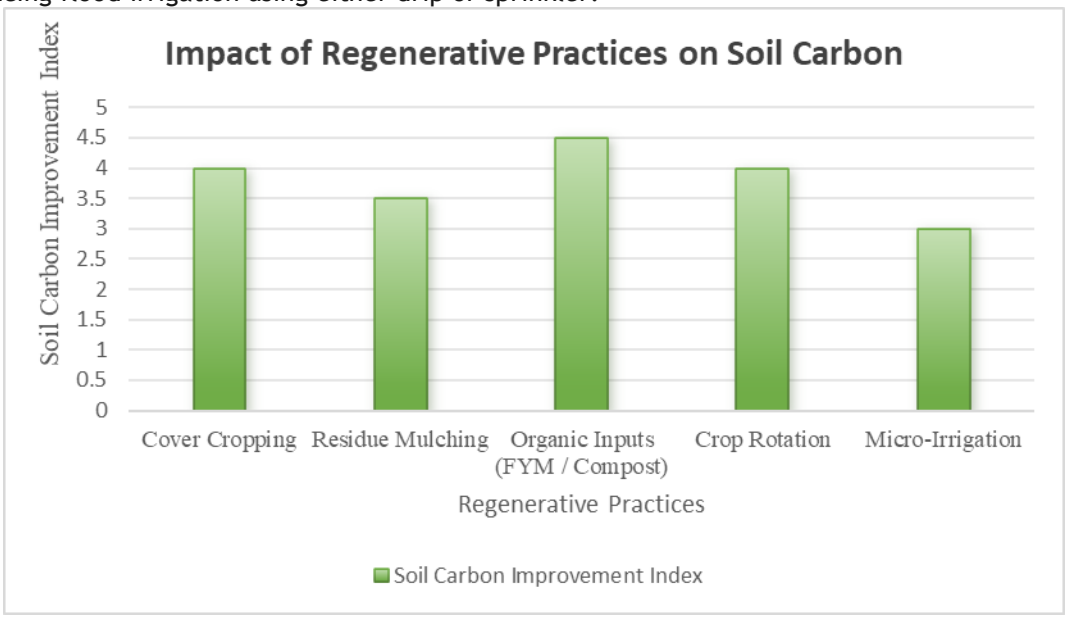


Figure 2. Regenerative agricultural practices contributing to soil carbon enhancement

While these practices improve yields and soil health over time, they may involve short-term costs and learning curves, underscoring the need for financial incentive. When farmers start to practice these old methods for a few seasons, the carbon content of soil starts improving. And the yield also increases. However, farmers may need an incentive to adopt these practices as they can be time-consuming and expensive, and unremunerative in the short term. The ability to trade carbon credits at voluntary carbon markets can serve as this incentive.

Carbon Credit Monetization can be the Nudge

Since the improvement of soil health is innately linked with the ability to increase soil carbon levels, achieving it demands the continuous monitoring of soil carbon levels and the incentivizing its improvement. Monetizing soil carbon requires a good understanding of carbon credits. Carbon credits are certificates that represent quantities of greenhouse gases that have been kept out of the air or removed from it. One carbon credit certifies that one metric tons of carbon dioxide has been removed from the atmosphere. Advancements in remote sensing data and AI have enabled the prediction of carbon levels through satellite data, and this serves as one of the methods through which carbon credits are calculated. Companies and governments purchase carbon credits to meet the climate commitments that they market.



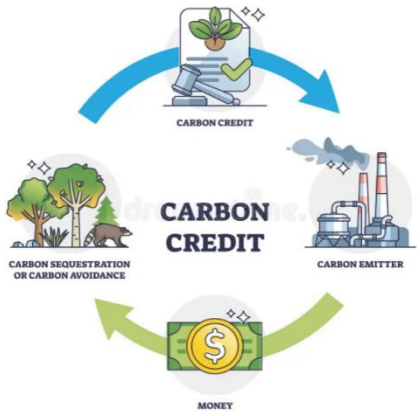
Lifecycle of a Carbon- Credit
Once retired, the credit is permanently used.

Framework & Policy Foundation for carbon credits: Energy Conservation (Amendment) Act, 2022 legally established the framework for carbon trading via the Carbon Credit Trading Scheme (CCTS), with voluntary phase kicking off in the year 2023. The government issued the Carbon Credit Trading Scheme (CCTS) 2023, detailing both Compliance (for

industrial sectors from 2026) and offset voluntary credits for sectors like forestry, agriculture, waste, energy efficiency, transport into effect.

Farmers can Benefit from Participating in the Carbon Market

The direct benefit is that farmers receive cash-based incentives for the carbon they have helped sequester in their lands. A farmer who sequesters 1 carbon credit can earn approximately INR 780 at current market prices, but large corporations are likely to provide better rates as high as INR 2,000 to farmers when directly purchasing large chunks of carbon credits. The improvement in soil after regenerative practices can be gauged by determining whether the soil is displaying any of the following characteristics like Increased water-holding capacity, lower soil density, increased water infiltration rate, increased nutrient availability, and decreased soil surface temperature.



Major Pilot projects in India:

a. Mumbai Metro Lines 2A & 7 achieved carbon neutrality by earning ~85,849 Carbon Offset Units for modal shift benefits (Jan 2023–Dec 2024) certified via Universal Carbon Registry (Times of India, 2024).

b. Biochar project by Varaha & Google (2025): Google's first Indian CDR purchase securing 100,000 t credits via converting agricultural waste to biochar across small farms (Reliance foundation)

How does Carbon Credit Programme for Farmers Work?

While it is not easy for individual farmers to go down this route at the present context, but the nonprofit organizations and farmer producer organizations (FPOs) can help them avail themselves of the benefits of the carbon credit programmes.

Ways to monetize through Farmer Produce Organizations:

1. Following regenerative agriculture practices as a member of Farmer Producer Organizations: The first step is for nonprofit organizations FPOs to promote regenerative agriculture practices among their farmer groups with special focus on increasing soil organic matter and soil carbon. It can take time and initially leads to lower yields due to the effect of chemical residues; it is important to handhold and support the farmers during the initial year by the FPO/ NGO working with carbon credit.

2. Identify an Agri-tech partner or project partner selling carbon credit: FPO or Non-Government Organizations has to identify and connect with the Agri-tech companies such as Boo Mitra, Nurture. Farm, CarbonX, carbon credit trade in voluntary carbon markets. Linking with these companies will enable the farmers' project to be listed and traded.

3. Onboarding and third-party verification of carbon credits: Once the projects are identified and listed, third-party agencies such as Verra etc., verify these projects. After verification and approval, these credits are sold in credit markets, and the incentives are distributed to the FPO/NGO as well as the farmers. Usually this takes between eight and 12 months from the time the project is listed.

Challenges and Way Forward

Despite strong prospects, challenges persist:

1. Complexity in soil carbon measurement and verification
2. Delayed payments (12–18 months from project initiation)
3. Limited farm awareness
4. Fragmented policy alignment across farming scheme
5. Integrating carbon programs with existing natural, organic, and regenerative farming schemes can significantly improve participation and impact.

References

1. Cariappa, A. G., et al. (2024). *Carbon farming projects not always inclusive and equitable*. Climate Policy / Mongabay India.
2. Economic Times. (2024). *Indian farmers rack up carbon credits with climate-conscious practices*.
3. Gopinath, K. A., Singh, V. K., & Prabhakar, M. (2025). *Voluntary carbon market in Indian agriculture: Status, challenges and way forward*. ICAR-CRIDA.
4. KPMG. (2024). *Development of carbon credit and green credit markets in India*.
5. Policy Circle. (2024). *India's carbon credit market must serve farmers, not just corporations*.
6. Tarun, V., & Pabreja, S. (2023). *Soil carbon sequestration as a measure to mitigate climate change*. ICAR.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Agro-Processing for Value Addition

Article ID: 72740

Nikhil Kumar[1], Ravi Ranjan Kumar[2], Avinash Kumar[3]
[1]B.Sc. (Hons.) Horticulture Student, Horticulture College Khuntpani, Chaibasa, Birsa Agricultural University, Ranchi.
[2,3]Assistant Professor-cum-Junior Scientist, Horticulture College, Khuntpani, Chaibasa, Birsa Agricultural University, Ranchi.

Introduction

Agro-processing refers to the set of activities that transform raw agricultural products into more valuable forms through physical, chemical, or biological methods. It serves as a vital link between agriculture and industry, enhancing the economic value of farm produce while reducing post-harvest losses. The importance of agro-processing lies in its ability to generate additional income for farmers, create rural employment, and stimulate industrial development. By introducing value addition at the local level, farmers can earn higher returns compared to selling raw produce directly. It also encourages entrepreneurship in rural areas, as small-scale and cottage industries can be established with moderate investment. Moreover, agro-processing industries play a crucial role in ensuring food security by extending the shelf life of perishable commodities and minimizing wastage.

In recent years, the focus on sustainable and eco-friendly processing methods has also gained prominence. By utilizing agricultural by-products and promoting cleaner production practices, agro-processing can support environmental conservation alongside economic development. Agriculture is the backbone of many economies, especially in developing countries like India, where it provides livelihoods to a large section of the population. However, the direct sale of raw agricultural products often results in low returns to farmers due to their perishable nature, market fluctuations, and lack of value enhancement. This is where agro-processing plays a crucial role by transforming raw agricultural commodities into processed, usable, or more marketable forms, thereby increasing their value, shelf life, and demand.

Importance of Agro-Processing

1. Reduce the post-harvest losses: India is a leader in producing many agricultural and horticultural crops, but after harvesting and during harvesting, some reasons due to losses of crop, such major reason is lack of cold storage, harvest injury, lack of knowledge, etc. Such problems solve by the agro-processing like harvest injury in potato that potato as soon as possible can be transformed in high value potato chips product.

2. Solve the market glut situation: In the crop season, many farmers produce the same crop in the same geographical area. Then, after harvesting, crops come into the market the creating high supply and low demand is called market glut. That condition reduces the price of a particular crop in the market. If in this condition the crop does not sell in the market where whereas the use of agro-processing techniques for value addition, then the value-added product gives a high economic return compared to the market glut economic return.

3. Maximum utilization of crop: After the sale of crop remains amount can be transformed into various products like mangoes transformed into mango juice, pickle, squash, amchur powder, etc., that give additional benefit to the farmer.

4. Availability of crop around the year: Use of agro-processing techniques to available of crop throughout the year in many forms, such as tomato available in non-seasonal markets in the form of dehydrated products, sauce, and ketchup, etc.

Agro-Processing Techniques

1. Canning: Process of sealing foods hermetically in containers and sterilizing them by heat, which was referred to known as canning. Food material, such as fruit and vegetables, is canned in the season when the raw material is available in plenty. The canned products are sold out of season and give better returns to the grower.

2. Freezing: Freezing is a method of preserving food by lowering its temperature below the freezing point, which slows or halts microbial growth and enzymatic reactions, significantly extending shelf life.

3. Fermentation: Fermentation is a process where microorganisms like yeast and bacteria convert carbohydrates into acids, gases, or alcohol to preserve and transform agricultural products. This technique enhances flavor, texture, and nutritional value, and increases shelf life for foods like vegetables, dairy, and soy products.

4. Milling: Milling is the process of breaking down cereal grains into smaller particles like flour, meal, or semolina. It typically involves cleaning the grain, tempering it with moisture, and then grinding it to separate the endosperm (flour), bran, and germ.

5. Pickling: The preservation of fruit in common salt (NaCl) or in vinegar or edible oil with the addition of spices and condiments is known as pickling. It is one of the most ancient/oldest methods for the preservation of fruits and vegetables. Salt, vinegar, edible oil, and lactic acid act as preservatives in pickle making. Several kinds of pickles are sold in the Indian market.

Post-Harvest Loss of Agricultural Produce

The degradation in the quantity and quality of agricultural produce from the time of harvest until it reaches the consumer, caused by issues like spoilage, disease, improper handling, and poor storage and transportation

Table 4.1: Post-harvest losses of different crops:

Crops	Loss (%)	
	As per the ICAR-CIPHET Study (2015)	As per the NABCONS study (2022)
Cereal	4.65 - 5.99	3.89 - 5.92
Pulses	6.39 - 8.41	5.65 - 6.74
Oil Seed	3.08 - 9.96	2.87 - 7.51
Fruit	6.70 - 15.88	6.02 - 15.05
Vegetables	4.58 - 12.44	4.87 - 11.61
Plantation Crops and Species	1.18 - 7.89	1.29 - 7.33

Source: Minister of State for Food Processing Industries, Shri Prahlad Singh Patel, in a written reply in Lok Sabha.

An ICRIER brief estimated that crop and allied-produce losses for 2020–22 totalled US$18.5 billion annually, with specific losses like 15.34 % for soybean and 7.87 % for wheat. Losses in horticultural crops are estimated at Rs 31,4860 million (US $4,630 million) annually.

Government Initiatives

1. Pradhan Mantri Kisan Sampada Yojana (PMKSY): The Pradhan Mantri Kisan Sampada Yojana (PMKSY) is a flagship scheme of the Ministry of Food Processing Industries (MoFPI), Government of India, launched in 2017. It aims to create a modern infrastructure for the food processing sector, reduce post-harvest losses, and ensure better returns to farmers through value addition. PMKSY is a Central Sector Scheme with financial assistance shared between the government and private investors. The government provides a grant-in-aid up to 35–75% depending on project type and region.

2. Production Linked Incentive Scheme for Food Processing Industry (PLISFPI): The Production Linked Incentive Scheme for Food Processing Industry (PLISFPI) was launched by the Ministry of Food Processing Industries (MoFPI), Government of India, in 2021. The scheme aims to boost domestic manufacturing, create global food brands, and increase exports by offering financial incentives to food processing companies based on their production and sales performance. Financial incentives are given to eligible companies based on incremental sales and investment over a base year. The scheme is implemented for six years (2021–22 to 2026–27) with a budget of approximately ₹10,900 crores.

3. Pradhan Mantri Formalization of Micro Food Processing Enterprises Scheme (PMFME): The Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) scheme was launched by the Ministry of Food Processing Industries (MoFPI), Government of India, in 2020 under the Aatmanirbhar Bharat Abhiyan. The aim is to provide financial, technical, and business support to establish or upgrade micro food processing enterprises for the period of 5 years (2020-21 to 2024-25). The budget is allocated INR 10,000 Crore.

Conclusion

Agro-processing plays a crucial role in strengthening the agricultural economy by transforming raw farm produce into value-added products that ensure higher income for farmers and generate employment opportunities in rural areas. It bridges the gap between agriculture and industry, minimizes post-harvest losses, and contributes to food and nutritional security. By using modern processing techniques such as canning, freezing, fermentation, milling, and pickling, agricultural commodities can be preserved, diversified, and marketed effectively throughout the year. The data on post-harvest losses in India highlights the urgent need for better processing infrastructure and value-addition practices. With significant losses occurring in fruits, vegetables, cereals, and pulses, agro-processing emerges as a sustainable solution to reduce waste and increase profitability. The Indian government has recognized this potential and implemented various initiatives that build modern infrastructure, support micro and small entrepreneurs, and encourage domestic as well as global food manufacturing.

References

1. Nanda, S. K., Vishwakarma, R. K., Bathla, H. V. L., Rai, A., & Chandra, P. (*2012*). Harvest and post-harvest losses of major crops and livestock produce in India. All India Coordinated Research Project on Post-Harvest Technology, ICAR.
2. Anupama Verma and P. Shrivastava. 2023. “Scope & challenges in value addition & agro processing in Indian Agriculture”. International Journal of Development Research, 13, (10), 63886-63888.

3. Anonymous, 2025. Government of India Press Information Bureau. https://www.pib.gov.in/PressNoteDetails.aspx?id=155126&NoteId=155126&ModuleId=3.
4. Anonymous, 2025. Indian Council for Research on International Economic Relations. https://icrier.org/.
5. Wills, R. B. H., McGlasson, W. B., Graham, D., Joyce, D., & Wilkinson, B. G. (2007). Postharvest: An Introduction to the Physiology and Handling of Fruit, Vegetables, and Ornamentals (5th ed.). CABI Publishing.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Government Programmes for Increasing Family Financial Security

Article ID: 72741

Ch. Bhavya Padmini[1], V. Vijaya Lakshmi[2], Ch. Sneha Latha[3]
[1]Ph.D Scholar, [2]Professor, [3]Assistant Professor, Department of RMCS, College of Community Science, Professor Jayashankar Telangana State Agricultural University, Saifabad, Hyderabad, India.

National development is the capacity of the country to raise the standard of living of its residents. It can be achieved by providing individuals with basic livelihood requirements and supplying them with employment, etc.

Development is a process that creates growth, brings in progress and positive change. Development is a healthy sign. Two aspects of development are

1. Economic growth or increase in people's income.
2. Social progress includes literacy, health and the provision of public services.

National Government Programme for Increasing Family Financial Security

1. Pradhan Mantri Jan Dhan Yojana (PMJDY):

a. Hon'ble Prime Minister announced Pradhan Mantri Jan Dhan Yojana as the National Mission on Financial Inclusion in his Independence Day address on 15th August 2014, to ensure comprehensive financial inclusion of all the households in the country by providing universal access to banking facilities.

b. Under this, a person not having a savings account can open an account without the requirement of any minimum balance and, in case they self-certify that they do not have any of the officially valid documents required for opening a savings account, they may open a small account.

c. Thus, PMJDY offers unbanked persons easy access to banking services and awareness about financial products through financial literacy programmes.

d. In addition, they receive a RuPay debit card, with inbuilt accident insurance cover of Rs. 2 lakh, and access to overdraft facility upon satisfactory operation of account or credit history of six months.

e. Further, through Prime Minister's Social Security Schemes, launched by the Hon'ble Prime Minister on 9th May 2015, all eligible account holders can access through their bank accounts personal accident insurance cover under Pradhan Mantri Suraksha Bima Yojana, life insurance cover under Pradhan Mantri Jeevan Jyoti Bima Yojana, and guaranteed minimum pension to subscribers under Atal Pension Yojana.

f. PMJDY was conceived as a bold, innovative and ambitious mission. The inclusive aspect of this is evident from the fact that 28.70 crore (66.69%) of PMJDY accounts are in rural areas and 23.87 crore (over 55.47%) PMJDY account holders are women.

g. The deposit base of PMJDY accounts has expanded over time. As on 18.08.2021, the deposit balance in PMJDY accounts is Rs. 1,46,230.71 crore. The average deposit per account has more than Triple from Rs. 1,064 in March 2015 to Rs. 3397 in August 2021.

2. From Jan Dhan to Jan Suraksha: For creating a universal social security system for all Indians, especially the poor and the under-privileged the Hon'ble Prime Minister launched three Social Security Schemes in the Insurance and Pension sectors on 9th of May, 2015.

3. Pradhan Mantri Jeevan Jyoti Bima Yojana (PMJJBY):

a. The PMJJBY is available to people in the age group of 18 to 50 years having a bank account who give their consent to join / enable auto-debit.

b. Aadhar is the primary KYC for the bank account. The life cover of Rs. 2 lakh is for the one year period stretching from 1st June to 31st May and is renewable.

c. Risk coverage under this scheme is for Rs. 2 lakh in case of death of the insured, due to any reason. The premium is Rs. 330 per annum which is to be auto-debited in one installment from the subscriber's bank account as per the option given by him on or before 31st May of each annual coverage period under the scheme.

d. The scheme is being offered by the Life Insurance Corporation and all other life insurers who are willing to offer the product on similar terms with necessary approvals and tie up with banks for this purpose. As on 28.02.2022, cumulative enrollment is over 12.38 crore under PMJJBY.

4. Pradhan Mantri Suraksha Bima Yojana (PMSBY):

a. The Scheme is available to people in the age group 18 to 70 years with a bank account who give their consent to join / enable auto-debit on or before 31st May for the coverage period 1st June to 31st May on an annual renewal basis.

b. Aadhar would be the primary KYC for the bank account. The risk coverage under the scheme is Rs. 2 lakh for accidental death and full disability and Rs. 1 lakh for partial disability.

c. The premium of Rs.12 per annum is to be deducted from the account holder's bank account through 'auto-debit' facility in one installment.
d. The scheme is being offered by Public Sector General Insurance Companies or any other General Insurance Company who are willing to offer the product on similar terms with necessary approvals and tie up with banks for this purpose. As on 28.02.2022, cumulative enrollment is over 27.70 crore under PMSBY.

5. Atal Pension Yojana (APY):

a. APY was launched on 9th May, 2015 by the Prime Minister. APY is open to all saving bank/post office saving bank account holders in the age group of 18 to 40 years and the contributions differ, based on pension amount chosen.
b. Subscribers would receive the guaranteed minimum monthly pension of Rs. 1,000 or Rs. 2,000 or Rs. 3,000 or Rs. 4,000 or Rs. 5,000 at the age of 60 years.
c. Under APY, the monthly pension would be available to the subscriber, and after him to his spouse and after their death, the pension corpus, as accumulated at age 60 of the subscriber, would be returned to the nominee of the subscriber.
d. The minimum pension would be guaranteed by the Government, i.e., if the accumulated corpus based on contributions earns a lower than estimated return on investment and is inadequate to provide the minimum guaranteed pension, the Central Government would fund such inadequacy.
e. Alternatively, if the returns on investment are higher, the subscribers would get enhanced pensionary benefits.

6. Pradhan Mantri Mudra Yojana:

a. The scheme was launched on 8th April 2015. Under the scheme a loan of upto Rs. 50,000 is given under sub-scheme 'Shishu'; between Rs. 50,000 to 5.0 Lakhs under sub-scheme 'Kishore'; and between 5.0 Lakhs to 10.0 Lakhs under sub-scheme 'Tarun'. Loans taken do not require collaterals.
b. These measures are aimed at increasing the confidence of young, educated or skilled workers who would now be able to aspire to become first generation entrepreneurs; existing small businesses, too, will be able to expand their activates. As on 20.08.2021, Rs. 16,22,203 crores sanctioned in 30.7 crores accounts.

7. Stand Up India Scheme:

a. Government of India launched the Stand Up India scheme on 5th April, 2016.
b. The Scheme facilitates bank loans between Rs.10 lakh and Rs.1 crore to at least one Scheduled Caste/ Scheduled Tribe borrower and at least one Woman borrower per bank branch for setting up greenfield enterprises.
c. This enterprise may be in manufacturing, services or the trading sector activities allied to agriculture.

The scheme which is being implemented through all Scheduled Commercial Banks is to benefit at least 2.5 lakh borrowers. The scheme is operational and the loan is being extended through Scheduled Commercial Banks across the country.

a. Stand Up India scheme caters to promoting entrepreneurship amongst women, SC & ST category i.e those sections of the population facing significant hurdles due to lack of advice/mentorship as well as inadequate and delayed credit.
b. The scheme intends to leverage the institutional credit structure to reach out to these underserved sectors of the population in starting greenfield enterprises.
c. It caters to both ready and trainee borrowers.

8. Pradhan Mantri Vaya Vandana Yojana:

a. The 'Pradhan Mantri Vaya Vandana Yojana (PMVVY) has been launched by the Government to protect elderly persons aged 60 years and above against a future fall in their interest income due to uncertain market conditions, as also to provide social security during old age.
b. The scheme is implemented through the Life Insurance Corporation of India (LIC) and open for subscription upto 31st March, 2023.
c. PMVVY offers an assured rate of return 7.40% per annum for the financial year 2020-21 for policy duration of 10 years.
d. In subsequent years, while the scheme is in operation, there will be annual reset of assured rate of return with effect from April 1st of the financial year in line with applicable rate of return of Senior Citizens Saving Scheme(SCSS) upto a ceiling of 7.75% with fresh appraisal of the scheme on breach of this threshold at any point.
e. Mode of pension payment under the Yojna is on a monthly, quarterly, half-yearly or annual basis depending on the option exercised by the subscriber.
f. Minimum purchase price under the scheme is Rs. 1,62,162/- for a minimum pension of Rs. 1000/- per month and the maximum purchase price is Rs. 15 lakh per senior citizen for getting a pension amount of Rs. 9,250/- per month.

Telangana State Government Programme for Increasing Family Financial Security

1. Dalit Bandhu:

a. The Telangana Government has recently embarked on a magnanimous journey to solve the issues and problems faced by the Dalits in the State with the introduction of 'Dalit Bandhu Scheme'.

b. The scheme provides an one-time grant of Rs. 10,00,000/- to the beneficiaries thereby instilling a sense of financial security and hope for a better future.

c. The Telangana Government will handhold the beneficiaries for judiciously utilising the financial assistance. Hon'ble CM Sri K. Chandrashekar Rao formally launched the Dalit Bandhu scheme in Shalapally of the Huzurabad Assembly constituency in Karimnagar District on 16th August 2021.

2. 'Rythu Bandhu' Scheme:

a. To enhance agriculture productivity and income to the farmers besides breaking the vicious cycle of rural indebtedness Agriculture Investment Support Scheme, popularly known as Rythu Bandhu is introduced from the year 2018-19 Kharif season to take care of initial investment needs of every farmer.

b. Investment Support for Agriculture and Horticulture crops is being provided by way of grant of Rs. 5,000 per acre per season for purchase of inputs like Seeds, Fertilizers, Pesticides, Labour and other investments twice a year, for Rabi (Yasangi) and Kharif (Rainy) seasons.

c. This is a first direct farmer investment support scheme in India, where the cash is paid directly.

3. KCR Kit:

a. The state government has launched KCR Kit Scheme for pregnant women. Pregnant women can utilize this scheme for maximum 2 deliveries.

b. Women who give birth at a government hospital can utilize this scheme.

c. The main aim of this scheme is to provide all the necessary items for pregnant women and the newborn baby.

d. Under this scheme, pregnant women will be provided with financial assistance of Rs. 12,000 in three phases. In case of a baby girl, an additional Rs. 1000 will be given by the government.

e. KCR Kit contains Baby oil, Soaps useful for mother and child, Mosquito net, Dresses, Handbag, Toys for child, Diapers, Powder, Shampoo, Sarees, Towel and Napkins, Baby bed.

4. Kalyana Lakshmi/ Shaadi Mubarak:

a. To alleviate financial distress of SC/ST and minority families, Government decided to sanction a one-time financial assistance of Rs. 1,00,116 at the time of marriage for brides who are residents of Telangana State.

b. Accordingly, Kalyana Lakshmi and Shaadi Mubaarak Schemes have been introduced with effect from October 2, 2014 for unmarried girls, who have completed 18 years of age at the time of marriage and whose parental income does not exceed Rs. 2 lakh per annum.

5. Aasara pensions:

a. As a part of its welfare measures and social safety net strategy, the Telangana government has introduced the " Aasara " pensions, with a view to ensure secured life with dignity for all the poor.

b. 'Aasara' pension scheme is meant to protect the most vulnerable sections of society in particular the old and infirm, people with HIV-AIDS, widows, incapacitated weavers and toddy tappers, who have lost their means of livelihood with growing age, in order to support their day to day minimum needs required to lead a life of dignity and social security.

c. The Telangana Government introduced " Aasara " - a new Pension scheme - enhancing the monthly pension from Rs. 200 to Rs. 1000 for the old aged, widows, weavers, toddy tappers and AIDS patients and Rs. 500 to Rs. 1500 for disabled persons.

d. From 2020-21 the government is providing Aasara pension of Rs. 2,016 to senior citizens, widows, beedi workers, filaria victims, single women, handloom weavers, toddy tappers and AIDS victims, and Rs. 3,016 for disabled pensions.

6. Housing for the poor:

a. This hallmark initiative of the Telangana government is intended to provide quality and respectable housing to the poor.

b. The 'housing for the poor' plan provides for two and three storied buildings with the 2 BHK flats in Hyderabad and other urban areas while they are to be built as independent houses in rural areas.

c. A pilot has been taken up at IDH Colony in Bhoidguda, Secunderabad. As many as 396 units - with each comprising of two bedrooms, hall and kitchen - are being constructed in 32 blocks of G+2 on 580 square yards at a cost of Rs 37 crore at 7.9 lakh per each flat.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Crop Insurance Schemes for Farmers' Benefit

Article ID: 72742

Ch. Bhavya Padmini[1], V. Vijaya Lakshmi[2], Ch. Sneha Latha[3]
[1]Ph.D Scholar, [2]Professor, [3]Assistant Professor, Department of RMCS, College of Community Science, Professor Jayashankar Telangana State Agricultural University, Saifabad, Hyderabad, India.

Pradhan Mantri Fasal Bheema Yojana

The new Crop Insurance Scheme was in line with One Nation – One Scheme theme. It incorporates the best features of all previous schemes and at the same time, all previous shortcomings / weaknesses have been removed. The PMFBY will replace the existing two schemes National Agricultural Insurance Scheme as well as the Modified NAIS.

1. Objectives of Pradhan Mantri Fasal Bheema Yojana:

a. To provide insurance coverage and financial support to the farmers in the event of failure of any of the notified crop as a result of natural calamities, pests & diseases.
b. To stabilize the income of farmers to ensure their continuance in farming.
c. To encourage farmers to adopt innovative and modern agricultural practices.
d. To ensure flow of credit to the agriculture sector.

2. Highlights of Pradhan Mantri Fasal Bheema Yojana:

a. Here will be a uniform premium of only 2% to be paid by farmers for all Kharif crops and 1.5% for all Rabi crops.
b. In case of annual commercial and horticultural crops, the premium to be paid by farmers will be only 5%.
c. The premium rates to be paid by farmers are very low and balance premium will be paid by the Government to provide full insured amount to the farmers against crop loss on account of natural calamities.
d. There is no upper limit on Government subsidy.
e. Even if balance premium is 90%, it will be borne by the Government.
f. Earlier, there was a provision of capping the premium rate which resulted in low claims being paid to farmers. This capping was done to limit Government outgo on the premium subsidy.
g. This capping has now been removed and farmers will get claim against full sum insured without any reduction.
h. The use of technology will be encouraged to a great extent. Smart phones will be used to capture and upload data of crop cutting to reduce the delays in claim payment to farmers.
i. Remote sensing will be used to reduce the number of crop cutting experiments.
j. PMFBY is a replacement scheme of NAIS / MNAIS, there will be exemption from Service Tax liability of all the services involved in the implementation of the scheme.
k. It is estimated that the new scheme will ensure about 75-80 per cent of subsidy for the farmers in insurance premium.

All farmers growing notified crops in a notified area during the season who have insurable interest in the crop are eligible.

3. To address the demand of farmers, the scheme has been made voluntary for all farmers from Kharif 2020: Earlier to Kharif 2020, the enrollment under the scheme was compulsory for following categories of farmers:

a. Farmers in the notified area who possess a Crop Loan account/KCC account (called as Loanee Farmers) to whom credit limit is sanctioned/renewed for the notified crop during the crop season. and
b. Such other farmers whom the Government may decide to include from time to time.

4. Voluntary coverage:

a. Yield Losses (standing crops, on notified area basis). Comprehensive risk insurance is provided to cover yield losses due to non-preventable risks, such as Natural Fire and Lightning, Storm, Hailstorm, Cyclone, Typhoon, Tempest, Hurricane, Tornado.
b. Risks due to Flood, Inundation and Landslide, Drought, Dry spells, Pests/ Diseases also will be covered.
c. In cases where majority of the insured farmers of a notified area, having intent to sow/plant and incurred expenditure for the purpose, are prevented from sowing/planting the insured crop due to adverse weather conditions, shall be eligible for indemnity claims upto a maximum of 25 per cent of the sum-insured.
d. In post-harvest losses, coverage will be available up to a maximum period of 14 days from harvesting for those crops which are kept in "cut & spread" condition to dry in the field.
f. For certain localized problems, Loss / damage resulting from occurrence of identified localized risks like hailstorm, landslide, and Inundation affecting isolated farms in the notified area would also be covered.

5. Unit of Insurance: The Scheme shall be implemented on an 'Area Approach basis' i.e., Defined Areas for each notified crop for widespread calamities with the assumption that all the insured farmers, in a Unit of Insurance, to be defined as "Notified Area" for a crop, face similar risk exposures, incur to a large extent, identical cost of production per hectare,

earn comparable farm income per hectare, and experience similar extent of crop loss due to the operation of an insured peril, in the notified area.

Defined Area (i.e., unit area of insurance) is Village/Village Panchayat level by whatsoever name these areas may be called for major crops and for other crops it may be a unit of size above the level of Village/Village Panchayat. In due course of time, the Unit of Insurance can be a Geo-Fenced/Geo-mapped region having homogenous Risk Profile for the notified crop.

For Risks of Localised calamities and Post-Harvest losses on account of defined peril, the Unit of Insurance for loss assessment shall be the affected insured field of the individual farmer.

Kisan Credit Card (KCC) Scheme

The Kisan Credit Card (KCC) scheme was introduced in 1998 for issue of Kisan Credit Cards to farmers on the basis of their holdings for uniform adoption by the banks so that farmers may use them to readily purchase agriculture inputs such as seeds, fertilizers, pesticides etc. and draw cash for their production needs. The scheme was further extended for the investment credit requirement of farmers viz. allied and non-farm activities in the year 2004. The scheme was further revisited in 2012 by a working Group under the Chairmanship of Shri T. M. Bhasin, CMD, Indian Bank with a view to simplify the scheme and facilitate issue of Electronic Kisan Credit Cards. The scheme provides broad guidelines to banks for operational zing the KCC scheme. Implementing banks will have the discretion to adopt the same to suit institution/location specific requirements.

1. Applicability of the Scheme: The Kisan Credit Card Scheme detailed in the ensuing paragraphs is to be implemented by Commercial Banks, RRBs, Small Finance Banks and Cooperatives.

2. Objective / Purpose: The Kisan Credit Card scheme aims at providing adequate and timely credit support from the banking system under a single window with flexible and simplified procedure to the farmers for their cultivation and other needs as indicated below:

a. To meet the short term credit requirements for cultivation of crops;
b. Post-harvest expenses;
c. Produce marketing loan;
d. Consumption requirements of farmer household;
e. Working capital for maintenance of farm assets and activities allied to agriculture;
f. Investment credit requirement for agriculture and allied activities.

3. Eligibility

a. Farmers - individual/joint borrowers who are owner cultivators;
b. Tenant farmers, oral lessees & share croppers;
c. Self Help Groups (SHGs) or Joint Liability Groups (JLGs) of farmers including tenant farmers, share croppers etc.

4. Fixation of credit limit / Loan amount: The credit limit under the Kisan Credit Card may be fixed as under:

a. The short term limit to be arrived for the first year (For cultivating single crop in a year): Scale of finance for the crop (as decided by District Level Technical Committee) x Extent of area cultivated + 10% of limit towards post-harvest/household/ consumption requirements + 20% of limit towards repairs and maintenance expenses of farm assets + crop insurance and/or accident insurance including PAIS, health insurance & asset insurance.

b. Limit for second & subsequent year: First year limit for crop cultivation purpose arrived at as above plus 10% of the limit towards cost escalation / increase in scale of finance for every successive year (2nd, 3rd, 4th and 5th year) and estimated term loan component for the tenure of Kisan Credit Card, i.e., five years. **(Illustration I)**

c. For cultivating more than one crop in a year: The limit is to be fixed as above depending upon the crops cultivated as per proposed cropping pattern for the first year plus an additional 10% of the limit towards cost escalation / increase in scale of finance for every successive year (2nd, 3rd, 4th and 5th year). It is assumed that the farmer adopts the same cropping pattern for the succeeding four years. In case the cropping pattern adopted by the farmer is changed in the subsequent year, the limit may be reworked. **(Illustration I)**

d. Term loan for investment: The term loan for investment is to be made towards land development, minor irrigation, purchase of farm equipment and allied agricultural activities. The banks may fix the quantum of credit for term and working capital limit for agricultural and allied activities, etc., based on the unit cost of the asset/s proposed to be acquired by the farmer, the allied activities already being undertaken on the farm, the bank's judgment on repayment capacity vis-a-vis total loan burden devolving on the farmer, including existing loan obligations. The long term loan limit should be based on the proposed investment(s) during the five year period and the bank's perception on the repaying capacity of the farmer.

e. Maximum Permissible Limit: The short term loan limit arrived for the 5th year plus the estimated long term loan requirement will be the Maximum Permissible Limit (MPL) and is to be treated as the Kisan Credit Card limit.

f. Fixation of Sub-limits:

i. Short term loans and term loans are governed by different interest rates. At present, short term crop loans upto ₹ 3 lakh are covered under Interest Subvention Scheme/Prompt Repayment Incentive scheme of the Government of India. Further, repayment schedule and norms are different for short term and term loans. Hence, in order to have operational and accounting convenience, the card limit is to be bifurcated into separate sub-limits for short term cash credit limit cum savings account and term loans.

ii. Drawing limit for short term cash credit should be fixed based on the cropping pattern. The amount(s) for crop production, repair and maintenance of farm assets and consumption may be allowed to be drawn as per the convenience of the farmer. In case the revision of scale of finance for any year by the district level technical committee exceeds the notional hike of 10% contemplated while fixing the five year limit, a revised drawable limit may be fixed in consultation with the farmer. In case such revisions require the card limit itself to be enhanced (4th or 5th year), the same may be done and the farmer be so advised.

iii. For term loans, installments may be allowed to be withdrawn based on the nature of investment and repayment schedule drawn as per the economic life of the proposed investments. It is to be ensured that at any point of time the total liability should be within the drawing limit of the concerned year.

iv. Wherever the card limit / liability so arrived warrants additional security, the banks may take suitable collateral as per their policy.

g. For Marginal Farmers: A flexible limit of ₹ 10, 000 to ₹ 50, 000 may be provided (as Flexi KCC) based on the land holding and crops grown including post-harvest warehouse storage related credit needs and other farm expenses, consumption needs, etc., plus small term loan investment(s) like purchase of farm equipment(s), establishing mini dairy/backyard poultry as per assessment of the Branch Manager without relating it to the value of land. The composite KCC limit is to be fixed for a period of five years on this basis. Wherever higher limit is required due to change in cropping pattern and / or scale of finance, the limit may be arrived at as per the estimation indicated at para 4.1 **(Illustration II).**

5. Disbursement: The short-term component of the KCC limit is in the nature of revolving cash credit facility. There should be no restriction on the number of debits and credits. The drawing limit for the current season/year could be allowed to be drawn using any of the following delivery channels.

a. Operation through branch.
b. Operation using cheque facility.
c. Withdrawal through ATM /debit cards
d. Operation through Business Correspondents and 'banking outlet/part-time banking outlet'[3]
e. Operation through PoS available in Sugar Mills/Contract farming companies, etc., especially for tie-up advances.
f. Operations through PoS are available with input dealers.
g. Mobile-based transfer transactions at agricultural input dealers and mandies.

The long-term loan for investment purposes may be drawn as per installment fixed.

6. Issue of Electronic Kisan Credit Cards: All new KCC must be issued as smart card cum debit card as laid down in Part II of the Annex. Further, at the time of renewal of existing KCC; farmers must be issued smart card cum debit card.

The short-term credit limit and the term loan limit are two distinct components of the aggregate KCC limit bearing different rates of interest and repayment periods. Until a composite card could be issued with appropriate software to separate account transactions in the sub limits, two separate electronic cards may be issued for all new/renewed cards.

7. Validity/Renewal:

a. Banks may determine the validity period of KCC and its periodic review.
b. The review may result in continuation of the facility, enhancement of limit or cancellation of the limit/withdrawal of the facility depending upon increase in cropping area/pattern and performance of the borrower.
c. When the bank has granted extension and/or re-schedule the period of repayment on account of natural calamities affecting the farmer, the period for reckoning the status of operations as satisfactory or otherwise would get extended together with the extended limit. When the proposed extension is beyond one crop season, the aggregate of debits for which extension is granted is to be transferred to a separate term loan account with stipulation for repayment in installments.

8. Rate of Interest (ROI): The rate of interest will be as stipulated in DBR Master Directions on Interest Rate on Advances.

9. Repayment Period:

a. The repayment period may be fixed by banks as per the anticipated harvesting and marketing period for the crops for which the loan has been granted.
b. The term loan component will be normally repayable within a period of 5 years depending on the type of activity/investment as per the existing guidelines applicable for investment credit.

c. Financing banks may, at their discretion, provide longer repayment period for term loan depending on the type of investment.

10. Security: Security will be applicable as per RBI guidelines prescribed from time to time.

a. Hypothecation of crops: For KCC limit upto ₹ 1.00 lakh banks are to waive margin/security requirements.

b. With tie-up for recovery: Banks may consider sanctioning loans on hypothecation of crops up to card limit of ₹ 3.00 lakh without insisting on collateral security.

c. Collateral security: Collateral security may be obtained at the discretion of Bank for loan limits above ₹ 1.00 lakh in case of non-tie-up and above ₹ 3.00 lakh in case of tie-up advances.

d. In states where banks have the facility of on-line creation of charge on the land records, the same shall be ensured.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Structural and Functional Aspects of Agriculture Market

Article ID: 72743

Ch. Bhavya Padmini[1], V. Vijaya Lakshmi[2], Ch. Sneha Latha[3]
[1]Ph.D Scholar, [2]Professor, [3]Assistant Professor, Department of RMCS, College of Community Science, Professor Jayashankar Telangana State Agricultural University, Saifabad, Hyderabad, India.

Agricultural Marketing

The term agricultural marketing was composed of two words-agriculture and marketing. Agriculture, in the broadest sense, means activities aimed at the use of natural resources for human welfare, i.e., it includes all the primary activities of production. But, generally, it was used to mean growing and/or raising crops and livestock. Marketing connotes a series of activities involved in moving the goods from the point of production to the point of consumption. It includes all the activities involved in the creation of time, place, form and possession utility. According to Thomsen, the study of agricultural marketing, comprises all the operations, and the agencies conducting them, involved in the movement of farm-produced foods, raw materials and their derivatives.

Agricultural Market Infrastructure

Efficient marketing infrastructure such as wholesale, retail and assembly markets and storage facilities is essential for cost-effective marketing, to minimize post-harvest losses and to reduce health risks. Markets play an important role in rural development, income generation, food security, and developing rural-market linkages. Experience shows that planners need to be aware of how to design markets that meet a community's social and economic needs and how to choose a suitable site for a new market. In many cases sites are chosen that are inappropriate and result in under-use or even no use of the infrastructure constructed. It is also not sufficient just to build a market: attention needs to be paid to how that market will be managed, operated and maintained.

Rural assembly markets are located in production areas and primarily serve as places where farmers can meet with traders to sell their products. These may be occasional (perhaps weekly) markets, such as haat bazaars in India and Nepal, or permanent. Terminal wholesale markets are located in major metropolitan areas, where produce is finally channelled to consumers through trade between wholesalers and retailers, caterers, etc. The characteristics of wholesale markets have changed considerably as retailing changes in response to urban growth, the increasing role of supermarkets and increased consumer spending capacity. These changes may require responses in the way in which traditional wholesale markets are organized and managed.

Objectives of Market Regulation

1. To prevent the exploitation of farmers by overcoming the handicaps in the marketing of their products.

2. To make the marketing system more effective and efficient so that farmers may get better prices for their produce and the goods are made available to the customers at reasonable prices.

3. To provide incentive prices to the farmers for inducing them to increase production both in quantitative and qualitative terms.

4. To promote and orderly marketing of agricultural produce by improving the infrastructural facilities.

Types of Agricultural Markets

1. Local Markets:

a. This market is confined to a particular village, where producers and intermediaries or consumers meet for the purchase and sale of farm products. The products produced in that village are brought for sale in these markets.
b. The local market is also known as growers' market and is available in the vicinity of rural areas. They are generally located in small towns and at their convenient places, where rural producers bring their produce and sell to the buyers.

2. Primary Markets:

a. Primary markets are periodical markets locally called as "Shandies or Haats". They are generally held once a week on a particular day. They are generally held in the open place or in roadside groves in centrally situated areas. Generally these markets are situated in the producing areas, commodities produced in the nearby surrounding areas are brought here and sold in these markets.
b. The agricultural produce is purchased by intermediaries, which later they sell it into wholesale markets. Besides agricultural produce, a number of other articles required by rural folks such as locally made agricultural inputs such as threshers, hannovers, winnovers are available and consumables such as pulses, salt, jaggery, oil,

fruits and vegetables, spices, cloth, hosiery products and ornaments of cheap metal are also sold in these markets.

3. Secondary Markets:

a. These markets are situated at district headquarters and other towns. They are also known as 'Mandis' or 'Gunjs'. These are regular wholesale markets and provide a permanent place for daily transaction. The quantum of commodities transacted is in bulk. Large quantities of commodities arrive from other markets into these markets.

b. Therefore, there are middlemen, market agents, weighmen and commission agents are involved in the marketing system. These markets also have grading, packing, warehousing, loading, transportation, telephone and banking facilities. These facilities available in 'Central Markets' make it possible to handle business at large scale. There are about 2,500 secondary markets in India.

4. Terminal Markets:

a. A terminal market is a market where the produce is either finally disposed of to the consumer or to the processor or assembled for export. In these markets, merchants are well organized and use modern methods of marketing. In this market the price locating activities operate and buyers and sellers represent the different regions or nations sometimes meet to adjust the supply and demand.

b. It is a combination of three processes of marketing, concentration, dispersion and equalization. These markets handle large scale business with large numbers of buyers and sellers and the facilities such as grading, transportation, information, packing, weighing, loading, etc., are available in these markets, which are required to boost the volume of trading. The terminal markets are located in highly populated cities like Mumbai, Chennai, Delhi, Kolkata, Bangalore etc.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

The Secret Life of Food Additives: How Tiny Ingredients Shape What We Eat

Article ID: 72744

Pallvi Katoch[1], Tanisha Bhangalia[1], Anshu Sharma[1], Anil Kumar Verma[1]
[1]Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Department of Food Science and Technology.

Abstract
Food additives, denoted by European Numbers (E No.) on packaging, are essential ingredients that enhance food quality, safety and appeal. From ancient times these natural or synthetic substances are used as preservatives, antioxidants, colourants, flavour enhancers, emulsifiers and more enabling longer shelf life, consistent textures and global food distribution. This article explores their classification, production via chemical synthesis or natural extraction and rigorous safety testing for acceptable daily intake. In India, the Food Safety Standard Authority of India (FSSAI) regulates food additives, similar to bodies like the FDA and EFSA. However, there is ongoing debate about possible health risks from ultra-processed foods, including gut inflammation, allergies, hyperactivity and chronic diseases. Food additives have transformed dietary patterns towards enhanced convenience and palatability, prompting a "clean-label" shifted to phyto-derived antimicrobial/ plant-derived preservatives and biological-derived substitutes. While industry analyses cost-effectiveness, regional regulations diverge; consumer guidance stresses scrutinizing ingredient lists and prioritizing whole foods, as additives equilibrate functional advantages against health monitoring to faster sustainable innovations in food science.

Keywords: Food additives, E-numbers, Clean-label and FSSAI.

Introduction
There are many strange codes on food packaging these days; these are E-numbers coded for food additives. These are just tiny ingredients, but they play a crucial role in determining the quality and acceptability of food. Nowadays, food additives are far more than just salt, vinegar, herbs and spices; these can be either natural or artificial based on source. Whether it's a pack of crispy chips or a juice can, you would be surprised at just how common these additives are and at what stage they impact your food. Their role will be seen from vendors on the streets of Mumbai to large food manufacturers around the world.

Food additives have been used since primordial times. They are the most important to impart artificial flavours and improve the quality of food and drinks. Food additives are added to food during preparation, processing, manufacturing, treatment or packaging to modify chemical, biological, sensory or physical characteristics and most of them do not have any nutritional value. In addition, the demand for food additives in the food processing industries has sharply increased due to consumer's preferences and the commercial advantage they provide to the manufactured food because of longer shelf-life, standardised composition and convenience in processing.

Additives in Food Processing
The food industry utilises classifications for additives based on their functions and providing the industry with various useful tools.

1. Preservatives: These are used to prevent or slow down spoilage caused by microorganisms (bacteria, yeasts, & moulds) and to extend shelf life. Examples include sodium benzoate (in beverages) and nitrites (in cured meats).

2. Antioxidants: These prevent the oxidation of fats and oils, which causes rancidity, off-flavours and discolouration. Examples include ascorbic acid (Vitamin C) and BHA/BHT (in snack foods and cereals).

3. Colourants: Added to restore colour lost during processing or to enhance the natural colour of a food to make it more appealing. Examples range from natural sources like beta-carotene to synthetic dyes like tartrazine (Yellow 5).

4. Flavouring Agents and Enhancers: Flavourings add specific tastes and aromas, while flavour enhancers increase the power of existing flavours. Monosodium glutamate (MSG) is a common flavour enhancer.

5. Sweeteners: These provide sweetness with or without calories and are used in products like diet beverages and sugar-free candies. Examples include aspartame and sucralose.

6. Emulsifiers, Stabilisers and Thickeners: These modify the texture and consistency of food products. Emulsifiers (such as lecithin) help to mix oil and water, while thickeners and stabilisers (like xanthan gum or carrageenan) provide a smooth, uniform texture and prevent ingredients from separating.

7. Acidity Regulators: These control the pH level of foods to maintain flavour, stability and safety. Citric acid and lactic acid are common examples.

8. Anti-caking Agents: Used in powdered or granulated products to prevent the formation of lumps. Silicon dioxide is an example found in salt and spice mixes.

9. Nutritional Additives: Vitamins, minerals and amino acids are sometimes added to restore nutrients lost during processing or to fortify foods to address dietary deficiencies.

E-Number Range	Additive Type	Examples
E100-E199	Colours	E120: Carmine E133: Brilliant Blue
E200-E299	Preservatives	E201: Sodium Sorbate E214: Ethylparaben
E300-E399	Anti-oxidants & Acidity regulators	E300: Vitamin C E375: Niacin
E400-E499	Thickeners, stabilisers & emulsifiers	E406: Agar E412: Guar Gum
E500-E599	pH regulators and anti-caking agents	E513: Sulphuric acid E553b: Talc
E600-E699	Flavour enhancers	E621: Monosodium Glutamate E636: Maltol
E700-E799	Antibiotics	E705: Penicillin E712: Flavomycin
E900-E999	Glazing agents, gases and sweeteners	E905: Paraffins E925: Chlorine
E1000-E1599	New chemicals which do not fall into standard classification schemes	E1403: Bleached starch (stabiliser) E1503: Castor Oil

Impact on Health

While regulatory bodies like the FDA and WHO generally consider approved additives safe within Acceptable Daily Intakes (ADI), research has linked high or long-term consumption of certain additives to various health issues in susceptible individuals.

1. Digestive and Inflammatory Issues: Emulsifiers (polysorbate-80, carboxymethylcellulose) and carrageenan have been linked to disruptions in the gut microbiota, damage to the intestinal barrier (leaky gut) and low-grade inflammation, potentially contributing to inflammatory bowel diseases (IBD) and metabolic syndrome.

2. Allergic Reactions and Intolerances: Certain additives, notably sulphites (preservatives), MSG (flavour enhancer) and specific artificial colours like tartrazine (Yellow 5), can trigger hypersensitivity reactions such as asthma, hives and abdominal pain in sensitive people.

3. Behavioural and Neurological Effects: Artificial food colourings and sodium benzoate have been associated with increased hyperactivity, irritability and attention deficit hyperactivity disorder (ADHD) in some children. Emerging evidence also suggests potential neurotoxic effects for some compounds, especially during early development.

4. Chronic Disease Risks: Diets high in ultra-processed foods containing various additives (nitrates/nitrites in processed meats, certain sweeteners) are associated with an increased risk of chronic conditions, including obesity, type 2 diabetes, cardiovascular disease and certain cancers.

5. Vulnerable Populations: Children and pregnant women may be particularly susceptible to the effects of some food additives due to the ongoing development of their metabolic and organ systems.

Future Trends & Innovations

1. Use of plant preservatives made from green tea and rosemary instead of traditional preservatives.

2. Technologies for encapsulation that safeguard critical additives, such as vitamins, via microencapsulation for enhancing stability within processed food.

3. Smart labels with QR codes containing detailed info about food additives and satisfying customers who want detailed info.

4. Clean labelling ingredients that appear on product labels but are more limited and recognisable.

5. Food additives obtained through fermentation, for instance, yeast-based flavour ingredients.

Dealing with Food with Additives can be Easy with these Habits

1. Read labels carefully and identify additives contained within a product.
2. Opt for clean-label products with natural ingredients and fewer artificial additives.
3. Use natural preservatives like lemon juice, vinegar or spice and herb extractions while making food.

4. Use food additives developed from natural sources.

Conclusion

Food additives are very useful tools that have greatly influenced and determined food consumption today. Natural vs. Synthetic – The Clean-Label Shift is trending. They help determine food tastes, appearances, shelf life and safety. Ranging from food preservatives that extend bread life to additives that can enhance snack food taste, these components have a very big role in the food sector. To be aware of their functions, guidelines that govern their usage and safety and research towards more natural preservatives will enable an understanding of food science. The next time you pick up a packaged food product, check out the ingredients list and appreciate that there's some science at work with regard to it tasting as it does.

References

1. Urrutia-Pereira, M., Silva, D., Pizzichini, E., & Pizzichini, M. M. (2025). Food additives and their impact on human health. Allergologia et Immunopathologia, 53(2), 26–31.
2. Awuchi, C. G., Igwe, V. S., & Amagwula, I. O. (2020). Food additives and food preservatives for domestic and industrial food applications. Journal of Animal Health, 2(1), 1–16.
3. Stevens, L. J., Kuczek, T., Burgess, J. R., Hurt, E., & Arnold, L. E. (2014). Dietary sensitivities and ADHD symptoms: Artificial food colors. Clinical Pediatrics, 53(2), 133–140.
4. Gyawali, R., & Ibrahim, S. A. (2014). Natural products as antimicrobial agents. Food Control, 46, 412–429.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Year Wise MSP (Minimum Support Prices) Fixed by Commission for Agricultural Cost and Prices (CACP) for Different Kharif Crops

Article ID: 72745

Sangita J. Kadlag[1]

[1]Assistant Professor of Agricultural Economics, MVP's K.D.S.P College of Agriculture, Chachadgaon, Nashik Peth Highway, Tal-Dindori Dist-Nashik.

Introduction

The Commission for Agricultural Costs & Prices (CACP) plays a pivotal role by recommending Minimum Support Prices (MSP) for 22 crops, acting as an advisor to the government, not the final decider. CACP analyzes production costs (A2+FL, C2), demand-supply, market trends, inter-crop price parity, and terms of trade to suggest a balanced price ensuring a minimum 50% margin over cost, aiming to protect farmers from price drops and encourage production, with the government making the final announcement after consultation.

CACP's Role & Process

1. Data Collection & Analysis: Gathers data on costs (seeds, fertilizer, labor), market prices (domestic/international), demand, supply, and existing stock levels.

2. Recommendation Formulation: Develops price recommendations for Kharif (rainy season) and Rabi (winter season) crops, submitting reports to the government.

3. Factor Consideration: Balances various factors like cost of cultivation, market price trends, inter-crop price parity, and terms of trade between agriculture and non-agriculture sectors.

4. Margin Assurance: Ensures recommendations provide at least a 50% margin over the cost of production (A2+FL) to ensure farmer profitability.

Government's Final Decision

1. Consultation: The government considers CACP's recommendations along with inputs from State Governments and Central Ministries.

2. Announcement: The Cabinet Committee on Economic Affairs (CCEA), chaired by the Prime Minister, announces the final MSP before the sowing season.

CACP's Broader Objectives

1. Price Stability: Provides a safety net against sharp price falls, preventing distress sales.

2. Incentivize Production: Encourages technology adoption and balanced crop production aligned with national needs.

3. Non-Price Measures: Also suggests policy measures to support agricultural objectives.

The Minimum Support Price (MSP) recommended by the Commission for Agricultural Costs and Prices (CACP) and the price ultimately fixed by the Government of India (Cabinet Committee on Economic Affairs - CCEA) are often identical or very similar because the CACP is an expert body that already incorporates government policy, demand-supply scenarios, and cost factors into its recommendations.

The Kharif season involves 14 mandated crops for which the government decides Minimum Support Prices (MSP) based on CACP recommendations, including cereals like Paddy, Maize, Jowar, Bajra, Ragi, pulses such as Tur, Moong, Urad, oilseeds like Groundnut, Soybean, Sesamum, Sunflower, Nigerseed, and commercial crops like Cotton, Jute, along with others like Copra, Toria, De-husked Coconut and VFC Tobacco.

The Commission for Agricultural Costs & Prices (CACP) in the Ministry of Agriculture recommends MSPs for 23 crops (22 mandated crops and fair and remunerative price (FRP) for sugarcane) but MSP is declared for 25 crops (toria and de-husked coconut).

Table no-1 Year wise prices of different crops from (2015-16 to 2019-20):

Sr no	Crop	2015-16		2016-17		2017-18		2018-19		2019-20	
		Recommended	Fixed	Recommended	Fixed	Recommended	Fixed	Recommended	Fixed	Recommended	Fixed
1	Paddy (General)	1410	1410	1470	1470	1550	1550	1745	1745	1815	1815
2	Paddy (A Grade)	1450	1450	1510	1510	1590	1590	1770	1770	1835	1835
3	Jowar (Hybrid)	1570	1570	1625	1625	1700	1700	2430	2430	2550	2550
4	Jowar	1590	1590	1650	1650	1725	1725	2450	2450	2570	2570

	(Maldandi)										
5	Bajra	1275	1275	1330	1330	1425	1425	1950	1950	2000	2000
6	Maize	1325	1325	1365	1365	1425	1425	1700	1700	1760	1760
7	Nagli	1650	1650	1725	1725	1900	1900	2895	2895	3150	3150
8	Tur	4425 *	4625	4625 *	5050	5250 *	5450	5675	5675	5800	5800
9	Green gram	4650 *	4850	4800 *	5250	5375*	5575	6975	6975	7050	7050
10	Blackgram	4425 *	4625	4575 *	5000	5200 *	5400	5600	5600	5700	5700
11	G.Nut	4030	4030	4120 *	4220	4250 *	4450	4890	4890	5090	5090
12	Sunflower	3800	3800	3850 *	3950	4000 *	4100	5385 *	5388	5650	5650
13	Soybean	2600	2600	2675 *	2775	2850 *	3050	3390 *	3399	3710	3710
14	Sesamum	4700	4700	4800 *	5000	5200 *	5300	6230 *	6249	6485	6485
15	Niger	3650	3650	3725 *	3825	3950 *	4050	5860 *	5877	5940	5940
16	Cotton (Medium thread)	3800	3800	3860	3860	4020	4020	5150	5150	5255	5255
17	Cotton (Long Thread)	4100	4100	4160	4160	4320	4320	5450	5450	5550	5550

Source: Kharif niyojan

From the above table it is seen that for the crops like tur, green gram and black gram there is difference in recommended prices and fixed prices in year 2015-16,2016-17,2017-18 While for the crops like groundnut, sunflower, soybean sesamum, Niger have the difference in recommended and fixed prices for the year 2016-17,2017-18,2018-19.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Lisianthus: The Rising Star of Modern Floriculture

Article ID: 72746

S. P. Mirunalini[1], A. Shanthi[1], C. Jayalakshmi[1], M. Manikandan[1]
[1]Department of Horticulture, Pandit Jawaharlal Nehru College of Agriculture & Research Institute, Karaikal – 609 603.

A New Star Blooms in the Floral Galaxy

In the world of flowers, where roses, lilies and orchids have long held the spotlight, a new contender has quietly stepped forward, Lisianthus (*Eustoma grandiflorum*). Elegant, refined and remarkably versatile, Lisianthus is increasingly becoming the flower of choice for premium bouquets, event décor and commercial floriculture ventures. From wedding stages to export consignments, this delicate yet resilient bloom is rewriting what elegance means in the flower market.



The Soft Magic of Petals and Pastels

The charm of Lisianthus lies in its subtlety. At first glance, many mistake it for a rose but a second look reveals something more delicate, more serene. The petals, soft and swirling, open gracefully, forming a bloom that feels both luxurious and weightless. Its colours are another marvel, pure whites for classic arrangements, soft pinks and lavenders for romantic themes, deep violets for dramatic displays, and attractive bi-colours that create instant visual appeal. These shades, combined with a natural sheen on the foliage, give Lisianthus an almost ethereal presence.



From Wild Prairie to Global Fame

What makes this flower even more fascinating is its origin. Lisianthus traces its roots back to the prairies of North America, where it grew as a wild species known as the “prairie gentian.” For decades, it remained a modest wildflower until breeders in Japan, the Netherlands and the United States identified its potential as a cut flower. Through systematic hybridisation and selection, they transformed a simple prairie plant into a globally celebrated ornamental species. This journey from a tough grassland plant to a premium floral commodity perfectly encapsulates the evolution of modern floriculture.

Beauty That Lasts: The Power of Long Vase Life

Today, Lisianthus enjoys a special place in global flower markets not just because of its beauty but also because of its remarkable vase life. Under proper conditions, it remains fresh for 10–14 days, often outlasting many traditional cut flowers. This durability, coupled with its ability to open buds even after harvest, makes it extremely attractive for retail florists and exporters. Consumers appreciate it too, as it retains freshness longer on home shelves, making every bouquet feel more worthwhile.



Where Science Meets Sophistication

Behind this visual appeal lies a fascinating science. Lisianthus is a crop that responds beautifully to controlled environments. It thrives under moderate temperatures, good air circulation and diffused natural light. Protected cultivation particularly greenhouse and polyhouse structures has enabled year-round production, improved quality and consistent stem length. Growers who once struggled with rosetting, a common physiological challenge where the plant remains at a short rosette stage, now manage it effectively through photoperiod control and the selection of heat-tolerant varieties. Modern hybrids have been bred specifically for tropical and subtropical climates, making Lisianthus production increasingly feasible in regions like India.



Patience That Pays: The Grower's Reward

The crop cycle of Lisianthus is long often spanning from 16 to 24 weeks requiring patience and precision. Yet growers who commit to its requirements are rewarded with high market returns. The demand for premium flowers has been steadily increasing, especially in metropolitan cities where florists and event planners seek unique blooms that elevate the sophistication of their arrangements. Lisianthus fits perfectly into this niche. Its slender stems, abundant buds and elegant posture make it ideal for bridal bouquets, luxury centrepieces and contemporary minimalist designs.



A Flower for Every Artistic Expression

Another factor driving its popularity is its adaptability to various floral styles. In European arrangements, Lisianthus adds volume and softness; in Japanese Ikebana, its clean lines and delicate blooms create a sense of calm and balance. Even in modern Indian decoration, where the blend of tradition and contemporary aesthetics is highly valued, Lisianthus has found an enthusiastic audience. Its availability in pastel tones pairs beautifully with wedding palettes, while its sturdiness makes it suitable for outdoor events too.



As a floriculturist, the trends shift toward speciality crops and high-value flowers, Lisianthus stands poised to become a key player. Countries like Japan and Ecuador have already established large-scale cultivation for export. India, with its expanding greenhouse sector, is moving in the same direction. Regions in Karnataka, Tamil Nadu and parts of Himachal Pradesh have begun experimenting with commercial production, reporting encouraging results both in domestic and international markets. The flower's premium price, long shelf life and aesthetic versatility make it a promising enterprise for progressive growers.



Rising Markets and Global Recognition

Beyond commerce, Lisianthus has gradually also become a favourite among garden enthusiasts. Compact dwarf varieties have been introduced for pots and terrace gardens, allowing hobbyists to enjoy the beauty of this flower in home landscapes. The plant's glaucous blue-green leaves and graceful flowers add a soft charm to balconies and patios, making it a delightful choice for ornamental gardening.

Garden to Balcony: Beauty for Every Home

In many ways, Lisianthus reflects the evolution of modern floriculture itself, a blend of science, creativity and global influence. It symbolizes how thoughtful breeding, environmental control and consumer demand can come together to transform a relatively unknown species into a premium flower of international repute. With ongoing advancements in breeding, disease management and climate-resilient cultivation, Lisianthus is set to shine even brighter in the years ahead.



Lisianthus: The Future Bloom of Modern Floriculture

From bridal bouquets to export consignments, from boutique florists to protected cultivation fields, Lisianthus has quietly secured a place in hearts and markets. It stands today not just as a flower of elegance but as a symbol of how beauty, science and innovation can bloom together and its paving a way for its uniqueness over the other flowers.



AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Applications of Crop Modeling in Agriculture

Article ID: 72747

Alakuntla Likhitha[1]
[1]Department of Agronomy, Agriculture Polytechnic, Kampasagar, PJTAU, Hyderabad.

Introduction

Prediction of productivity of any crop in a season has great economic importance for a country. To improve crop yields, information on appropriate management practices is increasing rapidly; however, generating new data through conventional agronomic research is often slow and insufficient to meet these growing demands. It is important for a country, where productivity of crops in any season may vary greatly depending on the prevailing weather conditions of that season (Jones *et al.*, 2003). In recent years, several dynamic crop growth simulation models have been developed to support this predictive process. Model accuracy in prediction and their sensitivity also help in midcourse correction, so that farmer can adopt measure to avoid any drop in potential production of any crops. The primary objective of a crop simulation model is to estimate crop production, resource use and environmental impact as a function of local weather and soil conditions and crop management (Hoogenboom, 2000).

Why we Need Simulation Models?

1. To incorporate knowledge gain from field experimentation.
2. To provide a structure that promotes interdisciplinary cooperation.
3. To promote the use of systems investigation for solving troubles.
4. To offer dynamic, quantitative tools for analysing the difficulty of cropping systems. For using crop models, it requires certain input data which is used by the model to further generate the required output. Most popular and widely used crop simulation models in agriculture are APSIM, DSSAT, AUACROP and INFOCROP.

What is Model?

Model is a simplified representation of a system. It is a set of mathematical equations describing a physical system. Crop models are mathematical algorithms that capture the quantitative information of agronomy and physiology experiments in a way that can explain and predict crop growth and development. They can simulate many seasons, locations, treatments, and scenarios in a few minutes. Crop models contribute to agriculture in many ways. They help explore the dynamics between the atmosphere, the crop, and the soil, assist in crop agronomy, pest management, breeding, and natural resource management, and assess the impact of climate change. Considering the complexity of agricultural systems and the existing gaps in present knowledge, it seems impossible to express entire processes of a crop system in mathematical terms provided that agricultural models are still simplified versions of reality (Wallach *et al.*, 2016). The ultimate purpose of developing crop models is to get a precise estimation of the economic yield. However, depending on the availability of information and data at the interested scale, crop models are developed at different levels of complexity. Therefore, they may range from multivariate regression, so-called empirical models based on monthly weather variables intended to predict crop yields at regional scale (Paswan and Ara Begum, 2018).

Crop Models -Input Data Required

Today, Lisianthus enjoys a special place in global flower markets not just because of its beauty but also because of its remarkable vase life. Under proper conditions, it remains fresh for 10–14 days, often outlasting many traditional cut flowers. This durability, coupled with its ability to open buds even after harvest, makes it extremely attractive for retail florists and exporters. Consumers appreciate it too, as it retains freshness longer on home shelves, making every bouquet feel more worthwhile.

Where Science Meets Sophistication

Crop modeling requires data related to weather, crop, soil, management practices and insect-pests.

1. Weather data includes: Maximum and minimum temperature, rainfall, relative humidity, solar radiation and wind speed. Weather data is required at daily time step to assess daily crop growth processes.

2. Crop data includes: Crop name, variety name, crop phenology (days to anthesis, days to maturity etc.), leaf area index, grain yield above ground biomass, 1000 grain weight.

3. Soil data includes: Thickness of soil layer, pH, EC, N, P, K, soil organic carbon, soil texture, sand and clay percent, soil moisture, saturation, field capacity and wilting point of soil, bulk density.

4. Crop management data includes: Date of sowing of crop is required to initiate the simulation process. Generally sowing date is taken as the start time for the simulation. In case of transplanted rice date of transplanting is used instead of sowing date. Seed rate and depth of seeding are also required. Use of inputs in the crop field, namely, irrigation, fertilizer, manure, crop residue etc. needs to be mentioned. Amount of these inputs are specified along with their type, date of application and depth of placement. If crop residues or organic nutrient sources are applied in the field then C:N ratio of those sources is quantified.

5. Pest data includes: Name and type of the pest, their mode of attack, pest population at different crop growth stages. Data on insects or pests are included only in those models which contain the pest module.

Steps in Modelling

1. Define goals: Agricultural system is complex comprising of various disciplines. In order to develop or understand a crop model one requires strong knowledge base of different subjects. Depending upon the objective of study, knowledge base of different disciplines is integrated to develop a crop model.

2. Define system and its boundaries: In agriculture, crop field is chosen as a system.

3. Define key variables in system: Variables include state, rate, driving and auxillary variables.

State variables are those which can be measured or quantified, e.g. soil moisture content, crop yield etc.
Rate variables are the rates of different processes operating in a system, e.g. photosynthesis rate, transpiration rate.
Driving variables are the variables which are not part of the system but the affect the system, e.g. sunshine, rainfall.
Supplementary variables are the intermediated products, e.g. dry matter partitioning, water stress etc. These variables are identified in the crop field.

4. Quantify relationships: Once the relationship is established it then quantifies the yield.

5. Validation: First the model is run with any experimental data set and calibrated accordingly. **6**. **Calibration** is done by the trial-and-error method.

Calibrated model is then validated with another experimental dataset to check its simulation ability under different situations or environment factors (e.g. temperature, rainfall, N dose).

This is done to check whether the model is responding to changes in those factors or not.

7. Simplification: Any model is initially written in computer programming but they are made simple by making it user friendly.

8. Use of models in decision support: Once developed, calibrated and validated any Crop model can be used in any decision support system for forecasting or making suitable decisions regarding crop management.

Application of Crop Modeling in Agriculture

1. Crop modeling and simulation of plant yield helps in the management of cropping systems.

2. The mathematical models used in these contexts have different forms and can be used in different ways.

3. For instance, some or several intermediate state variables can be removed, and some parameters are maintained constant for a particular case.

4. The crop models are run with observed data which helps in improving the code and relationships of crop models to give more accurate responses to climatic, and genetic factors.

5. The crop models are calibrated with climate and economic models to assess the impact of different climate scenarios on crop production and food security for different regions.

6. This helps in developing methodologies for simulating climate impacts on agriculture for locations with low soil fertility and low water availability.

7. Crop modelers work very closely with agronomists, soil scientists, plant scientists, etc. for different regions.

8. The regional data like weather and soils are collected to understand, develop and evaluate adaptation and mitigation strategies under future climatic conditions.

9. These adaptations will include crop management and genetic improvement.

10. The relevance of crop models one thing to keep in mind is that there is no right or wrong model, but models with variable degrees of suitability for a certain circumstance or set of variables.

Limitations

Lack of available data in crop model input format and model performance is limited to the quality of input data. Difficulties in using data from climate change models and scenarios, Complexities in methodologies used for crop

simulation and unreliable and unrealistic projections of changes in climate variability. Inappropriate results for Heterogeneous plot and inherent soil heterogeneity over relatively small distances. Rudimentary model validation methodology, misuse of models. An ideal crop model cannot be developed because of complex biological system.

Conclusion

Crop simulation models serve as tools for agriculture research, decision making. Theses models support wide range of applications, including identifying knowledge gaps, optimising research planning. They enable cost effective investigations regarding various management practices which helps for policy making. They support the yield forecasting in different conditions.

References

1. Jones J.W, Hoogenboom G, Porter C.H, Boote K.J, Batchelor W.D, Hunt L.A, Wilkens P.W, Singh U, Gijsman A.J and Ritchie J.T, 2003. The DSSAT cropping system model. *European journal of agronomy*, 18(3-4):235-265.
2. Hoogenboom G, 2000. Contribution of agrometeorology to the simulation of crop production and its applications. *Agricultural and forest meteorology*, 103(1-2):137-157.
3. Wallach D, Mearns L.O, Ruane A.C, Rötter R.P and Asseng S, 2016. Lessons from climate modeling on the design and use of ensembles for crop modeling. *Climatic Change*, 139(3):551-564.
4. Paswan R.P, Begum S.A and Hemochandran L, 2018. GA-ANN HYBRID MODEL FOR PREDICTION OF AREA AND CROP PRODUCTION. *International Journal of Agricultural & Statistical Sciences*, 14.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Vegetables: Pillars of a Nutritious and Harmonious Diet

Article ID: 72748

Krishna Kumar Sharma[1]
[1]Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan 313 001.

Vegetables are an essential component of a balanced diet, serving as a rich source of vital nutrients and vitamins that is necessary for human health. They provide an abundance of micronutrients, including Vitamin A, C, K and folate along with essential minerals like potassium, magnesium and iron. Additionally, vegetables are packed with dietary fibre antioxidants and phytochemicals that contribute to overall well-being by supporting immune function, reducing the risk of chronic diseases and promoting digestive health. Regular consumption of a variety of vegetables helps maintain optimal physiological functions, enhances metabolism and plays a crucial role in disease prevention. This article explores the nutritional significance of vegetables and their role in maintaining a healthy lifestyle.

Introduction

India is the second-largest vegetable producer globally, covering 11.43 million hectares and producing 214.56 million metric tonnes (First Advance Estimate, 2024-25). Despite this, vegetable availability is only 210 grams per capita per day, below the recommended 300 grams, comprising 125 grams of leafy greens, 75 grams of other vegetables and 100 grams of root and tuber vegetables. With a population growth rate of 1.8% per year, India's population was projected to surpass 1.51 billion by 2030, increasing food demand and concerns over malnutrition. While agricultural advancements have boosted production, living standards remain low and vegetable production must be enhanced to address malnutrition and reduce reliance on cereals. Including vegetables in the diet offers health benefits like improved gastrointestinal health and reduced risks of heart disease and stroke. To increase productivity, adopting hi-tech horticulture practices like greenhouses and developing heat-tolerant, pest resistant and high-yield cultivars is essential.

Role of Vegetable in Food Security

Vegetables are vital for household food security and combating micronutrient malnutrition, affecting around 2 billion people globally, especially children. They generate employment and income for small-scale farmers, particularly women, while conserving natural resources. Despite their benefits, vegetable production is often overlooked due to policies flavouring staple crops for calorie-based food security. Promoting crop diversification to increase nutrient-rich vegetable production is essential to ensure affordable access to vitamins and minerals. A vegetable-rich diet is linked to a lower risk of cardiovascular disease, yet per capita consumption remains low due to limited availability, high prices and insufficient awareness. Increasing vegetable accessibility and affordability along with promoting awareness, is crucial. Investment in research, development, education and advocacy is necessary to address these challenges. Regional cooperation and partnerships will further support initiatives to enhance nutrition and alleviate malnutrition through diverse protective foods.

Health Benefits of Vegetables

The World Health Organization emphasis the vital role of vegetables in the human diet, recommending a daily intake of at least 400 grams. This guideline is designed to ensure that individuals receive essential nutrients and optimal health benefits, particularly by addressing nutrient gaps present in other food groups. Regular vegetable consumption has been linked to enhanced overall health, improved gastrointestinal function and vision as well as a decreased risk of developing several chronic conditions, including certain cancers, heart disease, stroke, diabetes, anaemia, gastric ulcers and rheumatoid arthritis. Vegetables are rich in phytonutrients such as dietary fibre vitamins, minerals, antioxidants and flavonoids that are believed to contribute to their protective effects against these chronic diseases.

Vitamins

Vegetables are a vital source of essential vitamins like A, B, C, D, E, K, carotene and lycopene, crucial for maintaining body functions, cell regulation, growth and development. Since the body cannot produce these vitamins adequately, they must come from the diet. Dark leafy greens, broccoli, bell peppers, peas and winter squash are rich in vitamins, with broccoli, green peppers and tomatoes high in vitamin C, while spinach and squash contain vitamin E. Carotenoids, responsible for yellow, orange and red colours, enhance the antioxidant effects of vitamin E, promoting overall health and well-being.

Minerals

Minerals are essential inorganic sub stances originally derived from rocks and soil and vegetables are rich sources of these vital nutrients. Minerals are classified into major minerals (macro nutrients) like calcium, magnesium and

potassium and trace minerals (micronutrients) such as iron, zinc and selenium. Calcium supports strong bones, magnesium aids in bone health, muscle relaxation and energy production, while potassium is vital for cell function and growth. Iron is crucial for forming oxygen-binding proteins like haemoglobin and zinc is important for immunity and growth. Dark leafy greens, beans, peas, pumpkin seeds and legumes are excellent sources of these minerals.

Proteins

Proteins are complex nitrogen containing organic compounds. They constitute a major part of protoplasm. Daily requirement of proteins is 60-70 g. Vegetables contain less protein compared to the product of animal origin. Although sulfo-amino acids (methionine and cystine) are most of the time limited in vegetable proteins. Peas, beans and leafy vegetables are good source of proteins.

Dietary Fibre

Dietary fibre includes heterogeneous mixture mostly include non-starch polysaccharides such as celluloses, hemicelluloses, gums and lignin, pectin, resistant dextrin and resistant starches which are indigestible in the small intestine. Some excellent sources of soluble fibre are green peas, spinach, carrot, parsnips, beet green, turnip, green beans, eggplant, asparagus, cabbage, lettuce, broccoli and leeks. Foods rich in fibre satisfies hunger without contributing excessive calories thus aids weight loss and lowers blood pressure level. Most health agencies recommend that adults should consume 20 to 35 grams of fibre daily.

Dietary Antioxidants

Antioxidants protect the body by neutralizing harmful free radicals and reactive oxygen species, preventing cellular damage. The body's natural defence system relies on antioxidant nutrients like vitamin C, vitamin E and carotenoids, supported by phytochemicals from the diet. Vegetables contain various antioxidants, with orange, yellow and green leafy vegetables being particularly rich in carotenoids. Except for vitamin E, these antioxidants are abundantly found in vegetables.

Flavonoids

A major group of anti-oxidant phytonutrients found in vegetables, are classified into anthocyanins, flavanols, flavones and iso-flavonoids. High intake of flavonoid-rich foods is associated with protection against diseases like cancer and a reduced risk of cardiovascular issues. Anthocyanins, responsible for purple and red pigments in vegetables such as eggplant, red cabbage and beets, may lower coronary heart disease risk by inhibiting platelet aggregation. Flavanols like quercetin, kaempferol and rutin are abundant, with quercetin commonly found in onions. Flavones have gained attention for potential benefits against osteoporosis, diabetes and certain cancers.

Carbohydrates

Carbohydrates are chief source of energy in the food. It is also called as protein sparing food. Daily requirement of CHO is 400-500 g. Vegetables like potato, sweet potato, cassava, elephant foot yam, taro, garlic, pea and onion are good source of carbohydrates. In fact, sweet potato is cheapest source of calorie.

Conclusion

Vegetables are a powerhouse of essential nutrients and vitamins, playing a crucial role in main- training overall health and preventing various diseases. Rich in vitamins A, C, E and folate, as well as minerals like potassium and magnesium, they support vital bodily functions, including immune defence, heart health and proper cell development. Additionally, their high fiber content aids digestion, regulates blood sugar levels and lowers the risk of chronic conditions such as heart disease and cancer. The presence of antioxidants and phytochemicals further enhances their protective benefits, reducing inflammation and combating oxidative stress. Consuming a diverse range of vegetables ensures the body receives a well-balanced mix of nutrients, promoting longevity and overall well-being. Given their immense health benefits, incorporating vegetables into daily meals is essential for a nutritious and balanced diet. By making vegetables a dietary staple, individuals can improve their quality of life and sustain long-term health.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Shrikhand: A Traditional Indian Fermented Dessert in the Context of Emerging Plant-Based Milk Alternatives and Sustainability

Article ID: 72749

Dukare Amol[1], R. B. Kshirsagar[1], Chaitanya Girhepunje[2], Kishor Anerao[3]
[1]Department of Food Engineering, CFT, VNMKV, Parbhani.
[2]Department of Food Chemistry and Nutrition, CFT, VNMKV, Parbhani.
[3]Department of Food Microbiology and Safety, CFT, VNMKV, Parbhani.

Abstract
Shrikhand is a traditional Indian dessert made from strained yogurt (chakka), combined with sugar and flavouring agents, celebrated for its unique sweet and slightly sour flavour. Often enriched with ingredients such as cardamom, saffron, and various nuts and fruits, it exemplifies the rich culinary heritage of India, particularly in Western regions. With strict quality standards ensuring authenticity, Shrikhand is not only a festive delicacy but also an integral part of cultural rituals. In recent years, there has been a notable shift towards plant-based milk alternatives driven by increasing veganism, lactose intolerance, and environmental concerns. This paper explores the nutritional benefits and growing market trends associated with plant-based milks, such as soy, almond, oat, coconut, and rice, which offer viable alternatives to dairy. The research highlights how these alternatives can meet diverse dietary needs while promoting sustainability. Ultimately, as consumer preferences evolve, both Shrikhand and plant-based options reflect a broader transition towards healthier, environmentally conscious eating practices.

Keywords: Shrikhand, Plant-based alternatives, Veganism, Nutritional benefits, Sustainability.

Introduction
Shrikhand, a beloved traditional Indian dessert, is a delectable creation made from chakka—strained yogurt or skimmed milk chakka—blended harmoniously with sugar and flavouring agents. This exquisite dish offers a delightful balance of slightly sour and sweet flavours, making it not only a cherished dessert but also a delightful accompaniment to various meals. To preserve its authenticity and quality, Shrikhand adheres to strict standards set by the Food Safety and Standards Authority of India (FSSAI), requiring a minimum of 7.0% milk fat and 9.0% milk protein on a dry basis, free from any artificial colours or flavouring agents. This commitment ensures a wholesome culinary experience that celebrates the essence of traditional Indian cuisine.

Historically rooted in Western India, Shrikhand's exact origins are shrouded in legend. It is believed to have first emerged in Gujarat and Rajasthan, with variations found in Maharashtra and Punjab (Nigam et al., 2009). Stories suggest that traveling herdsmen developed this delightful treat by hanging curd overnight, creating a thick yogurt that was sweetened and mixed with nuts for sustenance during their journeys (Singh and Kansal, 2003). The fermentation process of Shrikhand involves lactic acid bacteria, including *Lactobacillus acidophilus* and *Bifidobacterium bifidum*, which contribute not only to its distinct flavour but also to its health benefits. Rich in probiotics, Shrikhand promotes digestion, enhances immunity, and aids those with lactose intolerance, making it both a flavourful and nourishing choice (Nigam et al., 2009).

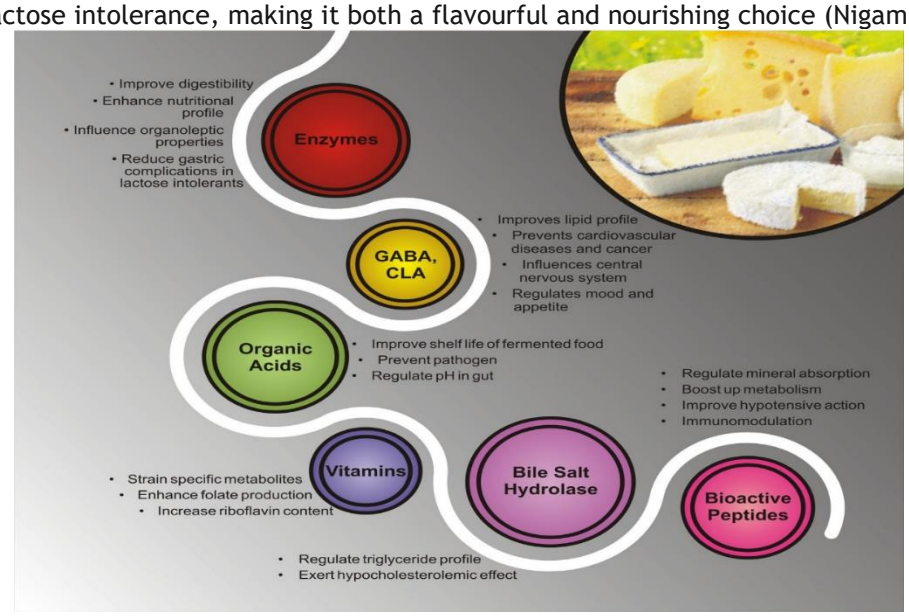


Fig. 1: Health Benefits

In addition to its traditional ingredients, Shrikhand can incorporate custard apple pulp, which has a creamy texture and is rich in carbohydrates like fructose, sucrose, and glucose (Kumhar, 2014). Innovative ingredients like agar serve as plant-based gelling agents, broadening its appeal (Yudkin, 1986). Furthermore, coconut milk, often confused with coconut cream, serves as a versatile ingredient in various dishes (Banzon, 1990). Shrikhand, a traditional fermented milk product in India, derives its name from the Sanskrit word "Shikharani," meaning a curd prepared with added sugar and flavouring agents like saffron. This indigenous dessert is created through the fermentation of milk using specific strains of lactic acid bacteria. Shrikhand is particularly popular in regions such as Maharashtra, Gujarat, Karnataka, and parts of South India, where it is enjoyed during religious functions and celebrations (Aneja et al., 2002).

1. Cultural Significance and Origins: Historically, the exact origins of Shrikhand are shrouded in mystery, though it is believed to have first emerged in Western India, particularly in Gujarat and Rajasthan, with delightful variations found in Maharashtra and Punjab. This concoction was then sweetened with sugar and enriched with nuts, serving as sustenance during their journeys (Singh and Kansal, 2003). Culturally, Shrikhand holds significant importance in Indian cuisine, particularly during festivals and celebrations. Often served as a delightful dessert, it is integral to various religious rituals, enhancing its status as a beloved delicacy in communal gatherings (Aneja et al., 2002).

2. Vegan Shift: The Growing Trend of Plant-Based Milk Alternatives: The rise of veganism, lactose intolerance, and concerns for animal welfare have led to a significant increase in the consumption of plant-based milk alternatives in recent years. These substitutes, such as soy, almond, oat, coconut, and rice milk, offer a range of flavours and nutritional profiles, making them appealing to those seeking healthier, environmentally friendly options. With over 50% of the population in regions like South America, Africa, and Asia affected by lactose intolerance, plant-based milks provide a viable alternative for those who cannot consume dairy. Nutritionally, many plant-based milk alternatives can offer distinct benefits. For instance, soy milk is rich in protein and often fortified with calcium and vitamin D. Almond milk boasts high levels of vitamin E but is lower in protein, while oat milk is notable for its fibre content and fortification with vitamin B12, essential for vegans. However, it's crucial to recognize that while these alternatives may not naturally contain the same levels of calcium as cow's milk, many are fortified to match nutritional needs (Messina, 2016; Weaver et al., 2013). From an environmental perspective, the production of plant-based milks generally requires fewer resources than dairy. Studies show that plant-based alternatives, particularly almond and oat milk, have lower water usage and carbon footprints compared to cow's milk (Subroto et al., 2021).

The market for plant-based milk alternatives has been rapidly growing in recent years and is expected to continue to expand in the future. The global plant-based milk market was valued at USD 12.3 billion in 2020 and is projected to reach USD 38.6 billion by 2028, growing at a CAGR of 14.5% from 2021 to 2028. One of the main drivers of this growth is the increasing number of consumers who are switching to plant based diets for various reasons, including health, environmental concerns, and ethical reasons. This trend not only reflects a shift towards healthier dietary choices but also supports sustainable food practices, making plant-based milk alternatives a smart choice for consumers seeking to reduce their reliance on animal products (Samiksha, 2023).

For approximately 8,000 years, dairy products have been integral to human diets, valued for their high calcium, protein, and vitamin content. However, with increasing awareness of health, ethical concerns, and dietary restrictions, such as lactose intolerance, which affects a significant portion of the global population, particularly in regions like South America, Africa, and Asia, there is a growing demand for vegan alternatives (Lomer et al, 2008).

Coconut milk, a notable alternative, is extracted from the flesh of mature coconuts and is rich in medium-chain triglycerides (MCTs) that provide quick energy. It offers numerous health benefits, including anti-carcinogenic properties and support for digestion, skin health, and immune function (Grumezescu & Holban, 2019; Belewu & Belewu, 2007). Moreover, coconut milk's lower environmental impact compared to dairy is significant; it requires less land and emits fewer greenhouse gases during production. In fact, the carbon footprint of coconut milk is approximately 0.42 kg of CO_2 equivalent per litre, compared to up to 2.50 kg for cow's milk (Stephen et al., 2017).

The increasing urbanization and health consciousness among populations, particularly in countries like Ghana, are leading to a surge in demand for dairy products. However, high prices and accessibility issues with cow milk present challenges. This scenario creates an opportunity for utilizing local resources, like coconuts, to produce non-dairy milk products. Such innovations can not only supplement dairy consumption but also contribute to sustainable food practices and align with the United Nations Sustainable Development Goals focused on health and well-being.

3. Traditional ingredients of Shrikhand: Shrikhand, a popular Indian dessert, is traditionally made using a variety of rich and flavourful ingredients. The base of shrikhand consists of 2.5 litres of raw mixed milk sourced from dairy farms, which is crucial for achieving its creamy texture. To initiate the fermentation process, an inoculum of bacteria isolated from curd, such as Lactobacillus spp., is added, contributing to the distinctive tangy flavour. Sweetness is enhanced with sugar powder, balancing the tartness of the yogurt. Various ingredients, such as fresh strawberries, pistachios (pista), almonds, and cashews, are incorporated to add both taste and texture. For aromatic depth, cardamom is included, while gulkand, a sweet preserve made from rose petals, adds a unique floral note. Finally, desi rose petals are often used as a garnish, enhancing the visual appeal and tying the flavours together. This combination of ingredients results in a delightful dessert that is both refreshing and indulgent.

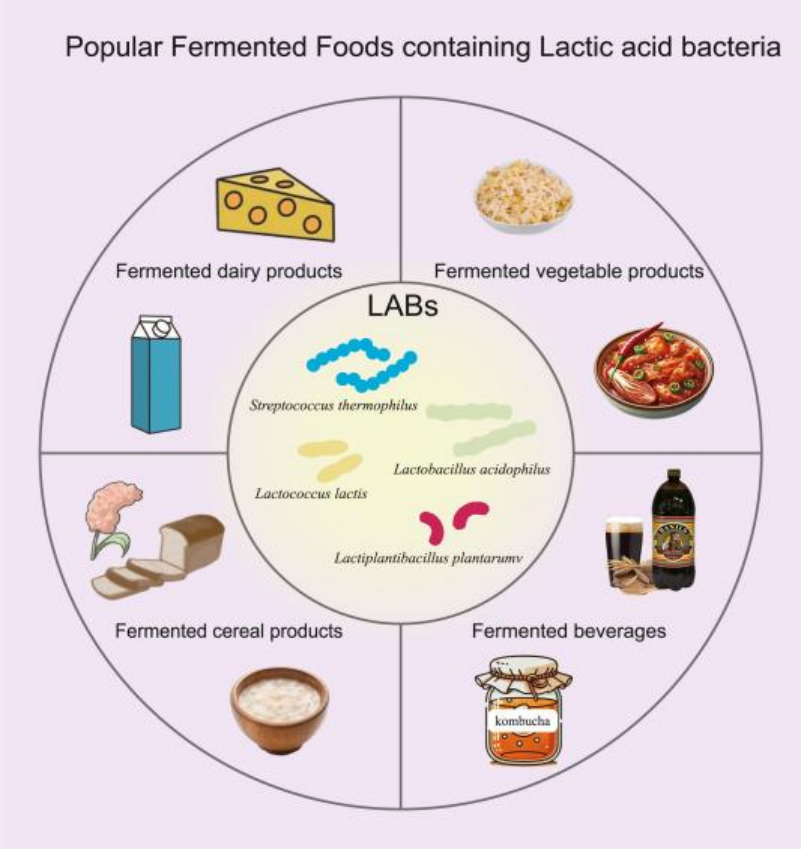


Fig. 2: Popular Fermented Foods Containing Lactic Acid Bacteria

Preparation of Shrikhand

Receiving Milk
↓
Heating (at 79-88°C for 4-5 minutes)
↓
Stirring and Adding While Heating
↓
Cooling (39-43° C)
↓
Addition of probiotics starter culture (2%)
↓
Incubation (at 32-34°C for 9-12 hours)
↓
Curd formation
↓
Draining out water by tying and hanging curd with muslin cloth
↓
Chakka
↓
Adding jaggery and fruit pulp.
↓
Mixing
↓
Adding nuts
↓
Shrikhand
↓
Filling in Polystyrene cup
↓
Stored (at Refrigerated temp 5 °C)

Fig 1: Flow sheet for the preparation of shrikhand

Plant-Based Yogurt Alternatives

These have gained significant popularity in recent years, offering a variety of options such as soy, almond, oat, coconut, and rice yogurts, each with distinct nutritional profiles and health benefits. Soy yogurt is derived from soy milk and stands out as one of the most nutrient-dense choices available. Rich in protein, calcium, and iron, soy yogurt boasts the highest protein content among plant-based alternatives, making it an excellent option for those seeking to increase their protein intake while following a dairy-free diet (Subroto et al., 2021).

Almond yogurt is made from almond milk and is characterized by its low calorie content and nutty flavour. While it provides a delightful taste, almond yogurt is relatively low in protein and calcium compared to cow's milk and some other plant-based options (Woolf et al., 2021). Oat yogurt is produced from oat milk, which is increasingly recognized for its high fibre content and the presence of important nutrients like vitamin B12 and iron. Research has highlighted oat milk's superior fibre levels compared to other plant-based milks, making oat yogurt a beneficial option for digestive health (Riaz et al., 2020). Its creamy texture and slightly sweet flavour also make it a favourite among those looking for a satisfying yogurt alternative.

Coconut yogurt is crafted from coconut milk, known for containing medium-chain triglycerides (MCTs) that are beneficial for heart health. While coconut yogurt offers unique flavour and health benefits, it is important to note that it is higher in saturated fat and calories compared to other plant-based yogurts (Woolf et al., 2021). This makes it a good option for those looking for a rich and creamy alternative, but it should be consumed in moderation, particularly by individuals monitoring their fat intake.

Rice yogurt, made from rice milk, is another plant-based alternative that is low in fat and cholesterol. However, it tends to be lower in protein and calcium, which may limit its nutritional benefits compared to other options (Woolf et al., 2021). This makes rice yogurt a suitable choice for those with dietary restrictions, such as allergies to nuts or soy, but it may not provide the same level of nutritional benefits as its counterparts.

Plant-Based Ingredients

They offer a range of health benefits, making them valuable additions to a vegan diet. Soy is recognized as a complete protein, meaning it contains all essential amino acids necessary for the body’s functions. This makes it an excellent protein source for those following a plant-based diet. In addition to its high protein content, soy is rich in calcium and iron, both of which are crucial for maintaining bone health and preventing anaemia. Research indicates that regular consumption of soy can lead to lower cholesterol levels and a reduced risk of heart disease, contributing to overall cardiovascular health (Subroto et al., 2021). The health benefits of soy extend beyond its nutritional profile, as it also contains various bioactive compounds, such as isoflavones, which may provide additional protective effects against certain chronic diseases.

Almonds, commonly found in almond milk, are another powerhouse of nutrition. They are an excellent source of healthy fats, particularly monounsaturated fats, which are known to support heart health by reducing levels of bad cholesterol. Almonds are also rich in vitamin E, a potent antioxidant that helps protect cells from oxidative stress and may improve skin health by enhancing skin hydration and reducing signs of aging. Furthermore, the satiating properties of almonds can aid in weight management, making them a smart choice for those looking to control their appetite and maintain a healthy weight (Anderson et al., 1995). Their versatility allows them to be incorporated into a variety of dishes, enhancing both flavour and nutritional value. Oats also play a significant role in regulating blood sugar levels, making them particularly beneficial for individuals with diabetes or those seeking to maintain stable energy levels throughout the day (Riaz et al., 2020).

Coconut is unique in that it provides medium-chain triglycerides (MCTs), which are metabolized differently than other fats. MCTs may support weight management by promoting fat oxidation and providing quick energy, making them an excellent choice for athletes and active individuals. Additionally, coconut contains lauric acid, which is known for its antimicrobial properties, potentially offering protective effects against harmful bacteria and viruses (Messina, 2016).

While rice is relatively low in protein compared to other plant-based sources, it serves as a valuable source of carbohydrates, providing essential energy for daily activities (Woolf et al., 2021). Its mild flavour allows it to be used in a wide range of recipes, from sweet to savoury, making it a versatile staple in many diets. Plant-based milk substitutes offer a more nutritious option compared to cow's milk and can be fortified to enhance their nutritional profile. Many of these alternatives are enriched with essential vitamins and minerals, such as calcium, vitamin D, and vitamin B12, to match the nutritional value of dairy (Messina, 2016).

Soy milk stands out as a suitable option for those who are lactose intolerant or allergic to dairy, being high in calcium, vitamin B12, and protein (Messina, 2016). Almond milk, with its lower calorie count, provides a significant source of vitamin E, an antioxidant that protects the body from oxidative stress (Weaver et al., 2013). Oat milk is particularly beneficial for vegans and vegetarians due to its high fibre content and rich supply of calcium, iron and vitamins B12 and D. Coconut milk, although high in saturated fat, contains vitamins C, E, and B6, contributing to its overall nutritional profile. Rice milk is low in fat and calories and is often fortified to boost its vitamin and mineral content.

Plant-based milk alternatives are abundant in phytonutrients, which possess anti-inflammatory and antioxidant properties. For example, soy milk contains isoflavones, which may lower the risk of certain cancers and cardiovascular diseases (Messina et al., 2010) Almond milk contains flavonoids, known for their anti-inflammatory effects (Mandalari et al., 2018), while the beta-glucans in oat milk are linked to lower cholesterol levels and improved heart health (Rondaneli et al., 2020).

Conclusions

In conclusion, Shrikhand stands as a delightful representation of India's rich culinary traditions, cherished for its unique flavours and cultural significance. This traditional dessert not only delights the palate but also reflects a deep-rooted heritage that continues to thrive, particularly during festive occasions. As consumer preferences shift towards healthier and more sustainable dietary choices, the rise of plant-based milk alternatives presents exciting opportunities for innovation in traditional recipes like Shrikhand.

References

1. Aneja, R. P., Mathur, B. N., Chandan, R. C., & Banerjee, A. K. (2002). *Technology of Indian milk products*. Dairy India Publication.
2. Anderson, J. W., Johnstone, B. M., & Cook-Newell, M. E. (1995). Meta-analysis of the effects of soy protein intake on serum lipids. *New England Journal of Medicine, 333*(5), 276-282.
3. Banzon, J. A. (1990). The coconut palm and its fruit. In J. A. Banzon, O. N. Gonzalez, S. Y. Leon, & P. C. Sanchez (Eds.), *Coconut as food* (pp. 3-7). Philippines Coconut Research and Development of Food Technology.
4. Belewu, M. A., & Belewu, K. Y. (2007). Comparative physicochemical evaluation of tiger nut, soybean, and coconut milk sources. *International Journal of Agriculture and Biology, 5*(6), 787.
5. Dendy, D., & Timmins, W. (1973). Development of a process to extract protein and oil from fresh coconut. *Oleagineux, 28*, 589–594.
6. Food Safety Standards Authority of India (FSSAI). (2011). *Food Safety Standards Authority of India, FDA Bhawan near Bal Bhavan, Kotla Road, New Delhi*.Food and Agriculture Organization (FAO). (2019). *Dairy sector global facts*.
7. Grumezescu, A, & Holban, A. M. (2019). *Value-Added Ingredients and Enrichments of Beverages: Volume 14: The Science of Beverages*. Academic Press.
8. Haas, R., Schnepps, A., Pichler, A., & Meixner, O. (2019). Cow milk versus plant-based milk substitutes: A comparison of product image and motivational structure of consumption. *Sustainability, 11*(20), 5046.
9. Kumhar, D. S., Pareek, S., & Ameta, K. D. (2014). Effect of antioxidants and storage temperatures on browning and quality of custard apple (*Annona squamosa* L.) pulp. *Journal of scientific and Industrial Reserch,* 73, 622-626.
10. Lomer, M. C. E., Parkes, G. C., & Sanderson, J. D. (2008). Review article: Lactose intolerance in clinical practice—Myths and realities. *Alimentary Pharmacology & Therapeutics, 27*, 93–103.
11. Mäkinen, O. E., Wanhalinna, V., Zannini, E., & Arendt, E. K. (2016). Foods for special dietary needs: Non-dairy plant-based milk substitutes and fermented dairy-type products. *Critical Reviews in Food Science and Nutrition, 56*(3), 339–349.
12. Messina, M. (2016). Soy and health update: Evaluation of the clinical and epidemiologic Market Research Future. (2019). *Coconut milk market research report: Forecast to 2023*. https://www.marketresearchfuture.com/reports/coconut-milk-market-3024
13. Nigam, N., Singh, R., & Upadhayay, P. K. (2009). Incorporation of chakka by papaya pulp in the manufacture of shrikhand. *Journal of Dairying, Foods & Home Sciences*, 28(2), 115-118.
14. Rozenberg, S., Body, J. J., Bruyère, O., Bergmann, P., Brandi, M. L., Cooper, C., Devogelaer, J. P., Gielen, E., Goemaere, S., & Kaufman, J. M. (2016). Effects of dairy products consumption on health: Benefits and beliefs. A commentary from the Belgian Bone Club and the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis, and Musculoskeletal Diseases. *Calcified Tissue International, 98*(1), 1–17.
15. Subroto, E., Koesnandar, D., & Bintang, M. (2021). Protein content, physicochemical, and sensory properties of soy milk with addition of sprouted lentil powder. *Journal of Food Science and Technology, 58*(5), 1795-1802.
16. Sharma, S. (2023). A review on plant-based milk alternative. *The Pharma Innovation Journal, 12*(5), 3205-3208.
17. Swapna, G., & Chavannavar, S. V. (2013). Shrikhand—Value added traditional dairy product. *International Journal of Food and Nutritional Sciences, 2*(4), 45-51.
18. Seow, C. C., & Gwee, C. N. (1997). Coconut milk: Chemistry and technology. *International Journal of Food Science and Technology, 32*(3), 189–201.
19. Sringam, S. (1991). *Production of coconut butter* (Master's dissertation, Kasetsart University).
20. Stephen, C., Enda, C., & Karli, V. (2017). Systematic review of greenhouse gas emissions for different fresh food categories. *Journal of Cleaner Production, 140*(Part 2), 766–783.
21. Singh, R., & Kansal, V. K. (2003). Augmentation of immune response in mice fed with dahi fermented milk containing *Leuconostoc citrovorum* and *Lactococcus lactis*. *Milchwissenschaft*, 58, 280-282.
22. Vanga, S. K., Singh, A., Orsat, V., Gariepy, Y., Kalkan, F., & Raghavan, V. (2015). Effect of thermal and high electric fields on secondary structure of peanut protein. *International Journal of Food Properties, 19*(6), 1259–1271.

23. Weaver, C. M., Proulx, W. R., & Heaney, R. (1999). Choices for achieving adequate dietary calcium with a vegetarian diet. *The American journal of clinical nutrition*, *70*(3), 543S-548S. United States Department of Agriculture (USDA). (2004). *National nutrient database for standard reference*.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Prime Editing in Crop Improvement: From Cutting DNA to Writing the Genetic Code

Article ID: 72750

K. Yaksha[1], Kolloju Dharani Sree[1], Hima Kumar Anakali[1]
[1]Ph.D. Scholars, Department of Genetics and Plant Breeding, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Telangana-500030.

Introduction

Global agriculture is under pressure as never before. Climate change, declining soil fertility, emerging pests, and a growing population demand crops that are more productive, resilient, and resource-efficient. Traditional breeding has delivered remarkable gains, but it is inherently slow and dependent on naturally occurring variation. The rise of genome editing transformed plant biotechnology by enabling direct modification of DNA. Among these tools, CRISPR Cas9 emerged as a breakthrough technology, fundamentally changing how scientists manipulate genomes (Doudna and Charpentier, 2014). However, classical CRISPR editing relies on creating double-strand breaks (DSBs) in DNA, which are repaired by cellular pathways that often introduce unpredictable insertions or deletions. Because many agronomic traits are controlled by single-nucleotide changes rather than gene knockouts, a more precise genome editing system was needed. This need led to the development of prime editing, a technology that allows direct rewriting of genetic information with unprecedented accuracy.

Genome Cutting to Genome Writing

Early genome editing approaches, including zinc finger nucleases and TALENs, demonstrated that targeted DNA manipulation was possible but required complex protein engineering (Hu *et al.*, 2014). The advent of CRISPR simplified targeting by using RNA guides, making genome editing accessible to laboratories worldwide (Doudna and Charpentier, 2014). Despite its power, CRISPR Cas9 acts like molecular scissors. Once DNA is cut, the cell repairs the damage, often introducing errors. While effective for disabling genes, this approach is less suitable for applications requiring precise allele replacement or fine-tuning of gene function. Prime editing represents a conceptual leap forward by shifting from cutting DNA to writing new genetic information directly into the genome.

What is Prime Editing?

Prime editing was first introduced by Anzalone *et al.* (2019) as a "search-and-replace" genome editing technology. Unlike earlier methods, prime editing does not require double-strand breaks or donor DNA templates. The system consists of a Cas9 nickase that cuts only one DNA strand, a reverse transcriptase enzyme that synthesizes new DNA and a prime editing guide RNA (pegRNA) that both targets the genomic site and encodes the desired edit. After nicking the DNA, the reverse transcriptase copies the new genetic information from the pegRNA directly into the genome, resulting in highly precise edits (Anzalone *et al.*, 2019; Yan *et al.*, 2020).

Prime Editing- A Breakthrough for Crops

Prime editing offers several advantages that make it uniquely suited for crop improvement. Unlike earlier genome-editing technologies, it enables the introduction of all twelve possible base-to-base substitutions, along with precise small insertions and deletions, greatly expanding the range of achievable genetic modifications. Importantly, prime editing does not require donor DNA templates and avoids the creation of DSBs, thereby significantly reducing unintended mutations. Together, these features allow breeders to modify both coding genes and regulatory regions with exceptional precision, facilitating fine-scale genetic improvements rather than disruptive gene knockouts (Hassan *et al.*, 2020).

Prime Editing in Plants

Prime editing was successfully demonstrated in plants. Li *et al.* (2020) reported precise modifications of both endogenous and exogenous genes in rice, confirming the feasibility of prime editing in plant cells. A landmark study by Butt *et al.* (2020) demonstrated the practical value of prime editing by engineering herbicide resistance in rice through a precise mutation in the acetolactate synthase (ALS) gene. This study showed that prime editing can deliver agriculturally relevant traits with high specificity.

Further improvements were reported by Lin *et al.* (2021), who developed optimized paired pegRNAs that dramatically increased prime editing efficiency in plants. One of the challenges of plant genome editing is polyploidy, where multiple copies of each gene exist. Veillet *et al.* (2020) demonstrated that prime editing is achievable even in tetraploid potato, although editing efficiency remains lower than in diploid species. These advances represent a major step toward routine application of prime editing in crop breeding.

Precision Trait Engineering and Functional Genomics

With the expansion of genome sequencing and association studies, thousands of SNPs linked to yield, disease resistance, and stress tolerance have been identified. However, functional validation of these variants remains a major bottleneck. Prime editing enables direct testing of candidate alleles by introducing specific SNPs into elite varieties, reverting mutations to confirm their phenotypic effects and validating causal variants underlying quantitative traits. This capability bridges the gap between genomics and breeding (Hassan *et al.*, 2020; Yan *et al.*, 2020).

Engineering Disease and Stress Resistance

Many plant disease resistance genes differ by only a few nucleotides, and even minor sequence changes can convert a fully functional resistance gene into a pseudogene, rendering the plant susceptible to pathogens. Such subtle mutations often arise naturally during evolution or domestication and are difficult to correct using conventional breeding or knockout-based genome editing approaches. Prime editing provides a powerful solution by enabling the precise correction of these mutations at the single-nucleotide level, thereby restoring gene function without altering surrounding genomic regions (Hassan *et al.*, 2020). This capability opens new possibilities for recovering lost resistance traits in elite cultivars and enhancing durability of disease resistance without introducing foreign DNA.

Beyond biotic stress, prime editing holds significant promise for improving tolerance to abiotic stresses such as drought, salinity, heat, and nutrient deficiency. Rather than disrupting protein-coding genes, which can lead to undesirable pleiotropic effects, prime editing allows targeted modification of *cis*-regulatory elements that control when, where, and how strongly a gene is expressed. Subtle edits in promoters or transcription factor binding sites can fine-tune stress-responsive gene expression, improve tolerance while preserving normal growth and yield. This level of regulatory precision makes prime editing particularly attractive for developing climate-resilient crops that can adapt to changing environmental conditions with minimal trade-offs.

Directed Evolution Inside Plant Cells

Directed evolution has long been a powerful strategy for improving protein function, but its application has largely been restricted to microbial systems such as bacteria and yeast, where rapid growth and easy genetic manipulation allow the generation and screening of large mutant libraries. Applying similar approaches directly in plants has been challenging due to longer generation times and the difficulty of creating controlled, heritable genetic variation. Prime editing offers a transformative opportunity to overcome these limitations by enabling the introduction of targeted substitutions and small insertions or deletions directly within plant genomes, thereby generating precise and predictable genetic diversity (Yan *et al.*, 2020).

This precision-guided evolution can be used to incrementally improve the activity, stability, or specificity of enzymes involved in key metabolic pathways, refine signalling proteins that regulate growth and stress responses, or optimize transcription factors controlling yield and quality traits. By iteratively introducing and evaluating defined genetic variants, prime editing enables a form of in planta directed evolution, accelerating the development of superior alleles while avoiding disruptive mutations that often compromise plant fitness.

Current Limitations and Future Directions

Despite its promise, prime editing in plants still faces technical challenges:

1. Lower editing efficiency compared to animal systems
2. Limited editing window size
3. Large construct size complicating delivery
4. Need for efficient multiplex editing strategies

Ongoing research aims to address these limitations through improved pegRNA design, optimized promoters and advanced delivery methods (Lin *et al.*, 2021; Hassan *et al.*, 2020).

Conclusion: The Future of Precision Crop Breeding

Prime editing represents a fundamental shift in crop biotechnology from the disruption of genes to the deliberate design of superior alleles. By enabling precise, predictable, and highly versatile genome modifications, this technology aligns seamlessly with modern breeding objectives that prioritize sustainability, productivity, and resilience. Unlike earlier genome-editing approaches that often rely on gene knockouts, prime editing allows breeders to fine-tune genetic variation at the level of individual nucleotides, closely mimicking natural allelic diversity while retaining full control over the outcome.

These advances will pave the way for broader adoption across diverse crop species, including those with complex or polyploid genomes. In the long term, prime editing has the potential to integrate seamlessly with genomic selection, speed breeding, and precision phenotyping, forming a powerful toolkit for next-generation crop improvement. By enabling targeted innovation without introducing foreign DNA, prime editing may quietly but profoundly reshape plant

breeding strategies helping agriculture adapt to climate change and ensuring global food security in an increasingly unpredictable world.

References

1. Anzalone, A.V., Randolph, P.B., Davis, J.R., Sousa, A.A., Koblan, L.W., Levy, J.M., Chen, P.J., Wilson, C., Newby, G.A., Raguram, A. and Liu, D.R. 2019. Search-and-replace genome editing without double-strand breaks or donor DNA. *Nature*, *576*(7785): 149-157.
2. Butt, H., Rao, G.S., Sedeek, K., Aman, R., Kamel, R. and Mahfouz, M. 2020. Engineering herbicide resistance via prime editing in rice. *Plant Biotechnology Journal*, *18*(12): 2370.
3. Doudna, J.A. and Charpentier, E. 2014. The new frontier of genome engineering with CRISPR-Cas9. *Science* 346, 1258096
4. Hassan, M.M., Yuan, G., Chen, J.G., Tuskan, G.A. and Yang, X. 2020. Prime editing technology and its prospects for future applications in plant biology research. *BioDesign Research*: 1-14
5. Hu, J., Lei, Y., Wong, W.-K., Liu, S., Lee, K.-C., He, X. *et al*. 2014. Direct activation of human and mouse Oct4 genes using engineered TALE and Cas9 transcription factors. *Nucleic Acids Res*. 42: 4375–4390
6. Li, H., Li, J., Chen, J., Yan, L. and Xia, L. 2020. Precise modifications of both exogenous and endogenous genes in rice by prime editing. *Molecular Plant*, *13*(5): 671-674.
7. Lin, Q., Jin, S., Zong, Y., Yu, H., Zhu, Z., Liu, G., Kou, L., Wang, Y., Qiu, J.L., Li, J. and Gao, C. 2021. High-efficiency prime editing with optimized, paired pegRNAs in plants. *Nature Biotechnology*, *39*(8): 923-927.
8. Veillet, F., Kermarrec, M.P., Chauvin, L., Guyon-Debast, A., Chauvin, J.E., Gallois, J.L. and Nogué, F. 2020. Prime editing is achievable in the tetraploid potato, but needs improvement. *BioRxiv*, 2020:06.
9. Yan, J., Cirincione, A. and Adamson, B. 2020. Prime editing: precision genome editing by reverse transcription. *Molecular Cell*, *77*(2): 210-212.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Monsoon Variability and Its Agricultural Implications in Haryana During 2025

Article ID: 72751

P. Bhasker[1], Vinod Goyal[1]

[1]Department of Botany and Plant Physiology, CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India.

Abstract

The 2025 monsoon season in Haryana was marked by exceptionally heavy and prolonged rainfall, resulting in extensive agricultural losses across key *Kharif* crops. The southwest monsoon brought heavy and widespread rainfall across Haryana, significantly affecting agricultural productivity, particularly during the rainy season. Excess rainfall, prolonged waterlogging, and repeated flooding events severely damaged major crops such as cotton, paddy, guar and pulses, resulting in notable yield losses across several districts. More than 31 lakh acres of agricultural land were registered for crop damage claims across 12 districts, highlighting the widespread nature of the impact. Districts including Bhiwani, Hisar, Rohtak, Fatehabad, Mahendragarh, and Jhajjar were among the worst affected, where prolonged water stagnation disrupted crop growth in major cotton- and paddy-growing belts. In addition, low-lying areas along the Yamuna River, particularly in Radaur, Jagadhari, and Khizarabad blocks of Yamunanagar district, experienced substantial crop losses due to river swelling and overflow. This review synthesizes meteorological data, district-level crop damage and advisories to the impact of extreme rainfall on the agricultural sector. The article also evaluates policy responses and highlights the long-term implications for climate-resilient agriculture in the region.

Introduction: A Monsoon of Extremes

Agriculture in Haryana holds a vital place in India's food security and rural economy, with the state known as one of the country's major contributors of wheat, rice, sugarcane, cotton, and horticultural crops. The state falls in the semi-arid to sub-humid climatic zone, receiving heavy downpours, cloudbursts, and prolonged wet spells leading to waterlogging, soil erosion, nutrient loss, flooding, and severely affected crop production through multiple pathways. One of the immediate impacts is waterlogging, which restricts oxygen availability in the root zone. Crops such as cotton, mustard, pulses, vegetables, and horticultural plants are particularly sensitive to excess moisture, resulting in reduced germination, stunted growth, wilting, and increased mortality. Even crops like paddy, which tolerate standing water, can be negatively affected when rainfall exceeds optimum levels, leading to lodging, weakening of stems, increased pest incidence, and poor grain quality. In areas where farmers practice direct-seeded rice, heavy rains can lead to seed displacement, uneven crop stands, and substantial yield reduction. Other kharif crops such as bajra, maize, mungbean and guar, heavy rainfall during flowering or grain-filling stages causes physiological stress and poor pollination. Thus, unpredictable rainfall patterns directly influence crop productivity and farming profitability.

Another severe consequence of heavy rainfall is soil erosion and nutrient leaching. High-intensity rains wash away the fertile topsoil, which is rich in organic matter and essential nutrients such as nitrogen, phosphorus, and potassium. This not only reduces soil fertility but also affects long-term soil structure, making agricultural land more prone to crusting, compaction, and reduced water infiltration. Nutrient leaching further decreases fertilizer-use efficiency and increases input costs for farmers. The silt deposition caused by run-off water clogs canals and drains, which disrupts irrigation infrastructure and increases the threat of future flooding. In many parts of Haryana, especially in low-lying areas, heavy rains cause accumulation of saline water, which exacerbates soil salinity issues and reduces crop productivity.

Heavy and prolonged rainfall also creates a favourable environment for pest and disease outbreaks. High humidity and wet conditions promote fungal infections such as sheath blight and blast in paddy, wilt and rot in cotton, and leaf spot diseases in vegetable crops. Excess moisture also leads to increased incidence of bacterial and viral diseases, affecting both field crops and horticultural plantations. The proliferation of pests such as stem borers, whiteflies, and leaf hoppers increases with fluctuating rainfall and humidity. These biotic stresses further compound the production losses incurred during heavy rainfall events.

Rainfall Pattern During the 2025 Monsoon

Over the decades, Haryana has achieved remarkable progress in agricultural productivity due to technological advancement, irrigation infrastructure, and adoption of high-yielding varieties. Despite these achievements, the sector remains vulnerable to climatic variability, especially extreme rainfall events. The southwest monsoon of 2025 in Haryana was characterized by early onset, widespread coverage, and above-normal rainfall, reflecting increasing variability in regional monsoon behaviour. The monsoon advanced into parts of the state on 24th June and covered the entire region by 29th June. Historically, the earliest onset in Haryana occurred on 13 June 2008, while the most delayed onset was recorded on 27 July 1987. Seasonal forecasts issued in April 2025 had indicated a high probability of above-normal rainfall (>105% of the Long Period Average), which was largely realized during the season.

During the monsoon period from 1 June to 30 September 2025, Haryana received 568.4 mm of rainfall against a normal value of 426 mm, representing an excess of about 34%. In a long-term perspective (1901–2025), the highest monsoon rainfall was recorded in 1988 (1108.8 mm), followed by 1995 (939.0 mm) and 1933 (826.9 mm), whereas the lowest was in 1918 (196.2 mm). Although 2025 was not an extreme record year, the overall surplus rainfall significantly influenced agricultural and hydrological conditions across the state.

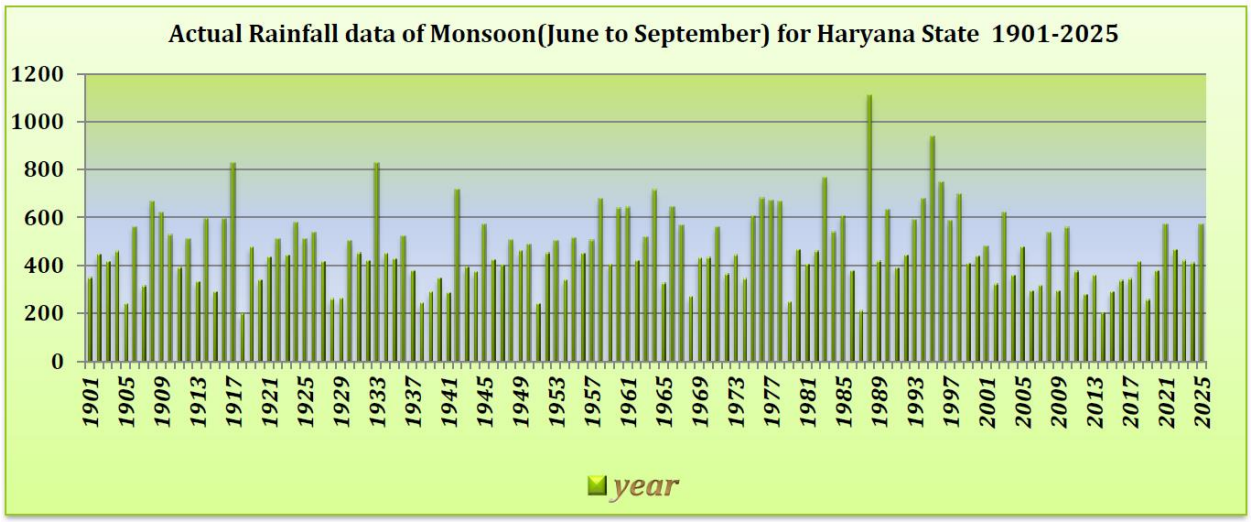


Figure 1. Actual Rainfall of Monsoon since 1901 for Haryana (mausam.imd.gov.in)

Monthly rainfall distribution during the season was uneven. June contributed about 30% of seasonal rainfall, July 17%, August 33%, and September showed a notably high departure of about 70% above normal. Such concentration of rainfall toward the later part of the monsoon increased the risk of waterlogging and crop stress, particularly during sensitive growth and maturity stages. Spatially, rainfall was well distributed but largely excessive, out of 22 districts, six experienced large excess rainfall, nine recorded excess rainfall, and seven remained within the normal category, no district reported deficient rainfall. Fatehabad recorded the highest positive departure (118%), followed by Mahendragarh (108%), Kurukshetra (86%), Jhajjar (82%), and Hisar (72%) (Figure 2). Rivers such as the Yamuna, Ghaggar, Markanda, and Tangri overflowed, aggravating flooding in low-lying agricultural areas. The persistence of rainfall rather than its intensity alone caused prolonged water stagnation, which proved particularly harmful for standing crops.

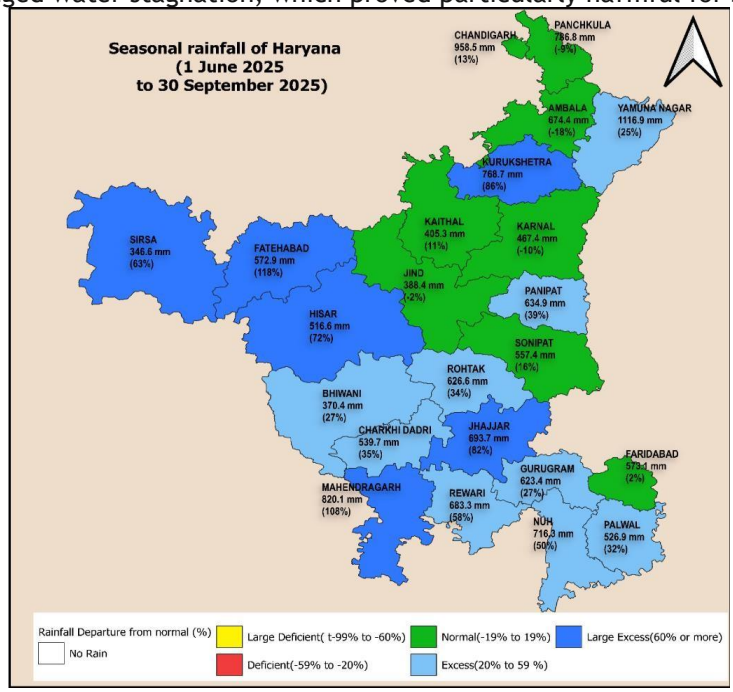


Figure 2. Rainfall for Haryana state during Monsoon 2025 (mausam.imd.gov.in)

Two major active monsoon spells occurred between 25–26 August and 1–3 September, during which heavy to very heavy rainfall was reported across several parts of Haryana. These intense rainfall events are typical of vigorous monsoon phases and are often associated with flooding, temporary water stagnation, soil erosion, and damage to standing crops. Such short-duration but high-intensity rainfall episodes pose serious challenges to farm management and rural infrastructure.

Frequency, intensity, and unpredictability of heavy rainfall situations have increased significantly due to climate change. This has created new challenges for farmers, agricultural planners, and policymakers. Heavy rainfall, often occurring within a short duration, disrupts farming operations, damages crops and soil quality, affects livestock, and undermines agricultural sustainability. Understanding the effects of heavy rainfall on agriculture in Haryana is therefore essential for evolving climate-resilient strategies and ensuring long-term productivity.

Extent of Agricultural Damage

Large-scale crop damage was reported from districts including Hisar, Bhiwani, Fatehabad, Sirsa, Rohtak, Jhajjar, Jind, Mahendragarh, Kurukshetra, Yamunanagar, Karnal, Panipat, Sonipat, Kaithal and Ambala reported crop losses due to excess rainfall. The most affected crops were paddy and cotton, followed by pulses, millets, fodder, groundnut, and vegetables. In many locations, damage ranged from partial yield reduction to complete crop failure due to prolonged waterlogging. Over 31 lakh acres of farmland across 12 districts were registered for crop loss claims on the e-Kshatipurti portal. The crops impacted through multiple pathways: waterlogging, root suffocation, delayed operations, increased pests and diseases, leaching of nutrients, soil erosion, and damage during flowering and harvesting stages. The effects vary according to crop type, soil conditions, and the region's topography. Hisar district alone reported 3.42 lakh acres of crop damage, with cotton losses ranging from 26–100%. Multiple canal breaches in Hisar, including Chuli Kalan–Shahpur and Patan–Kaimri, led to submergence of nearly 80,000 acres. Yamunanagar, Ambala, and Kurukshetra reported severe flooding along river basins, affecting both crop fields and rural habitations.

Crop-Wise Impact of Excess Rainfall

Rice: Rice is the most dominant kharif crop in Haryana, particularly in Eastern and North-Eastern districts. While rice is generally water-loving, excess rainfall beyond the optimum limit causes lodging of plants due to weak stems, reduced grain filling and poor panicle emergence, increased fungal infections such as blast, sheath blight, and bacterial sheath rot and delayed harvesting and poor grain quality. In several districts, average yields declined with reductions of 10–12 quintals per acre reported in some areas. Direct Seeded Rice, which is gaining popularity, is even more vulnerable. Heavy rains after sowing cause seed displacement, patchy germination, and the need for re-sowing, increasing input costs.



Plate 1. Waterlogged rice field following heavy monsoon rainfall in Haryana

Cotton: Cotton-growing regions of Hisar, Sirsa, Fatehabad, and Bhiwani are extremely sensitive to erratic rainfall. Heavy rains result in waterlogging, leading to root damage and plant mortality, increased attacks of pests such as whiteflies and bollworms, burst bolls due to excess moisture, reducing fibre quality, delayed maturity and stunted plant growth and defoliation and stem rot diseases. Unseasonal showers in September–October, coinciding with the harvesting phase, cause severe losses because the open bolls absorb moisture and deteriorate rapidly.



Plate 2. Cotton fields affected by heavy monsoon rainfall in Haryana

Maize and Bajra: These are crucial kharif crops in rainfed regions. Heavy rainfall causes root suffocation and plant collapse, poor cob formation, increased stalk rot, reduced pollination due to high humidity, fungal diseases such as downy mildew, excess rainfall at early stages results in weak seedlings and lower yield potential.



Plate 3. Maize and bajra crops damaged by excessive monsoon rains in Haryana

Sugarcane: Although sugarcane is relatively resilient, excessive rainfall can still affect it by waterlogging in clayey soils leading to cane rot, More incidence of borers and fungal infections, Lodging, which increases harvesting difficulty and nutrient leaching and slow growth. Prolonged standing water also affects ratoon crops, reducing their regeneration capacity.



Plate 4. Waterlogged sugarcane fields following heavy monsoon rainfall in Haryana

Pulses (Moong, Mash, Arhar): Pulses are extremely sensitive to heavy rainfall due to their shallow root systems. Excess rain leads to root rot and stem rot, flower drop and pod abortion, pest outbreaks, waterlogging leading to total crop failure. In many cases, heavy rainfall can destroy pulse crops within a few days.



Plate 5. Pulses affected by prolonged monsoon rainfall in Haryana

Horticultural crops: Fruits such as kinnow, guava, ber, and mango are also affected. Heavy rainfall can cause fruit cracking, drop of flowers or immature fruits, fungal attacks, soil erosion around plant bases, reduced sweetness due to nutrient dilution and kinnow orchards experience root rot when water stagnates for long periods.



Plate 6. Horticultural crops damaged due to heavy monsoon rainfall in Haryana

Fodder crops: Fodder like berseem, sorghum, and cowpea are impacted through lodging, fungal infestations, poor regrowth after cutting, contamination leading to livestock diseases. This ultimately affects Haryana's dairy sector, which is closely tied to fodder availability.



Plate 7. Fodder crops impacted by waterlogging during the monsoon season in Haryana

Table: Rainfall affected crops and types of damage in Haryana:

Rainfall condition	Crop	Type of damage observed	Advisory / management suggestions
Heavy & continuous rainfall	Rice (transplanted)	Lodging, poor grain filling, fungal diseases (blast, blight), delayed harvesting, reduced grain quality	Ensure rapid field drainage within 48–72 h; avoid excess nitrogen; apply need-based fungicides after rain; support lodged crop by drainage and timely harvesting once fields dry
Heavy rainfall after sowing	Rice (direct-seeded)	Seed displacement, patchy germination, uneven crop stand, need for re-sowing	Re-sow in gaps after soil stabilizes; prefer line sowing; use seed priming; improve field leveling and drainage before next season
Excess rainfall during vegetative stage	Cotton	Waterlogging, root rot, whitefly attack, boll rot, leaf defoliation	Provide surface drainage; avoid irrigation; apply recommended fungicides/insecticides during dry intervals; improve soil aeration through shallow interculture
Heavy rains during harvest	Cotton	Open bolls absorb moisture, fiber discoloration, boll rot, severe yield and quality loss	Harvest immediately after rainfall-free periods; avoid storing wet kapas; promote timely picking and drying
Excess rainfall in monsoon	Sugarcane	Cane rot, lodging, delayed growth, nutrient leaching	Ensure ridge-furrow drainage; apply split nitrogen after drainage; remove lodged canes; avoid prolonged water stagnation
Heavy rainfall in early season	Maize	Weak seedlings, poor cob formation, stalk rot	Improve drainage; re-sow in severely affected patches; apply balanced nutrients after excess moisture recedes
Rainfall during tasseling / silking	Maize	Poor pollination, reduced grain set	Maintain field drainage; avoid stress through balanced nutrition; use tolerant hybrids in high-rainfall zones
Heavy monsoon spells	Bajra	Root damage, lodging, downy mildew	Grow resistant varieties; ensure raised beds; remove infected plants; apply fungicides if disease appears
Excess rainfall in kharif	Pulses (moong, mash, arhar)	Root rot, flower drop, pod abortion, crop failure under waterlogging	Avoid low-lying fields; adopt raised beds; improve drainage; prefer short-duration and tolerant varieties
Continuous rainy days	Vegetables (tomato, brinjal, cauliflower)	Fruit cracking, fungal diseases, rotting, poor market quality	Use mulching and raised beds; ensure proper spacing; apply protective fungicides; harvest at proper maturity
Rainfall in orchards	Kinnow, guava, mango	Fruit cracking, flower drop, fungal and bacterial infections	Improve orchard drainage; apply preventive sprays; regulate irrigation; prune diseased branches
Heavy rains in fodder fields	Berseem, sorghum, cowpea	Lodging, fungal infestation, poor regrowth	Harvest early before lodging; improve drainage; apply light nitrogen after rain for regrowth

Livestock farming, an integral part of Haryana's agricultural economy, is equally affected. Heavy rains deteriorate fodder quality, damage stored feed, and increase the risk of parasitic infections in animals. Flooded sheds and contaminated water sources threaten livestock health, reducing milk productivity and increasing veterinary expenses. Thus, heavy rainfall influences the entire agricultural ecosystem, affecting crops, livestock, soil health, and rural livelihoods.

Waterlogging Stress in Subsequent Rabi Crops

Large areas in the state experienced water stagnation in agricultural fields, which has created serious challenges for the sowing of the subsequent rabi crops. Continuous standing water adversely affects soil physical, chemical, and biological properties, thereby disturbing timely field preparation and seed establishment. Prolonged waterlogging leads to soil compaction and poor aeration, reducing oxygen availability in the root zone. Under such anaerobic conditions, beneficial soil microorganisms decline, while harmful anaerobic microbes increase, resulting in nutrient imbalance and reduced soil fertility. The soil structure deteriorates, forming hard crusts or puddled layers after drying, which makes land preparation difficult and delays tillage operations required for rabi sowing.

Excess moisture also causes nutrient losses through leaching and denitrification, particularly nitrogen, leading to reduced soil nutrient availability for the next crop. In addition, accumulation of toxic substances such as ferrous iron and sulfides under waterlogged conditions can negatively affect seed germination and early seedling growth. As a result, rabi crops like wheat, mustard, chickpea, and vegetables may show poor emergence, uneven plant stand, and weak early growth if sown immediately after drainage. Another major constraint is the buildup of soil-borne pathogens and pests, increasing the risk of diseases such as root rot, damping-off, and seedling blight in the subsequent crop.

Excess Rainfall Necessitates Timely Adaptive Measures

Therefore, heavy rainfall and stagnant water during the monsoon not only damage standing kharif crops but also pose serious constraints for the succeeding rabi season. To minimize these effects, rapid drainage, proper land leveling, shallow tillage after drying, use of raised beds, and selection of suitable sowing windows and tolerant varieties are essential. Farmers are also advised to avoid irrigation and chemical spraying during rainy periods, ensure effective field drainage, and remove stagnant water promptly. Harvested produce should not be left in open fields, and fertilizer or pesticide application should be postponed until weather conditions stabilize. During heavy rainfall or thunderstorms, farming operations should be suspended, and people should avoid waterlogged areas, weak structures, and water bodies, while taking shelter in safe locations rather than under trees. These measures can help restore soil health, facilitate timely rabi sowing, and improve crop establishment and productivity under post-flood conditions.

Conclusion

Overall, the 2025 monsoon season in Haryana stands as a clear indicator of climate variability and its far-reaching consequences on agriculture. The extensive flooding, severe crop losses, pest outbreaks, and economic distress among farmers underscore the vulnerabilities in current agricultural systems. While government interventions provided immediate relief, the season's experiences point to a pressing need for integrated climate-resilient strategies. Strengthening drainage infrastructure, promoting crop diversification, developing stress-tolerant varieties, and ensuring effective risk-mitigation schemes will be critical for sustaining agricultural productivity in Haryana in the coming decades. Furthermore, integrating climate-smart agricultural practices with digital technologies, remote-sensing tools, and real-time weather forecasting can significantly enhance farmers' adaptive capacity. A detailed and systematic understanding of heavy-rainfall impacts will therefore play a central role in designing future agricultural policies and promoting sustainable farming systems in the state.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Cultivation of Wheat (*Triticum aestivum*)

Article ID: 72752

Mayank Parate[1]
[1]B.Sc. (Hons) Agriculture, School of Agriculture, Eklavya University (Madhya Pradesh)- 470661.

Abstract
Wheat *(Triticum aestivum)* is one of the principal cereal crops which is grown on a large scale for its edible value. Wheat thrives in a temperate climate with moderate water requirements. The necessary requirements for improved yield include proper land preparation, proper timing of sowing, high-quality seeds, balanced fertilizers, proper water management, as well as effective measures for the suppression of weeds, pests, and diseases. If proper care is taken, wheat is a reliable crop even for rain-fed areas.

Introduction
Wheat is the world's chief cereal and a primary source of food for the majority of the world's population. Wheat is planted in its significant position in agriculture as a result of adaptability and utilization for food preparation as bread, chapati, and pasta among others. In the Indian situation, wheat is one of the key crops planted during the "rabi season" and is of paramount importance for food security and the economy of the rural areas.

Origin
The origin of wheat is Southwest Asia, mainly the region now known as turkey.

Area and Distribution
Wheat is the most widely grown cereal in the world, holding a very significant position in agriculture globally. It is grown on huge land of about 220 million hectares. Wheat occupies the leading place in land coverage and production among all the cereals. The biggest land is utilized for wheat in India, followed by China. The total production of China is standing at number one and that of India is standing at number two. In India, it is taken as the second most important cereal crop after rice. Maximum land and production are found in Uttar Pradesh, while Punjab has the highest productivity per hectare, followed by Haryana. In agriculture, India contributes to 12 percent of total wheat production of the world.

Climate and Soil Requirement
Wheat is a Rabi crop and is suitable for growth in cool and dry climatic conditions. Temperature is one of the vital parameters for the growth and development of wheat. During its growing season, the ideal temperature for growing wheat is between 20-25°C. At low temperatures during early growth periods, better tillering occurs and during the maturation stage, warm and dry conditions are required for better quality grains. The right amount of rainfall is required for successfully growing wheat. It mainly requires about 500 to 750 mm of well-distributed rainfall during its growth period. Too much rain, especially during the initial growth stages as well as maturity, is harmful, whereas any deficiency in the reproductive phase is liable to reduce the yield. Various types of soil are suitable for growing wheat. However, clay loam to loam soils with good structure and proper water-holding capacity and drainage are considered as the most suitable for growing wheat. They are favorable for better root development and optimum utilization of nutrients and water.



Varieties
Single dwarf gene variety: Sonalika, UP-262, WL-711, Girija : Double gene dwarf variety: Kalyan sona, Janak, Arjan, UP-215, HD-2204, Pratap. : Triple gene dwarf variety: Hira, Moti, Jawahar, Jyoti, Sangam, HD-1941,1977, UP-301, 319 : Late variety: Lok-1, HD-334,134.: Commercial variety: PBW-343,154,367, NDW-1010,1011,1009,1001.

Land Preparation

The soil should be tilted using the disk or mold board plough. In places where the tractor is accessible, the operation should consist of deep ploughing, followed by 2-3 planking, and in places where the power resource is bullocks, the operation should consist of deep ploughing, followed by 2-3 harrowing or 4-5 intercross ploughing. Planking should take place following every operation.

Sowing

Timely sowing is a key factor for good germination and higher production in wheat. For broadcast sowing, the seed rate is advised to be 100 kg per hectare for timely sowing and 125 kg per hectare for late sowing. For dibbling sowing, only 25 to 30 kg of seeds per hectare is sufficient. The treatment of seeds with Vitavax, Thiram, Agrosan, and Bavistin at a rate of 2.5 g per kg of seed is advised to make seeds immune to seed and soil-borne diseases. The spacing pattern is advised to be 22.5×10 cm with a depth of sowing of about 5 cm for higher production in wheat. The best time to sow is in the first fortnight of November, but in rain-fed areas, sowing is done in mid-October, and in late sowing, it is done up to mid-December.

Nutrient Management

For appropriate nutrient utilization in wheat, it is necessary to give 10 to 15 quintals of farm yard manure per hectare, which is to be done 15 days before sowing to increase fertility and ensure good soil structure. The fertilizer requirement for wheat is actually NPK-150:70:125 kg/ha. The entire dose of phosphoric and potash fertilizers must be done at the time of sowing; while in the case of nitrogenous fertilizer, it must be done in two splits – half at sowing and another half after the first watering session.

Water Management

Adequate water management is necessary for achieving optimal yield of wheat. The crop needs irrigation at various critical phases of its life. The critical phases of irrigation are CRI or crown root initiation phase at 40-45 days from sowing, late jointing phase at 70-75 days, flowering phase at 90-95 days, milking phase at 100-115 days, or dough phase at 105-125 days. In cases where only one irrigation is done, it should be carried out during the CRI phase. In situations where there are two irrigations, these should occur during CRI and flowering phases. In circumstances where three irrigations are done, these should occur during CRI, late jointing, and milking phases. In cases where there are four irrigations, these should occur during CRI, tillering, late jointing, and flowering phases.



Weed Management

The wheat crop is commonly infested by both dicot and monocot weeds, which compete for nutrients, moisture, light, and space, resulting in yield reduction. Major dicot weeds include *Chenopodium album* (Bathua), *Fumaria parviflora* (Gajri), *Cirsium arvense* (Kateli), *Anagallis arvensis* (Krishna neel), *Melilotus alba*, and *Melilotus indica* (Chatri matri). Important monocot weeds are *Phalaris minor* (Gehu ka mama), *Avena fatua* (wild oat), and *Cyperus rotundus* (Motha). For weed control, 2,4-D is effective against most dicot weeds without affecting Phalaris minor. For Phalaris minor management, one can use sulfosulfuron or isoproturon herbicides at a 0.5 percent solution. Apart from chemical control, good and timely field operations can also reduce the population of weeds and enhance the growth of the crop.

Pest and Disease

Effective pest and disease control is required to achieve better yields and better grains with the wheat. Serious pests of wheat are termites, gujhia weevil, army worm, and rodents, which damage seedlings, leaves, and stalks of the wheat. Control of rodents can be done by having aluminum phosphide tablets inside the burrows, and termite, gujhia weevil, and army worm pests be controlled through spraying 0.2 to 0.5 percent methyl parathion, or monocrotophos, or carbaryl.

Wheat gets infested with brown rust, yellow rust, black rust, loose smut, karnel bunt, and powdery mildew. The rusts, along with powdery mildew, can be tackled by spraying 0.5 percent mancozeb. The treatment of seeds through crop rotation can help decrease the incidence of the disease, while the use of varieties that are resistant to karnel bunt, such as HD-2428, PBW-435, Raj-3765, HS-240, and BL-616, is specifically advised to control the disease. The other methods include the use of a systemic fungicide such as TILT @ 500 ml/ha at the booting stage to control karnel bunt.

Harvesting and Thrashing

High yield dwarf variety of wheat should be harvested when the leaves and stem turn yellow and dry. In order to avoid a loss of yield, the crop should be harvested not having lost its full value, i.e., before it is dead ripe. It is harvested, failing which the grain, having been damaged, might suffer a loss due to damage.

Yield

In an irrigated climate, an average yield of wheat under optimal conditions is about 40 to 45 quintals for every hectare of land. Its average yield is congenial at about 20 to 25 quintals per hectare of land in rainfed and dry areas receiving low water supply. Yield may be influenced by variety, timely sowing, nutrition, irrigation, and proper methods of weed, pest, and disease control.

Post Harvest Management

Post harvest management helps to preserve the quality of the produce and ensure that there is little storage loss. Once the crop is harvested, it needs to be dried to get the moisture content of the grains to 10 to 12 percent. The threshing and cleaning processes follow to separate the grains and straws. Cleaning and drying of the grains ensure that the grains are stored in a moisture-free and well-ventilated storage structure. Additionally, during storage, the produce requires protection from pests and fungi.

Conclusion

Wheat crop cultivation needs proper management from sowing to harvesting for optimal yield and quality. On time agricultural practices, nutrition, and irrigation are required for growing. Proper pest and disease control measures will also help in enhancing productivity. Scientific cultivation of wheat is essential for ensuring food security and sustainable agriculture.

References

1. Filip, E., Woronko, K., Stępień, E., & Czarniecka, N. (2023). An overview of factors affecting the functional quality of common wheat (Triticum aestivum L.). *International journal of molecular sciences*, *24*(8), 7524.
2. Miransari, M., & Smith, D. (2019). Sustainable wheat (Triticum aestivum L.) production in saline fields: a review. *Critical reviews in biotechnology*, *39*(8), 999-1014.
3. Raman, H., Ryan, P. R., Raman, R., Stodart, B. J., Zhang, K., Martin, P., ... & Delhaize, E. (2008). Analysis of TaALMT1 traces the transmission of aluminum resistance in cultivated common wheat (Triticum aestivum L.). *Theoretical and Applied Genetics*, *116*(3), 343-354.
4. Zaharieva, M., Ayana, N. G., Hakimi, A. A., Misra, S. C., & Monneveux, P. (2010). Cultivated emmer wheat (Triticum dicoccon Schrank), an old crop with promising future: a review. *Genetic resources and crop evolution*, *57*(6), 937-962.
5. Zargar, M., Polityko, P., Pakina, E., Bayat, M., Vandyshev, V., Kavhiza, N., & Kiselev, E. (2018). Productivity, quality and economics of four spring wheat (Triticum aestivum L.) cultivars as affected by three cultivation technologies.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Vertical Farming of Strawberry in PVC Pipes

Article ID: 72753

Shruthi Reddy. L[1], Rajasekhar. M[2]
[1]Ph.D (Horticulture), Fruit science.
[2]Professor, Sri Konda Laxman Telangana Horticultural University.

Introduction

Strawberry is a short, low growing perennial herb with a shallow fibrous root system. The stem is compressed into a rosette crown. The auxiliary buds in the leaf nodes of the crown either remain dormant or develop into branched crowns or stolons depending on the prevailing environment. Leaves are trifoliate having long petioles. Inflorescence is branched and flowers are monoecious and commercially propagated by runners (Sharma and Sharma, 2004).

The strawberry (*Fragaria x ananassa* Duch.) is one of the most widely consumed fruits in the world because of its delicious flavour and taste and is a rich source of minerals like calcium, phosphorus, potassium, iron, sodium and vitamins A, B, C, E and antioxidants. Ripe fruits contain ellagic acid, which prevents cancer and heart diseases, and thus, it has become important table fruit all around the world.

Strawberry is mainly a crop of temperate climate. However, introduction of suitable varieties which are adaptable to varied climatic conditions led to successful cultivation of strawberry even in subtropical and tropical regions.

Vertical Farming of Strawberry

Vertical farming is a method of farming aimed at utilizing vertical space for growing food. It offers many advantages over conventional horizontal- based farming in terms of increased crop production, conservation of resources, good impact on human health, urban growth, energy sustainability, etc. If designed properly, vertical farming may eliminate the need to create additional farmland, help to create a cleaner environment and solve the food crisis in growing cities and suburbs (Shomefun *et al.*, 2018). Vertical farming not only accommodates a greater number of plants per unit area but also saves energy and water, improves the economy, restores the ecosystem, enables sustainable and efficient food production and provides access to healthy food.

Strawberry, when compared to other fruit crops, has a shallow root system that only extends 20 to 30 cm and can be grown conveniently grown vertically by maximising crop production in a small area, which may assist in fulfilling the growing demand for strawberries with effective utilization of available resources for increasing the production per unit area enabling year round production of Strawberries contributing to sustainable agriculture. Vertical farming methods for growing strawberry, includes a variety of systems such as hydroponics, aeroponics, aquaponics, etc., where roots are directly treated with a nutrient solution without any use of media, while other methods includes use substrates such as cocopeat, perlite etc., for crop production.

Vertical Farming of Strawberry in PVC Pipes

1. Material and Methods: An experiment was conducted to evaluate the performance of Strawberry in PVC pipes, where, six inch diameter black PVC pipe was chosen and cut to a height of six feet, twenty four pouches (pockets/holes) were made on the pipe, cementing 1 foot in the ground. The prepared PVC pipe (Vertical Towers) were installed at a spacing of 3 x 3 feet. A 16mm drip lateral with 4 LPH capacity drippers was installed on top of the towers for irrigation and fertigation and a drainage pipe was attached underneath for the discharge of excess water. The growing medium was combined in the necessary ratios and pressed tightly to fill the space within the tower without any gaps. Each strawberry seedling was transplanted into individual pouches of the vertical tower. The emerging runners were removed time to time during the experiment.

2. Results: The total number of fruits obtained from all the plants of the vertical tower was recorded to calculate the total yield per tower. The yield per tower obtained was 4.79 kg with a benefit cost ratio of 1.63.

Conclusion

By this experiment, it can be concluded that, strawberry can be grown conveniently in vertical farming by utilizing PVC towers either commercially in large scale or in urban households on a smaller scale to meet the growing demand of strawberry in Indian households.

References

1. Sharma,V.P. and Sharma, R.R. 2004. The Strawberry, New Delhi, India: *Indian Council of* Agricultural Research (ICAR).

2. Shomefun,T.E, Awosope C. and Diagi, E.2018. Microcontroller-based vertical farming automation system. International Journal of Electrical and Computer engineering. 8(4):2046- 2053.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Cashew Apple: From By-Product to Value-Added Resource

Article ID: 72754

Trinayanee Sharma[1]
[1]Ph.D scholar, Department of Plantation, Spices, Medicinal and Aromatic Crops, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal.

Introduction

Approximately 7.25 lakh tonnes of cashew nuts and over 60 lakh tonnes of cashew apples are produced annually in India. In actuality, less than 10% of cashew apples are used; the rest are squandered. Researchers have emphasized the cashew apple's economic and nutritional significance. Cashew apple juice is still not commonly used for commercial processing, despite its high nutritious content. This is mostly because there is little research on juice quality factors and inadequate varietal characterisation (Sharma *et al.*, 2025). Cashew nuts are widely recognized for their health benefits, which include antioxidant activity, vitamin supply, cardiovascular protection, cancer prevention and nerve health support. Similarly, cashew apples have anti-inflammatory, wound-healing, antioxidant and anti-obesity qualities (Oliveira *et al.*, 2020). An excellent supplier of important minerals, especially calcium and phosphorus, is the cashew apple. The leftovers that remain after the juice extraction from cashew apple have nutritional value as well. Roughly 4% fat, 6% protein, 8% crude fibre and 10% pectin make up these residues. Because of its rich composition, cashew apples and their byproducts are frequently used to make jams, jellies and drinks. After drying, they are also fed to cattle (Nair, 2010). In addition to high-value cashew nuts, cashew apples have the potential to start their own business due to their numerous applications, including squash, syrup, jam, candies and wine, yet they end up in the trash due to ignorance. This demonstrates that, when compared to other fruits high in vitamin C, cashew apples are the primary source of ascorbic acid or vitamin C (Sharma *et al.*, 2025). The aim to review articles on the nutrient composition and health benefits associated with the consumption of cashew apples and thus encouraging its wider utilization and enhancing its contribution to food security and value addition.

Nutritional Composition of Cashew Apple

Studies have shown that cashew apples contain a significant amount of amino acids (Table 1) (Okpanachi *et al.*, 2015) , which are involved in numerous bodily physiological processes. It is well recognized that fruits are abundant in fibre, minerals and phytochemicals that can reduce the incidence of non-communicable diseases (NCDs), promote healthy living as well as ensuring food security (Das & Arora, 2017) . Table 1 (Singh *et al.*, 2019) presents the major biological molecules or elemental components found in cashew apples.

Table-1 Amino acid profile and chemical composition of cashew apple:

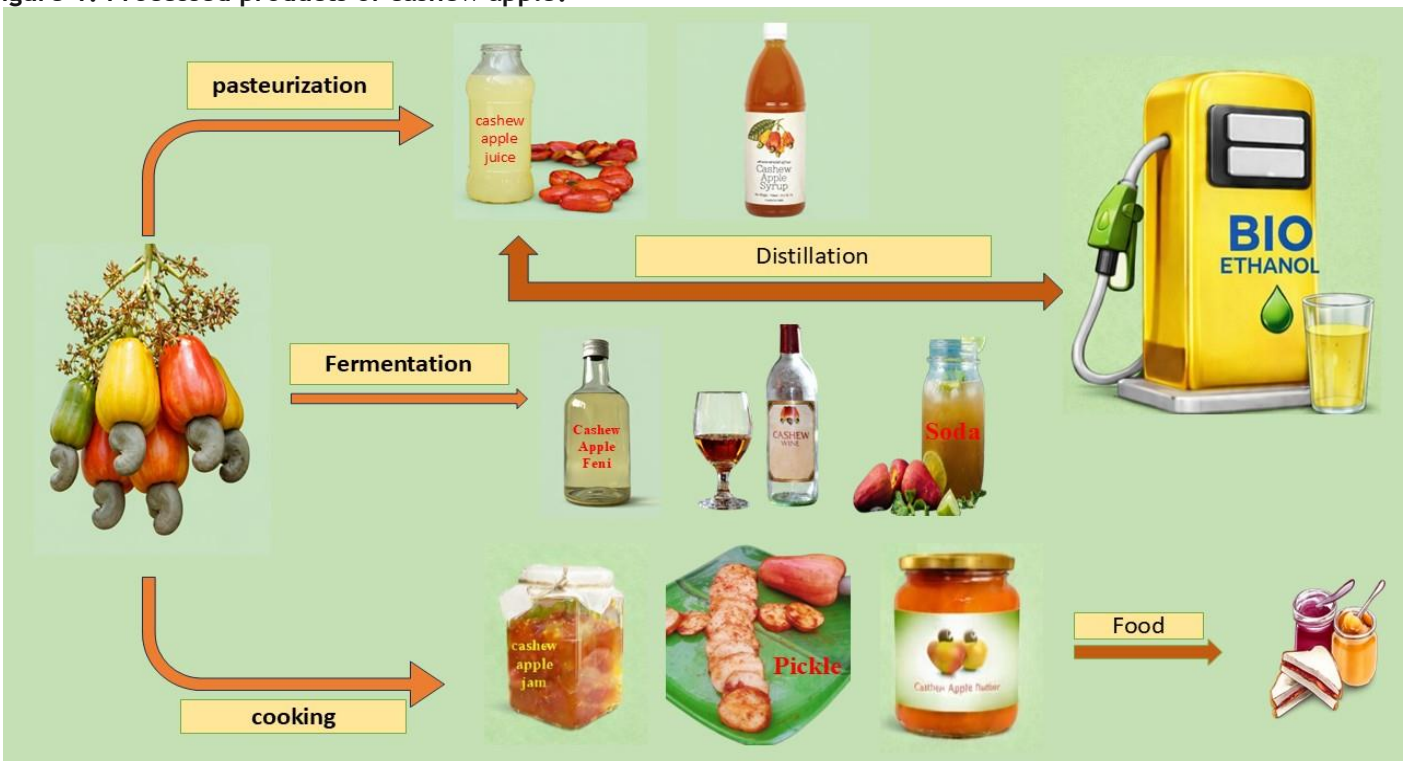
Amino acid content of cashew apple pulp	
Amino acid (mg/100 g)	Cashew apple pulp
Leucine	2.79 - 3.11
Tyrosine	1.11 - 1.27
Glycine	1.83 - 2.09
Alanine	1.99 - 2.28
Lysine	1.84 - 2.22
Serine	1.79 - 1.52
Threonine	1.41 - 1.93
Valine	2.20 - 2.61
Isoleucine	1.65 - 1.97
Cysteine	0.40 - 0.60
Methionine	0.49 - 0.63
Proline	2.24 - 2.65
Aspartic acid	3.32 - 3.97
Lysine	1.84 - 2.22
Arginine	1.47 - 1.90
Histidine	0.76 - 1.04
Phenylalanine	1.87 - 1.94
Glutamic acid	3.64 - 4.24

Chemical composition of cashew apples	
Component (mg/100 mL)	Cashew apples
Vitamin C	221.6 - 241.13
Total polyphenols	265.97 - 271.03
Anthocyanins	210.67 - 225.85
Potassium	36.10 - 43.61
Magnesium	1.22 - 4.13
Calcium	1.20 - 6.01
Iron	0.35 - 0.37
Phosphorus	2.15 - 2.21
Sulphur	0.45 - 0.46
Manganese	0.03 - 0.20
Total sugars (%)	2.37 -10.57
Proteins (%)	1.09 - 1.13
Lipids (%)	2.25 - 2.99

Processing And Value-Addition of Cashew Apple

By turning the cashew apples into intermediary items that are shelf-stable, high losses could be avoided. Numerous methods and procedures have been developed to turn cashew apples into value-added products, such as fruit powder used in cookies, chocolates, bread spreads, and sponge cakes; fermented beverages like wine and soda; unfermented cashew beverages like pulpy and clarified juice; and other products from cashew apple bagasse (cashew apple pomace powder in cookies, as fat replacers in burgers, and for increased fibre in cookies) (Preethi *et al.*,2021).

Figure 1. Processed products of cashew apple:



Conclusive Remarks

The minerals and phytochemicals found in cashew apples are crucial for preserving a robust immune system and healthy vision, in addition to helping to avoid cancer, obesity, ulcers and cardiovascular disorders. Thus, regular intake of cashew apples and their value-added products can support the cashew industry's expansion and sustainability while also offering a number of health benefits (Akyereko *et al.*, 2023). Cashew apples can be used more effectively by adding them to other food products or blending them with other fruit juices to lessen their inherent astringency, which will enhance their flavour, nutritional value and customer acceptability. Promoting the use of cashew apples requires more participation from governmental and non-governmental groups, industrial players, entrepreneurs, researchers, and engineers. This can be accomplished by creating policies that are favourable, establishing public awareness campaigns about the health advantages of the processing industry, offering small-scale processors financial support and incentives, and providing practical training in value addition. These initiatives will increase food security, decrease waste and generate more revenue.

References

1. Akyereko Y.G., Yeboah G.B., Wireko-Manu F.D., Alemawor F., Mills-Robertson F. C. & Odoom, W., (2023). Nutritional value and health benefits of cashew apple. *JSFA Reports*. 3:110–118.
2. Das I. & Arora A., (2017). Post-harvest processing technology for cashew apple–a review. *Journal of Food Engineering* . 194:87–98.
3. Nair K.P., (2010) The agronomy and economy of important tree crops of the developing world. Elsevier, Amsterdam
4. Okpanachi U., Attah S., Shaahu D.T., (2015). A comparative study between vitamins and amino acid profile of sun-dried red and yellow cashew pulp. *International Journal of Animal Biology*. 1(5):237–42.
5. Oliveira N.N., Mothe´ C.G., Mothe´ M,G. & Oliveira, L.G., (2020). Cashew nut and cashew apple: a scientific and technological monitoring worldwide review. *Journal of Food Science and Technology*. 57(1):12–21.
6. Preethi P., Mangalassery S., Shradha K., Pandiselvam R., Manikantan M.R., Reddy S.V.R., et al. (2021). Cashew apple pomace powder enriched the proximate, mineral, functional and structural properties of cereal based extrudates. LWT. 139:110539.

7. Sharma T., Bhattacharjee H., Medda P.S., Bhowmick N. & Nayak J.K., (2025). Biochemical evaluation of cashew apple (*Anacardium occidentale* L.) under terai agro climatic zone of West Bengal. *Journal of Medicinal Plants Studies*. 13(3):104-107.
8. Singh S.S., Abdullah S., Pradhan R.C. & Mishra S., (2019). Physical, chemical, textural, and thermal properties of cashew apple fruit. *Journal of Food Process Engineering*. 42(5):13094. 8.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Use of Plant Growth Regulators (PGRs) & New Chemicals for Enhancing Vegetable Production

Article ID: 72755

Aman Dev Verma[1], Dr. Vijay Bahadur[2]
[1]M.Sc. Horticulture (Vegetable Science), SHUATS, Prayagraj, U.P.
[2]Head of the Department, Department of Horticulture, SHUATS, Prayagraj, U.P.

Introduction

The word plant hormones are also known as Phytohormones. These hormones helps to Regulate growth of the plant and these Hormones are small molecules that derived From different essential metabolic pathways. Thimann in 1948 was coined the term „Phytohormone" as organic substance that Produce naturally in plants. The „Plant Hormones" are natural and „Plant Growth Regulators" are synthetic in nature. They play an important role to growth of plant (P. Hazra and M.G. Som, 2006). There are Five types of plant growth regulators such as Auxins, gibberellins, cytokinins, abscisic acid And ethylene.

The five group of natural hormones-Auxin, gibberellins, cytokinins, ethylene and Abscisic acid fit the classical definition of Hormones. Synthetic chemicals used as Hormones are referred to as plant growth Regulators. Plant growth regulators are widely Using in the agricultural sector for different Purposes from seed germination to final yield. PGRs improved the germination of vegetable Seeds, increased total yield, protected the plant From pests and sometimes also used to avoid the loss of yield due to unfavorable condition.

Plant Growth Regulators

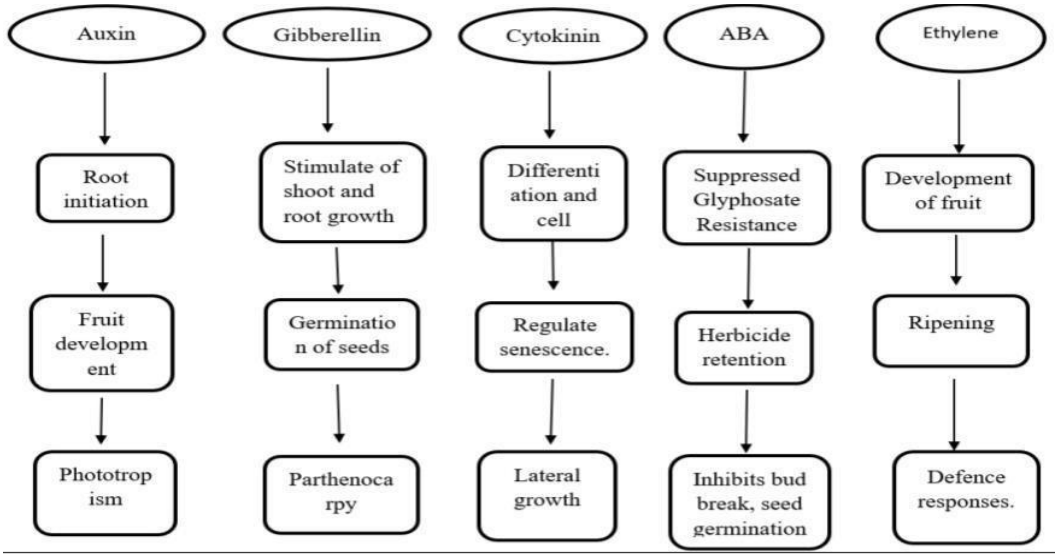
1. A growth regulator is
2. An organic compound.
3. Can be natural or synthetic, It modifies or controls one or more specific physiological processes within a plant but the sites of action and production are different.
4. If the compound is produced within the plant, it is called as plant hormone.
5. Both internal plant hormones and lab created hormones are called plant growth regulators.

Principal Five Hormones

The "classical" phytohormones fall into five well-established groups, sometimes known as the "big five," namely:

1. Auxins.
2. Gibberellic acid
3. Cytokinin
4. Abscisic acid
5. Ethylene

The PGRs are classified into different groups according to their structure and function in plant physiology. Each group has both stimulating and inhibiting effects and often interacts with other groups to regulate plant growth (Hajam et al., 2017) [17].



Auxin: Charles Darwing was the first who proposed The existence of auxin in 1880. It was the first Class growth regulator that was discovered. Auxins are those compounds that give positive Effect on formation of bud, enlargement of cell And root initiation and they are also helpful for The formation of other growth hormones. IAA Is natural occurring hormone while NAA,IBA, 2-4D etc. are synthetic in nature.

Gibberellin: Kurosava was the Japanese scientist who Discovered gibberellins in 1926. It is the Second growth regulator. It was extracted from The fungus *„Gibberella fujikuroi*" which is the Causal organism of "foolish seedling of rice".GA stimulate germination of seed and Maturation of flower and fruit.

Cytokinins: Skoog in 1995 experimented that when pith Tissues of „Nicotianatabaccum' were separated From the vascular tissues they grew without Division of cell. There are so many different Synthetic cytokinins such as 6-benzylamino Purine (BAP), kinetin, 6-(benzyl-amino)-9-(2- Tetrahydropyranyl)-9H-purine (PBA), 1,3-Diphenylurea, thidiazuron (TDZ), etc.

Ethylene: This hormone is a gaseous plant hormone Which is synthesized from methionine and it is Synthesized in all organs of plant.Abscisic acid It is also called plant stress hormone. It act as Inhibitory chemical compound that gives Direct effect on growth of bud, seed and Dormancy of bud. It has inhibitory effect and Occurs naturally in plants. It inhibit mRNA And synthesis of protein.

Other Plant Growth Regulators

Brassinolides: (Syn. Brassinosteroids or Terpenoids) Brassinolides are a plant steroid Discovered in pollen of member of the mustard Family. The have been studied in Arabadopsis. Brassinolides represent a new sixth class of Plant hormones with wide occurrences in the Plant kingdom in addition to auxins, gibberellins, Cytokinins, abscisic acid and ethylene. The Substances from various pollen sources named 'brassins' a steroidal lactone, termed brssinolide, Was first time isolated from pollen of Brassica Napus by Grove and his associates in 1979.

Jasmonates (Jasmonic Acid): Jasmonates are a group of fatty acid Derivatives. They appear to have a role in seed Germination, root growth and the storage of Protein (especially in seeds). In 1990, airborne Jasmonic acid methyl ester (JAME) was shown to Induce proteinase inhibitors in tomato, thereby Attributing to an 'immunization' against herbivore Attack. Jasmonic acid and JAME are lipid-Derived signals. Jasmonic acid and its related Compounds are short-chain alkylcyclopentane Or alkylcyclopentane carboxylic acids and their Derivatives. It is recognized as a new type of Plant growth regulator. It widely occurs in the Plant kingdom together with abscisic acid like Physiological activities at low concentrations.

Characteristics of Plant Growth Regulators

1. The concentration of hormones required for the plant response is very low (10-6 to 10-5M), comparing with the requirement of mineral and vitamin for plants.

2. The biosynthesis of plant hormones within plant is more diffuse and not always localized.

3. Plant hormones are not nutrient, but chemicals that in small amounts promote and influence the growth. Development, and differentiation of cells and tissues.

Application of PGRs in Major Vegetable Crops

1. Enhancement of seen germination: Pre-sowing seed treatment with NAA @ 20 mg/ enhances seed germination in okra and solanaceous vegetable like crops, wherman, seed soaking in ethephon@ 480 mg/l for 24 hr Improved germination in muskmelon, bottle gourd, squash melon and watermelon at low temperature.

2. Induction of flowering: Application of GA 50mg to men flowering potato results into profuse flowering even under short day condition, This strategy can also be applied to induce flowering in any long day plant under short day conditions

3. Reduce flower abscission: Pre-bloom application of 2 4-D @ 2-5 ppm reduced flower abscission before pollination in tomato, brinjal chilli and capsicum.

4. Increase fruit set in adverse weather: NAA @ 40 ppm or GA @ 10-20 ppm are used to enhance Fruit set in Solanaceous vegetable crops, especially chillli (Chaudhary et al. 2005)

5. Induce parthenocarpy in vegetables: Para-chlorophenoxy acetic acid MCPA or GA, @ 50 ppm is reported to induce parthenocarpy in tomato and cucumber.

6. Increase draught tolerance: Chlormequat Chlorides @50ppm used in pea to protect against drought.

List of Plant Growth Regulator Sand their Important Uses in Vegetable Crops

Growth Regulators	Conc. (mg/l)	Method of application	Crops	Attributes affected
Indole-3-Aceticacid(IAA)	10-15	Foliar spray	Okra, tomato, brinjal	Seed germination, fruit set and yield
Naphthalene acetic acid (NAA)	0.2	Seedling roots	Tomato, brinjal, onion	Growth and yield
	10-20		Chillies and tomato	Flower drop, fruit set and yield
	25-30	Foliar sprays	okra, Tomato, brinjal,	Seed germination, growth and yield
		Seed/ foliar	onion, cucurbits	
Naphthoxy-Acetic acid (NOA)	25-100	Seed/ foliar	Tomato, okra	Germination, growth and yield
Para – Chloro Phenoxy Acetic acid (PCPA)	50	Foliar spray	Tomato	Fruit set and Yield
Gibberellic acid (GA)	10	Foliar spray	Water melon, tomato	Sex expression, fruiting, yield
Ethephon (CEPA)	100-500	Foliar spray	Cucurbits, okra and tomato	Flowering, fruiting, sex expression and yield
	2000	Post- harvest	Tomato, chillies	Fruit ripening
Silver nitrate	500	Foliar spray	Cucumber	Induction of male flower in gyn.Lines
Silver thiosulphate	400	-	Musk melon	Induction of male flower in gynoecious lines
Cycocel (CCC)	250-500	Foliar spray	Cucurbits, tomato, okra	Flowering, sex expression, fruit yield
2,3-5, tri-iodobenzoic acid (TIBA)	25-50	Foliar spray	Cucurbits	Flowering, sex expression and yield
Tricontanol	2	Foliar spray	Chilli and peas	Fruit set and yield

Application of Plant Growth Regulators in Different Vegetable Crops

Tomato: The function of plant growth regulators is Advantageous for tomato growth parameters. The tomato plants were exposed to various soil concentrations of NAA at 25, 50, 75, and 100 ppm and GA3 at 20, 40, 60, and 80 ppm. It Was reported that the use of NAA at 100 ppm And GA3 at 80 ppm resulted in maximum plant Heights of 85.3 cm and 82.3 cm, respectively, And increased yields of 483.6 q/ha and 472.2 q/ha (Prasad et al., 2013). The highest plant height, number of leaves, number of branches per plant, number of fruits, number of flowers, number of clusters of fruit, diameter of fruit, yield per plant (kg), yield per plot (kg), and yield per hectare (tonnes) were all obtained with GA3 at 125 ppm (Akand et al., 2015).

Chilli: The higher dose 60 ppm NAA resulted in Increasing maximum plant height (67.82 cm),Number of leaves (185.10), number of branches (25.42) and it also increased the, yield attributing Characters such as fruit length (12.44 cm), fruit Girth (1.15 cm), number of fruits per plant (140.77), number of seeds per plant (49.24),Seed weight per fruits (0.81 g), chlorophyll Content (2.56 mg/ 100g), capsicum content (0.18%), ascorbic acid content (121.54 mg/100g) and fruit yield per hectare (13.34 t) Followed by 40 ppm NAA. There was an increase Of 35 per cent in fruit yield with application of NAA 60 ppm respectively as compared to control. The minimum values of these characters Were recorded under control (Anbarasi et al., 2022).

Cauliflower: Sitapara et al., (2011) studied the Effectiveness of GA3 and NAA on the “SNOWBALL- 16” type of cauliflower at various Stages, including root dipping and foliar spraying. The diameter of the curd (17.78 cm), the length Of the stalk (5.22 cm), the net weight of the curd (3.53 kg/plant), the curd yield (12.5 kg/plot), and The necessary minimum days to 50% marketable Curd were all observed to be improved by the Foliar application of GA3 at 50 mg/l in cauliflower (88.80 days). By applying IAA 10ppm + GA3 70ppm instead of control, the highest plant Height (63.10 cm), number of leaves per plant (23.66), leaf length (59.05 cm), leaf breadth (18.98 cm), diameter of curd (22.39 cm), and Marketable yield per hectare (29.88 t/ha) were Observed. Additionally, it was discovered that Planting on November 15 produced the highest Plant height (65.96 cm), number of leaves per Plant (26.42), leaf length (63.64 cm), leaf breadth (20.92 cm), curd diameter (25.75 cm), and Marketable yield per hectare (31.03 t/ha) Measurements, as well as IAA 10 ppm and GA37 0 ppm (Rahman et al., 2016). Different doses of NAA@ 100, 120, and 140 ppm were tested by Jadon et al., (2009).

Okra: IAA @ 100 ppm gave maximum plant Height (107.74 cm). However, the use of GA3 @150 ppm needed a minimum number of days for First blooming (39.67 days) and a minimum Number of days for first harvesting (44.67 days).The best seed quality attributes were provided By GA3 @ 50 ppm, such as average pod weight(g) and 100 seed weight (g). While thiourea @500 ppm gave the largest number of pods per Plant, length of pod (cm), number of seeds per Pod, per plant seed yield (g), and seed Production per hectare, GA3 gave the maximum Plant height, number of leaves, and number of Nodes per plant (q) (Ravat et al., 2015).

Onion and Garlic: According to Patel et al., (2010), root Dipping treatment with NAA @ 100 ppm Dramatically decreased physiological weight loss And decreased loss in spoiling. According to Anbukkarasi et al. (2013), fungicides, ethylene, And CCC all have a significant impact on the Shelf life and delay of sprouting in onions. To Increase the shelf life of onions, pre- and post-Harvest treatments have been studied, according To Bannu Priya et al., (2014).

Cucurbits: According to Hidayatullah et al., (2012), Bottle gourds grown with GA3 @ 30 ppm Produced more pistillate flowers, the greatest Number of fruits, and heavier fruits than controls.According to Dalai et al. (2015), GA3At 20 ppm + NAA @ 100 ppm produced the most wine Length/plant (cm) and amount of leaves/plant. However, for cucumber, GA3 @ 20 ppm + NAA @ 100 ppm had the highest yield. According to Sandra et al., 2015, NAA at 200 ppm, GA3 at 50 Ppm, and ethereal at 50 ppm were all highly Efficient for enhancing vegetative growth, fruit And seed yield, and modifying sex expressions. GA3 at 50 ppm was also successful in producing Hybrid seed in bitter gourd.

Potato: Ethrel at 250 ppm applied topically Changed the phenotypic of the plant and Increased plant height, shoot diameter, number Of tubers produced per plant, and overall tuber Output as compared to the control (Awati et al.,2016). The plant's height increased after GA3 Was applied 60 days after transplanting, but the Quantity of tubers, weight, and dry matter content Were unaffected. Inducing a large percentage of Sprouted tubers before harvest and increasing The physiological age of the tubers are both Results of late application of GA3 (Alexios et al., 2006).

Pea: According to Singh et al. (2016), GA3 at 200 ppm greatly enhanced plant height, the Number of leaves, the total number of branches, The number of pods, the length of the pods, and The weight of 100 seeds. This review's findings Suggest that PGRS regulate physiological Processes in crop plants, such as roots, Flowering, growth, sprouting, and ripening, and That its application in the production of diverse Vegetable crops has been proven to be Advantageous for yield and yield contributing Traits.

Conclusion

Thus, it can be concluded from this Review, use of plant growth regulator in Vegetables has been found beneficial for Improve yield, quality, synchronization in Flowering, earliness, cold and high temperature Fruit setting, sex modification, increases post-Harvest life, and develop resistance to biotic and Abiotic stresses. Those are also very effective for Induction of male sterility in vegetable crops.

References

1. Akand, M.H., Mazed, H.K., Islam, M.A., Pulok, M. and Moonmoon, SNCJF. (2015) Growth and yield of tomato (Lycopersicon Esculentum Mill.) as influenced by Different level of gibberellic acid Application. International Journal of Applied Research 1 (3):71-74.
2. Alexopoulos, A.A., Akoumianakis, K.A. and Passam, H.C. (2006) Effect of plant Growth regulators on the tuberization and Physiological age of potato (Solanum Tuberosum L.) tubers grown from true Potato seed. Canadian journal of plant Science 86 (4):1217-1225.
3. Anbukkarasi, V., Paramaguru, P., Pugalendhi, L., Ragupathi, N. and Jeyakumar, P. (2013) Studies on pre- and post-harvest Treatments for extending shelf life in Onion-A review. Agri. Review 34 (4):256-268.
4. Anbarasi, D., & Venkatraman, M. (2022) Effect of Plant growth regulators on growth, yield And quality characters of chilli (Capsicum Annuum L.) Annals of Plant and Soil Research 24 (4):543- 546.
5. Rahman, M.A., Imran, M., Ikrum, M., Rahman, M.H. and Rabbani, M.G. (2016) Effects of Planting Date and Growth Hormone on Growth and Yield of Cauliflower. Journal Of Environmental Science and Natural Resources 9 (2):143-150.
6. Ravat, A.K. and Nirav, M. (2015) Influence of Plant growth regulators on growth, seed Yield and seed quality in okra [Abelmoschus esculentus (L.) Moench] cv. GAO-5 under middle Gujarat condition. International Journal of Agricultural Sciences 11 (1):151-157.
7. Sandra, N., Kumar, L.S., Chakrabarty, S.K. and Talukdar, A. (2015) Effect of plant growth Regulators on sex expression, fruit Setting, seed yield and quality in the Parental lines for hybrid seed production In bitter gourd (Momordica charantia). Indian Journal of Agricultural Sciences 85 (9):1185-91.
8. Singh, M., John, S.A., Rout, S. and Patra, S.S. (2016) Effect of GA3and NAA on growth And quality of garden Pea (Pisum Sativum L.) cv. Arkel. The Bioscan 10 (3):381-383.
9. Sitapara, H. H., Vihol, N.J., Patel, M.J., Patel, J.S. (2011) Effect of growth regulators And micro nutrient on growth and yield of Cauliflower cv. 'Snowball-16'. Asian Journal of Horticulture 6 (2):348-351.
10. Yadav, V., Yadav, M. S., & Prasad, F. M. (2019) Effect of gibberellic acid and boron on Growth and biochemical composition of Tomato (Lycopersicon esculentum) Plants. Annals of Plant and Soil Research 21 (2): 141-144.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Artificial Intelligence in Precision Agriculture

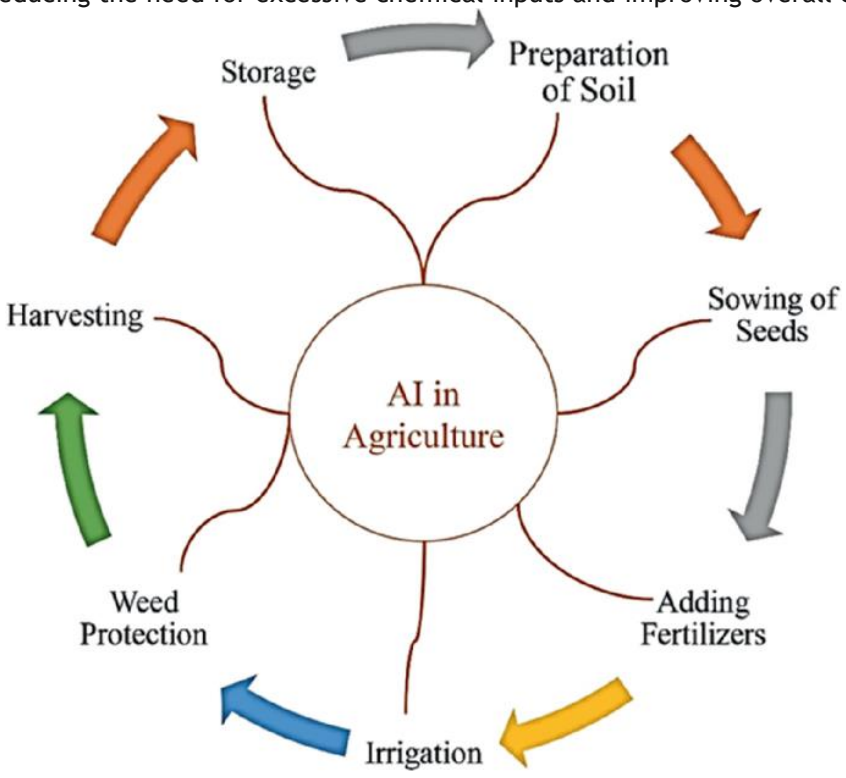
Article ID: 72756

A Uma Maheswari[1], B Chinna Gopi[2]
[1,2]Third year BSc. (Hons.) Agri students, Department of Vignan Institute Of Agriculture And Technology, Vignan's University, Guntur, Tenali Road, Vadlamudi-522213 (Andhra Pradesh).

Abstract
Artificial Intelligence (AI) is emerging as a transformative technology in agriculture by enabling precision-based farming practices that improve productivity, reduce input costs, and promote sustainability. Precision agriculture uses data-driven approaches to manage crop production by considering spatial and temporal variability within fields. This article discusses the role of AI in precision agriculture, including its applications in crop monitoring, soil management, irrigation scheduling, and pest control. The benefits, challenges, and future prospects of AI-based farming systems are also highlighted, emphasizing their importance in addressing food security and climate change challenges.

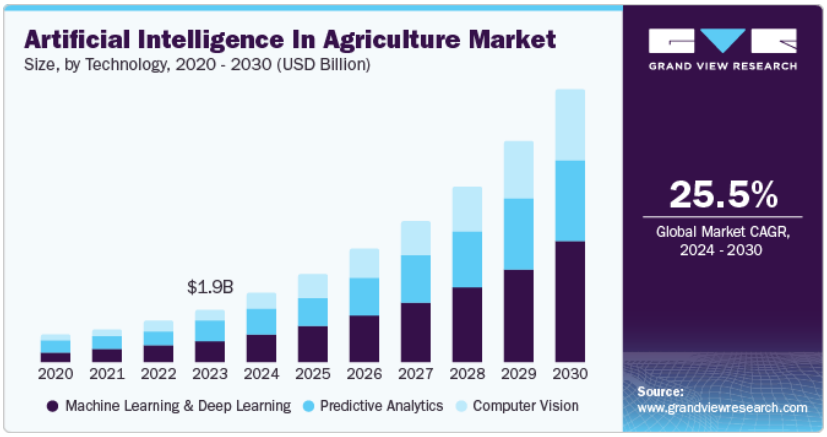
Introduction
Agriculture is undergoing a major transformation due to rapid advancements in digital technologies, among which Artificial Intelligence plays a crucial role. Precision agriculture aims to optimize farm management by applying the right input at the right place and time, and AI enables this by analyzing large volumes of agricultural data. With increasing pressure on food production due to population growth, climate variability, and limited natural resources, AI-based precision agriculture offers innovative solutions to enhance efficiency, profitability, and sustainability in modern farming systems.

Applications of AI in Precision Agriculture
AI has multiple applications in precision agriculture, including crop monitoring using satellite imagery and drones to detect stress, diseases, and nutrient deficiencies at early stages. Machine learning models analyze soil data to recommend precise fertilizer application, while AI-driven irrigation systems optimize water use based on crop requirements and weather conditions. Additionally, computer vision-based systems help in automated weed detection and pest management, reducing the need for excessive chemical inputs and improving overall crop health.



Current Status of Artificial Intelligence in Agriculture
Artificial Intelligence is increasingly being adopted in agriculture through tools such as machine learning algorithms, computer vision, drones, and sensors. These technologies are used for real-time crop health monitoring, yield prediction,

soil nutrient analysis, and weather forecasting. In many countries, AI-powered platforms assist farmers in decision-making by providing recommendations on sowing, fertilization, irrigation, and harvesting. Although adoption is still in the early stages in developing nations, government initiatives and private-sector innovations are accelerating the integration of AI in agriculture.



Advantages of AI-Based Precision Agriculture

The adoption of AI in precision agriculture offers several advantages such as increased crop productivity, efficient use of inputs, and reduced environmental impact. By enabling site-specific management, AI helps minimize wastage of water, fertilizers, and pesticides, thereby lowering production costs. It also improves decision-making accuracy and supports climate-resilient farming practices. Overall, AI enhances farm profitability while promoting sustainable agricultural development.

Challenges and Limitations

Despite its potential, the implementation of AI in precision agriculture faces several challenges, particularly in developing countries. High initial investment costs, lack of technical knowledge, limited access to digital infrastructure, and data privacy concerns restrict widespread adoption. Small and marginal farmers may find it difficult to use advanced technologies without proper training and institutional support.

Future Scope and Way Forward

The future of AI in precision agriculture is promising, with continuous advancements in data analytics, sensor technologies, and automation. Integration of AI with Internet of Things (IoT), robotics, and blockchain can further enhance transparency and efficiency in agricultural systems. Capacity building, farmer training programs, and supportive policies will be essential to ensure inclusive adoption. With proper implementation, AI-based precision agriculture can play a key role in ensuring food security and sustainable farming in the coming decades.

Conclusion

Artificial Intelligence has the potential to revolutionize precision agriculture by enabling data-driven and resource-efficient farming practices. Its applications in crop management, soil health monitoring, irrigation, and pest control contribute to increased productivity and sustainability. Although challenges exist, strategic investments, policy support, and awareness programs can help overcome these barriers. Embracing AI in agriculture is essential for meeting future food demands while protecting natural resources.

References

1. **ICAR.** (2021). *Digital Agriculture in India: Technologies and Applications*. Indian Council of Agricultural Research.
2. **Kamilaris, A., & Prenafeta-Boldú, F. X.** (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*, 147, 70–90.
3. **Liakos, K. G., et al.** (2018). Machine learning in agriculture: A review. *Sensors*, 18(8), 2674.
4. **Wolfert, S., et al.** (2017). Big data in smart farming – A review. *Agricultural Systems*, 153, 69–80.
5. **Zhang, C., & Kovacs, J. M.** (2012). The application of small unmanned aerial systems for precision agriculture. *Precision Agriculture*, 13, 693–712.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Melatonin: The Secret Weapon Protecting Our Fruits and Vegetables from Disease

Article ID: 72757

A. Kingsly Raj[1], A. Ajay Raja[1], P. Agalya[1]
[1]Department of Vegetable Science, Horticultural College and Research Institute, TNAU, Coimbatore, Tamil Nadu, India - 641 003.

Abstract
Melatonin, a molecule traditionally linked to sleep regulation in animals, is emerging as a revolutionary natural defense agent in plants. Horticultural crops face relentless threats from bacterial, fungal, and viral pathogens, leading to substantial economic and nutritional losses. Scientific research now demonstrates that applying melatonin can profoundly enhance a plant's innate immunity. It functions as a multi-faceted shield by boosting antioxidant enzyme activity, scavenging harmful reactive oxygen species, and modulating key defense hormones like salicylic and jasmonic acid. This priming effect strengthens cellular structures and activates disease-resistance genes, reducing infection severity and improving crop vigour. As a biodegradable and non-toxic compound, melatonin presents a highly promising, eco-friendly tool for sustainable agriculture, offering a powerful strategy to safeguard crop yields and global food security.

Keywords: Melatonin, horticultural crops, plant defense, antioxidant, sustainable agriculture, crop protection.

Introduction
From apples and tomatoes to grapes and leafy greens, horticultural crops play a vital role in feeding the world. They provide essential vitamins, minerals, and income, especially in developing regions. Yet, these valuable plants face constant attack from pathogens viz. bacteria, fungi, and viruses that can devastate yields and quality. Traditional chemical pesticides are often used to combat these threats, but they come with environmental and health concerns. In recent years, scientists have turned to natural alternatives, and one molecule stands out: melatonin.

Long recognized for regulating sleep in humans, melatonin is also produced by plants, where it acts as a versatile signalling compound. Research now shows that melatonin helps plants fend off diseases, tolerate stress, and maintain growth under challenging conditions. Whether applied as a spray, soil treatment, or seed soak, melatonin primes plants to activate their internal defense systems. This article delves into the science behind melatonin's protective role, highlighting its potential to revolutionize how we grow and protect our food naturally and sustainably.

How Melatonin Protects Against Bacterial Diseases?
Bacterial infections, such as citrus greening (Huanglongbing) and cassava bacterial blight, can cripple entire crops. Melatonin steps in as a natural defender by boosting the plant's own immune responses. Studies on citrus trees show that melatonin increases levels of defensive hormones like salicylic acid and jasmonic acid, which help plants recognize and resist bacterial invaders. In cassava, melatonin triggers the upregulation of key biosynthesis genes, enhancing the plant's internal melatonin production and improving disease tolerance.

Melatonin also exhibits direct antibacterial properties. In cherry tomatoes, it inhibits the growth of foodborne bacteria like *Bacillus subtilis* by disrupting cell division and reducing biofilm formation. Additionally, melatonin enhances the plant's antioxidant capacity, protecting cells from oxidative damage during infection. Perhaps most intriguingly, melatonin helps plants "close up" at night, acting as a darkness signal that promotes stomatal closure, preventing bacteria from entering leaves. These multi-layered actions make melatonin a promising tool for managing bacterial diseases without relying on antibiotics or harsh chemicals.

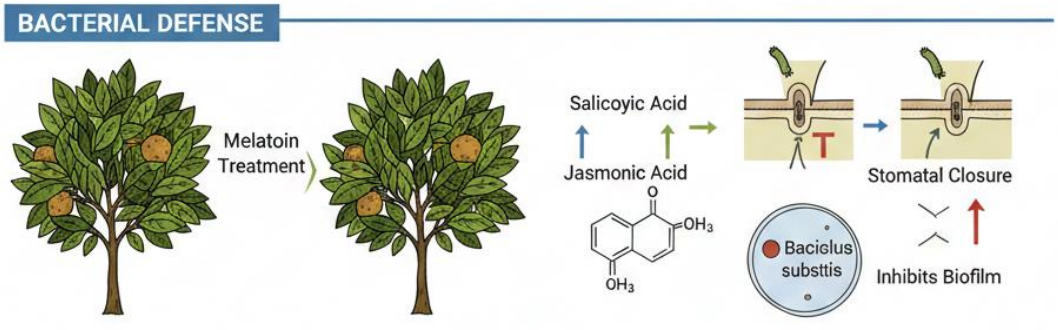


Fig. 1. Melatonin against Bacterial diseases

Melatonin's Role in Fighting Fungal Infections

Melatonin has become a key tool in protecting horticultural crops from destructive fungal diseases. It strengthens plant defenses through multiple pathways. In apples, it manages Marssonina blotch by balancing hydrogen peroxide and boosting defensive enzymes like peroxidase. For bananas, it builds resistance to Fusarium wilt by adjusting heat-shock proteins and stress hormones. In grapes, it lowers gray mold by increasing protective phenolics and stabilizing cell membranes.

A major benefit is melatonin's activation of secondary metabolism. In litchi, it stimulates the phenylpropanoid pathway, raising antifungal flavonoids and phenolics. Similarly, in mango, it enhances defense enzymes and strengthens cell walls against anthracnose.

Melatonin also improves soil health. In apple replant disease, it reshapes the root microbiome and lowers soil phenolics, aiding growth. However, effects can vary; in citrus with green mold, melatonin may over-reduce hydrogen peroxide, weakening defenses. This underscores the importance of crop-specific application strategies for consistent protection.

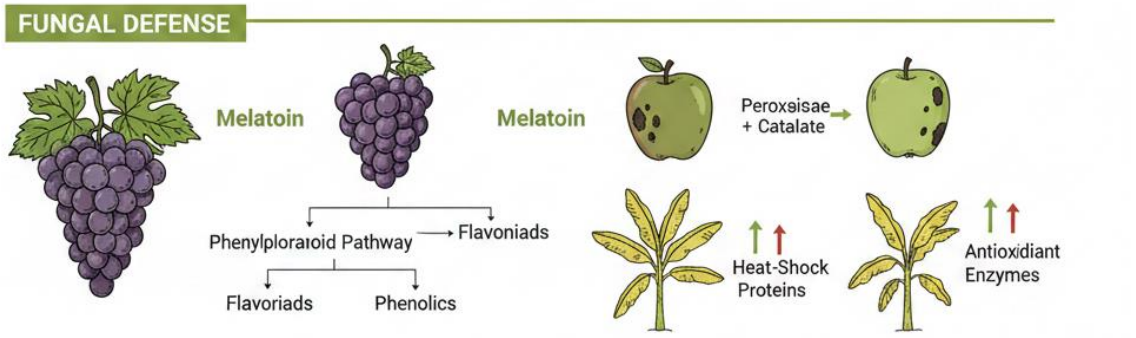


Fig. 2. Melatonin against Fungal diseases

Viral Defense: A New Frontier for Melatonin

Viral diseases are particularly challenging to control because they infect plant cells directly, often with no cure. Yet, emerging evidence suggests melatonin can help plants resist viruses as well.

In apple, melatonin application reduces the concentration of apple stem grooving virus and promotes the growth of virus-free shoots. In tomatoes, melatonin boosts the production of salicylic acid and nitric oxide, key signalling molecules in antiviral defense, while also lowering viral RNA levels. Eggplants treated with melatonin show improved chlorophyll content and antioxidant enzyme activity when infected with alfalfa mosaic virus, helping them maintain photosynthesis and growth.

Melatonin appears to work by priming the plant's immune system, upregulating pathogen-recognition genes, and reducing oxidative stress during viral infection. Although research in this area is still developing, these findings suggest melatonin could become part of integrated management strategies for viral diseases in horticulture.

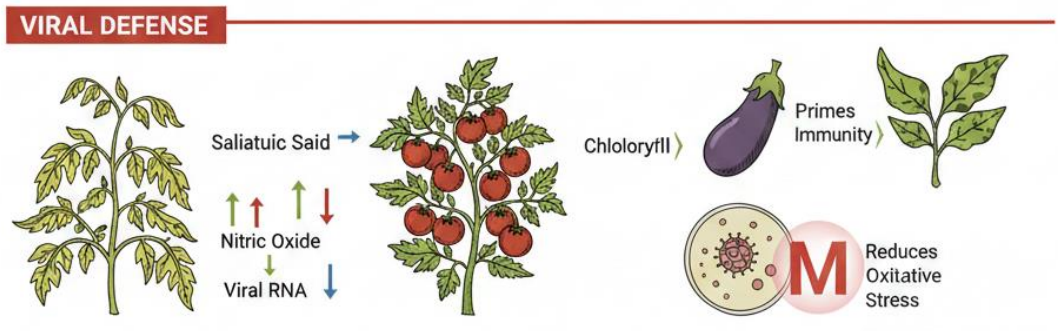


Fig. 3. Melatonin against Viral diseases

How Melatonin Works: The Science Behind the Shield?

Melatonin doesn't just act as a single-purpose compound, orchestrating a broad-spectrum defense system within the plant. At the physiological level, it enhances antioxidant enzyme activity (such as SOD, POD, and CAT), scavenges harmful reactive oxygen species, and protects cellular structures like chloroplasts. This helps maintain plant vitality under stress.

At the molecular level, melatonin influences hormone signalling pathways, modulating the production of jasmonic acid, salicylic acid, auxin, and ethylene, all of which play roles in stress response and immunity. It also upregulates genes involved in melatonin biosynthesis, defense protein production, and secondary metabolism. By tuning these pathways, melatonin helps plants mount a faster, stronger response to pathogens.

Importantly, melatonin is non-toxic, biodegradable, and already produced by plants, making it an attractive alternative to synthetic agrochemicals. Its ability to improve both disease resistance and overall plant health positions it as a dual-benefit solution for modern horticulture.

Future Directions and Practical Applications

While the laboratory and greenhouse results are promising, more research is needed to optimize melatonin use in real-world farming. Key areas include:

1. Dose and Timing: Determining the right concentration and application method for different crops and diseases.

2. Field Trials: Large-scale studies to evaluate effectiveness under varying environmental conditions.

3. Combination Strategies: Exploring how melatonin can be integrated with biocontrol agents, organic practices, or reduced-chemical programs.

4. Safety and Regulation: Confirming the non-toxic nature of melatonin residues on food products and establishing guidelines for agricultural use.

Additionally, researchers are beginning to explore melatonin's potential against other stresses like nematodes, insects, and weeds, areas where current knowledge is limited. As genomic and metabolomic tools advance, we will gain deeper insights into how melatonin interacts with plant genetics and physiology.

Conclusion

Melatonin is far more than a sleep aid, it's a potent plant protector with the ability to enhance disease resistance, support growth, and reduce reliance on chemical pesticides. From battling bacterial blights and fungal rots to curbing viral spread, melatonin offers a natural, sustainable, and scientifically backed tool for securing our food supply. As research progresses, this versatile molecule could become a cornerstone of eco-friendly horticulture, helping growers produce healthier crops in a changing world.

References

1. Gao, T., Liu, X., Tan, K., Zhang, D., Zhu, B., Ma, F., & Li, C. (2022). Introducing melatonin to the horticultural industry: physiological roles, potential applications, and challenges. Horticulture Research, 9, uhac094.
2. Hao, X., Ren, J., Xu, M., Sun, B., Li, R., Yang, S., & Xu, W. (2025). Melatonin in Plant Pathogen Defense: A Review of Its Role in Horticultural Crops. Horticulture Research, uhaf150.
3. Zhao, J., & Hu, J. (2023). Melatonin: Current status and future perspectives in horticultural plants. *Frontiers in Plant Science*, *14*, 1140803.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Invisible Shields: How Nanotechnology Is Empowering Horticultural Crops to Survive Environmental Stress

Article ID: 72758

A. Kingsly Raj[1], A. Ajay Raja[1], P. Agalya[1]
[1]Department of Vegetable Science, Horticultural College and Research Institute, TNAU, Coimbatore, Tamil Nadu, India - 641 003.

Abstract
Horticultural crops play a central role in ensuring dietary and nutritional security by contributing essential micronutrients, natural antioxidants, and health-promoting phytochemicals. However, the productivity and quality of these crops are increasingly constrained by a wide range of environmental stresses associated with climate variability, soil deterioration, and intensified farming systems. Abiotic stresses such as water scarcity, salinity, temperature fluctuations, and toxic metal accumulation, together with biotic stresses from insect pests and pathogenic organisms, disrupt physiological processes and reduce marketable yield. Conventional stress mitigation practices, including genetic improvement, agrochemical application, and irrigation-based interventions, are often constrained by high input costs, slow response, and environmental risks. In this scenario, nanotechnology has gained prominence as an innovative strategy to enhance plant stress tolerance. Nanoparticles possess unique physicochemical properties that enable efficient interaction with plant tissues, leading to improved nutrient delivery, enhanced antioxidant activity, modulation of stress-related signaling pathways, and strengthened defense responses. This article outlines the potential of nanotechnology in mitigating environmental stresses and advancing sustainable, climate-resilient horticultural production systems.

Keywords: Nanotechnology, horticultural crops, abiotic stress, biotic stress, nanoparticles, sustainable agriculture.

Introduction
Horticultural crops such as fruits, vegetables, flowers, and plantation crops are vital components of human diets and play a significant role in public health and rural livelihoods. These crops are highly valued for their richness in essential vitamins, minerals, dietary fibre, and antioxidant compounds. Despite their importance, horticultural production systems are particularly vulnerable to adverse environmental conditions. Ongoing climate change has increased the intensity and unpredictability of stresses such as drought, salinity, heat and cold extremes, and irregular rainfall. Additionally, soil contamination along with rising pest and disease incidence further compromises crop performance, resulting in considerable losses in yield and quality.

Environmental stresses interfere with fundamental physiological and biochemical processes, including photosynthesis, nutrient absorption, membrane integrity, and enzyme activity, thereby limiting plant growth and productivity. Although traditional strategies such as genetic improvement, chemical crop protection, and refined agronomic practices have helped mitigate stress effects to some extent, their effectiveness is often constrained by high costs, environmental concerns, and slow outcomes. In this context, nanotechnology has emerged as a promising and efficient approach for enhancing stress tolerance in horticultural crops. By operating at the cellular and molecular scale, nano-based interventions offer new opportunities to strengthen plant defense mechanisms and improve resilience under changing environmental conditions.

Nature of Environmental Stress in Horticultural Crops
Environmental stress is defined as any external factor that negatively affects plant growth, development, and productivity. Abiotic stresses are among the most damaging constraints in horticulture. Drought stress limits water availability, reduces cell turgidity, restricts stomatal conductance, and suppresses photosynthesis. Salinity stress imposes both osmotic stress and ionic toxicity, particularly due to excessive sodium and chloride accumulation in plant tissues. Temperature extremes cause protein denaturation, membrane destabilization, and metabolic imbalance. Heavy metal stress arises from the accumulation of toxic elements such as cadmium, lead, and arsenic, which interfere with enzymatic reactions and induce oxidative stress.

Biotic stresses caused by insects, fungi, bacteria, viruses, and nematodes further compound the problem. These organisms damage plant tissues, reduce photosynthetic area, and divert energy from growth to defense. Under combined or prolonged stress conditions, the inherent defense mechanisms of plants are often insufficient, highlighting the need for innovative technological interventions.

Unique Features of Nanotechnology in Agriculture
Nanotechnology involves the manipulation of materials at the nanoscale, typically ranging from 1 to 100 nanometers. At this scale, materials exhibit unique physicochemical properties such as increased surface area, enhanced reactivity,

improved solubility, and controlled release behaviour. These properties distinguish nanoparticles from their bulk counterparts and make them highly suitable for agricultural applications.

In horticulture, nanoparticles may be composed of metals, metal oxides, carbon-based materials, or natural polymers. Their small size allows them to penetrate plant tissues more efficiently and interact directly with cellular components. Nanotechnology enables the development of nano fertilizers, nano pesticides, nano elicitors, and stress-alleviating agents that are precise, efficient, and environmentally friendly.

Uptake, Transport, and Localization of Nanoparticles in Plants

Nanoparticles can be introduced into plants through seed treatment, soil application, or foliar spray. Root uptake occurs through the epidermis and cortex, followed by transport through the xylem to aerial parts. Foliar-applied nanoparticles may enter through stomata, trichomes, or cuticular pores. Once inside the plant, nanoparticles move via apo plastic or symplastic pathways and may localize in specific tissues or organelles.

The uptake and movement of nanoparticles depend on several factors, including particle size, surface charge, concentration, coating material, plant species, and developmental stage. When properly engineered and applied at appropriate doses, nanoparticles can exert beneficial effects without causing toxicity.

Nanotechnology in Alleviating Abiotic Stress

Nanoparticles enhance abiotic stress tolerance through multiple interconnected mechanisms. One of the primary effects is improved nutrient acquisition and utilization. Nanofertilizers ensure a steady and targeted supply of essential nutrients, enabling plants to maintain metabolic activity under stress conditions.

Nanoparticles also play a critical role in strengthening the antioxidant defense system. Abiotic stresses induce excessive production of reactive oxygen species, which damage cellular structures. Nanoparticles stimulate antioxidant enzymes such as superoxide dismutase, catalase, ascorbate peroxidase, and glutathione reductase, thereby reducing oxidative damage.

Under drought stress, nanoparticles such as silicon, zinc oxide, and titanium dioxide improve relative water content, chlorophyll retention, stomatal regulation, and photosynthetic efficiency. Selenium nanoparticles reduce lipid peroxidation and enhance osmolyte accumulation. In saline environments, nanoparticles help regulate ion homeostasis by limiting sodium uptake and enhancing potassium retention. For temperature stress, nanoparticles stabilize membranes, enhance heat shock protein expression, and improve metabolic resilience.

Managing Heavy Metal Stress Through Nanotechnology

Heavy metal contamination is an increasing concern in horticultural production systems, particularly in peri-urban and industrial regions. Nanotechnology offers novel solutions by reducing metal mobility and bioavailability in soils. Nanoparticles such as iron oxide, silica, and hydroxyapatite can immobilize toxic metals through adsorption and complexation.

In plants, nanoparticles activate antioxidant and detoxification pathways, reducing oxidative stress caused by metal toxicity. This dual action not only protects plant growth and yield but also limits the accumulation of harmful metals in edible plant parts, thereby improving food safety and consumer health.

Nanotechnology for Biotic Stress Management

Nanoparticles also contribute significantly to the management of pests and diseases in horticultural crops. Certain metallic nanoparticles exhibit direct antimicrobial activity by disrupting pathogen cell membranes, inhibiting enzyme function, and interfering with genetic material. Silver, copper, and sulfur nanoparticles are particularly effective against fungal and bacterial pathogens.

Polymeric nanoparticles such as chitosan-based formulations act as carriers for pesticides and bioactive compounds, enabling controlled release and reducing chemical usage. In addition, nanoparticles function as elicitors that stimulate plant immune responses, enhancing the production of defense-related enzymes, phenolic compounds, and phytohormones. As a result, plants become more resistant to pathogen invasion with reduced environmental impact.

Nanotechnology and Sustainable Horticultural Production

Sustainability is a central objective of modern horticulture, and nanotechnology supports this goal by improving resource-use efficiency and reducing environmental pollution. Nanoparticles minimize nutrient losses through leaching and volatilization, lower pesticide residues, and decrease production costs. Nano-enabled sensors further enhance precision agriculture by enabling real-time monitoring of plant health and stress signals.

By integrating nanotechnology with conventional agronomic practices, horticultural systems can become more resilient to climate variability while maintaining productivity and ecological balance.

Challenges, Risks, and Future Perspectives

Despite its immense potential, the application of nanotechnology in horticulture requires careful consideration. Excessive or inappropriate use of nanoparticles may result in phytotoxicity or unintended ecological effects. Long-term studies on nanoparticle behaviour in soil–plant–microbe systems and food chains are essential. Clear regulatory guidelines, interdisciplinary research, and farmer awareness programs will play a crucial role in ensuring safe and responsible adoption.

Conclusion

Nanotechnology represents a powerful and forward-looking approach to managing environmental stresses in horticultural crops. By enhancing nutrient efficiency, strengthening antioxidant defenses, regulating stress-responsive pathways, and improving resistance to pests and diseases, nanoparticles enable plants to withstand challenging growing conditions. Although further research is needed to optimize safety and field-scale application, nanotechnology holds great promise for developing climate-resilient, sustainable horticultural systems and safeguarding future food and nutritional security.

References

1. Abdelsalam, I. M., Ghosh, S., AlKafaas, S. S., Bedair, H., Malloum, A., ElKafas, S. S., & Saad-Allah, K. M. (2023). Nanotechnology as a tool for abiotic stress mitigation in horticultural crops. *Biologia*, *78*(1), 163-178.
2. Khalid, M. F., Iqbal Khan, R., Jawaid, M. Z., Shafqat, W., Hussain, S., Ahmed, T., ... & Alina Marc, R. (2022). Nanoparticles: the plant saviour under abiotic stresses. *Nanomaterials*, *12*(21), 3915.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Seeds Under Stress: How Climate Change is Reshaping Grain Quality and Reproductive Success

Article ID: 72759

A. Kingsly Raj[1], A. Ajay Raja[1], P. Agalya[1]
[1]Department of Vegetable Science, Horticultural College and Research Institute, TNAU, Coimbatore, Tamil Nadu, India - 641 003.

Abstract
Climate change poses a major threat to global agriculture by altering not only crop yields but also the quality of grains and seeds. Rising temperatures, elevated atmospheric carbon dioxide (CO_2), irregular rainfall and increased ultraviolet (UV) radiation collectively disrupt grain development, seed filling, nutrient composition and reproductive processes. These climatic drivers influence key physiological, biochemical and molecular pathways that regulate seed formation, germination and vigour. High-temperature stress accelerates crop development, shortens grain filling duration and impairs starch and protein metabolism, resulting in poor seed set and inferior grain quality. Elevated CO_2 often enhances seed mass through increased carbon assimilation but simultaneously dilutes protein and micronutrient concentrations due to altered carbon–nitrogen balance. Excess rainfall promotes pre-harvest sprouting and reduces seed longevity, while enhanced UV radiation negatively affects photosynthesis, hormonal regulation and seed size. Interactions among climate factors frequently generate complex and crop-specific responses. Understanding these effects is essential for strengthening seed systems, ensuring food and nutritional security and developing climate-resilient crop improvement strategies.

Keywords: Climate change, grain quality, seed development, heat stress, elevated CO_2, seed vigour.

Introduction
Seeds represent the foundation of agricultural production, serving as both the primary reproductive unit of crops and a critical determinant of yield, quality and food security. Grain quality parameters such as size, weight, nutritional composition, processing characteristics and germination capacity are highly sensitive to environmental conditions experienced during seed development. In recent decades, climate change has intensified stresses on agroecosystems, altering temperature regimes, atmospheric composition, precipitation patterns and radiation levels at an unprecedented rate.

Since the onset of industrialization, anthropogenic activities have significantly increased greenhouse gas emissions, resulting in a steady rise in global mean temperature. Projections indicate that temperature extremes will become more frequent and severe, accompanied by elevated CO_2 concentrations, unpredictable rainfall and higher UV radiation exposure. These factors do not operate in isolation; rather, they interact in complex ways to influence plant growth, reproductive success and seed quality. Understanding these interactions is crucial for sustaining crop productivity and ensuring the availability of high-quality seeds under future climates.

This article provides a comprehensive yet accessible overview of how major climate change drivers affect grain development and seed quality, with emphasis on physiological processes, hormonal regulation and biochemical composition across major crops.

Nature of Environmental Stress in Horticultural Crops
Environmental stress is defined as any external factor that negatively affects plant growth, development, and productivity. Abiotic stresses are among the most damaging constraints in horticulture. Drought stress limits water availability, reduces cell turgidity, restricts stomatal conductance, and suppresses photosynthesis. Salinity stress imposes both osmotic stress and ionic toxicity, particularly due to excessive sodium and chloride accumulation in plant tissues. Temperature extremes cause protein denaturation, membrane destabilization, and metabolic imbalance. Heavy metal stress arises from the accumulation of toxic elements such as cadmium, lead, and arsenic, which interfere with enzymatic reactions and induce oxidative stress.

Biotic stresses caused by insects, fungi, bacteria, viruses, and nematodes further compound the problem. These organisms damage plant tissues, reduce photosynthetic area, and divert energy from growth to defense. Under combined or prolonged stress conditions, the inherent defense mechanisms of plants are often insufficient, highlighting the need for innovative technological interventions.

High Temperature Stress and Seed Quality
Effects on Grain Development and Filling: High temperature is one of the most detrimental climatic factors influencing seed development. Exposure to temperatures above the crop-specific optimum during flowering and grain filling

accelerates developmental processes, leading to premature maturity. As a result, the duration of seed filling is shortened, often producing lighter and smaller grains. This reduction in seed weight is closely linked to impaired carbohydrate metabolism, including decreased activity of sucrose synthase and starch-synthesizing enzymes essential for endosperm development.

Heat stress also suppresses photosynthesis and hastens leaf senescence, reducing the supply of assimilates available for translocation to developing grains. Consequently, the balance between source and sink tissues is disturbed, limiting starch accumulation and final grain size.

Impact on Reproductive Processes: The reproductive phase is particularly vulnerable to high temperatures. During spikelet initiation and floral organ development, heat stress can distort floral structures and reduce their number and size. Pollen development is highly sensitive, with elevated temperatures causing abnormalities in pollen proteins, reduced pollen viability and increased spikelet sterility.

Heat stress during meiosis and anther development often leads to premature degeneration of tapetal cells, which are essential for nourishing developing microspores. At anthesis, high temperatures interfere with anther dehiscence, pollen release, stigma receptivity and pollen tube growth. These disruptions severely compromise fertilization, ultimately reducing grain number and yield.

Seed Germination and Vigour: Temperature conditions experienced by the mother plant can have lasting effects on seed performance. Heat stress before physiological maturity predominantly affects seed germination, whereas stress after maturity mainly reduces seed vigour. Elevated temperatures often induce oxidative stress in seeds, leading to excessive production of reactive oxygen species (ROS). While controlled ROS levels are necessary for normal germination, their overaccumulation damages cellular membranes, mitochondria and enzymes, reducing metabolic efficiency and energy availability.

Hormonal imbalance further contributes to reduced germination under heat stress. Increased accumulation of abscisic acid (ABA), coupled with reduced gibberellic acid (GA) levels, reinforces seed dormancy and inhibits germination. This hormonal shift has been well documented in crops such as rice and model plants, highlighting the antagonistic roles of ABA and GA in regulating seed dormancy and germination.

Elevated CO_2 and Seed Quality

Seed Size, Weight and Composition: Rising atmospheric CO_2 concentration enhances photosynthetic carbon assimilation, often increasing the availability of carbohydrates for seed development. In many cases, this leads to heavier seeds, particularly in legumes, where enhanced carbon supply supports greater biological nitrogen fixation. However, the response to elevated CO_2 is highly variable across species and functional groups. Some crops show increased seed mass, others exhibit no change and a few even display reduced seed weight.

A major concern associated with elevated CO_2 is the dilution of seed nutrients. Increased carbohydrate accumulation is frequently accompanied by reduced nitrogen concentration, resulting in higher carbon-to-nitrogen (C/N) ratios. This imbalance often translates into lower protein content and altered amino acid composition, with implications for both nutritional quality and seed germination potential.

Effects on Germination and Vigour: The influence of elevated CO_2 on seed germination is inconsistent. In some crops, germination is reduced due to altered hormonal balance or nutrient composition, whereas in others, germination remains unaffected or even improves. Importantly, laboratory germination tests may not fully reflect field performance, making seed vigour a more reliable indicator under stress conditions. Evidence on the impact of elevated CO_2 on seed vigour remains limited, although extremely high CO_2 levels have been associated with increased abnormal seedlings and reduced seed viability in certain crops.

High Rainfall, Humidity and Seed Quality

Erratic and excessive rainfall during the reproductive and maturation stages poses serious risks to seed quality. One of the most damaging consequences is pre-harvest sprouting (PHS), where physiologically mature grains germinate on the mother plant under humid conditions. PHS has been reported in cereals, legumes and oilseeds, leading to significant losses in yield, seed quality and market value.

Rainfall during the ripening stage also reduces seed longevity and storage potential by increasing moisture content and promoting fungal infection. While moderate rainfall during post-anthesis stages may enhance seed protein content, excessive rainfall often produces the opposite effect, deteriorating both nutritional and processing quality. Seasonal timing of rainfall thus plays a critical role in determining final seed quality outcomes.

Ultraviolet Radiation and Seed Development

The depletion of the stratospheric ozone layer has increased the penetration of UV-B radiation to the earth's surface, exposing crops to additional stress. Enhanced UV radiation disrupts photosynthesis, carbon partitioning and hormonal regulation, ultimately affecting reproductive development and seed quality.

High UV-B levels reduce chlorophyll content, soluble proteins and Rubisco activity, particularly in C_3 plants. At the seed level, UV radiation has been associated with reduced protein content, lower concentrations of free amino acids and impaired cell division in cotyledons. As seed size is determined by both cell number and cell volume, UV-induced reductions in cell proliferation led to smaller seeds.

Although certain yield components, such as seeds per pod, appear to be genetically regulated and less sensitive to UV stress, seed size and overall biomass are negatively affected, underscoring the importance of radiation stress in shaping seed traits.

Interactive Effects of Climate Change Factors

Climate change drivers often act simultaneously, producing interactive effects that differ from individual stress responses. For example, elevated CO_2 may partially offset yield losses caused by moderate heat stress by enhancing carbon assimilation. However, under severe heat stress, the benefits of elevated CO_2 are frequently negated due to shortened grain filling duration and impaired starch synthesis.

Interactions among CO_2, temperature and ozone also influence grain quality traits such as amylose content, protein concentration and mineral composition. Elevated CO_2 generally reduces micronutrient concentrations, including zinc and iron, while ozone stress tends to increase grain nitrogen content. Interestingly, elevated CO_2 can counteract some of the negative effects of ozone on mineral accumulation, highlighting the complexity of multi-stress environments.

Crop-Specific Responses: Wheat, Rice and Oilseeds

In wheat, elevated CO_2 consistently reduces grain protein concentration, particularly gluten-forming fractions, thereby compromising baking quality. Changes in amino acid composition and grain size distribution further influence end-use quality. In rice, heat stress reduces amylose content and affects palatability, while elevated CO_2 alters protein and micronutrient concentrations depending on genotype and nutrient management.

Oilseed crops such as groundnut and soybean exhibit pronounced changes in fatty acid composition under climate stress. Elevated temperatures and CO_2 levels often increase oleic acid while reducing linoleic acid content, with important implications for oil stability and nutritional value. The underground development of groundnut pods adds another layer of complexity, as soil temperature strongly influences seed oil composition.

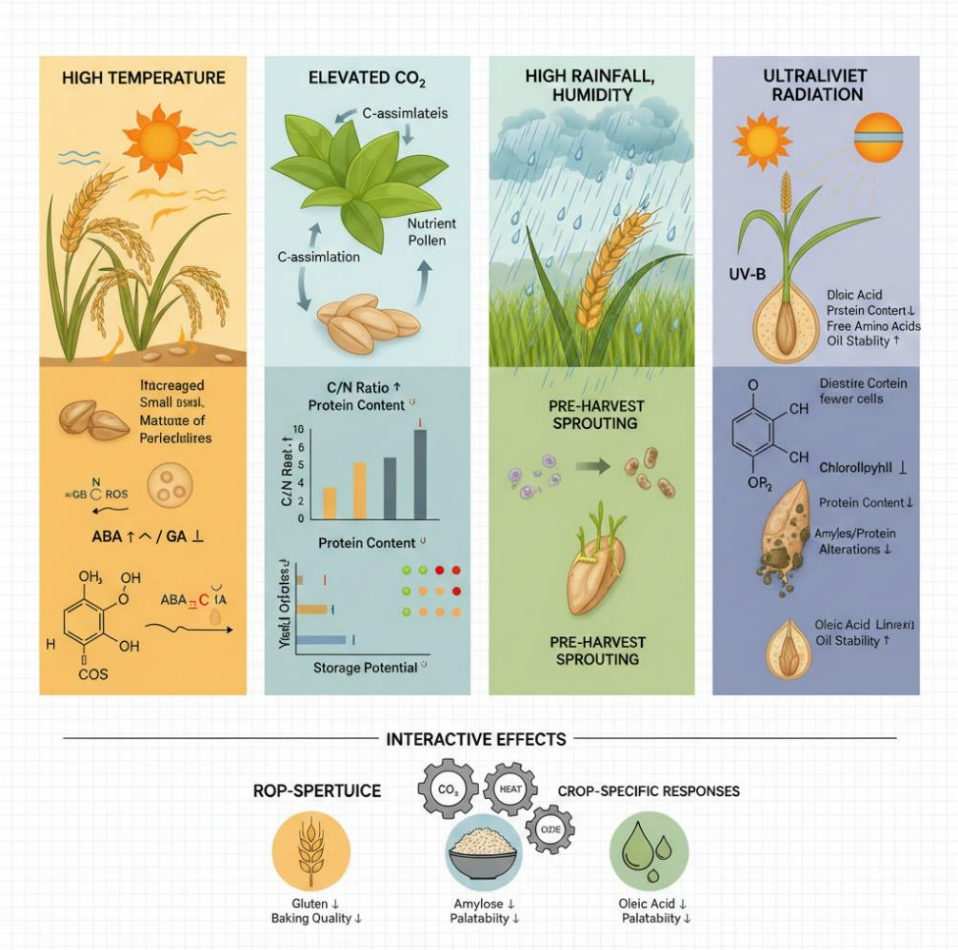


Fig. 1. Diagrammatic Representation of Climate Change Effects on Grain Quality

Conclusion

Climate change is redefining the biological and biochemical pathways that govern grain development and seed quality. High temperature, elevated CO_2, altered rainfall regimes and increased UV radiation individually and collectively influence reproductive success, seed filling, nutrient composition and seed performance. While some climate drivers may enhance certain traits, such as seed weight under elevated CO_2, these gains are often offset by declines in protein content, micronutrient density and seed vigour.

The variability in crop and genotype responses underscores the need for climate-resilient breeding strategies that prioritize not only yield but also seed quality and nutritional value. Integrating physiological, molecular and agronomic approaches will be essential to safeguard seed systems and food security in a rapidly changing climate. Understanding and managing the complex interactions among climate change drivers will be a defining challenge for future crop improvement and sustainable agriculture.

References

1. Ben Mariem, S., Soba, D., Zhou, B., Loladze, I., Morales, F., & Aranjuelo, I. (2021). Climate change, crop yields and grain quality of C3 cereals: A meta-analysis of [CO2], temperature and drought effects. Plants, 10(6), 1052.
2. Maity, A., Paul, D., Lamichaney, A., Sarkar, A., Babbar, N., Mandal, N., ... & Chakrabarty Chakrabarty, S. K. (2023). Climate change impacts on seed production and quality: current knowledge, implications and mitigation strategies. *Seed Science and Technology*, *51*(1), 65-96.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Krishi Vigyan Kendras: Bridging the Gap Between Agricultural Research and Farmers' Fields

Article ID: 72760

Hariraj N[1], Sahla Salam[2]

[1]Ph.D. Scholar, Department of Agricultural Extension and Rural Sociology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India- 641003.

[2]Ph.D. Scholar, Department of Agricultural Extension, College of Agriculture, Gandhi Krishi Vignana Kendra, UAS Bangalore – 560092.

Introduction

Krishi Vigyan Kendras are institutional platforms established by the Indian Council of Agricultural Research (ICAR) with the primary mandate of technology assessment, refinement, and dissemination under local agro-ecological and socio-economic conditions. Since the establishment of the first KVK in 1974, the network has expanded to cover almost all districts of the country, enabling region-specific problem solving and technology validation. This extensive reach allows KVKs to function as localized centres of agricultural innovation and knowledge exchange.

Unlike conventional extension approaches that emphasize one-way information dissemination, KVKs adopt a research-linked and participatory extension model based on the principle of "learning by doing and seeing by believing." Through On-Farm Testing (OFT), KVKs evaluate newly developed technologies in farmers' fields, while Front Line Demonstrations (FLDs) showcase the performance and benefits of proven practices. In addition, KVKs organize capacity-building programmes for farmers, farm women, and rural youth to enhance technical skills and decision-making abilities.

From a research perspective, KVKs play a critical role in generating field-level empirical evidence and facilitating two-way knowledge flow between researchers and farmers. Feedback from KVK activities helps refine technologies, identify adoption constraints, and reorient research priorities. By acting as key intermediaries within the Agricultural Innovation System, KVKs ensure that agricultural research remains relevant, location-specific, and impactful, thereby contributing to sustainable agricultural development and improved farmers' livelihoods.

Origin and Establishment of KVKs in India

The concept of KVK was introduced in 1974 by the Indian Council of Agricultural Research (ICAR). The first KVK was established at Puducherry to test and demonstrate agricultural technologies under real farm conditions. Today, KVKs function in almost every district of India.

Objectives of Krishi Vigyan Kendra

The main objective of KVK is to improve the socio-economic condition of farmers through skill-oriented training, assessment of new technologies, and dissemination of proven practices suited to local agro-ecological conditions.

Evolution of KVKs & Conceptual Foundation

KVKs were established by the Indian Council of Agricultural Research (ICAR) in 1974 with the mandate of district-level technology assessment and refinement. Unlike conventional extension systems, KVKs follow a technology validation–demonstration–capacity building continuum.

Key conceptual pillars include:

1. Location-specific research orientation
2. Participatory technology assessment
3. Learning-by-doing approach
4. Strong feedback loop to research institutions

This makes KVKs unique as research-linked extension systems rather than mere dissemination agencies.

Main Roles of Krishi Vigyan Kendras (KVKs)

1. Technology Assessment
2. Technology Refinement
3. Technology Demonstration
4. Capacity Building of Farmers
5. Skill Development of Rural Youth

6. Empowerment of Farm Women
7. Extension Advisory Services
8. Promotion of Sustainable Agriculture
9. Dissemination of Agricultural Information
10. Linkage Between Research and Farmers
11. Support to Government Schemes
12. Documentation of Success Stories.

Organizational Structure of Krishi Vigyan Kendras

Krishi Vigyan Kendra's function under the administrative control of ICAR through Agricultural Universities, research institutes, NGOs, and State Departments. Each KVK is headed by a Programme Coordinator and supported by Subject Matter Specialists (SMS) in disciplines such as agronomy, horticulture, plant protection, animal science, agricultural extension, and home science. This multidisciplinary structure enables KVKs to address diverse farming system issues at the district level.

Contributions

KVKs play a significant role in promoting climate-resilient and sustainable agricultural development by introducing drought-tolerant crop varieties, climate-smart agronomic practices, water-saving technologies, and integrated farming systems suited to local conditions. At the same time, KVKs actively promote natural and sustainable farming approaches such as natural farming, organic agriculture, integrated nutrient management, and eco-friendly pest management practices by validating low-cost and resource-efficient technologies. In recent years, KVKs have strengthened their outreach through digital and ICT-based extension initiatives, including mobile advisory services, social media platforms, WhatsApp groups, and digital decision-support tools, which ensure timely dissemination of real-time agricultural information. These combined interventions have resulted in improved adoption of scientific practices, increased crop productivity, reduced cost of cultivation, enhanced farm income, and diversified livelihood opportunities through skill-oriented training and enterprise development, thereby contributing significantly to the socio-economic well-being of farming communities.

Challenges Faced by Krishi Vigyan Kendras

Despite their achievements, KVKs face challenges such as limited manpower, resource constraints, increasing farmer expectations, and the need to address emerging issues like climate change and market volatility. Addressing these challenges is essential to strengthen their effectiveness and outreach. i want more content with point wise manner.

Future Directions for Strengthening KVKs

Future efforts to strengthen Krishi Vigyan Kendras should focus on reinforcing research–extension–farmer linkages to ensure faster and more effective technology transfer. Greater emphasis on digital extension and ICT-based advisory services will help expand outreach and deliver timely, location-specific information to farmers. Promoting convergence with line departments, development agencies, and private stakeholders can enhance resource utilization and program effectiveness, while increased farmer participation in technology assessment and refinement will improve relevance and adoption. In addition, continuous capacity building of KVK personnel, along with adequate financial and infrastructural support, is essential to enhance the overall performance and impact of KVKs.

Conclusion

Krishi Vigyan Kendras serve as vital institutional mechanisms for translating agricultural research into field-level action. Through systematic technology assessment, frontline demonstrations, capacity building, and innovation facilitation, KVKs effectively bridge the gap between research institutions and farmers' fields. Strengthening KVKs is therefore crucial for achieving sustainable agricultural development, enhancing climate resilience, and improving the livelihoods and socio-economic well-being of farming communities.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Vegetable Grafting for Enhanced Vegetable Production

Article ID: 72761

Deepak Yadav[1], Dr. Vijay Bahadur[2]
[1]Vegetable Science, Department of Horticulture, SHUATS, Prayagraj (UP).
[2]Professor& Head, Department of Horticulture, SHUATS, Prayagraj (UP).

Introduction and Purpose of Vegetable Grafting

Vegetable grafting is a plant propagation technique that joins a desirable scion (the shoot system) onto a vigorous rootstock (the root system). This practice is analogous to the grafting techniques used for fruit trees.

The primary purpose of vegetable grafting is to create a **"super-plant"**:

1. The **scion** is selected for traits like high-quality fruit, taste, and yield.

2. The **rootstock** is selected for vigor and its ability to protect the plant from adverse conditions.

By combining these two parts, the resulting plant delivers high-quality fruit while being protected from soil diseases, pests, and environmental stress, ultimately leading to higher yields and increased farm profitability. Historically, crops like tomatoes have been grafted, and the practice has expanded to include peppers, eggplant, and melons.

Historical Background of Vegetable Grafting

Ancient and Early Commercial Use:

Ancient Origins: The earliest known records of grafting date back to **China around 500 BCE**. It was initially used primarily for increasing the size of gourds.
Commercial Development in Asia: Commercial grafting specifically for disease resistance began in the late 1920s in Japan and Korea. This was a targeted solution for managing *Fusarium* wilt in watermelon by grafting it onto gourd rootstock.
Eggplant Grafting: In the 1950s, eggplant (*Solanum melongena*) was grafted onto scarlet eggplant (*Solanum integrifolium Poir.*).

Global Spread and Modern Adoption:

Introduction to North America: Grafting was introduced to North America from Europe in the late 20th century.
Current Adoption: The process is now common in Asia, parts of Europe, and the Middle East. It is described as "an old technology with new techniques". It is attracting growing interest from both greenhouse growers and organic producers.

Initial Work in India:

The initial, systematic work on vegetable grafting in India was started by Dr. R. M. Bhatt and his team at the Indian Institute of Horticultural Research (IIHR) in Bengaluru.
Their main focus was on identifying suitable rootstocks to address significant challenges in Indian agriculture, such as waterlogged soil conditions and soil-borne diseases.

Benefits of Growing Grafted Vegetables

Grafting imparts numerous advantages by utilizing the robust traits of the rootstock:

Category	Specific Benefit	Detail/Mechanism
Stress Tolerance	Resistance to **Biotic Stress**	Tolerance to diseases and pests. In organic cultivation, this eliminates the use of chemicals for disease control.
Environmental Tolerance	Tolerance to **Abiotic Stress**	Includes resilience to low temperature, salinity, drought, and flooding.

Category	Specific Benefit	Detail/Mechanism
Growth & Efficiency	Enhanced **Nutrient and Water Uptake**	Driven by a stronger, more vigorous root system.
	Improved **Plant Growth**	Overall more robust plant development.
	Reduced Needs	Requires less water and fertilizer.
Productivity	**Yield Increase**	Higher productivity through enhanced water and nutrient uptake, and manipulation of the harvest period.
Fruit Quality	Rootstock effect on Fruit Quality	Can affect characteristics like flavor, pH, sugar, color, and texture. Can increase ascorbic acid and lycopene content in tomatoes.

Specific Stress Tolerance Mechanisms

Low Temperature Tolerance:

Cold Hardiness: Grafted plants are often more cold hardy. For example, the roots of figleaf gourd can function at 8^0C, whereas cucumber roots require temperatures above 10^0C.

Physiological Changes: Grafted plants exhibit higher content of **Linolenic acid**, which aids survival under low temperatures. They also have higher concentrations of **proline, vitamin-C, and water-soluble sugars** compared to ungrafted seedlings.

Practical Use: Grafting is useful to initiate flowering and fruit set at low temperatures and may save energy in poly houses in cooler parts of the world.

High Temperature Tolerance (Thermal Stress)

a. The use of grafted tomatoes may provide a certain degree of resistance against thermal stress.
b. Grafting tomato onto **eggplant rootstocks** has appeared promising at higher temperatures.
c. Eggplants grafted onto a heat-tolerant eggplant rootstock showed prolonged growth stages and up to a **10% yield increase**.
d. Chilli grafted on **sweet pepper rootstocks** has yielded the highest results under high-temperature conditions.

High Salt Tolerance (Salinity): Grafting has been effectively used to enhance vegetable tolerance to salinity and provide high yield, offering an alternative way to improve salt tolerance.

Flood Tolerance:

a. Inter-generic grafting can impart flood tolerance in cucurbits.
b. A specific example is the improved flooding tolerance of bitter gourd (*Momordia charanthia*) when grafted onto **sponge gourd** (*Luffa cylindria* Roem).

Disadvantages of Grafting

Despite the numerous benefits, grafting presents certain drawbacks:

High Cost: Grafting can be expensive due to:

a. Labor (if manually performed).
b. The cost for a **robot** (if performed automatically).
c. The **rootstock** itself is not cheap.

Grafting Incompatibility: There is always a risk of incompatibility between the scion and rootstock.

Fruit Quality: Fruit quality could be negatively affected, depending on the combination of rootstock/scion varieties chosen.

Major Grafting Methods and Applications

The following table summarizes common methods and their characteristics:

Grafting Method (Y)	Description & Characteristics	Primary Use/Suitability
Cleft Grafting (Y=3)	Simple and easy method.	Suitable for rootstocks with **wide hypocotyls**. Can be practiced in all vegetables.
Tongue Approach Grafting (Y=2)	Widely used by farmers and small nurseries. High seedling survival rate, even for beginners. Requires more space and is not suitable for hollow hypocotyls.	Popular for cucumber grafting (e.g., F_1 *Cucurbits maxima* x *Cucurbits moschata*).
Hole Insertion Method (Y=1)	Scion is inserted into a hole created in the rootstock. One person can produce 1,500 or more grafts/day. Requires high humidity (95%) for success.	Most popular in **cucurbits**. Preferred when both scion and rootstock have **hollow hypocotyls**.
Tube Grafting (Y=4)	Similar to slant grafting, but an **elastic tube** is used instead of clips to hold the union.	More popular in **Tomato** and **Brinjal**.

Rootstock-Scion Combinations and Purposes (X)

Vegetable (Scion)	Popular Rootstock Species	Grafting Method (Y)	Purpose (X)
Watermelon	Guard (*Lagernaria siceraria*), Wax guard, Pumpkin (*Cucurbita moschata*), Squash, Sicyos angulatus	1, 2, 3	Tolerance to fungal wilt (X=1), growth promotion (X=2), low temperature tolerance (X=3).
Vegetable (Scion)	Popular Rootstock Species	Grafting Method (Y)	Purpose (X)
Cucumber	Fig leaf guard (*Cucurbita ficifolia*), F1 hybrid (*C. maxima x C. moschata*), Sicyos	2	X=1, 2, 3, 4, 5. Resistant to nematode (X=5). Extension of

	angulatus		growth period (X=4).
Tomato	*Lycopersicon pimpinellifolium, L. hirsutum, L. esculentum*	3, 4	X=5 (Resistant to nematode).
Brinjal (Eggplant)	*Solanum integrifolium, Solanum torvum*	2, 3	Bacterial wilt tolerance (X=6). Reduction of virus infection (X=7).

Automated and Micro Grafting Techniques

Automated Grafting: Automated grafting has been developed to reduce labor costs and increase efficiency:

a. Simple Grafting Machine: Can produce **350-600 grafts/hour** with 2 operators. This is faster than manual techniques, which produce about 1,000 grafts/person/day.

b. Fully Automated Robot: A fully automated grafting robot can perform **750 grafts/hour** with a high success rate of 90-93%.

c. Commercial Examples:

i. AG1000 robot: Fully automated, developed in Japan (1994) for Solanaceous vegetables.

ii. Amakai S.A.: Semi-automated, developed in Spain (2000) for Cucurbits and Solanaceous.

iii. GR-800 & CDR-600: Semi-automated, developed by Helper Robotic Co., Korea (2004) for Cucurbits.

Micro grafting:

a. Definition: micro grafting is the grafting of **meristematic tissues in vitro** (in the laboratory). Shoots of one plant are grafted onto the shoots or roots of another plant to combine characteristics.

b. Origins: First used in 1952 by Morel and Martin.

c. Purpose: Initially used to study the physiological basis of grafting and the chemical basis of cell-to-cell union.

d. Commercial Scale: Started recently to reduce the high cost of production associated with classical methods.

i. High costs are often due to the high price of hybrid vegetable seed. micro grafting requires only a small number of seeds for the rootstock and scion.

ii. Several thousand transplants can be produced from 2-3 week seedlings within a short period.

e. Success Rate: The success rate of micro grafting for tomatoes is relatively high (80-90%).

Case Studies and Applications

Applications in India:

a. Tomato/ Chilli on Brinjal : Dr. Shreeram Palav of Jalna Maharashtra (KKV Dapoli) successfully grafted chilli and tomato onto brinjal plants.

b. Grafting for Disease Resistance: Grafting has been used to impart disease resistance in brinjal by using the **devil plant** as a rootstock.

c. Pomato (Tomato and potato): Farmer Manohar Lal (Ranchi) has cultivated a unique plant that bears both tomato and potato.

d. Brimato: Brimato is a single plant that produces both brinjal (eggplant) and tomato by using a dual grafting technique on a brinjal rootstock. This innovation, developed by scientists at the Indian Council of Agricultural Research (ICAR) Indian Institute of Vegetable Research (IIVR) in Varanasi, is designed to save space and resources, making it ideal for urban and peri-urban farming where land is limited.

e. Stress Mitigation: Narayan Chawda (MAHASAMUND) successfully identified various rootstock-scion combinations in cucurbit and solanaceous vegetables to mitigate the adverse effects of stressful conditions.

Cucurbit Grafting and Production:

a. *Momordica cochinchinensis* is a dioecious plant (having separate male and female plants). To increase its production, the **female plants are grafted onto the male plants**.

b. A high **98% graft success** has been observed for cucurbit grafting at the NBPGR regional station, Thrissur, Kerala.

c. Specific information about the date of the earliest cucurbit grafting and the exact percentage of profits is not available, but it is known from the **National Institutes of Health (NIH):** "The first published scientific paper showing that grafting watermelon onto pumpkin improved disease resistance and increased fruit yield was published in 1927".

d. Scion: Watermelon (*Citrullus lanatus*).

e. Rootstock: Pumpkin (*Cucurbita moschata Duch*).

f. Benefits: Grafting has become an important technique that increases fruit yield.

Tomato and Solanaceous Vegetables:

a. Tomato grafting started around 1960-1970.

b. It is crucial in Southeast Asian countries where tomato production is severely constrained during the hot-wet season by biotic and abiotic factors, including **flooding, high temperature, and soil-borne diseases** like bacterial wilt and nematodes.

c. The first grafting of tomatoes and other **Solanaceae** vegetables involved grafting a scion of salti (*Solanum lycopersicum*) onto the rootstock of another Solanaceae plant, such ascactus *(Solanum melongena*) or wild

tomato (*Solanum lycopersicum var. cerasiforme*). The profit percentage of grafting in India is difficult to estimate, as it depends on many factors, such as the variety, production method, and market demand. Variety: Commercial hybrid varieties, such as 'Better Boy' and 'Big Boy', can yield higher profits.

d. The first Solanaceae vegetable (tomato) grafting in India was performed in 1988 by Dr. S.P. Mathur and Dr. D.K. Majumdar of the Indian Agricultural Research Institute (IARI), New Delhi, using eggplant (Solanum lycopersicum) as the rootstock for tomato Solanum melongena). This experiment resulted in a yield increase of 20-25% and the technique proved to be a significant development for Indian agriculture.

The "Pomato"

a. The Pomato plant is a result of grafting a **Tomato** scion onto a **Potato** rootstock.

b. This innovation allows for the harvest of tomatoes (the fruit) on the top of the plant and potatoes (the tuber/root) under the soil.

c. To produce pomato, tomatoes (*Solanum lycopersicum*) are typically used as the scion and potatoes (*Solanum tuberosum*) as the rootstock. This grafting technique was commercialized by Thompson & Morgan in September 2013 in the United Kingdom **under the TomTato** brand. However, this grafting technique requires further study regarding its large-scale commercialization and profitability, as it began primarily as an experimental and aesthetic interest. When commercially launched in **September 2013.**

Yield and Yield Attributes of Watermelon as Influenced by Grafting with Bottle Gourd

Treatment	No. of fruits plant-1	Individual fruit wt. (kg)	Fruit length (cm)	Total fruit yield (t/ha)
Grafted	3.5	4.11	32.4	42.01
Non-grafted	2.8	3.80	29.3	28.25
T-test	NS	NS	NS	**

Rootstocks Suggested for Improving Biotic Stress Resistance in Tomato

Disease	Rootstock	Reference
Fusarium wilt	Maxifort (no symptom)	Rivard, Louws 2008a
	Robust (intermediate)	Rivard, Louws 2008a
Bacterial wilt	CRA 66, Hawaii 7996	Rivard, Louws 2008a
	RST 105 (100% control)	Rivard, Louws 2008b
	Dai Honmei (intermediate)	Rivard, Louws 2008b
Southern blight	Bigpower, Maxifort, Beaufort	Rivard et al. 2010

Growth and Flowering Behavior of Watermelon as Influenced by Grafting with Bottle Gourd

Treatment	Length of main stem (m)	No. of lateral stems	No. of male flowers	No. of female flowers	Sex ratio	Days to 1st male flower	Days to 1st female flower	Survival %
Grafted	2.89	15.2	45.2	26.8	1.69	49.8	56.5	100
Non-grafted	1.88	12.8	50.6	21.8	2.32	43.4	49.9	71.05
T-test	*	NS	NS	NS	*	NS	NS	**

Rootstocks Suggested for Improving Yield and Quality of Tomato

Scion	Rootstock	Reference
Cecilia F1	Maxifort, Beaufort	Mohammed et al. 2009
Jermy	Maxifort, Vigomax	Miskovic et al. 2009
Boludo	Radja	Flores et al. 2010
Rita	Beaufort	Romano, Paratore 2001

Rootstocks Suggested for Improving Yield and Quality of Cucurbits

Crop	Scion	Rootstock	Reference
Muskmelon	Ofir	Adir	Cohen et al. 2007
Cucumber	cucumber	Pumpkin	Davis et al. 2008
Watermelon	Watermelon	Bottlegourd	Yetisir et al. 2006

Rootstocks Suggested for Improving Abiotic Stress Resistance in Cucurbits

Abiotic Stress	Crop	Rootstock	Reference
Low temperature	Cucurbits	Shin-tosa	Okimura et al. 1986

Drought	Watermelon	Waxgourd	Sakata et al. 2007
Drought	Bittergourd	Spongegourd	Liao and Lin, 1996

Rootstocks Suggested for Improving Biotic Stress Resistance in Cucurbits

Crop	Disease	Rootstock	Reference
Cucumber	Stem & Root rot	Peto42.91, TS 1358, TZ 148	Pavlou et al. 2002
	Fusarium wilt	Brava (Interspecific hybrid)	Edelstein et al. 1999
Muskmelon	Fusarium wilt	Muskmelon, cucurbit sps.	Cohen et al. 2007
		Squash interspecific hybrids	Crino et al. 2007
	Nematode	Cucumis & Cucurbit asps.	Siguenza et al. 2005
	Gummy Stem blight	Squash interspecific hybrids	Crino et al. 2007

Countries Position of Vegetable Grafting in the World

Country	Watermelon	Cucumber	Melon	Tomato	Brinjal	Pepper
Israel	70%	72%	30%	15%	5%	-
Japan	93%	95%	95%	48%	5%	-
Korea	98%	-	72%	30%	65%	5%
Greece	100%	5-10%	40-50%	15%	2%	25%
Spain	98%	-	3%	2-3%	-	-
Morocco	-	-	-	4500 ha	-	-
Cyprus	80%	-	-	75%	-	-
Italy	30%	-	-	170 ha	-	-
France	-	3%	-	5-6 dmillion	-	-
Netherlands	-	5%	-	1200 ha	-	-
Turkey	-	-	3%	2800 ha	-	50%
Spain	-	-	-	25%	-	-
France	-	-	-	-	-	5%
Netherlands	-	-	-	-	50%	-
Turkey	30%	-	-	-	25%	10%

Conclusion

Grafting represents a powerful and versatile tool for sustainable agriculture.

1. It serves as a **site-specific management tool** for soil-borne diseases.
2. It integrates seamlessly into **organic and integrated crop production systems**.
3. By reducing the need for soil disinfectants, it contributes to lower **environmental pollution**.
4. Grafting is a **rapid alternative tool** to the relatively slow breeding methodology aimed at increasing biotic and abiotic stress tolerance of fruit vegetables.
6. It holds significant potential for promoting cultivation in non-traditional and fragile agro-ecosystems.

References

1. Chandanshive A., Sonavane P., Gaikwad S., Kumar V. 2023. Response of tomato (*Solanum lycopersicum*) grafted on wild brinjal (*Solanum torvum*) rootstock for growth and yield. *Indian J. Agric. Sci.* 93, 881–887. doi: 10.56093/ijas.v93i8.138103.
2. Bahadur, A., Rai, N., Kumar, R., Tiwari, S. K., Singh, A., Rai, A., Singh, U., Patel, P., Tiwari, V., Rai, A., Singh, M., Singh, Dr. B. 2015. Grafting tomato on eggplant as a potential tool to improve waterlogging tolerance in hybrid tomato. 10.13140/RG.2.1.1298.2645.
3. Kumar R., Thakur N., Dogra B. S., Kaur J., Aakriti 2023. Vegetable Grafting: A novel approach for tolerance against environmental stresses. *Pharma Innovation* J. 12, 2501-2507.
4. Mahbou S., Ntsomboh-N. G., Aminatou M., Lessa F., Onana G., Youmbi E. 2022. Effect of grafting on growth and shelf life of tomatoes (*Solanum lycopersicum* L.) grafted on two local solanum species. Adv. Bioscience Biotechnol. 13, 401–418. doi: 10.4236/abb.2022.139026.
5. Musa I., Rafii M. Y., Ahmad K., Ramlee S. I., Hatta M. A., Oladosu Y. 2020. Effects of grafting on morphophysiological and yield characteristic of eggplant (*Solanum melongena* L.) grafted onto wild relative rootstocks. Plants 9 (11), 1583.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

The Importance of Colored Fruits in Human Health

Article ID: 72762

Jushma Meikam[1], Meinam Chanchan[2], Shailendra Kumar[3]
[1&2]Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal, Manipur
[3]Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh.

Introduction

Fruits are fundamental components of a balanced diet, providing essential nutrients that contribute to overall health and well-being. They are rich sources of vitamins, minerals, fiber, and phytochemicals, which play critical roles in the prevention of chronic diseases (Boeing *et al.*, 2012). Among these, colored fruits stand out due to their diverse array of phytochemicals, which are bioactive compounds that offer numerous health benefits (Dreher and Davenport, 2013). Each color group represents different types of phytochemicals and nutrients that can positively impact human health, making it crucial to incorporate a wide variety of these foods into our daily diets.

The vibrant colors of fruits are indicative of their unique nutrient profiles. For instance, red fruits such as tomatoes and strawberries are rich in lycopene and anthocyanins, which have been associated with reduced risk of certain cancers and cardiovascular diseases (Kucuk *et al.*, 2002). Purple and blue fruits like blueberries and eggplants contain anthocyanins that may enhance cognitive function and reduce inflammation.

Red Fruits

1. Cherries: Cherries are rich in anthocyanins, which may help reduce inflammation and lower the risk of chronic diseases (Basu *et al.*, 2010). They also promote better sleep due to their melatonin content.



2. Red Grapes: Red grapes contain resveratrol, an antioxidant that supports heart health by improving endothelial function (Timmers *et al.*, 2011). They may also have anti-cancer properties.



3. Pomegranate: Pomegranates are rich in polyphenols, which have anti-inflammatory effects and may reduce the risk of heart disease (Aviram *et al.*, 2000). They also support cognitive function.



4. Cranberries: Cranberries are known for their role in urinary tract health due to their ability to prevent bacterial adhesion. They are also high in antioxidants.



5. Red Apples: It contain quercetin, an antioxidant that may lower blood pressure and improve heart health (Boyer and Liu, 2004). Their fiber content aids digestion.



6. Strawberry: Strawberries are not only delicious but also packed with nutrients. They are an excellent source of vitamin C, manganese, and antioxidants, which support immune health and protect against oxidative stress (Basu *et al.*, 2010). Studies have indicated that regular consumption of strawberries can improve cardiovascular health by reducing LDL cholesterol levels and improving endothelial function (Hadi *et al.*, 2019). Their high fiber content also aids in digestion and helps regulate blood sugar levels.



7. Raspberries: These are packed with dietary fiber and antioxidants, which can help lower cholesterol levels and support heart health (Basu *et al.*, 2010). They also have anti-inflammatory properties beneficial for overall health.



Orange and Yellow Fruits

1. Sweet Orange: These are well-known for their high vitamin C content, which plays a vital role in collagen synthesis and immune function (Carr and Maggini, 2017). Additionally, oranges contain flavonoids that have anti-inflammatory and antioxidant properties. Regular consumption of oranges has been associated with a reduced risk of kidney stones and improved heart health due to their ability to lower cholesterol levels (Barghouthy and Somani, 2021).



2. Apricot: Apricots are high in vitamins A and C, supporting skin health and immune function (Dreher and Davenport, 2013). Their antioxidants may help protect against oxidative stress.



3. Mango: Mangoes provide vitamins A and C, which are important for immune function and skin health. They also contain enzymes that aid digestion.



4. Papaya: Papayas are rich in papain, an enzyme that aids digestion. They also provide vitamin C and antioxidants that support overall health. Papayas are rich source of vitamin A which can improve eye health and proper vision.



5. Persimmon: Persimmons are rich in dietary fiber and antioxidants, which may help reduce the risk of heart disease. They also support digestive health.



6. Nectarine: Nectarines provide vitamins A and C, which support immune function and skin health (Dreher and Davenport, 2013). Their fiber content aids digestion.



7. Tangerine: Tangerines are a good source of vitamin C and folate, supporting immune function and cell division (Carr and Maggini, 2017). Their antioxidants may reduce inflammation.



8. Banana: Bananas are rich in potassium, which is essential for heart health and muscle function (U.S. Department of Agriculture, 2020). Their fiber content aids digestion.



9. Pineapple: Pineapples contain bromelain, an enzyme that aids digestion and may reduce inflammation. They are also high in vitamin C.



10. Lemon: Lemons are high in vitamin C and flavonoids that support immune function and have anti-inflammatory properties (Carr and Maggini, 2017). They also aid digestion.



11. Golden Kiwi: Golden kiwis are rich in vitamin C and dietary fiber, promoting immune health and aiding digestion (Boyer and Liu, 2004).



12. Star fruit: It is low in calories but high in vitamin C and antioxidants that support overall health (U.S. Department of Agriculture, 2020).



13. Yellow Apple: Yellow apples provide dietary fiber and antioxidants that may support heart health (Boyer and Liu, 2004).



Green Fruits

1. Avocado: Avocados are unique among fruits due to their high content of healthy monounsaturated fats. These fats are beneficial for heart health as they can help lower bad cholesterol levels. Avocados are also rich in fiber, potassium, and vitamins E and K, contributing to overall health. Studies have shown that avocado consumption is associated with improved nutrient absorption and better weight management (Fulgoni *et al.*, 2013).



2. Green Apple: Green apples contain quercetin and dietary fiber that may lower blood pressure and improve heart health (Boyer and Liu, 2004).



3. Lime: Limes are high in vitamin C and antioxidants that support immune function and overall health (Carr and Maggini, 2017).



4. Guava: Guava is a tropical fruit celebrated not only for its delicious taste but also for its impressive nutritional profile and health benefits. One of the standout features of guava is its high vitamin C content, which plays a vital role in immune function. According to Carr and Maggini (2017), vitamin C is essential for the growth and repair of tissues, as well as for the proper functioning of the immune system. Regular consumption of guava can help enhance the body's defense against infections and may reduce the duration and severity of colds.



Blue and Purple Fruits

1. Blueberry: Blueberries are often hailed as a superfood due to their high levels of antioxidants, particularly anthocyanins. Research has indicated that regular consumption of blueberries may enhance cognitive function and delay brain aging (Krikorian *et al.*, 2010). Additionally, blueberries have been shown to improve cardiovascular health by reducing blood pressure and cholesterol levels (Basu *et al.*, 2010).



2. Purple Grapes: These are not only delicious but also packed with resveratrol, a compound known for its anti-inflammatory properties. Research has suggested that resveratrol may help protect against cardiovascular diseases by improving endothelial function (Timmers *et al.*, 2011). Additionally, purple grapes contain antioxidants that may reduce the risk of certain cancers and support overall health.



Conclusion

Incorporating a variety of colored fruits into our diets is essential for maintaining optimal health. Each color group offers unique nutrients and health benefits that contribute to overall well-being. By understanding the importance of these colorful foods, individuals can make informed dietary choices that promote long-term health. Emphasizing a diverse intake of fruits can lead to improved nutrition, reduced risk of chronic diseases and enhanced quality of life.

References

1. Aviram M., Dornfeld L., Rosenblat M., Volkova N., Kaplan M., Coleman R., Hayek T., Presser D. and Fuhrman, B. (2000). Pomegranate juice consumption reduces oxidative stress, atherogenic modifications to LDL, and platelet aggregation: Studies in humans and in atherosclerotic apolipoprotein E-deficient mice. American Journal of Clinical Nutrition, **71**(5): 1062-1076.
2. Barghouthy Y. and Somani B.K. (2021). Role of Citrus Fruit Juices in Prevention of Kidney Stone Disease (KSD): A Narrative Review. Nutrients. **13**(11): 4117.
3. Basu A., Rhone M. and Lyons, T.J. (2010). Berries: Emerging impact on cardiovascular health. Nutrition Reviews, **68**(3): 168–177.
4. Boeing H., Bechthold A., Bub A., Ellinger S., Haller D., Kroke A., Leschik-Bonnet W., Muller M.J., Oberriter H., Schulze M., Stehle P. and Watzl B. (2012). Critical Review: Vegetables and Fruit in the Prevention of Chronic Diseases. European Journal of Nutrition, 51: 637-663.
5. Boyer J. and Liu R.H. (2004). Apple phytochemicals and their health benefits. Nutritional Reviews, **62**(7): 403-415.
6. Carr A.C. and Maggini, S. (2017). Vitamin C and Immune Function. Nutrients, 9: 1211.
7. Dreher M.L. and Davenport A.J. (2013). Hass avocado composition: Nutritional benefits for the consumer. California Avocado Commission.
8. Fulgoni V.L., Keast D.R. and Dreher M.L. (2013). Avocado consumption is associated with better nutrient intake and diet quality in US adults: Results from the National Health and Nutrition Examination Survey (NHANES) 2001–2008. Nutrition Journal, **12**(1): 1-10.
9. Hadi A., Askarpour M., Miraghajani M., Symonds M.E., Sheikhi A. and Ghaedi E. (2019). Effects of strawberry supplementation on cardiovascular risk factors: a comprehensive systematic review and meta-analysis of randomized controlled trials. Food Function, 1**0**(11): 6987-6998.
10. Krikorian R., Shidler A.M. and Nash L.M. (2010). Blueberry supplementation improves memory in older adults. Nutritional Neuroscience, **13**(3): 103-110.
11. Kucuk O., Sarkar F.H., Djuric Z., Sakr W., Pollak M.N., Khachik F., Banerjee M., Bertram J.S. and Wood D.P.J. (2002). Effects of lycopene supplementation in patients with localized prostate cancer. Experiment of Biological Mededicine (Maywood), **227**(10): 881-885.
12. Timmers, S., Groot J.E. and Meer J.W. (2011). Caloric restriction alters the metabolic response to resveratrol supplementation in humans: A randomized controlled trial. Diabetes, **60**(11): 2905-2912.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Nutraceutical Benefits of Citrus: The Science behind Citrus Superfood

Article ID: 72763

Banio Haobam[1], Meinam Chanchan[2], Shailendra Kumar[3]
[1&2]Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal, Manipur
[3]Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh.

Introduction

Citrus fruits, belonging to the family Rutaceae, are among the most widely cultivated and consumed fruits in the world. They include oranges (*Citrus sinensis*), lemons (*Cirtus limon*), limes (*Citrus aurantifolia*), grapefruits (*Citrus x paradisi*), mandarins (*Citrus reticulata*) and pomelo (*Cirtus maxima*), each of which contributes uniquely to human nutrition and overall well-being. While they are primarily valued for their refreshing taste and culinary versatility, their importance extends far beyond flavour. Citrus fruits are increasingly recognized for their nutraceutical potential, offering a wide array of bioactive compounds that help prevent, manage and even treat various chronic health conditions. These compounds, including vitamins, minerals, flavonoids, carotenoids and essential oils, provide multiple health-promoting effects. This article presents an elaborated discussion of the nutraceutical benefits of citrus, highlighting their nutritional richness, phytochemical composition and health-related impacts based on scientific evidence.



Pomel



Lemon



Sweet orange



Lime



Mandari



Grapefruit

Nutritional Composition of Citrus Fruits

Citrus fruits are nutritionally dense and simultaneously low in calories, fat, and sodium, making them ideal components of healthy diets. Their most notable nutrient is vitamin C, a water-soluble vitamin that plays a key role in collagen synthesis, wound healing, iron absorption, and immune defense. Regular consumption of citrus can easily provide the daily requirement of vitamin C, with just 100 grams of orange or lemon supplying more than half of the recommended daily intake (Dietary references intake, 2006). Alongside vitamin C, citrus fruits provide a substantial quantity of dietary fibre, particularly soluble pectin, which helps lower cholesterol, stabilizes blood sugar levels, and supports digestive health by nurturing beneficial gut microbiota.

Folate is another critical nutrient found in citrus fruits, playing an important role in DNA synthesis and repair. Adequate folate intake is particularly crucial during pregnancy, as it reduces the risk of neural tube defects in newborns. In addition, citrus fruits contain essential minerals such as potassium, magnesium, and calcium. These minerals regulate electrolyte balance, support muscle contraction, maintain bone density, and contribute to blood pressure regulation. Unlike high-calorie processed foods, citrus fruits are light in calories yet nutritionally rich, providing both satiety and long-term health benefits (Green, 2002).

Bioactive Compounds of Citrus

Beyond their basic nutritional profile, citrus fruits are abundant in bioactive phytochemicals. These compounds are largely responsible for the nutraceutical properties attributed to citrus consumption. They include flavonoids, carotenoids, limonoids, terpenes and essential oils, each playing specific roles in human health (Turner and Burri, 2013).

1. Flavonoids: Flavonoids are polyphenolic compounds that constitute one of the most important groups of bioactives in citrus. They exist in significant concentrations in both peel and pulp of the fruits. The most studied citrus flavonoids include hesperidin, naringin, narirutin, eriocitrin and rutin. A unique subclass of citrus flavonoids, polymethoxylated flavones (PMFs) such as nobiletin and tangeretin, occur in relatively high amounts in mandarins and sweet oranges. Flavonoids act as powerful antioxidants, reducing oxidative stress by neutralizing free radicals. They have anti-inflammatory properties, improve vascular function, and promote brain health. Studies have also linked PMFs to anticancer activity, anti-obesity effects and protective functions against atherosclerosis. The presence of these flavonoids gives citrus fruits a strong therapeutic potential beyond their role as simple dietary components.

2. Carotenoids and Apocarotenoids: Citrus fruits also contain significant amounts of carotenoids, which are naturally occurring pigments responsible for the yellow, orange, and red hues of the fruits. These compounds include ß-carotene, lutein, zeaxanthin, and ß-cryptoxanthin. Carotenoids are well known for their ability to act as precursors of vitamin A, which is essential for vision, immune response, and epithelial health. ß-cryptoxanthin, abundant in mandarins and certain varieties of oranges, has been particularly associated with bone health and reduced risk of specific cancers. In addition to carotenoids, citrus fruits also contain apocarotenoids, which are derived from carotenoid cleavage and contribute to both color and potential health benefits. Together, carotenoids and apocarotenoids provide antioxidant defense, support eye health, and protect against oxidative stress-related degenerative diseases.

3. Limonoids: Limonoids are highly distinctive bioactive compounds found primarily in citrus seeds and peels. Limonin and nomilin are the most notable limonoids studied for their pharmacological activity. These compounds are associated with anticarcinogenic effects, particularly in preventing oral, lung and colon cancers. In addition, limonoids have been shown to lower cholesterol levels and possess antimicrobial properties. Their role in detoxification processes, combined with their antioxidant activities, highlights their relevance as nutraceutical agents.

4. Terpenes and Essential Oils: The essential oils of citrus fruits, particularly extracted from the peel, are rich in terpenes such as D-limonene, γ-terpinene and linalool. D-limonene alone can account for 45 to 90 percent of the terpene fraction in citrus oils. These volatile compounds contribute not only to the aroma and flavor of citrus but also to their therapeutic effects. Citrus essential oils have been found to possess antimicrobial, antioxidant, and even anxiolytic properties. They are widely used in the pharmaceutical, food, and cosmetics industries. In alternative medicine, citrus essential oils are increasingly studied for their potential role in reducing stress and enhancing mood, further emphasizing the multifaceted nutraceutical potential of citrus.

Health Benefits of Citrus Nutraceuticals (Riaz *et al.*, 2022)

1. Antioxidant Properties: Citrus fruits provide robust antioxidant protection through their high vitamin C content and complementary flavonoids. These compounds work synergistically to neutralize free radicals and reduce oxidative damage in cells. Antioxidant defense is crucial in lowering the risk of conditions such as cardiovascular disease, diabetes, cancer and neurodegenerative disorders. Regular consumption of citrus, whether as whole fruits or juices, significantly enhances antioxidant status in the body.

2. Cardiovascular Health: Citrus consumption is strongly associated with cardiovascular benefits. Flavonoids such as hesperidin improve endothelial function, leading to better blood flow and reduced arterial stiffness. The potassium content in citrus also aids in lowering blood pressure by balancing sodium levels in the body. Moreover, the soluble fibers reduce cholesterol absorption, contributing to healthier lipid profiles. These combined effects reduce the risk of atherosclerosis, heart attacks and strokes, making citrus a valuable dietary component for heart health.

3. Antidiabetic Effects: Compounds such as naringin and naringenin in citrus fruits play a significant role in improving insulin sensitivity and regulating blood glucose levels. Citrus consumption has been linked to reduced fasting blood sugar and better glycemic control in diabetic individuals. The presence of soluble fibre further supports blood sugar regulation by slowing down glucose absorption. Thus, citrus fruits act as natural dietary interventions for the management of type 2 diabetes (Shen *et al.*, 2012).

4. Anti-Inflammatory and Immunomodulatory Roles: Citrus phyto-chemicalexhibit potent anti-inflammatory properties. They reduce the production of pro-inflammatory cytokines and alleviate systemic inflammation, which is a root cause of many chronic diseases. Vitamin C, in particular, enhances the activity of white blood cells, strengthening immune defense against infections. Regular consumption of citrus fruits has been linked to fewer incidences of common colds, faster recovery from infections and improved resilience against environmental stressors.

5. Anticancer Potential: The role of citrus in cancer prevention is an area of active research. Limonoids and polymethoxylated flavones have demonstrated chemopreventive potential by modulating cell signaling pathways, reducing DNA damage, and promoting apoptosis in malignant cells. Carotenoids such as ß-carotene and ß-cryptoxanthin

also contribute by scavenging free radicals that can initiate tumor growth. These findings highlight the importance of citrus consumption in long-term dietary strategies for cancer prevention (Grosso *et al.*, 2013).

6. Neuroprotective Effects: Citrus bioactives have shown promising effects in protecting brain health. Polymethoxylated flavones, particularly nobiletin, have been found to modulate oxidative stress and reduce inflammation in the nervous system. These effects are especially significant in neurodegenerative conditions such as Alzheimer's and Parkinson's diseases. Citrus compounds may improve memory, cognitive function, and overall brain resilience, underscoring their nutraceutical value in neurological health.

7. Gut Health: The dietary fiber content in citrus fruits, primarily in the form of pectin, plays a key role in supporting digestive health. Pectin acts as a prebiotic, stimulating the growth of beneficial gut microbiota, which in turn contributes to improved digestion and immunity. Moreover, fiber-rich diets are associated with a reduced risk of colorectal cancer. By promoting bowel regularity and gut microbial balance, citrus fruits enhance gastrointestinal well-being.

Utilization of Citrus Byproducts

The nutraceutical potential of citrus is not confined to the fruit itself. Byproducts such as peel, pulp, and seeds are valuable sources of bioactive compounds. Citrus peel contains high concentrations of essential oils, flavonoids, and carotenoids. These byproducts are increasingly being utilized in nutraceutical supplements, functional foods, and natural preservatives (Marangoni, 2016). For example, citrus peel extracts are used in dietary formulations for their antioxidant and antimicrobial benefits. Industrial processing of citrus generates large volumes of byproducts, and their efficient utilization ensures sustainable approaches to harnessing citrus bioactives (Casquete *et al.*, 2014).

Conclusion

Citrus fruits stand out not only as dietary staples but also as natural reservoirs of nutraceutical compounds. Their combination of essential nutrients, flavonoids, carotenoids, limonoids and essential oils confers a wide range of health benefits, from antioxidant defense and cardiovascular protection to diabetes management, cancer prevention and neurological health. Furthermore, the sustainable use of citrus byproducts adds to their nutraceutical value, extending their application beyond fresh consumption. Integrating citrus fruits regularly into the diet is therefore not just a matter of taste or tradition but a strategic approach to promoting health and preventing chronic diseases.

References

1. Casquete, R. *et al* (2014). High pressure extraction of phenolic compounds from Citrus peels. High Pressure Research, **34**(4): 447-451.
2. Dietary Reference Intakes (2006). The Essential Guide to Nutrient Requirements; The National Academies Press: Washington, DC, USA,
3. Green, N.S. (2002). Folic acid supplementation and prevention of birth defects. Journal of Nutrition, 132: 2356–2360.
4. Grosso, G., Bei, R., Mistretta, A., Marventano, S., Calabrese, G. and Masuelli, L. (2013). Effects of vitamin C on health: A review of evidence. Frontiers in Bioscience.18:1017-1029.
5. Marangoni, A.G. (2016). Editorial overview: Food chemistry and biochemistry. Current Opinion in Food Science, 7: 04-05.
6. Riaz, S., Ahmad, A., Farooq, R., Hussain, N., Riaz, T., Hussain, K. and Mazahir, M. (2022). Citrus: An Overview of Food Uses and Health Benefits.
7. Shen W., Xu Y. and Lu Y.H. (2012). Inhibitory effects of Citrus flavonoids on starch digestion and anti hyperglycemic effects in HepG2 Cells. Journal of Agriculturaland Food Chemistry, **60**(38): 9609-9619.
8. Turner, T. and Burri, B. J. (2013). Potential Nutritional Benefits of Current Citrus Consumption. Agriculture, 3(1): 170–187.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

SWOT Analysis of Sweet Corn (*Zea Mays saccharate* L.) Cultivation in Rajasthan State of India

Article ID: 72764

Rohit Meena[1], Kishan Kumar[2], Khushi Ram Meena[3], Riya Jajoo[4], Ashik Kumar Meena[5], Deepu Kumari[6], Kiran Jitrawal[7], Anupurba Saha[8], Vishnu Suman[9]

[1]M.Sc. Research Scholar, Department of Agronomy, School of Agricultural Sciences, Medziphema, Nagaland University, Nagaland.
[2]Ph.D. Research Scholar, Department of Soil Science and Agricultural Chemistry, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan.
[3]Ph.D. Research Scholar, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan.
[4]PhD Researcher Scholar, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan.
[5]Ph.D. Research Scholar, Department of Agronomy, School of Agricultural Sciences, Medziphema, Nagaland University, Nagaland.
[6]M.Sc. Research Scholar, Department of Agronomy, College of Agriculture Jodhpur, Agriculture University, Jodhpur, Rajasthan.
[7]Ph.D. Scholar (Agronomy), S.K.N. College of Agriculture, Jobner (Sri Karan Narendra Agriculture University, Jobner), Rajasthan.
[8]M.Sc. Agronomy, Palli Siksha Bhavana, Viswa Bharati University, Bolpur, West Bengal.
[9]M.Sc. Research Scholar, Department of Agronomy, School of Agricultural Sciences, Medziphema, Nagaland University, Nagaland.

Abstract

Sweet corn (*Zea mays saccharata* L.) is an emerging specialty vegetable crop in India with potential for higher returns per unit area relative to grain maize because of its premium market (fresh, canned, frozen, and processing). Rajasthan is a large, climatically diverse state offers both challenges (aridity, water scarcity, temperature extremes) and opportunities (proximity of peri-urban markets, increasing demand for off-season vegetables, government support for horticulture diversification). This review synthesizes available literature and regional agricultural statistics to present a detailed SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of sweet corn cultivation in Rajasthan, and concludes with agronomic, policy and market recommendations for scaling sustainable sweet-corn production in the state.

Introduction

Sweet corn is harvested at the immature "green-cob" stage and differs genetically and physiologically from field (grain) maize — traits include higher sugar content, different plant density responses, and different fertiliser and harvest windows. In India, sweet corn cultivation has expanded beyond traditional maize belts into peri-urban and irrigated pockets because of higher per-hectare returns and growing urban demand. This review focuses on Rajasthan's agroecological zones, available evidence on sweet-corn trials and varietal performance in the state, production statistics, constraints, and potential pathways for sustainable intensification. Key sources for this synthesis include state agricultural statistics and regional varietal evaluation trials, along with recent reviews of sweet-corn agronomy and genetics.

Methodology

This is a narrative, literature-based review drawing on: (a) Rajasthan's published agricultural statistics (district/crop-wise area and production data), (b) peer-reviewed varietal evaluation and agronomy trials conducted in western India (including evaluations performed inside Rajasthan), and (c) recent comprehensive reviews of sweet-corn research (genetics, agronomy, postharvest). These sources were selected for regional relevance and technical credibility. Where Rajasthan-specific data are lacking, national or nearby-state experimental evidence (e.g., Gujarat/Junagadh, southern Rajasthan trials) is used cautiously to infer likely performance under similar management.

Crop & Region Overview (Rajasthan Context)

1. Agroecology and cropping systems: Rajasthan covers arid to semi-arid zones (Thar desert, arid western plains) as well as semi-humid eastern/central districts with irrigated pockets fed by canal systems, tube-wells and tanks. The state's agriculture is largely dominated by coarse grains (bajra), pulses, oilseeds and cotton, but irrigated areas and

peri-urban farms cultivate vegetables and specialty crops including maize variations. Patterns of irrigation, soil types (sandy to loamy), high evaporative demand and wide diurnal temperature ranges are key determinants for sweet-corn scheduling, cultivar choice and water management. State statistics provide district-wise production/area and irrigation indices important for planning crop introduction.

2. Market & socio-economic context: Rajasthan has significant urban centres (Jaipur, Jodhpur, Kota) where demand for fresh vegetables and processed vegetable inputs exists. Peri-urban producers can capture fresh-market premiums. Moreover, linkages to processing (canning/frozen) remain limited but are a potential growth path. Labour availability, mechanisation for planting/harvest, and cold-chain gaps shape commercialization routes.

Agronomy and Production Considerations (Key Facts)

1. Crop duration & planting windows: Sweet corn is typically grown as spring/summer or rabi/summer crop depending on irrigation availability; crop scheduling must avoid extreme heat at tasselling to maintain cob quality.

2. Fertiliser & planting density: Sweet-corn agronomy often uses higher plant populations and adjusted N:P:K scheduling compared with grain maize to optimize cob size and sugar retention. Regional trials (including Junagadh and Rajasthan evaluations) show significant cultivar × fertility interactions and suggest locally-tested fertilizer regimes are important.

3. Varietal selection: Cultivars/hybrids differ in sweetness genes (shrunken2, sugary1, sugary-enhancer su-separable alleles) and in adaptation to semi-arid conditions — selecting heat-tolerant sweet-corn hybrids tested in western India is key. Regional varietal evaluations have included sweet-corn entries and shown promising hybrids adapted to Rajasthan's conditions.

4. Pests & diseases: Maize pests (stem borers, aphids, fall armyworm where present) and ear rots are relevant; pest pressure may be moderated by timing and integrated pest management (IPM). Pest diversity studies highlight the role of temperature and humidity in pest outbreaks, which is relevant for Rajasthan's microclimates.

SWOT Analysis

Strengths (internal, favourable):

a. High value per unit area: Sweet corn fetches higher market prices than grain maize when marketed fresh or to processing units, improving farm income in irrigated pockets and peri-urban farms. (Supported by agronomy/economics literature showing higher gross returns for green-cob crop vs grain.)

b. Short crop duration & multiple windows: Sweet corn's relatively short time to harvest (compared with some vegetables) allows cropping intensification and catchment of off-season markets in peri-urban areas.

c. Adaptability to irrigated niches: Where canal or groundwater irrigation exists (eastern/central Rajasthan districts), sweet corn can be incorporated into existing cropping patterns. State statistics identify irrigated areas suitable for diversification.

d. Growing consumer demand: Urban consumer preference for convenience vegetables (fresh, baby/sweet corn in restaurants, hotels) supports market uptake; processors also increasingly source sweet corn for frozen/canned segments. Recent reviews show rising interest in specialty maize markets.

Weaknesses (internal, limiting):

a. Water sensitivity: Sweet corn requires reliable water at critical stages (silking/tasselling). Rajasthan's water scarcity and high evapotranspiration impose higher irrigation costs and risk of yield loss under deficit irrigation. This reduces the crop's robustness in rainfed or water-stressed smallholder farms.

b. Limited localized agronomic protocols: While national/regional sweet-corn trials exist, location-specific best practices (optimum planting dates, densities, fertigation schedules for Rajasthan's soils and climates) remain limited; extension packages tailored to the state are scarce.

c. Post-harvest & cold chain gaps: Sweet corn quality declines rapidly after harvest; inadequate cold storage, transport and rapid marketing reduce returns and increase losses, especially in distant rural production pockets.

d. Mechanisation & labour constraints at harvest: Sweet-corn harvest is time-sensitive (narrow window of green-cob maturity). Lack of timely labour or mechanised harvest solutions raises risk of quality loss and reduces scalability for larger farms.

Opportunities (external, favourable):

a. Peri-urban production & contract farming: Proximity to Jaipur, Kota and other urban markets offers growers premium fresh-market opportunities. Contract arrangements with hotels, restaurants and processors could de-risk adoption and provide assured offtake.

b. Value-chain development & processing: Investment in local processing (blanching, freezing, canning) or aggregation hubs would enable price stabilization, reduce wastage and expand markets (national supermarket chains, institutional buyers). The global/Indian trend toward frozen vegetable consumption supports this.

c. Improved cultivars & precision irrigation: Adoption of heat-tolerant, short-duration sweet-corn hybrids and practices like drip irrigation, fertigation and mulching can boost water-use efficiency and yield stability in

Rajasthan's semi-arid zones. Research indicates soil and foliar micronutrient management (e.g., Zn) can improve productivity under local conditions.

d. Diversification & allied enterprises: Sweet corn fits well into diversified vegetable portfolios and can be integrated with protected cultivation (shade/net houses) for off-season production and reduced evapotranspiration.

Threats (external, limiting):

a. Climatic extremes & monsoon variability: Rajasthan experiences highly variable rainfall and heat waves; extreme temperatures during floral stages reduce cob set and sugar accumulation. Erratic monsoons complicate scheduling and increase risk of crop failure. Recent seasonal reports emphasize erratic sowing and rainfall impacts on kharif crops in the region.

b. Pest outbreaks and invasive pests: Emergence or spread of pests (e.g., fall armyworm in maize belts) and insect vectors can cause severe losses if IPM is not rapidly adopted. Pest dynamics are sensitive to temperature and humidity, which may change under climatic variability.

c. Market volatility & competition: Price collapse risks if supply increases rapidly without marketing channels; competition from imported frozen products or cheaper grain maize derivatives can depress farmer margins.

d. Resource constraints (finance & inputs): Smallholders may lack access to hybrid seed, quality fertilizers, irrigation investment and credit which are necessary to realize sweet-corn's higher returns.

Evidence from Rajasthan and Nearby Trials

1. Varietal evaluations: Trials conducted in Rajasthan and adjacent regions have included sweet-corn entries with variable success; results underline the importance of testing hybrids under local soil and heat stress conditions before large-scale adoption. (ICAR regional evaluations document varietal responses in southern-western Rajasthan.)

2. Agronomic experiments: Studies from Gujarat/Junagadh and other western Indian trial stations report optimum fertilizer ranges and show that nutrient management (N levels, Zn application) significantly affects green-cob yield and quality — findings that are transferable after local calibration.

Post-Harvest, Processing & Marketing Considerations

1. Harvest window and handling: Sweet corn must be harvested and cooled quickly; on-farm grading and immediate chilling prolong shelf life and maintain sugar content. Without chilling, sugars convert to starch and fetch lower prices.

2. Aggregation models: Farmer producer organisations (FPOs), cooperative cold-rooms and contract farming tie-ups with processors reduce transaction costs and loss. Bringing smallholders into aggregated supply chains can allow access to distant premium markets.

3. Value addition: Frozen, canned and pre-cut sweet-corn products can stabilize demand and absorb off-season supply; however, initial investments and assured supply quantities are required to attract processors.

Policy, Extension & Research Recommendations

1. State-level demonstrations & adaptive trials: Launch systematic demonstrations across Rajasthan's agroecological zones to identify locally-adapted hybrids and irrigation schedules. Use KVKs/ICAR institutes for multilocational trials and extension.

2. Water-use efficiency measures: Promote drip irrigation, mulching and scheduling (deficit irrigation at non-critical stages) to increase water productivity of sweet corn in semi-arid areas. Evidence from semi-arid maize studies supports mulching and precision irrigation to improve yields and water use.

3. Market linkages & aggregation: Facilitate FPO formation, cold-chain investments and processor linkages via public-private partnerships to create assured demand and reduce post-harvest losses. State agricultural statistics and planning documents can help target districts with irrigated area for such investments.

4. Pest surveillance & IPM adoption: Strengthen monitoring for key maize pests, train farmers in IPM and support quick response to invasive pests (e.g., early detection and control). Pest-diversity research highlights environmental drivers of outbreaks reinforcing need for surveillance.

5. Capacity building & finance: Provide credit, subsidies for hybrid seed, and training on harvest timing and post-harvest cooling to reduce entry barriers for smallholders.

Practical Checklist for a Grower in Rajasthan (Concise)

1. Select a **locally-tested heat-tolerant sweet-corn hybrid**.
2. Plant in an **irrigated plot** or ensure drip/tanker irrigation is available for silking/tassel stage.
3. Use recommended **planting density and NPK** (refer to local KVK/ICAR package) and consider Zn foliar application where soils are Zn-deficient.

4. Monitor pests and use IPM; harvest **within the optimal green-cob window** and cool rapidly.

6. Link with **buyers (processors, hotels)** before scaling up and explore aggregation via FPOs.

Conclusion

Sweet corn offers Rajasthan an opportunity for crop diversification and enhanced farm income in irrigated and peri-urban pockets, but success depends on targeted varietal selection, efficient water management, improved post-harvest logistics and market linkages. The state's heterogeneity (from arid western tracts to irrigated eastern districts) means interventions must be location-specific. Coordinated action — on adaptive research (multilocation trials), extension, cold-chain investment and market development — will enable sweet-corn to shift from a niche crop to a viable, scalable option for Rajasthan's farmers.

References

1. Directorate of Economics & Statistics, Government of Rajasthan. *Agricultural Statistics of Rajasthan 2022-23* (district-wise data on area, production, irrigation). Jaipur: Directorate of Economics & Statistics, 2023.
2. Varietal evaluation and agronomy trials reporting sweet-corn performance in western India / Rajasthan contexts: ICAR e-publication on evaluation of maize varieties and sweet corn entries (varietal trials in southern-west Rajasthan). (See: ICAR e-publications: "Evaluation of varieties of different types of maize under …").
3. Sidahmed H., Vad A., Nagy J. *Advances in Sweet Corn (Zea mays L. saccharata) Research from 2010 to 2025: Genetics, Agronomy, and Sustainable Production.* Agronomy (MDPI). 2025;15:1260. (Comprehensive review of sweet-corn research and trends).

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Millets in Focus: The Aftermath of International Year of Millets (2023)

Article ID: 72765

Dr. Babu Kakumanu[1]
[1]Faculty of Botany, Department of Botany & Microbiology, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur, Andhra Pradesh, India.

Abstract

The International Year of Millets (IYoM) 2023, declared by the United Nations General Assembly and coordinated by the Food and Agriculture Organization, marked a watershed moment in the global recognition of millets as climate-resilient, nutritionally superior, and socio-economically important crops. The Year catalysed unprecedented policy attention, research investments, market experimentation and public awareness, particularly in India, which played a leading role in advocating for and implementing IYoM initiatives. While tangible gains were recorded in awareness generation, research outputs, institutional pilots and value-addition efforts, the post-2023 phase reveals that the transition from celebration to consolidation remains incomplete. Structural bottlenecks such as weak procurement mechanisms, fragmented value chains, limited post-harvest infrastructure and uneven consumer acceptance continue to constrain large-scale adoption. This expanded review critically examines the outcomes of International Year of Millets 2023, assesses its immediate and medium-term impacts, identifies persistent gaps, and proposes strategic pathways to ensure that the momentum generated translates into durable transformations in agri-food systems, nutrition security and climate resilience.

Background and Rationale of the International Year of Millets

Millets comprise a diverse group of small-seeded cereals, including pearl millet (bajra), finger millet (Ragi) and several small millets, that have historically sustained farming and food systems in arid, semi-arid and marginal environments. These crops are characterized by low water requirements, tolerance to heat and poor soils, and high nutritional value, notably dietary fibre, essential minerals and complex carbohydrates. Despite these advantages, millets experienced a long phase of neglect following the Green Revolution, which prioritised rice and wheat through research, subsidies and public procurement.

The declaration of Indian Institute of Millets Research (ICAR-IIMR) 2023 aimed to reverse this historical marginalisation by repositioning millets within global food, nutrition and climate discourses. Coordinated by Food and Agriculture Organization of the United Nations (FAO), the Year sought to enhance awareness, stimulate policy actions, promote research and innovation, and strengthen value chains from farm to fork. India's leadership—through sustained diplomatic engagement and domestic policy mobilisation—made the country a focal point for Indian Institute of Millets Research (ICAR-IIMR) activities and outcomes.

Global and National Awareness Outcomes

One of the most immediate and visible achievements of Indian Institute of Millets Research (ICAR-IIMR) 2023 was the dramatic increase in awareness among policymakers, consumers, researchers and private stakeholders. Globally, FAO-led campaigns, international conferences, exhibitions and publications highlighted millets as "smart foods" for climate change mitigation and nutrition security. The Year functioned as a global advocacy platform, aligning millets with the Sustainable Development Goals, particularly those related to zero hunger, good health, climate action and sustainable agriculture.

In India, Indian Institute of Millets Research (ICAR-IIMR) translated into nationwide outreach programmes, culinary festivals, recipe competitions, educational materials and extensive media coverage. Millets were repositioned from being perceived as "coarse" or "inferior" grains to being "nutri-cereals" with premium health value. This narrative shift is a significant socio-cultural achievement, as consumer perception strongly influences market demand and farmer incentives.

Policy Interventions and Institutional Momentum

1. National-level initiatives: Indian Institute of Millets Research (ICAR-IIMR) 2023 accelerated the integration of millets into policy frameworks across agriculture, nutrition and rural development. At the national level, India strengthened ongoing millet-centric initiatives through convergence of ministries and departments. Policy emphasis was placed on promoting millet cultivation in rainfed regions, supporting Farmer Producer Organizations (FPOs), and encouraging millet-based entrepreneurship and processing units.

The Year also prompted renewed discussion on mainstreaming millets into public food programmes, including school meals and government institutions. These discussions represent an important step toward demand creation, as institutional procurement can generate stable markets and price signals for farmers.

2. State-level innovations: Several Indian states launched or expanded millet missions during and after IYoM 2023. These missions focused on region-specific millet species, agronomic support, local procurement and value addition. Documentation of state best practices illustrates a diversity of approaches, ranging from decentralised procurement models to integration of millets into local nutrition programmes. However, the scale and sustainability of these initiatives vary widely across states, highlighting the need for coordinated national guidance and long-term financing.

Research, Breeding and Technological Advancements

The Indian Institute of Millets Research (ICAR-IIMR) period coincided with intensified research efforts by national and international institutions. In India, Indian Institute of Millets Research (ICAR-IIMR) played a central role in advancing millet science. Research outputs during and immediately after 2023 included the development of improved varieties with higher yield potential, better stress tolerance and enhanced nutritional traits. Efforts were also made to improve seed systems, particularly for small millets that suffer from chronic seed shortages.

Technological innovations extended beyond the field to post-harvest processing and product development. Mechanisation options for sowing, harvesting and processing were tested to reduce labour constraints, while food technologists developed diversified millet-based products aimed at urban and institutional markets. These innovations are critical for making millets competitive with refined cereals in terms of convenience and shelf life.

Market Development and Value-Chain Interventions

International Year of Millets 2023 stimulated renewed interest from the private sector, including startups, cooperatives and established food companies. New millet-based products—such as ready-to-cook mixes, bakery items and extruded snacks—entered niche health food markets. Pilot linkages between FPOs and processors sought to shorten value chains and improve farmer margins.

Despite these positive signals, millet markets remain fragmented and relatively small compared with rice and wheat systems. Limited aggregation, inconsistent quality, lack of branding and weak logistics constrains scale-up. The post-International Year of Millets phase thus underscores the need to move from scattered entrepreneurial initiatives to structured value-chain development supported by policy and infrastructure investment.

Nutrition, Food Security and Public Programmes

A major justification for promoting millets lies in their nutritional superiority and potential contribution to dietary diversification. During International Year of Millets 2023, several pilot initiatives explored the inclusion of millets in public nutrition programmes such as school meals and Anganwadi feeding. These pilots aimed not only to improve nutrient intake but also to familiarise children and communities with millet-based foods.

Initial experiences suggest that acceptability depends heavily on recipe design, processing quality and cultural preferences. Where millets were introduced in familiar or convenient forms, acceptance was higher. However, scaling such interventions requires sustained supply chains, training of cooks, standardised recipes and monitoring of nutritional outcomes.

Critical Assessment of Post-2023 Challenges

1. Procurement and price incentives: One of the most significant limitations revealed after International Year of Millets 2023 is the continued marginality of millets in public procurement systems. Without assured procurement and remunerative prices, farmers remain reluctant to expand millet cultivation beyond subsistence or niche markets.

2. Infrastructure and post-harvest constraints: Inadequate storage, cleaning, grading and processing infrastructure leads to post-harvest losses and quality deterioration. Small millets are particularly affected due to the absence of appropriate local-level processing facilities.

3. Consumer behaviour and demand sustainability: While awareness increased substantially during International Year of Millets, sustaining consumer demand requires continuous engagement, affordable pricing and convenient products. There is a risk that millets remain confined to premium health segments rather than becoming mainstream staples.

4. Equity and regional disparities: Benefits from millet promotion have been uneven across regions and social groups. Marginal farmers in remote areas often lack access to markets, processing units and institutional support, necessitating targeted inclusion strategies.

Strategic Pathways for Sustaining International Year of Millets Momentum

To convert the symbolic success of International Year of Millets 2023 into structural change, a multi-pronged strategy is required. Key priorities include:

1. Institutionalising millet procurement in public programmes to create stable demand.
2. Investing in decentralised processing and storage infrastructure linked to FPOs.
3. Strengthening seed systems and extension services for diverse millet species.
4. Promoting consumer-centric product innovation and culinary integration.
5. Establishing robust monitoring frameworks to evaluate nutritional, economic and environmental outcomes.

Conclusion

The International Year of Millets 2023 successfully repositioned millets within global and national agri-food narratives, generating momentum across policy, research, markets and public awareness. In India, the Year served as a catalyst for renewed policy focus, scientific advancement and entrepreneurial experimentation. However, the post-2023 scenario demonstrates that awareness alone is insufficient to ensure sustained adoption. Long-term commitment in procurement, infrastructure, research and behaviour change is essential to realise the full potential of millets as pillars of climate-resilient and nutrition-sensitive food systems. The legacy of IYoM will ultimately be judged not by the events of 2023, but by the durability of the transformations it inspires in the years ahead.

References

1. Food and Agriculture Organization of the United Nations. *International Year of Millets 2023: Final Report*. FAO, Rome.
2. Indian Council of Agricultural Research – Indian Institute of Millets Research. *Annual Report 2023-24*. ICAR-IIMR, Hyderabad.
3. NITI Aayog, Government of India. *Promoting Best Practices on Millets across States and Union Territories*. New Delhi.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Battling the Hidden Enemy: Stem Borer Infestation in Your Paddy Fields

Article ID: 72766

Kesoju Ravali[1], Irayya Hiremath[2], Mohammad Shafiqurrahaman[3]

[1]M.Sc. (Agriculture) in Genetics and Plant breeding,Junior Executive (Agri.), National Seeds Corporation Ltd. (NSCL), Warangal, Telangana.

[2]M.Sc. (Agriculture), Assistant Manager, National Seeds Corporation Ltd. (NSCL), Warangal, Telangana.

[3]Seed Certification Officer, Telangana State Seed and Oraganic Certification Authority (TGSOCA), Telangana.

Paddy, the lifeblood of millions, powers kitchens from Telangana villages to tables across Asia. This resilient crop thrives in flooded fields, delivering nutrition and income. But lurking inside its sturdy stems is a silent saboteur: the rice stem borer (Scirpophaga incertulas), a moth whose larvae can devastate yields by up to 80% in late-planted fields. If you've spotted "dead hearts" or ghostly "white ears" in your crop, this pest is likely the culprit. Let's dive into its sneaky lifecycle, telltale signs, and proven ways to fight back.

The Stem Borer's Ruthless Lifecycle Picture a tiny moth fluttering at dusk—harmless on its own. After mating, the female lays 400-600 eggs in clusters on leaf undersides, often at night. Eggs hatch in 5-8 days into pale, 1.5 mm larvae that silk their way down stems, boring in to feast on tender tissues. These voracious eaters grow to 20 mm over 4-5 weeks, molting five times while hollowing out the stem. Full-grown larvae pupate inside a silken cocoon for 6-10 days, emerging as adults with strong wings but short lives—they mate, lay eggs, and die in days. Multiple generations strike per season, turning healthy tillers into weak stalks.

Spotting the Damage Before It's Too Late

Early signs scream trouble: In young plants (vegetative stage), the central shoot dries into a "dead heart." Older plants show "white ears"—empty, chaffy panicles that spell yield disaster. Look for wilting leaves, lodging stems, tiny holes, or frass (insect poop) like sawdust. Slice open a suspect stem: wriggling larvae confirm the infestation. Scout weekly, especially 25-40 days after transplanting, when damage peaks.

Egg masses (15-80 eggs) on leaves are your first clue—young larvae even balloon on silk threads to nearby plants.

Why it's Paddy's Worst Nightmare?

Stem borers weaken plants from within, slashing tillers, inviting lodging, and spiking disease risk. Losses hit 20-70%, worst in rainy seasons or late planting. Unlike leaf-munching pests, these invaders hide deep, making them tough to spot until yields plummet.

Smart Strategies to Crush Stem Borers

Don't reach for chemicals first—integrated pest management (IPM) wins long-term. Combine these for a bulletproof defense:

Cultural Power Moves:

a. Plant early to dodge peak infestation.
b. Rotate with non-hosts like soybeans, groundnuts, or cotton.
c. Weed ruthlessly and sanitize fields post-harvest—burn stubble to kill overwintering pests.
d. Use resistant, early-maturing varieties with high tillering.
e. Flood fields periodically to drown eggs; split nitrogen doses to avoid lush growth that attracts borers.
f. Clip and burn egg masses from seedlings before transplanting.

Biological Allies:

a. Release Trichogramma wasps (e.g., T. japonicum thrice from 28 days after transplanting, then T. chilonis) to parasitize eggs.
b. Boost predators: ladybird beetles, spiders, birds (like coucals and kingfishers), and leafhoppers like Nephotettix virescens.
c. Apply microbial sprays (viruses, bacteria, fungi) or soil treatments with Pseudomonas fluorescens, neem cake, and farmyard manure.

Organic Hacks:

a. Intercrop with repellents like neem or tulsi.
b. Spray neem oil, garlic extracts, or botanical mixes for natural deterrence.
c. Seed-treat with PGPR consortia for healthier, resistant plants.

Chemical Backup (Use Wisely)

Reserve for 5%+ dead hearts: Granules like Cartap hydrochloride 4G (25 kg/ha) or Phorate 10G (10 kg/ha) in 3-4 cm water. Sprays include Monocrotophos 36 EC (1.4 L/ha) or combos like Coragen + neem oil. Always follow labels, rotate products, and protect bees—Virtako offers long-lasting control without harming vigor.

Victory Through Vigilance

Stem borers thrive on neglect, but proactive farmers triumph with IPM. Resistant seeds, clean fields, and nature's helpers keep populations low without over-relying on poisons. Monitor, act early, and harvest bountifully—your paddy deserves it.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

International Seed Certification: Bridging Global Borders through Quality Seeds

Article ID: 72767

Kesoju Ravali[1], Irayya Hiremath[2], Mohammad Shafiqurrahaman[3]

[1]M.Sc. (Agriculture) in Genetics and Plant breeding,Junior Executive (Agri.), National Seeds Corporation Ltd. (NSCL), Warangal, Telangana.

[2]M.Sc. (Agriculture), Assistant Manager, National Seeds Corporation Ltd. (NSCL), Warangal, Telangana.

[3]Seed Certification Officer, Telangana State Seed and Oraganic Certification Authority (TGSOCA), Telangana.

In the modern world of agriculture, the movement of seeds across borders is essential for food security and economic growth. However, ensuring that these seeds are of high quality and true to their variety is a complex challenge. This is where the OECD (Organization for Economic Co-operation and Development) Seed Schemes come into play, serving as a "passport" for seeds in international trade.

What is the OECD Seed Certification?

Established in 1961 and headquartered in Paris, the OECD is an inter-governmental organization that provides a framework for the varietal certification of seed moving in international trade.

With 61 participating countries, the scheme harmonizes technical standards so that a seed certified in one country is recognized and trusted in another. This eliminates technical trade barriers and ensures farmers receive "quality-guaranteed" seeds.

The Eight Agricultural Seed Schemes

The OECD framework isn't a "one-size-fits-all" model. It is divided into eight specific schemes based on the type of crop:

1. Cereals
2. Maize
3. Sorghum
4. Crucifers (and other oil/fiber species)
5. Grasses and Legumes
6. Fodder beet and Sugar beet
7. Subterranean clover (and similar species)
8. Vegetables.

Understanding the "Classes" of Seed

Not all seeds are the same. Certification follows a strict hierarchy of generations to maintain genetic purity. Each class is identified by a specific color-coded label:

Seed Class Description (Label Color)

Pre-Basic: Generations preceding Basic seed; used for further multiplication. (White with Violet Stripe)

Basic: Produced under the responsibility of the maintainer. (White)

Certified (C1): Direct descent from Basic seed; used for commercial sale. (Blue)

Certified (C2): Second generation of certified seed. (Red)

Standard: Mainly for vegetables; must be true to variety. (Dark Yellow)

Not Finally Certified: Exported after field approval but before final lab testing. (Grey)

How it Works: The Certification Procedure

The path from a laboratory variety to an exported seed lot involves a rigorous, multi-step process managed by a Designated Authority (DA).

1. Registration and Listing:

Maintainer Listing: The seed company must be listed as an official maintainer.
Varietal Listing: The specific hybrid or variety must be added to the OECD Varietal List.
Unit Registration: The company and its Seed Processing Unit (SPU) must register with the DA.

2. Field and Production Phase:

Area Registration: The specific seed production area is registered.

Field Inspections: Experts inspect the crop at different growth stages to check for "off-types" or disease.

3. Processing and Testing:

Cleaning: Seeds are processed and cleaned in registered units.

ISTA Testing: Samples are sent for International Seed Testing Association (ISTA) sampling and testing to check germination and purity.

4. Certification and Export:

Labeling: Once passed, OECD labels and Varietal Certificates are issued.

Post-Control: In many cases (like Basic seeds), "Post-Control Plot Testing" is performed even after export to double-check the quality of the lot.

Why Does it Matter?

The benefits of this system extend from the private seed company to the small-scale farmer:

Global Recognition: Facilitates trade by using globally recognized labels.

Public-Private Collaboration: Encourages cooperation between government authorities and private breeders.

Risk Reduction: Building a framework for seed production with other countries reduces the risk of crop failure due to poor seed quality.

By adhering to these international standards, the global community ensures that the foundation of our food system—the humble seed—is reliable, productive, and pure.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Role of Microproteins in Crop Improvement

Article ID: 72768

Kumari Rekha[1], Prity Sundaram[2]
[1]Mandan Bharti Agriculture College, Bihar Agricultural University, Sabour, Bhagalpur,
[2]Bhola Paswan Shastri Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur,
Assistant Professor-cum-Junior Scientist.

Summary

Microproteins are small functional proteins, usually less than 100 amino acids, encoded by small open reading frames (sORFs) that were previously thought to be non-coding regions of the genome. Despite their small size, microproteins play important regulatory roles in plants, animals, and microbes. Microproteins represent a newly recognized and crucial layer of biological regulation. Although small in size, they have a large impact on cellular functions and hold great potential for crop improvement and biotechnology.

Microproteins (also called *small proteins* or *small open reading frame-encoded peptides, SEPs*) are short proteins, usually less than 100–150 amino acids, encoded by small open reading frames (sORFs). Once considered non-functional, they are now recognized as important regulators of plant growth, development, and stress responses, making them valuable tools for crop improvement.

Regulation of Plant Growth and Development

Microproteins often act by modulating the activity of larger proteins, especially transcription factors.

1. They can form non-functional or altered complexes with target proteins (dominant-negative effect).
2. Influence key developmental processes such as:
    a. Root and shoot architecture
    b. Leaf size and shape
    c. Flowering time
    d. Seed development.

Example: LITTLE ZIPPER (ZPR) proteins interact with HD-ZIP III transcription factors, regulating meristem maintenance and leaf polarity.

Stress Tolerance (Abiotic and Biotic)

Microproteins play critical roles in plant responses to environmental stresses.

Abiotic stress:
a. Drought
b. Salinity
c. Heat and cold stress.

They regulate stress-responsive signaling pathways and hormone balance (ABA, auxin).

Biotic stress:
a. Defense against pathogens and pests
b. Regulation of immune signaling.

Application: Development of stress-resilient crop varieties suitable for climate change conditions.

Hormonal Signaling and Crosstalk

Microproteins fine-tune plant hormone pathways, ensuring balanced growth and stress adaptation.

Involved in:
a. Auxin signaling
b. Gibberellin responses
c. Brassinosteroid signaling
d. Abscisic acid–mediated stress responses.

Example: Certain microproteins interfere with transcriptional regulators of hormone-responsive genes, acting as molecular switches.

Application: Controlled growth regulation without major genetic disruption.

Improvement of Yield and Productivity

By modifying developmental pathways, microproteins can influence:

a. Grain size and number
b. Biomass accumulation
c. Nutrient uptake efficiency.

Because of **their small size**, microprotein genes are:

a. Easy to manipulate
b. Energy-efficient for the plant to express

Application: Yield enhancement with minimal metabolic cost.

Nutrient Use Efficiency

Some microproteins regulate nutrient signaling pathways:

a. Nitrogen uptake and assimilation
b. Phosphorus sensing
c. Iron and micronutrient homeostasis.

Application: Reduced fertilizer requirement and sustainable agriculture.

Tools for Precision Crop Engineering

Microproteins are emerging as novel biotechnological tools:

a. Can be designed synthetically to target specific proteins
b. Useful in gene editing and synthetic biology
c. Cause fewer pleiotropic effects compared to overexpressing large genes.

Application: Precise trait modification using CRISPR or transgenic approaches.

Advantages of Microproteins in Crop Improvement

1. Small gene size → easy cloning and transformation
2. High specificity in protein–protein interactions
3. Rapid evolutionary adaptability
4. Reduced risk of off-target effects.

Conclusion

Microproteins represent a new frontier in crop improvement, offering precise control over plant development, stress tolerance, and productivity. Their ability to regulate major signaling networks with minimal genetic input makes them promising candidates for developing high-yielding, stress-tolerant, and climate-smart crops.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Distribution, Biochemical Roles, and Nutritional Significance of Trace Elements in Milk: Implications for Human Health and Dairy Processing

Article ID: 72769

Nilesh Vadhiya[1], Pravin Chaudhary[2], Apeksha Sonara[3]
[1]Senior Application Executive (R & D), Novasol Ingredients Pvt. Ltd. Ahmedabad.
[2]Executive (QA), Gujarat Cooperative Milk Marketing Federation Ltd, Anand, India.
[3]Junior Officer Banas Dairy Palanpur, Gujarat.

Abstract
Milk is a nutritionally complex biological fluid and an important dietary source of essential minerals and trace elements. Although bovine milk contains a substantially higher total mineral content than human milk, nutritional relevance is determined not simply by concentration but by chemical speciation, protein association, and bioavailability. This review examines the distribution, biochemical roles, nutritional significance, and health implications of trace elements in milk, with particular emphasis on iron, zinc, copper, manganese, selenium, iodine, molybdenum, chromium, fluoride, and cobalt. Species-specific differences, lactational changes, and protein–mineral interactions that influence absorption and metabolism are discussed in detail. In addition, the review highlights the dual role of dairy products as valuable micronutrient carriers and potential vectors of heavy metal exposure, underscoring the importance of rigorous control throughout the dairy production chain. By integrating perspectives from milk mineral chemistry, human nutrition, and dairy processing, this synthesis provides a comprehensive framework for understanding the nutritional and safety dimensions of trace elements in milk.

Keywords: Milk minerals; Trace elements; Bioavailability; Dairy nutrition; Micronutrients; Heavy metals.

Introduction
Minerals are vital inorganic components needed by living things for cellular signaling, enzymatic activity, metabolic control, and structural integrity. Even though trace elements are needed in very small amounts, they have disproportionately large physiological effects in human nutrition and are essential for healthy growth and development. As a major source of highly bioavailable micronutrients, milk plays a crucial role in human diets, especially during infancy and early childhood. In addition to total concentration, the nutritional effectiveness of milk minerals is determined by a few other factors such as their being bound to casein micelles and whey proteins, their interactions with lactose and citrate, as well as the developmental stage and physiological status of the consumer. Hence, milk serves as an outstanding model system where mineral chemistry, protein structure, and nutritional function meet. The article critically scrutinizes the occurrence, distribution, and functional relevance of trace elements in milk, paying particular attention to their bioavailability, interspecies variability, and the impact on dairy processing and human health. By integrating the latest knowledge in these areas, the article also reveals the most crucial aspects that need further investigate.

Classification and Occurrence of Trace Elements in Milk
Minerals present in the diet are generally divided into macro-minerals, which are needed in amounts exceeding 100 mg·day^{-1}, and trace (micro) minerals, whose requirement quantities are much smaller. While macro-minerals make up the majority of the ash content of milk, trace elements perform essential catalytic, structural, and regulatory functions, which are indispensable for metabolic homeostasis. Of the roughly 20 trace elements that are deemed necessary for human nutrition, 14 of them at least play a crucial physiological role, which is well documented: iron, zinc, copper, manganese, selenium, iodine, chromium, cobalt, molybdenum, flourine, nickel, silicon, boron, and arsenic. Milk's mineral content is not a fixed feature but rather a variable one that depends on such factors as species, lactation stage, maternal diet, environmental exposure, and underlying physiological regulation. These variabilities have significant consequences for the nutritional value and safety of the food.

Iron
1. Distribution and Speciation in Milk: Normal milk has very low iron contents. Mature human milk contains about 0.3 mg·L^{-1} iron, while cow's milk contains about 0.5 mg·L^{-1} iron. However, human milk iron is much more bioavailable. In cow's milk, iron is unevenly spread in different milk components, with around 10–20% being associated with the milk fat globule membrane, 20–30% bound to casein micelles, and a similar amount being bound to whey proteins such as lactoferrin and serum albumin. In human milk, a large proportion of iron is complexed to lactoferrin, an iron-sequestering glycoprotein that occurs at a concentration of about 1.0–2.0 g·L^{-1} in both early and mature milk. One lactoferrin molecule can bind two ferric ions along with carbonate or bicarbonate anions, which helps to maintain iron stability, facilitates its absorption in the intestine, and deprives pathogenic microbes of iron.

2. Bioavailability and Physiological Function: Iron is involved in oxygen transport via the proteins hemoglobin and myoglobin, mitochondrial respiratory chain via cytochromes, generation of ATP via oxidative phosphorylation, as well as immune defense. It is estimated that the iron present in human milk is absorbed at the rate of 49 to 70% whereas those of cow's milk and regular infant formulas are significantly lower. This is attributed to the presence of iron-binder molecules in human milk and the lack of iron absorber inhibitors.

3. Nutritional Deficiency: Iron deficiency anemia is one of the most common nutritional diseases worldwide and it mostly affects babies, pregnant and breastfeeding women, and people whose diets are mainly derived from plants. This disease is clinically characterized by the production of small and pale red blood cells and it causes dementia, stunted growth, and weak immune system.

Zinc

1. Concentration and Protein Association: In milk, zinc is one of the major trace elements with the typical mean concentration of 2–4 $mg \cdot L^{-1}$ in mature human and bovine milk although there is a significant difference depending on the species and lactation stage. More than 90% of the zinc in the skim fraction of bovine milk is bound to casein micelles, while the remaining part is complexed with low-molecular-weight ligands such as citrate and phosphate.

2. Biochemical and Nutritional Role: Zinc is a structural or catalytic cofactor of more than 300 enzymes and it is crucial in cell proliferation, immune responses, antioxidant protection, and gene regulation through zinc-finger transcription factors. Additionally, it is indispensable for insulin storage and secretion, growth, and neurodevelopment, especially during infancy and early childhood.

Copper

Milk copper concentrations are quite low with mature human milk containing around 0.2–0.4 $mg \cdot L^{-1}$ while bovine milk contains only 0.05–0.1 $mg \cdot L^{-1}$. Copper is generally bound to caseins, low-molecular-weight ligands, and whey proteins such as ceruloplasmin and albumin. Copper is an integral part of many redox enzymes such as cytochrome c oxidase and Cu/Zn-superoxide dismutase. Besides, it is essential for the synthesis of hemoglobin, formation of the extracellular matrix, myelination of the nervous system, functioning of the immune system, as well as antioxidant defense. Although there is little copper deficiency in humans, it can cause anemia, bone problems, weakened immune system, and neurological disorders if it occurs.

Manganese

Milk contains manganese only at very low levels, usually about 3–6 $\mu g \cdot L^{-1}$ in mature human milk and 20–50 $\mu g \cdot L^{-1}$ in bovine milk, whereas the colostrum has been found to have even higher levels. Manganese acts as a cofactor of enzymes which participate in gluconeogenesis, antioxidant protection (mitochondrial superoxide dismutase), and glycoprotein synthesis.

Manganese deficiency hardly ever occurs but the problem of neurotoxicity coming from overexposure to this element (mainly from water or high-manganese formulas) in infants and young children has been raised lately.

Selenium

Selenium in milk varies with both the diet and the selenium content in the soil of the region, with the levels being generally higher in colostrum than in mature milk. Most of the selenium in milk is in the form of selenoproteins and low-molecular-weight selenocompounds, a concentration in the milk that can be increased if the diet of the dairy animals is supplemented. In fact, selenium is a crucial ingredient of glutathione peroxidases and in other antioxidant selenoproteins. Selenium-dependent iodothyronine deiodinases work as a key enzyme in thyroid hormone metabolism also.

Iodine

In many populations, milk and dairy products are the main dietary sources of iodine, especially in the areas where the consumption of seafood is restricted. Iodine is necessary for the production of thyroid hormones which, among other things, control the basal metabolic rate, growth, and neurodevelopment.

The iodine concentration in milk is highly dependent on the season as it changes with feeding practices, shelter, and the usage of iodine-fortified supplements. Such changes can have a significant impact on the iodine intake of the population and should thus be taken into account while making nutritional evaluations.

Other Trace Elements

Trace amounts of molybdenum, chromium, fluoride, and cobalt found in milk are intimately involved in enzyme systems responsible for purine metabolism, glucose homeostasis, dental health, and vitamin B_{12} synthesis, respectively. Despite being essential, there is only a narrow range of optimal intake for those elements, and going beyond such levels may cause toxicity. Besides this, nickel, silicon, boron, and arsenic can be found in small amounts, some of which have been

suggested to play physiological roles, and others serving mainly as toxicological concerns. This clearly illustrates the importance of monitoring essential as well as potentially harmful elements comprehensively.

Heavy Metals and Food Safety Considerations

Milk as such does not contain heavy metals; however, the dairy products may be contaminated with them through polluted feed, water, equipment, or environmental exposure. Of particular concern are lead, cadmium, mercury, and arsenic because of their cumulative toxicity and the potential for causing neurological, renal, and developmental problems. It is true that contaminant levels still remain below the official regulatory limits according to the studies of surveillance; however, issues of local exceedences and cumulative exposure cannot be disregarded. The described situation clearly calls for quality control and environmental monitoring measures to be backed up by stringent rules of good agricultural and manufacturing practice throughout the dairy supply chain.

Future Perspectives and Research Needs

The amino acid profiling of milk minerals has been done to such an extent that there are very few unknown elements present in the milk. Nonetheless, the disordering of mineral binding by dairy processing and the mineral ceiling functionality in-vivo are areas shot through with uncertainties. Further, the trace element balance in human and animal tissues and their holding-osteogenic and/or anti-osteoarthritic effects remain to be explored in the future. The further development of analytical techniques like high-resolution ICP-MS, speciation analysis, etc., together with controlled intervention studies, are giving promising potentials to fill these gaps. Mineral fortification at the cellular level and precision feeding of dairy animals could be the key to enhancing the nutritional value of dairy products while lessening the contamination risks and the environmental impacts. Comparable standards and routine monitoring are indispensable to facilitate evidence-based dietary guidelines and risk–benefit evaluations.

Conclusions

Milk is a biological world-optimized means for getting into the body essential trace elements that is supported by unique protein-mineral interactions which make bioavailability even more efficient, especially in the early stages of life. A detailed understanding of the chemical forms, physiological roles, and safety considerations associated with milk trace elements is critical for advancing dairy nutrition, protecting public health, and supporting sustainable dairy production systems.

References

1. Abbaspour, N., Hurrell, R., & Kelishadi, R. 2014. Review on iron and its importance for human health. Journal of Research in Medical Sciences. 19(2): 164–174.
2. ATSDR (Agency for Toxic Substances and Disease Registry). 2012. Toxicological Profile for Manganese. U.S. Department of Health and Human Services, Atlanta, GA.
3. Bai, S., Yang, J., Zhang, L., et al. 2024. Effects and impact of selenium on human health: A review. International Journal of Environmental Research and Public Health. 21(1): 1234. doi:10.3390/ijerph21011234.
4. Cashman, K.D. 2020. Milk minerals, trace elements, and microelements. In: McSweeney, P.L.H., & Fox, P.F. (eds.). Advanced Dairy Chemistry, Vol. 3. 4th ed. Springer, New York, pp. 209–250.
5. Chapas, C., Kaya, G., Yıldız, M., et al. 2025. Occurrence of potentially toxic metals detected in milk and dairy products: A health risk assessment. Food Chemistry: X. 19: 101245. doi:10.1016/j.fochx.2025.101245.
6. Cítek, J., Hanusová, L., Hanuš, O., et al. 2023. Iodine concentration in milk and human nutrition: A review. Czech Journal of Animal Science. 68(1): 1–13.
7. Dror, D.K., & Allen, L.H. 2014. Dairy product intake in children and adolescents in developed countries: Trends, nutritional contribution, and a review of association with health outcomes. Nutrition Reviews. 72(2): 68–81. doi:10.1111/nure.12078.
8. EFSA (European Food Safety Authority). 2010. Scientific opinion on lead in food. EFSA Journal. 8(4): 1570. doi:10.2903/j.efsa.2010.1570.
9. El Zokm, G.M., El-Kafrawy, S.B., El-Badry, M.O., et al. 2023. Heavy metal residues in milk and some dairy products with insight into human health risk assessment. Food Chemistry. 404: 134563. doi:10.1016/j.foodchem.2022.134563.
10. Erikson, K.M., Syversen, T., Aschner, J.L., & Aschner, M. 2011. Manganese exposure by inhalation: Historical background and current state of the art. In: Costa, L.G., & Aschner, M. (eds.). Manganese in Health and Disease. RSC Publishing, Cambridge, pp. 1–30.
11. Fox, P.F., Uniacke-Lowe, T., McSweeney, P.L.H., & O'Mahony, J.A. 2015. Dairy Chemistry and Biochemistry. 2nd ed. Springer, Cham.
12. Maares, M., & Haase, H. 2020. Zinc and immunity: An essential interrelation. Archives of Biochemistry and Biophysics. 611: 108628. doi:10.1016/j.abb.2020.108628.
13. Salem, H.M., Soliman, N.F., El-Laheth, R.A., & El-Ghitany, E.M. 2020. Heavy metal levels in milk and fermented milk products produced in Alexandria, Egypt. Veterinary World. 13(4): 754–760. doi:10.14202/vetworld.2020.754-760.

14. Schröder, T.H., Wiedemann, S., & Jahreis, G. 2024. Variation in milk-iodine concentration around the world: A systematic review and meta-analysis. Journal of Food Composition and Analysis. 125: 105908. doi:10.1016/j.jfca.2024.105908.
15. Soetan, K.O., Olaiya, C.O., & Oyewole, O.E. 2010. The importance of mineral elements for humans, domestic animals and plants: A review. African Journal of Food Science. 4(5): 200–222.
16. Taufek, N.H.M., et al. 2025. Circadian variation of zinc, copper, selenium, and bromine in human milk during the postpartum period. Journal of Paediatrics. (in press).
17. WHO (World Health Organization). 2011. Manganese in Drinking-water: Background Document for Development of WHO Guidelines for Drinking-water Quality.
18. Zimmermann, M.B., & Boelaert, K. 2015. Iodine deficiency and thyroid disorders. Lancet Diabetes & Endocrinology. 3(4): 286–295. doi:10.1016/S2213-8587(14)70225-6.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Role of Irradiation Technology in Post-Harvest of Fresh Fruits and Vegetables

Article ID: 72770

Manoj Kumar Burdak[1], Lalit Kumar Katariya[2], Sachin G. R.[3]

[1]M. Tech in Food Technology (Food safety and quality), Division of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir.

[2]Masters in Post-Harvest Management (Horticulture), Department of Food science and Technology, Sher-e-Kashmir university of agricultural sciences and technology of Kashmir.

[3]M. Tech in Food Technology (Process Engineering), Division of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir.

Abstract

Post-harvest losses of fresh fruits and vegetables constitute one of the most critical bottlenecks in achieving global food and nutritional security, particularly in developing and tropical countries. These losses arise due to microbial spoilage, insect infestation, physiological deterioration, and inadequate post-harvest infrastructure. Irradiation technology has emerged as a scientifically validated, non-thermal, and chemical-free post-harvest intervention capable of reducing microbial load, controlling quarantine pests, inhibiting sprouting, delaying ripening, and extending shelf life while largely preserving nutritional and sensory quality. Over several decades, extensive evaluations by international scientific bodies have conclusively demonstrated the safety and wholesomeness of irradiated foods when applied within prescribed dose limits. This comprehensive review elaborates on the principles of irradiation technology, types of irradiation systems, mechanisms of action in fresh produce, crop-wise applications, effects on nutritional and sensory quality, regulatory frameworks, advantages, limitations, and future prospects, with special emphasis on its role in reducing post-harvest losses and enhancing sustainable horticultural value chains.

Introduction

Fresh fruits and vegetables are metabolically active, living tissues even after harvest. They continue to respire, transpire, and undergo biochemical changes that lead to ripening, senescence, and eventual spoilage. High respiration rates, ethylene production, enzymatic browning, microbial invasion, and insect infestation significantly contribute to post-harvest losses, which may range from 20–40% in developing countries. Conventional post-harvest interventions such as refrigeration, chemical fumigation, waxing, and controlled atmosphere storage, although effective to some extent, are often constrained by high energy costs, chemical residue concerns, environmental hazards, and increasing regulatory restrictions.

Irradiation technology offers a promising alternative or complementary approach in post-harvest management. It involves exposing agricultural commodities to carefully controlled doses of ionizing radiation to achieve specific technological objectives, including disinfestation, microbial reduction, sprout inhibition, and delay of physiological processes. Importantly, irradiation does not make food radioactive, as the energy levels used are insufficient to induce radioactivity. Numerous toxicological, nutritional, and microbiological studies have confirmed the safety of irradiated fruits and vegetables for human consumption when used within internationally recommended dose limits (Mshelia, *et. al.*, 2022).

Types of Irradiation Technologies Used in Post-Harvest Systems

1. Gamma Irradiation: Gamma irradiation utilizes radioisotopes such as cobalt-60 or cesium-137 as radiation sources. Owing to its high penetration power, gamma irradiation is suitable for treating bulk consignments, pallet loads, and packaged fruits and vegetables. It is widely employed for phytosanitary treatments, sprout inhibition in tuber crops, and microbial load reduction. Gamma irradiation systems are reliable and effective but require stringent safety measures due to the use of radioactive sources.

2. Electron Beam Irradiation (E-beam): Electron beam irradiation uses high-energy electrons generated by accelerators. It offers very high dose rates and short treatment times, making it suitable for rapid processing. However, its penetration depth is lower than gamma rays, restricting its application mainly to surface treatment or thin layers of fresh produce. A major advantage of e-beam systems is that they do not involve radioactive materials and can be switched on and off as required.

3. X-Ray Irradiation: X-ray irradiation is produced when high-energy electrons strike a metal target. This technology combines the deep penetration capability of gamma rays with the operational flexibility of electron beam systems. X-ray irradiation is increasingly being adopted for pallet-scale and boxed produce treatment, especially for export-oriented horticultural commodities.

Mechanisms of Action in Fresh Produce

1. Insect Disinfestation: Ionizing radiation damages insect DNA and disrupts cellular division, rendering insects sterile or incapable of completing their life cycle. Unlike chemical fumigants, irradiation does not necessarily kill insects immediately but ensures they cannot reproduce or establish in importing regions. This makes irradiation particularly effective as a phytosanitary treatment for quarantine pest control.

2. Microbial Inactivation: Irradiation inactivates pathogenic and spoilage microorganisms by causing breaks in DNA strands and generating reactive free radicals. While low-dose irradiation does not sterilize fresh produce, it significantly reduces microbial populations, thereby improving food safety and slowing spoilage.

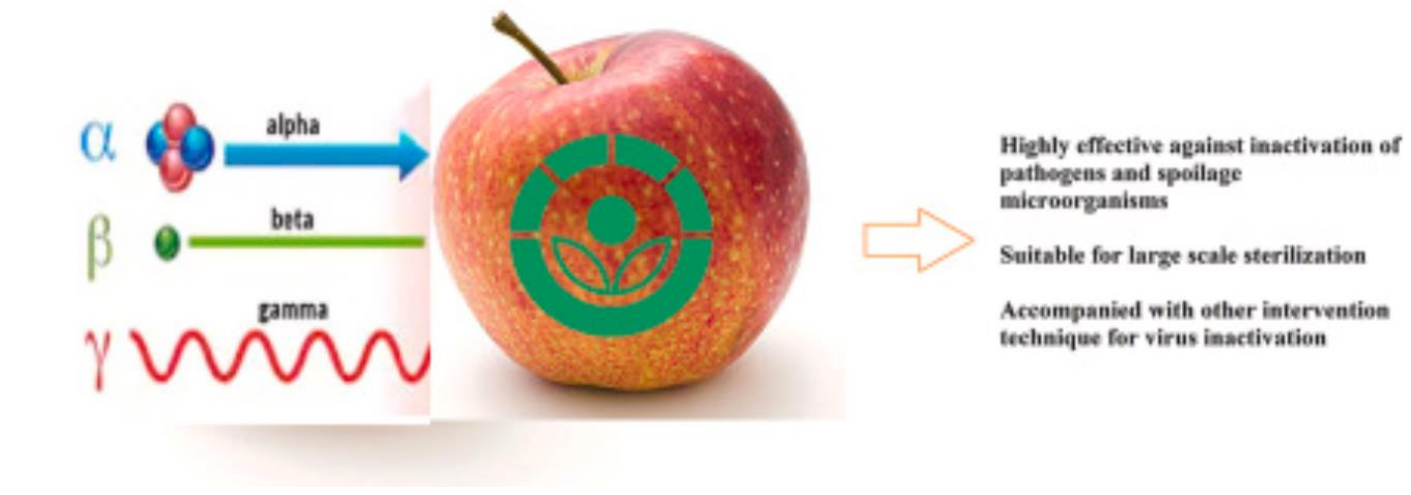
3. Delay of Physiological Processes: Low-dose irradiation can reduce respiration rate, suppress ethylene biosynthesis, and inhibit enzymatic activities associated with ripening and senescence. These effects collectively delay softening, colour change, and tissue breakdown, thereby extending shelf life.

4. Sprout Inhibition: In root and tuber crops such as potato, onion, garlic, and sweet potato, irradiation inhibits meristematic cell division, effectively preventing sprouting during storage without affecting eating quality.

Crop-Wise Applications of Irradiation Technology

Table 1. Crop-wise applications of irradiation technology in post-harvest management of fresh fruits and vegetables:

Crop / Commodity	Primary Post-Harvest Objective	Typical Dose Range (Gy)	Major Effects on Quality & Physiology	Key Benefits Achieved
Mango	Quarantine disinfestation; shelf-life extension	150-400	Slight delay in ripening; minimal sensory changes	Export compliance; fruit fly control
Papaya	Quarantine treatment; ripening delay	150-300	Reduced ethylene; slower softening	Extended marketable life
Banana	Ripening delay; microbial control	100-250	Delayed peel yellowing	Improved transport tolerance
Guava	Shelf-life extension	200-400	Maintained firmness	Reduced decay losses
Citrus fruits	Insect disinfestation; decay control	150-300	Maintained juice quality	Quarantine clearance
Apple	Senescence delay	200-500	Slower softening	Extended cold storage life
Grapes	Fungal spoilage reduction	100-300	Reduced mold growth	Lower post-harvest losses
Strawberry	Microbial reduction	100-200	Minimal texture changes	Enhanced food safety
Tomato	Ripening delay	100-250	Delayed color development	Better shelf life
Onion	Sprout inhibition	30-70	No flavor change	Reduced storage losses
Potato	Sprout suppression	50-150	Maintained nutritional quality	Chemical-free storage
Garlic	Sprout inhibition	50-100	Maintained bulb quality	Improved storability
Leafy vegetables	Surface decontamination	50-150	Reduced pathogens	Safer fresh produce



Applications in Post-Harvest Management

1. Phytosanitary Treatment: Phytosanitary irradiation is increasingly recognized as an effective alternative to chemical fumigants such as methyl bromide. International expert committees have recommended irradiation doses that ensure quarantine security without compromising produce quality. A maximum absorbed dose of 1 kGy for fruits and vegetables has been endorsed as safe by joint FAO–IAEA–WHO expert bodies (Akter *et. al.*, 2023).

2. Shelf-Life Extension: By reducing microbial growth and slowing physiological processes, irradiation significantly extends shelf life. When combined with cold storage, modified atmosphere packaging, or edible coatings, its effectiveness is further enhanced.

3. Reduction of Foodborne Pathogens: Low-dose irradiation reduces populations of pathogens such as *Salmonella*, *Listeria monocytogenes*, and *Escherichia coli*, contributing to improved public health safety, particularly for minimally processed fresh produce (Mshelia *et. al.*, 2022).

4. Reduction of Post-Harvest Losses: Irradiation minimizes quantitative and qualitative losses caused by insects, microbes, and physiological disorders, making it especially valuable for long-distance transportation and export supply chains.

Effects on Nutritional and Sensory Quality

1. Nutritional Quality: Macronutrients such as carbohydrates, proteins, and lipids remain largely unaffected by irradiation at recommended doses. Minerals are stable, while slight reductions in radiation-sensitive vitamins (e.g., vitamin C) may occur at higher doses. These losses are comparable to those observed during refrigeration and conventional storage (Akter *et. al.*, 2023).

2. Sensory Attributes: At phytosanitary and shelf-life extension doses, changes in colour, texture, flavour, and aroma are generally minimal and acceptable to consumers. Sensory effects are dose-dependent and vary among commodities.

Regulatory Framework and Safety Considerations

International standards for food irradiation have been established by the Codex Alimentarius Commission. Extensive scientific evidence supports the safety and wholesomeness of irradiated foods. The International Atomic Energy Agency actively assists member countries in developing irradiation facilities, regulatory guidelines, and quality assurance systems (International Atomic Energy Agency, 2025).

Advantages of Irradiation Technology

Irradiation technology offers several distinct advantages in post-harvest management of fresh fruits and vegetables, as it is a chemical-free and environmentally friendly intervention that eliminates the need for harmful fumigants and reduces chemical residues in food systems. It serves as an effective phytosanitary treatment by reliably controlling quarantine pests, thereby facilitating international trade and ensuring compliance with export regulations. Being a non-thermal process, irradiation preserves the fresh-like quality of produce by minimizing adverse changes in texture, flavour, colour, and nutritional attributes. Additionally, it significantly reduces post-harvest losses and food waste by controlling microbial spoilage, insect infestation, and physiological deterioration during storage and transportation. Importantly, irradiation is highly compatible with other post-harvest technologies such as refrigeration, modified atmosphere packaging (MAP), and cold storage, allowing its integration into existing post-harvest supply chains for enhanced overall efficiency and sustainability.

Limitations and Challenges

Despite its proven efficacy, irradiation technology faces several limitations and challenges that restrict its widespread adoption in post-harvest management systems. The establishment of irradiation facilities requires high initial capital investment and specialized infrastructure, which may not be economically feasible for small-scale producers and developing regions.

Consumer awareness and acceptance of irradiated foods remain limited, largely due to misconceptions and lack of effective communication regarding its safety and benefits. Additionally, irradiation responses are highly commodity-specific, necessitating careful dose optimization for different fruits and vegetables to avoid quality deterioration while achieving desired post-harvest objectives. Furthermore, regulatory, logistical, and policy-related constraints in certain regions, including limited access to irradiation facilities and complex approval processes, continue to pose significant challenges to the large-scale implementation of this technology.

Future Prospects

Future research should focus on crop-specific dose optimization, integration with emerging technologies such as cold plasma and nano-coatings, and large-scale adoption in developing countries. Public education and transparent labelling can further enhance consumer acceptance.

Conclusions

Irradiation technology is a scientifically proven, versatile, and sustainable post-harvest intervention for fresh fruits and vegetables. Its judicious application enhances food safety, extends shelf life, reduces post-harvest losses, and supports global trade. Wider adoption, supported by robust regulatory frameworks and consumer awareness, can significantly strengthen food system resilience and sustainability.

References

1. Mshelia, R.D., El-Mutwalli, H.I. and Al-Harbi, M.S. (2022). *Food irradiation: An effective but underutilized technique*. Radiation Physics and Chemistry, 193, 109993.
2. Akter, H., Rahman, M.M. and Kim, J.H. (2023). *Phytosanitary irradiation of fresh horticultural commodities: Principles, dose requirements, and quality considerations*. Agriculture, 13(2), 391.
3. International Atomic Energy Agency (2025). *Food irradiation: Technology, applications and safety*. IAEA Bulletin and Technical Reports, Vienna, Austria.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Role of Cold Plasma Technology in the Shelf-Life Extension of Fresh Fruits and Vegetables

Article ID: 72771

Manoj Kumar Burdak[1], Sachin G. R.[2], Lalit Kumar Katariya[3]

[1]M. Tech in Food Technology (Food safety and quality), Division of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir.

[2]M. Tech in Food Technology (Process Engineering), Division of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir.

[3]Masters in Post-Harvest Management (Horticulture), Department of Food science and Technology, Sher-e-Kashmir university of agricultural sciences and technology of Kashmir.

Abstract

Cold plasma (CP) technology has emerged as an advanced non-thermal post-harvest intervention capable of extending the shelf life of fresh fruits and vegetables while maintaining their fresh-like quality. The technology operates through the generation of reactive oxygen and nitrogen species (ROS and RNS), charged particles, UV photons, and transient electric fields at near-ambient temperatures. These reactive agents effectively inactivate surface-borne microorganisms, disrupt biofilms, suppress spoilage enzymes, and in some cases induce beneficial physiological responses in plant tissues. Compared with conventional chemical sanitizers and thermal treatments, cold plasma offers advantages such as chemical-free processing, minimal heat damage, and compatibility with consumer demand for "clean-label" produce. This review comprehensively elaborates the principles of cold plasma, mechanisms of action, crop-specific applications, effects on quality and nutritional attributes, integration with other post-harvest technologies, advantages, limitations, and future research needs, with special emphasis on fruits and vegetables of commercial importance.

Introduction

Fresh fruits and vegetables are living biological systems that continue to respire and metabolize after harvest. High moisture content, active enzymes, and nutrient-rich tissues make them highly susceptible to microbial spoilage, physiological deterioration, and quality loss during storage and transportation. Post-harvest losses in fruits and vegetables are particularly severe in developing countries due to inadequate cold chain infrastructure and reliance on chemical preservatives. Traditional preservation strategies such as refrigeration, modified atmosphere storage, waxing, and chemical sanitizers (chlorine, ozone, organic acids) reduce losses but suffer from drawbacks including residue concerns, incomplete microbial control, and negative consumer perception (Mani et al., 2023).

In this context, cold plasma technology has gained attention as a novel, non-thermal, and residue-free post-harvest treatment. Numerous studies have demonstrated that cold plasma can significantly reduce microbial populations on produce surfaces while preserving texture, colour, flavour, and nutritional quality. As a result, cold plasma is increasingly viewed as a promising alternative or complementary technology for shelf-life extension of fresh fruits and vegetables (Misra et al., 2019; Hertwig et al., 2020).

Fundamentals of Cold Plasma Technology

Plasma is often described as the fourth state of matter, consisting of a partially ionized gas containing electrons, ions, neutral atoms, radicals, and excited molecules. In cold plasma systems, although electrons possess high energy, the bulk gas temperature remains close to room temperature, making the technology suitable for heat-sensitive biological materials such as fruits and vegetables (Mani et al., 2023).

Cold plasma can be generated using several configurations, including dielectric barrier discharge (DBD), atmospheric pressure plasma jets, corona discharge, and gliding arc systems. Common feed gases include air, oxygen, nitrogen, argon, and helium, either alone or in combination. The choice of gas and reactor design strongly influences the composition and concentration of reactive species produced, which in turn determines antimicrobial efficacy and impact on produce quality (Hertwig et al., 2020).

Mechanisms of Shelf-Life Extension by Cold Plasma

1. Microbial Inactivation: The primary mechanism by which cold plasma extends shelf life is the inactivation of spoilage and pathogenic microorganisms on produce surfaces. Reactive oxygen and nitrogen species attack microbial cell membranes through lipid peroxidation, leading to increased permeability and cell leakage. Simultaneously, oxidative damage to proteins and nucleic acids disrupts essential cellular functions, ultimately causing cell death. Cold plasma has been reported to be effective against a wide range of microorganisms including *Escherichia coli*, *Salmonella spp.*, *Listeria monocytogenes*, yeasts, and filamentous fungi (Misra et al., 2019).

2. Biofilm Disruption: Many spoilage and pathogenic microorganisms exist as biofilms on fruit and vegetable surfaces, providing enhanced resistance to conventional sanitizers. Cold plasma generates highly reactive species capable of penetrating and degrading the extracellular polymeric substances of biofilms, thereby exposing embedded cells to oxidative stress and improving microbial inactivation efficiency (Hertwig et al., 2020).

3. Enzyme Modulation: Cold plasma can influence the activity of surface-associated and wound-induced enzymes such as polyphenol oxidase, peroxidase, pectin methylesterase, and cellulase. Controlled plasma exposure may reduce enzymatic browning and softening, thereby contributing to improved visual quality and textural stability during storage (Mani et al., 2023).

4. Physiological and Stress Responses: Mild cold plasma treatments may induce stress-related metabolic responses in plant tissues, leading to enhanced synthesis of phenolic compounds and antioxidants. Such responses can delay senescence and improve nutritional quality, although excessive treatment intensity may cause oxidative damage and quality degradation.

Effects on Quality and Nutritional Attributes

1. Texture and Firmness: Several studies have reported that cold plasma-treated fruits such as apples, tomatoes, peaches, and strawberries retain firmness for longer periods compared with untreated controls. Reduced microbial soft-rot and partial inhibition of cell-wall-degrading enzymes contribute to this effect.

2. Colour and Appearance: Optimized cold plasma treatments generally preserve surface colour and gloss of fruits and vegetables. In strawberries, cherries, grapes, and bell peppers, plasma treatment has been shown to delay discoloration and fungal growth without causing visible surface injury. However, excessive exposure may lead to surface bleaching or localized browning, highlighting the importance of dose optimization.

3. Nutritional Quality: Cold plasma has variable effects on nutritional components. In leafy vegetables such as lettuce and spinach, vitamin C retention is often comparable to untreated samples when mild treatments are applied. In fruits like blueberries, pomegranate arils, and apples, increased total phenolic content and antioxidant activity have been reported following short plasma exposure, attributed to stress-induced metabolic pathways (Misra et al., 2019).

Crop-Specific Applications and Examples (Mani et al., 2023)

Cold plasma technology has been tested on a wide range of fruits and vegetables, demonstrating its broad applicability:

1. Strawberry: Significant reduction in fungal decay and extension of shelf life under refrigerated storage, with minimal impact on colour and flavour.

2. Tomato: Reduction in surface microbial load, delayed softening, and slower ripening when plasma treatment is optimized.

3. Apple: Lower incidence of blue mold and maintenance of firmness and colour during cold storage.

4. Grapes: Suppression of *Botrytis cinerea* growth and reduced weight loss during storage.

5. Blueberry and Raspberry: Delayed mold development and maintenance of antioxidant capacity.

6. Lettuce and Spinach: Effective decontamination of pathogenic bacteria with acceptable retention of freshness.

7. Cucumber and Zucchini: Reduced surface spoilage and improved storage stability.

8. Mango and Papaya: Lower microbial load and delayed ripening, contributing to extended marketability.

9. Banana: Potential to slow crown rot development and maintain peel colour when used as a pre-storage treatment.

These examples collectively demonstrate that cold plasma is effective across commodities with diverse surface morphologies and physiological characteristics, although treatment parameters must be tailored for each crop.

Integration with Other Post-Harvest Technologies

Cold plasma is most effective when integrated within a hurdle technology framework. Combination with cold storage, modified atmosphere packaging, edible coatings, or mild chemical treatments can result in synergistic effects. For example, plasma treatment prior to refrigerated storage reduces initial microbial load, while low temperature suppresses subsequent microbial growth, together providing substantial shelf-life extension. Similarly, plasma-treated surfaces may enhance the adhesion and effectiveness of edible coatings.

Advantages of Cold Plasma Technology

Cold plasma offers several advantages over conventional post-harvest treatments:

1. Chemical-free and environmentally friendly process
2. Non-thermal nature preserves fresh-like quality
3. Broad-spectrum antimicrobial efficacy
4. Minimal water usage compared to washing treatments

5. Compatibility with organic and sustainable food systems.

Limitations and Challenges

Despite its promise, several challenges limit widespread commercial adoption:

1. High initial capital investment and equipment cost
2. Difficulty in achieving uniform treatment on complex or bulk produce
3. Risk of quality degradation at high treatment intensities
4. Limited large-scale and long-term storage studies
5. Regulatory uncertainty and lack of standardized processing guidelines.

Future Prospects and Research Needs

Future research should focus on developing standardized dose metrics, understanding long-term physiological effects on produce, scaling up reactor designs for continuous industrial processing, and conducting comprehensive safety and economic assessments. Greater emphasis on commodity-specific optimization and integration with existing post-harvest systems will accelerate commercial adoption.

Conclusions

Cold plasma technology represents a powerful, non-thermal, and sustainable approach for extending the shelf life of fresh fruits and vegetables. Through effective microbial inactivation, enzyme modulation, and preservation of quality attributes, cold plasma has the potential to significantly reduce post-harvest losses across a wide range of horticultural commodities. With continued research, optimization, and regulatory support, cold plasma is poised to become an important component of modern post-harvest management systems.

References

1. Misra, N. N., Jo, C., & Cullen, P. J. (2019). Cold plasma in food and agriculture: Fundamentals and applications. *Food Engineering Reviews*, 11, 117–130.
2. Hertwig, C., Meneses, N., Mathys, A., & Vogel, R. F. (2020). Cold atmospheric pressure plasma and its application in food processing. *Trends in Food Science & Technology*, 98, 30–40.
3. Pankaj, S. K., Wan, Z., & Keener, K. M. (2018). Effects of cold plasma on food quality: A review. *Journal of Food Science*, 83, 157–166.
4. Mani, A., Krishna, K. R., & Mirza, A. (2023). Post-harvest applications of cold plasma technology. *Agricultural Reviews*, 44(2), 131–144.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Development of High-Protein Millet Pancake & Dosa Mix- A New Product Concept

Article ID: 72772

Dhaval S Kugashiya[1]
[1]M.Tech-Dairy Technology, SMC College of Dairy Science, Anand.

Introduction

India's food market is witnessing rapid growth in health-focused and functional foods. Rising lifestyle diseases, fitness awareness, and preference for traditional grains have increased demand for millet-based products. The High-Protein Millet Pancake & Dosa Mix combines traditional Indian staples with modern nutrition, offering convenience, high protein, and clean-label benefits.

Advantages of Fortification

1. Helps address protein deficiency, especially among vegetarians.
2. Supports muscle health, satiety, and metabolic function.
3. Millets provide minerals like iron, calcium, and magnesium.
4. Aligns with Government of India's Millet Mission and nutrition goals.

Target Audience

1. Fitness enthusiasts.
2. Health-conscious consumers
3. Diabetics and pre-diabetics
4. Working professionals.
5. Children and elderly.

SWOT Analysis

Strengths:
1. High protein content
2. Use of traditional millets
3. Convenient and versatile usage

Weaknesses:
1. Slightly higher cost
2. Taste adaptation required

Opportunities:
1. Rising demand for millet-based foods
2. Institutional and export markets

Threats:
1. Competition from existing premixes
2. Regulatory compliance challenges.

Market Research

Gap in Market: Limited high-protein millet-based RTC breakfast options.
Consumer Insights: Demand for clean-label, diabetic-friendly foods.
Trend Analysis: Growth in millet, plant-protein, and low-GI foods.

Product Overview

Description:
1. Made from jowar, bajra, ragi, and plant proteins
2. No maida, no refined sugar
3. High protein (12–15 g per serving)
4. Easy preparation – add water and cook
5. Suitable for dosa, pancakes, uttapam.

Ingredient Sourcing

1. Jowar flour
2. Bajra flour

3. Ragi flour
4. Soy/pea protein isolate
5. Flaxseed powder
6. Natural leavening agents.

Product Formulation (Per 1 KG)

Ingredient	Quantity (g)	% w/w
Jowar flour	300	30.0
Bajra flour	250	25.0
Ragi flour	200	20.0
Soy/Pea protein isolate	120	12.0
Flaxseed powder	50	5.0
Natural leavening agents	15	1.5
Salt	20	2.0
Natural stabilizers/spices	45	4.5

Nutritional Information (Approx)

Nutrient (per 100 g)	Value
Energy	360-380 kcal
Protein	22-24 g
Carbohydrates	55-58 g
Total Fat	6-7 g
Dietary Fiber	10-12 g
Calcium	180-220 mg
Iron	4-6 mg

Process Flow Diagram

Raw material receiving → Cleaning & sieving → Milling → Weighing & batching → Dry blending → Metal detection → Packaging → Finished goods storage.

Haccp Plan (Summary)

Process Step	Hazard	Control Measure	CCP
Raw material receiving	Chemical/Microbial	Approved suppliers, COA	No
Sieving	Physical (stones or Other Physical Hazard which is not detection in the Metal Detector)	Sieves	Yes
Blending	Cross-contamination	GMP, sanitation	No
Metal detection	Metal contamination	Metal detector	Yes
Packaging	Moisture ingress	Controlled environment	No

Costing Calculation (Indicative)

Component	Cost (INR/kg)
Raw materials	140-160
Processing	20-25
Packaging	15-20
Overheads & QC	10-15
Total Cost	185-220
Suggested MRP	350-450

FSSAI Requirements

1. Product category: Cereal-based ready-to-cook mix
2. Valid FSSAI State/Central License mandatory
3. Labeling as per FSS (Labelling & Display) Regulations, 2020
4. Nutritional declaration mandatory
5. Shelf-life study and batch coding required.

Testing
1. Sensory evaluation
2. Nutritional analysis
3. Functional testing
4. Microbiological testing
5. Shelf-life testing.

Packaging & Storage
1. PET/PE pouches
2. Moisture and oxygen barrier
3. Store in cool, dry place below 25°C.

Commercialization
1. Online platforms
2. Retail health stores
3. B2B supply to cafes and gyms.

Marketing Strategy
Positioned as a high-protein, millet-based functional breakfast mix targeting health-conscious consumers, fitness enthusiasts, diabetics, and working professionals. Distribution through e-commerce, modern trade, and institutional channels.

Conclusions
The High-Protein Millet Pancake & Dosa Mix successfully blends traditional Indian foods with modern nutrition, catering to growing health-conscious markets with convenience and functional benefits.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Development of Moringa Pista Ice Cream

Article ID: 72773

Dhaval S Kugashiya[1]
[1]M.Tech-Dairy Technology, SMC College of Dairy Science, Anand.

Objective

Objective: To develop a healthy, functional ice cream enriched with Moringa and flavored naturally with green pistachio, offering a nutritious, low-fat, and sugar-free alternative to traditional Icecream for the Indian health-conscious segment.

Idea Generation & Screening

Identifying Consumer Needs & Trends:

1. Demand for natural, plant-based, functional ice creams is rising.
2. Diabetic-friendly and no-sugar-added products are in demand.
3. Moringa is gaining recognition as a superfood due to its high nutritional profile.
4. Pistachio is a popular flavor with universal acceptance.
5. Need for low-fat indulgent options for calorie-conscious consumers.

Market Analysis:

1. India's Icecream market is shifting toward clean-label, healthy options.
2. Superfood-based innovations (like Moringa) are still niche – a strong opportunity.
3. Pistachio remains one of the top 3 premium flavors across metro cities.

Target Audience:

1. Health-focused millennials
2. Diabetic and low-GI product seekers
3. Fitness and wellness enthusiasts
4. Age group: 20–50
5. Upper middle class, urban consumers.

Competitive Market Research

Brand	USP	Weaknesses
NOTO	Low-calorie, high protein	Aftertaste from sweeteners
WhiteCub	Vegan, cholesterol-free	Premium pricing, texture
Artinci	Diabetic-friendly, uses stevia	Limited availability
MoringaChill	Superfood-enriched (10% moringa), pistachio flavor, no added sugar	Needs taste masking for moringa

Differentiation Strategy

1. Moringa as Functional Ingredient → Rich in iron, calcium, antioxidants.
2. No Added Sugar → Sweetened with stevia and erythritol.
3. Low Fat Formulation → Skimmed milk base, optional vegan variants.
4. Pista Flavor → Popular and flavorful to mask any earthy moringa notes.

Concept Development & Testing

Key Selling Points:

a. Low-fat, no added sugar
b. Natural ingredients – no artificial sweeteners
c. Superfood enriched
d. Diabetic and fitness-friendly.

Proposed Variants:

a. Moringa Green Pista (primary focus)
b. Moringa Vanilla Almond
c. Moringa with Macha Tea (for future development).

Prototype Formulation & Recipe Development

Base Recipe:

Raw Material	Quantity (Kg)
Skimmed Milk	66.75
Polydextrose	8.00
SMP	10.00
Freeze Dried Moringa Powder	10.00
Erythritol	5.00
Stabilizer	0.25
Total	**100.00**
Sweetners, Colour and Flavors*	
Stevia	0.020%
Cream Flavour	0.2%
Pista Flavour	0.5%
Chlorophyl Color	0.015%

*Per 100 Kg Icecream mix

Prototype Preparation Process

1. Take the required quantity of Skimmed milk and heat it at 45^0C
2. Add Moringa powder, SMP, Erythritol, Polydextrose and Stabilizer-emulsifier Mixture thoroughly as per recipe.
3. Add pistachio paste and mix it properly.
4. Pasteurize the mix at 85°C for 15 seconds followed by cooling at 4°C.
5. The Mix is then subjected to ageing for minimum 8 hours.
6. Add Stevia, Chlorophyll (C.I. Natural Green 3) colour, Cream flavor & pista flavor as per recipe and mix it properly
7. Mix is then subjected to the freezing with desired overrun.
7. Packaging
8. Storage at -18°C.

Processing Feasibility

1. Easily compatible with current dairy or vegan ice cream production setups.
2. Equipment: Pasteurizer, homogenizer, freezer.
3. Minimal changes needed in standard cold chain setup.

Sensory Analysis & Consumer Testing

Attribute	Evaluation Metric
Texture	Creaminess, grit from moringa
Flavour	Pista-moringa balance, no bitterness
Aroma	Fresh, nutty, green
Mouthfeel	Smooth, non-greasy

Key Findings:

1. 81% liked pista as a masking flavor
2. 79% couldn't detect moringa bitterness
3. 88% found sweetness level acceptable
4. 72% said that they'd buy it if priced under ₹30/100ml.

Process Development

Ingredient Justification:

Ingredient	Function	Source	Availability Throughout Year
Moringa Powder	Superfood, nutrients	Tamil Nadu, Odisha	Available
Pistachio Paste	Flavour, fat	Iran/Local Indian pistachios	Available
Skimmed Milk	Base	Local vendors/Third Party	Available
Stevia + Erythritol	Natural sweetening	Ahmedabad/Bengaluru	Available
Erythritol	Artificial sweetners	Ahmedabad/Delhi	Available
Stabilizers-Emusifier Mixture	Texture, Overrun	Mumbai	Available

Nutritional Facts (Per Serving)

1 serving per container		
Serving Size: 100 mL (55g)		
Nutritional Parameters	**Amount per serving pack***	**%RDA#**
Energy, kcal	50.60	2.53%
Total Fat, g	0.22	0.33%
Saturated Fat, g	0.11	0.50%
Trans Fat, g	0.00	0.00%
Cholesterol, mg	1.93	
Carbohydrates, g	9.58	
Total Sugars, g	0.00	0.00%
Protein, g	4.71	
Sodium, mg	66.00	3.30%

#%RDA (Recommended Dietary Allowance) mentioned based on per serving size
* Approx values

HACCP & Food Safety Plan

CCP Step	Hazard	Control Measure
Moringa Powder	Microbial load	Supplier certification, lab test
Pasteurization	Pathogens	85°C for 15 seconds
Freezing	Spoilage risk	Maintain -18°C
Packaging	Contamination	Use sealed eco-friendly packs

Other Controls:
1. Visual inspection of raw powders
2. Temperature logs at pasteurization and storage
3. Final product microbial & heavy metal testing.

Packaging & Labelling

1. 100ml recyclable PP cup with lid
2. Transparent labeling: “Low-Fat,” “No Added Sugar,” “2X Calcium,” “Superfood Enriched”
3. QR Code → Explains health benefits of moringa.
4. FSSAI label compliance: nutrition table, ingredients, allergen info.

Manufacturing Process

1. Take the required quantity of Skimmed milk and heat it at 45^0C
2. Add Moringa powder, SMP, Erythritol, Polydextrose and Stabilizer-emulsifier Mixture thoroughly as per recipe.
3. Add pistachio paste and mix it properly.
4. Pasteurize the mix at 85°C for 15 seconds followed by cooling at 4°C.
5. The Mix is then subjected to ageing for minimum 8 hours.
6. Add Stevia, Chlorophyll (C.I. Natural Green 3) colour, Cream flavor & pista flavor as per recipe and mix it properly
7. Mix is then subjected to the freezing with desired overrun.
8. Packaging
9. Storage at -18°C.

SWOT Analysis

Strengths	**Weaknesses**
Unique superfood base	Moringa’s strong flavor
No added sugar	Awareness is low
Functional health benefits	Premium price
Popular pista flavor	Requires education efforts
Opportunities	**Threats**
Health food trend	Competition from protein/sugar-free ice creams
Urban wellness market	Ingredient sourcing variability

Pricing Strategy

Component	Cost (₹)
Raw Materials	7.80

Packaging	1.20
Labor/Overhead	2.00
Logistics	5.00
Marketing	5.00
Total	21.00

Retail Price: ₹35 per 100ml
Wholesale Price: ₹30
Premium pricing justified by superfood and no-sugar USP.

Market Testing & Validation

1. Pilot runs at farmer's markets and D2C sites
2. Feedback on taste, price, and packaging
3. Digital promotion via fitness influencers and dieticians.

Commercialization & Scaling

1. Partner with organic moringa suppliers
2. Scale via cloud kitchen cold storage
3. Collaborate with diabetic clinics, yoga centers.

Future Expansion

1. Moringa Ice Cream Bars
2. Seasonal Moringa-Flavored Gelatos
3. Probiotic Moringa Frozen Yogurt.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Drone Application - Flight of Courage

Article ID: 72774

Dr Ankita Sharma[1]
[1]Subject Matter Specialist, Krish Vigyan Kendra, Maulasar, District-Deedwana Kuchaman, Agriculture University, Jodhpur, Rajasthan.

Introduction

Achieving resilient, sustainable, and productive agriculture and food systems depends on innovation. Agricultural innovation involves developing new ways of working, adopting improved practices, and producing more and better outcomes with fewer resources. It offers a critical pathway for food systems to meet growing global demand while ensuring the sustainable use of increasingly scarce natural resources. Women innovators have their own place in agri-food system. Saroj Kanwar has parental land of one hectare area for cultivation. Her family is totally depending on rain and doing traditional farming. Their family income status was poor. She observed the life of a farmer closely and found it full of difficulties and struggle. But she was interested to do something different and new in the field of farming.She has completed her Bachelor of Science. She came in the contact with Krishi Vigyan Kendra, Maulasar, GSS Limted, Nimod, Rajeevika and IFFCO like organisations. She was motivated and inspired through day today activities of organisations. She decided to apply for drone training. She was selected and completed drone training of 15 days at Gwalior under PM Drone Didi Yojna in the year of 2024. After training, Drone was provided by IFFCO, Nagaur through GSS, Nimod of District Didwana-Kuchaman of worth of INR 15 lakh with its accessories for 5 years.

Pathway to Progress

After completion of training, she started to take work assignment of spray of fertilisers, weedicides, pesticides on crops. Now it became excellent source of income generation. She has decided the charges 150 INR/2500M Square area. Total gross income generation is about 1.0 lakh per year. She covered 3-4 nearby districts. The main limitation of district is long height and dense population of trees/plants as well as electric lines in the agricultural fields. But the drone technology is wonderful technology for plains.



Social Empowerment

Successful demonstration and training sessions was conducted at Krishi Vigyan Kendra to provide exposure to farmers, farm women, extension workers and students. Drone initiative improved her economic status, empowered socially and established a role model for other women farmers to take such initiative to make her to be independent and empowered.



Demonstration of Drone at Krishi Vigyan Kendra (KVK), Maulasar

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Role of Pseudocereals as Climate-Resilient Crops in Bihar

Article ID: 72775

Prity Sundaram[1], Kumari Rekha[2]
[1]Bhola Paswan Shastri Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur.
[2]Mandan Bharti Agriculture College, Bihar Agricultural University, Sabour, Bhagalpur.

Summary
Pseudocereals are non-grass plants whose seeds are used and consumed like true cereals. Unlike cereals (which belong to the *Poaceae* family), pseudocereals come from different botanical families but share similar nutritional and culinary uses. Major pseudocereals include Amaranth (*Amaranthus* spp.), Quinoa (*Chenopodium quinoa*), Buckwheat (*Fagopyrum esculentum*). Pseudocereals contribute to nutritional security, dietary diversification, and sustainable agriculture, making them valuable crops for future food systems.

Introduction
Bihar is an agrarian state in India where agriculture supports a large part of the economy and livelihoods. Yet, its farmers face increasing climate risks: erratic rainfall, more frequent floods and droughts, rising temperatures, and disruptions to cropping seasons. Traditional staple cereals—rice, wheat, maize—and pulses are under stress from these climatic variabilities. There is a strong need for diversification toward crops that are better adapted to abiotic stresses.

Pseudocereals—non-graminaceous grains such as amaranth, quinoa, buckwheat, chia, and fox nut (makhana) among others—offer promise in this respect. Although not yet as widely cultivated in Bihar as the main cereals, they have traits that could make them valuable tools in state's climate resilience, nutritional enrichment, and agro-economic diversification.

What are Pseudocereals & their Resilience Traits
Pseudocereals are plants whose seeds are used like cereals but belong to different families than grasses. Key resilience traits include:

1. Drought tolerance: Many pseudocereals have deep or ramified root systems, enabling extraction of moisture from deeper soil layers. They often require less overall water input.

2. Tolerance to poor soils: They can grow in soils with lower fertility, sometimes with higher salinity or pH extremes.

3. Short growing cycles: Many mature more rapidly, allowing flexibility in shifting cropping patterns when weather windows are narrow.

4. Nutritional superiority: High protein content, better essential amino acids, often rich in micronutrients (iron, zinc, calcium) and beneficial phytochemicals. This helps address "hidden hunger".

5. Low external input requirement: Many pseudocereals can perform reasonably without heavy chemical fertilization or high pesticide regimens. This suits small / marginal farmers with limited resources.

Relevance to Bihar's Agro-Climatic Context
Bihar exhibits a range of climate challenges:

a. Changes in rainfall (amount, seasonality), leading to more frequent floods in the north and droughts elsewhere.
b. Rising minimum temperatures, which affect rabi (winter) crops and crop growth periods.
c. Dependency on Kharif monsoon; rainfall variability translates to high risk in kharif crops.
d. Fragmented land holdings, small and marginal farmers, and limited irrigation in many areas.

In this context, pseudocereals can offer several advantages:

a. They can be deployed in rainfed or partially irrigated areas, helping to reduce dependency on monsoon reliability.
b. In flood-prone or drought-prone districts, having crops that can survive stress can reduce complete crop failures.
c. The shorter maturity period allows them to fit into cropping calendars where the main cereals fail due to shifts in seasons.
d. Improved nutrition among local populations—many of whom are dietarily vulnerable—is possible through inclusion of pseudocereals.

Additionally, makhana (fox nut) is already a crop of cultural-economic importance in Bihar (Madhubani, Darbhanga etc.), and there are moves for its organic cultivation and improved varieties. Its sensitivity to water, and dependence on

wetland ecosystems, however, also makes it vulnerable under changing climatic conditions. This shows both the promise and the risks that need careful management.

Potential Pseudocereals for Bihar

Here are some candidates which could be considered for wider adoption in Bihar:

1. Makhana (fox nut-pond based): already grown; improvements to its genetics, management, wetland protection, drying and processing would enhance resilience.

2. Quinoa: though more often tried in higher or cooler areas, varieties exist which tolerate wide temperature ranges and can grow under lower inputs. Its protein content makes it useful for nutrition.

3. Amaranth: both grain amaranth and leafy varieties; useful for marginal soils, short growing periods, and potential for dual use (leaves + grains).

4. Buckwheat: short duration, tolerates cooler or damp soils; however, might face challenges in warm/hot lowlands unless adapted varieties are used.

Challenges in Adopting Pseudocereals in Bihar

While the potential is strong, several hurdles must be addressed for pseudocereals to play a real role:

1. Seed availability and adapted varieties:
- a. Lack of locally adapted, high-yielding, stress tolerant pseudocereal varieties suited to Bihar's many agro-ecological zones.
- b. Seed multiplication, quality control, and access for small farmers are limited.

2. Knowledge & extension systems:
- a. Farmers often lack familiarity with pseudocereals in terms of cultivation practices: sowing times, spacing, pest and disease management, harvest & postharvest processing.
- b. Extension services are still more focused on traditional staples.

3. Market and value chain constraints:
- a. Even if yield is good, lack of reliable markets, processing facilities, consumer awareness limits profitability.
- b. Postharvest handling (drying, storage, milling) is often rudimentary.

4. Climatic extremes beyond tolerance:
- a. While pseudocereals are more resilient, extreme events (severe floods, prolonged droughts, heat waves) may still severely damage them.
- b. Some crops like makhana are very sensitive to water regime changes.

5. Policy support & investment:
- a. Subsidies, incentives, procurement policies are often aligned to major staples (rice, wheat). Pseudocereals generally don't enjoy such support.
- b. Infrastructure investment (irrigation, processing, storage) is required.

Strategies & Policy Recommendations

To leverage pseudocereals for climate resilience in Bihar, a multi-pronged approach is needed. Below are suggested strategies:

1. Research & Breeding:
- a. Identify, test and release varieties of pseudocereals (quinoa, amaranth, buckwheat etc.) adapted to Bihar's lowland, flood-prone, heat-stressed, and drought-stressed zones.
- b. Work on traits like shorter maturity, high tolerance to temperature extremes, disease resistance, salinity tolerance.

2. Seed systems & extension:
- a. Set up seed hubs or community seed banks for pseudocereals.
- b. Train extension agents and farmers in best cultivation practices, including climate-smart practices (mulching, soil moisture conservation, intercropping etc.).

3. Integration into cropping systems:
- a. Use pseudocereals as part of crop rotation or intercropping to break pest cycles, improve soil fertility, and spread risk.
- b. For example, in Kharif-Rabi cycles, or in fallow periods.

4. Infrastructure & processing:
- a. Improve post-harvest infrastructure (drying, storage) to reduce losses.

b. Develop small-scale processing units for value addition (e.g. popping makhana, flour from quinoa or amaranth) to fetch better price.

5. Market development & consumer awareness:

a. Promote pseudocereals in public nutrition programmes (school meals, mid-day meals) to generate stable demand.

b. Branding, GI tags (as with Mithila makhana) can help; organic cultivation could fetch premium.

6. Policy & financial incentives:

a. Include pseudocereals in climate-resilience agriculture programmes and subsidy schemes.

b. Provide insurance support, credit facilities designed for riskier or less well-known crops.

7. Ecological conservation:

a. For crops like makhana, protection and restoration of wetland ecosystems are vital to maintaining water regimes.

b. Soil conservation, flood control, rainwater harvesting to buffer climate extremes.

Emerging Initiatives in Bihar

1. The Bihar Agricultural University has launched an **Organic Makhana Cultivation Programme (OMCP)** under "Know Your Crop (KYC-Makhana)", aiming for scientific and organic methods, a high-yielding variety (Sabour Makhana-1) and expanding cultivation area.

2. Under its **Climate-Resilient Agriculture (CRA)** programme, the Bihar government is encouraging crop diversification and promoting crops requiring less water, especially in water-scarce districts in south Bihar.

These are positive steps showing recognition by the state government of the need for diversification and resilience.

Conclusion

Pseudocereals have high potential to contribute to climate resilience, nutritional security, and diversified livelihoods in Bihar. Their capacity to tolerate stressors—drought, variable rainfall, poor soils—aligns well with the climate challenges the state is already facing and expected to face more strongly in future. However, realizing this potential requires purposive action: breeding and seed work, extension, markets, infrastructure, policy support, and ecological conservation. If managed well, pseudocereals could be part of Bihar's path toward more resilient, nutritious, and sustainable agriculture, reducing vulnerability of small and marginal farmers and helping protect food security in a changing climate.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Development of Camel Milk Powder- A New Product Concept (Specialty Nutrition)

Article ID: 72776

Urmila Parmar[1]
[1]Food Safety Officer, Health Department, Bhavnagar Municipal Corporation.

Introduction

India's dairy market is experiencing a paradigm shift with increasing interest in specialty and functional dairy products. Camel milk, traditionally consumed in arid regions, is gaining global recognition for its unique nutritional profile and therapeutic properties. Camel Milk Powder addresses the challenges of limited shelf-life and geographical availability of fresh camel milk while preserving its bioactive compounds. This product targets health-conscious consumers, individuals with lactose intolerance, diabetics, and parents seeking alternative nutrition for children with cow milk allergies.

Advantages of Camel Milk

1. Easier to digest than cow milk with lower lactose content
2. Rich in insulin-like proteins beneficial for diabetics
3. Contains immunoglobulins and lactoferrin with antimicrobial properties
4. Suitable for individuals with cow milk protein allergies
5. High in vitamin C, iron, and unsaturated fatty acids
6. Proven benefits in autism spectrum disorders and autoimmune conditions.

Target Audience

1. Individuals with cow milk allergies or lactose intolerance
2. Diabetic patients seeking functional foods
3. Parents of children with autism spectrum disorders
4. Health and wellness enthusiasts
5. Athletes and fitness professionals
6. Export markets in Middle East, Europe, and North America.

SWOT Analysis

Strengths:

a. Unique nutritional profile with therapeutic benefits
b. Growing scientific evidence supporting health claims
c. Premium positioning and high margins

Weaknesses:

a. Limited raw material availability
b. High production cost
c. Consumer unfamiliarity in mainstream markets

Opportunities:

a. Rising demand for specialty and functional dairy
b. Government support for camel husbandry
c. Export potential to premium markets

Threats:

a. Seasonal variation in milk supply
b. Competition from plant-based alternatives
c. Regulatory challenges for health claims.

Market Research

Gap in Market: Limited availability of standardized camel milk products in powder form

Consumer Insights: Growing awareness of camel milk benefits among urban health-conscious consumers

Trend Analysis: Increasing demand for lactose-free, hypoallergenic, and functional dairy products.

Product Overview

Description:

a. Spray-dried camel milk powder from pure camel milk
b. Retains bioactive compounds and nutritional properties
c. Extended shelf-life (12-18 months)
d. Easy reconstitution with water
e. No additives or preservatives
f. Suitable for direct consumption, beverages, and food applications.

Ingredient Sourcing

1. Fresh camel milk from certified camel farms
2. Sourcing from Rajasthan, Gujarat, and Kutch regions
3. Quality parameters: SPC, coliform count, adulterant testing
4. Optional: Vitamin D3 fortification as per FSSAI standards.

Product Formulation

Ingredient	Quantity	% w/w
Fresh Camel Milk	10 kg (for 1 kg powder)	100.0
Spray drying yield	~1 kg powder	10% yield
Optional: Vitamin D3	400-800 IU per 100g	0.01

Nutritional Information (Approx)

Nutrient (per 100 g)	Value
Energy	495-510 kcal
Protein	24-26 g
Total Fat	22-26 g
Carbohydrates	36-38 g
Lactose	3.5-4.5 g
Calcium	900-1100 mg
Iron	0.8-1.2 mg
Vitamin C	3.5-4.5 mg

Process Flow Diagram

Raw camel milk collection → Chilling (4°C) → Filtration/Clarification → Standardization → Pasteurization (72°C/15 sec) → Homogenization → Preheating → Spray drying (Inlet 180-200°C, Outlet 80-90°C) → Powder collection → Sieving → Metal detection → Packaging → Storage (cool & dry).

HACCP Plan (Summary)

Process Step	Hazard	Control Measure	CCP
Raw milk receiving	Biological/Chemical	Supplier approval, testing, COA	Yes
Pasteurization	Microbial survival	Temperature-time monitoring	Yes
Spray drying	Microbial/moisture	Temperature control, moisture testing	Yes
Metal detection	Physical (metal)	Metal detector calibration	Yes
Packaging	Moisture ingress	Nitrogen flushing, sealed packaging	No

Costing Calculation (Indicative)

Component	Cost (INR/kg)
Raw camel milk (10 kg @ 90-120/L)	900-1200
Processing & spray drying	150-200
Packaging (premium pouches)	50-80
Overheads, QC & certification	100-150
Total Cost	1200-1630

Suggested MRP	2500-3500

FSSAI Requirements

1. Product category: Milk powder - Specialty dairy product
2. Valid FSSAI Central License mandatory
3. Compliance with FSS (Food Products Standards and Food Additives) Regulations, 2011
4. Labeling as per FSS (Labelling & Display) Regulations, 2020
5. Nutritional declaration mandatory
6. Batch coding, manufacturing date, and expiry date required
7. Storage instructions and reconstitution method on label.

Testing

1. Sensory evaluation (color, flavor, texture after reconstitution)
2. Proximate analysis (fat, protein, moisture, ash)
3. Microbiological testing (SPC, yeast & mold, coliforms, pathogens)
4. Functional properties (solubility index, dispersibility)
5. Shelf-life studies under accelerated and real-time conditions
6. Heavy metal analysis and pesticide residue testing.

Packaging & Storage

1. Multi-layer laminated pouches with aluminum foil barrier
2. Nitrogen flushing to prevent oxidation
3. Resealable zip-lock packaging for consumer convenience
4. Store in cool, dry place below 25°C
5. Avoid direct sunlight and moisture
6. Shelf-life: 12-18 months from manufacturing.

Commercialization

1. Premium health food stores and organic outlets
2. E-commerce platforms (Amazon, health-focused websites)
3. Direct-to-consumer model through company website
4. Export to Middle East, Europe, and North America
5. B2B supply to hospitals, clinics, and wellness centers.

Marketing Strategy

Positioned as a premium specialty nutrition product targeting health-conscious consumers, individuals with dietary restrictions, and parents seeking alternative nutrition. Emphasis on scientific research, therapeutic benefits, and traditional wisdom. Distribution through health stores, online platforms, medical practitioners, and export channels. Marketing through digital campaigns, influencer partnerships, medical endorsements, and participation in health and wellness expos.

Conclusion

Camel Milk Powder represents a significant innovation in specialty dairy nutrition, combining traditional knowledge with modern processing technology. With its unique nutritional profile, therapeutic potential, and growing consumer awareness, this product addresses critical market gaps in functional dairy and alternative nutrition segments. The product offers substantial opportunities for premium positioning and export markets while contributing to the development of camel husbandry in India.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Development of Salted Buttermilk with Electrolytes- A New Product Concept (Functional Beverage)

Article ID: 72777

Urmila Parmar[1]
[1]Food Safety Officer, Health Department, Bhavnagar Municipal Corporation.

Introduction

India's traditional beverages are experiencing a modern renaissance with functional fortification. Buttermilk (chaas), a staple in Indian households, is naturally probiotic-rich and aids digestion. With rising temperatures, active lifestyles, and increasing health awareness, there is growing demand for natural hydration solutions. Salted Buttermilk with Electrolytes combines traditional wisdom with sports nutrition science, offering natural rehydration, digestive benefits, and electrolyte replenishment. This product targets fitness enthusiasts, outdoor workers, athletes, and health-conscious consumers seeking natural alternatives to synthetic sports drinks.

Advantages of Electrolyte Fortification

1. Rapid rehydration and electrolyte balance restoration
2. Natural probiotics support gut health and immunity
3. Lower sugar content compared to commercial sports drinks
4. Aids in post-workout recovery and reduces muscle cramps
5. Traditional taste with functional benefits
6. Suitable for hot climates and physically demanding activities.

Target Audience

1. Athletes and fitness enthusiasts
2. Outdoor workers and laborers
3. Sports teams and gyms
4. Individuals in hot and humid climates
5. Health-conscious consumers seeking natural hydration
6. Institutional buyers (schools, offices, factories).

SWOT Analysis

Strengths:

a. Traditional Indian beverage with proven benefits
b. Natural probiotic and electrolyte source
c. Lower cost than imported sports drinks

Weaknesses:

a. Limited shelf-life (7-14 days under refrigeration)
b. Cold chain dependency
c. Taste preferences vary regionally.

Opportunities:

a. Growing sports and fitness culture in India
b. Rising demand for natural and clean-label beverages
c. Government initiatives promoting traditional foods.

Threats:

a. Competition from established sports drink brands
b. Consumer perception of buttermilk as a home-made product
c. Seasonal demand variations.

Market Research

Gap in Market: Lack of natural, probiotic-rich sports drinks with Indian flavor profile.

Consumer Insights: Increasing preference for natural ingredients over synthetic additives.

Trend Analysis: Growth in functional beverages, sports nutrition, and traditional food revival.

Product Overview

Description:

a. Traditional buttermilk fortified with essential electrolytes.
b. Contains sodium, potassium, magnesium, and calcium.
c. Natural probiotics from buttermilk culture.
d. Low-fat, refreshing, and naturally cooling.
e. Spiced with cumin, mint, and black salt for authentic taste.
f. Ready-to-drink format in PET bottles or tetra packs.

Ingredient Sourcing

1. Fresh buttermilk from standardized milk
2. Electrolyte salts: sodium chloride, potassium chloride, magnesium sulfate, calcium lactate
3. Natural flavoring: roasted cumin powder, dried mint, black salt
4. Preservatives (optional): Class II preservatives as per FSSAI
5. Water (potable, treated).

Product Formulation (Per 1 Liter)

Ingredient	Quantity	% w/v
Buttermilk (cultured)	700 ml	70.0
Water (potable)	270 ml	27.0
Sodium chloride (common salt)	1.5 g	0.15
Potassium chloride	0.5 g	0.05
Magnesium sulfate	0.3 g	0.03
Calcium lactate	0.4 g	0.04
Roasted cumin powder	1.5 g	0.15
Dried mint powder	0.5 g	0.05
Black salt (kala namak)	1.0 g	0.10
Black pepper powder	0.2 g	0.02
Citric acid	0.3 g	0.03
Optional: Class II preservative	As per FSSAI	-

Nutritional Information (Approx)

Nutrient (per 200 ml serving)	Value
Energy	45-55 kcal
Protein	2.5-3.0 g
Total Fat	1.0-1.5 g
Carbohydrates	6-7 g
Sodium	300-350 mg
Potassium	200-250 mg
Magnesium	25-30 mg
Calcium	120-150 mg
Probiotics (CFU)	10^6 - 10^8

Process Flow Diagram

Milk receiving → Standardization (fat 1.5%) → Pasteurization (90°C/5 min) → Cooling (30°C) → Inoculation with culture → Fermentation (18-20 hrs) → Churning → Addition of water and spices → Electrolyte mixing → Homogenization → Pasteurization (72°C/15 sec) → Cooling (4-6°C) → Filling in sterile bottles/packs → Storage under refrigeration (2-4°C).

HACCP Plan (Summary)

Process Step	Hazard	Control Measure	CCP
Raw milk receiving	Microbial/Chemical	Supplier approval, testing	Yes
Pasteurization	Pathogen survival	Temperature-time monitoring	Yes

Fermentation	Contamination	Culture purity, time-temp control	Yes
Electrolyte addition	Incorrect dosing	Weighing accuracy, verification	No
Final pasteurization	Recontamination	Sanitation, temperature control	Yes
Filling	Microbial contamination	Aseptic conditions, sterile packaging	Yes

Costing Calculation (Indicative)

Component	Cost (INR/Liter)
Raw milk for buttermilk	25-30
Electrolyte salts	2-3
Spices and flavoring	3-4
Culture and fermentation	2-3
Processing and pasteurization	5-7
Packaging (PET bottle/Tetra pack)	8-12
Cold chain and logistics	5-8
Overheads & QC	4-6
Total Cost	54-73
Suggested MRP (200ml pack)	15-25

FSSAI Requirements

1. Product category: Fermented milk products - Dahi/Buttermilk
2. Valid FSSAI State/Central License mandatory
3. Compliance with FSS (Food Products Standards and Food Additives) Regulations, 2011
4. Labeling as per FSS (Labelling & Display) Regulations, 2020
5. Nutritional and electrolyte declaration mandatory
6. Storage conditions: "Store under refrigeration at 2-4°C"
7. Shelf-life: 7-14 days from manufacturing
8. Use of permitted preservatives and additives only.

Testing

1. Sensory evaluation (taste, flavor, texture, appearance)
2. Physicochemical analysis (acidity, pH, fat, SNF)
3. Electrolyte content verification (Na, K, Mg, Ca)
4. Microbiological testing (SPC, coliform, yeast & mold, LAB count)
5. Probiotic viability testing
6. Shelf-life studies under refrigerated conditions
7. Heavy metal and pesticide residue analysis.

Packaging & Storage

1. Food-grade PET bottles (200 ml, 500 ml, 1 liter)
2. Tetra Pak or aseptic cartons for extended shelf-life
3. Tamper-proof sealing
4. Storage: Maintain cold chain at 2-4°C throughout distribution
5. Shelf-life: 7-14 days under proper refrigeration
6. Display clear "Keep Refrigerated" instruction on label.

Commercialization

1. Modern retail chains and supermarkets (chilled section)
2. Sports stores and gym outlets
3. Online grocery platforms with cold chain delivery
4. Institutional sales: schools, offices, factories, construction sites
5. Tie-ups with sports clubs and fitness centers
6. Vending machines in gyms and sports complexes.

Marketing Strategy

Positioned as a natural sports drink combining traditional Indian wisdom with modern sports nutrition. Target fitness enthusiasts, athletes, and outdoor workers through digital campaigns, influencer partnerships, and sports event sponsorships. Emphasize natural ingredients, probiotic benefits, lower sugar content, and electrolyte balance. Distribution through retail, institutional channels, and direct-to-consumer models. Sampling campaigns at gyms, marathons, cycling events, and construction sites to build awareness and trial.

Conclusion

Salted Buttermilk with Electrolytes represents a successful fusion of traditional Indian beverages with functional sports nutrition. By addressing the growing demand for natural hydration solutions, this product offers a compelling alternative to synthetic sports drinks while supporting digestive health through probiotics. With proper cold chain management and strategic marketing, this product has significant potential in India's rapidly growing functional beverage market, appealing to both traditional consumers and modern fitness enthusiasts.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Next-Generation Farming: Integrating AI and Blockchain in Agriculture

Article ID: 72778

Abhilash[1]
[1]College of Agriculture, University of Agricultural Sciences, Dharwad.

Summary of Article

The agricultural sector is experiencing a digital revolution driven by Artificial Intelligence (AI) and blockchain technology. AI enables precision farming through data-driven insights related to soil health, weather forecasting, and crop management. Meanwhile, blockchain ensures transparency, traceability, and trust across agricultural supply chains. The combined use of these technologies helps address key challenges such as low productivity, food fraud, delayed farmer payments, and inefficient market systems. This article highlights the applications, benefits, challenges, and future potential of AI and blockchain in transforming modern agriculture.

Introduction

Agriculture is essential for global food security and rural livelihoods, particularly in developing economies. However, the sector faces increasing challenges such as climate variability, shrinking natural resources, labor shortages, and post-harvest losses. Traditional farming methods, often based on experience rather than data, restrict productivity and sustainability (FAO, 2021).



Figure: AI-enabled drone monitoring in agriculture

Digital technologies offer promising solutions. Artificial Intelligence (AI) enhances decision-making through predictive analytics and automation, while blockchain technology provides secure and transparent data sharing across the agricultural value chain. Together, they represent a transformative shift toward smart, resilient and sustainable farming systems (Tripoli and Schmidhuber, 2018).

Role of Artificial Intelligence in Agriculture

AI plays a vital role in enabling precision agriculture. By analyzing data from satellites, drones, sensors, and weather stations, AI systems deliver real-time recommendations for irrigation, fertilization, and pest management (Kamilaris and Prenafeta-Boldú, 2018).

Machine learning models are widely used for crop yield prediction, disease detection and soil classification. Image recognition tools enable the early identification of pests and plant diseases, reducing crop losses and minimizing chemical usage (Liakos *et al.*, 2018).

AI-driven automation, including robotic harvesters and autonomous tractors, reduces dependence on manual labor while improving efficiency and consistency in farm operations.

Blockchain Technology in Agriculture

Blockchain technology introduces decentralization, transparency and immutability into agricultural systems. It is particularly effective in improving supply chain traceability and ensuring food safety.

Each transaction from farm production to processing and retail is recorded on a distributed ledger, reducing fraud and increasing consumer trust (Tian, 2017). Blockchain-based smart contracts automate agreements and payments, ensuring timely compensation to farmers and reducing the role of intermediaries (Kshetri, 2018).

Integration of AI and Blockchain in Farming

The integration of AI and blockchain creates a secure, intelligent agricultural ecosystem. AI generates insights from agricultural data, while blockchain ensures secure storage and trusted data sharing among stakeholders.

For example, AI-generated yield data stored on blockchain can support crop insurance claims and agricultural credit systems, reducing risks for farmers and financial institutions (Casino *et al.*, 2019). This integration also supports sustainability monitoring, including water use efficiency and carbon footprint tracking.

Table 1: Applications of AI and Blockchain in Agriculture:

Sl. No.	Technology	Application Area	Description	Benefits
1.	AI	Precision Farming	Data-driven irrigation, fertilization and crop monitoring	Higher yields, reduced input costs
2.	AI	Disease & Pest Detection	Image-based identification of crop diseases	Early intervention, reduced losses
3.	Blockchain	Supply Chain Traceability	Tracking food products from farm to consumer	Transparency, food safety
4.	Blockchain	Smart Contracts	Automated payments and agreements	Faster payments, reduced intermediaries
5.	AI + Blockchain	Crop Insurance & Finance	Secure yield data for claims and loans	Reduced risk, financial inclusion

Challenges and Limitations

Despite their potential, the adoption of AI and blockchain faces challenges such as high implementation costs, limited rural connectivity, lack of digital literacy and concerns about data ownership and privacy (World Bank, 2020).

Addressing these challenges requires investment in rural broadband infrastructure, capacity-building initiatives and farmer-friendly digital platforms.

Conclusion

Artificial Intelligence and blockchain technology are reshaping agriculture into a smart, transparent and sustainable sector. AI improves productivity and resource efficiency, while blockchain strengthens trust and traceability across supply chains. Their combined application empowers farmers, enhances food safety and supports sustainable development.

As global food demand rises and environmental pressures intensify, integrating AI and blockchain into agriculture will be crucial for building resilient and future-ready farming systems. Policy support, public–private partnerships and farmer education are critical to ensuring that these technologies deliver real benefits on the ground.

References

1. Casino F., Dasaklis T. K., and Patsakis C., (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and Informatics*. 36, 55–81.
2. FAO, (2021). *The State of Food and Agriculture*. Food and Agriculture Organization of the United Nations.
3. Kamilaris A., and Prenafeta-Boldú, F. X., (2018). Deep learning in agriculture: A survey. *Computers and Electronics in Agriculture*. 147, 70–90.
4. Kshetri N., (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*. 39, 80–89.
5. Liakos K. G., Busato P., Moshou D., Pearson S., and Bochtis D., (2018). Machine learning in agriculture: A review. *Sensors*. 18(8), 2674.
6. Tian F., (2017). A supply chain traceability system for food safety based on blockchain technology. *IEEE International Conference on Service Systems and Service Management*.
7. Tripoli M., and Schmidhuber J., (2018). *Emerging opportunities for the application of blockchain in the agri-food industry*. FAO & ICTSD.
8. World Bank., (2020). *Agriculture and Food Digital Transformation*. World Bank Publications.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Plastic Pandemic: Challenges and Innovations in Reducing Single-Use Waste

Article ID: 72779

Ch. Sneha Latha[1], Dr. Swetha Kodali[2]

[1]Assistant Professor Department of Resource Management and Consumer Science, College of Community Science, PJTAU, Saifabad, Hyderabad.

[2]Scientist, Family Resource Management, All India Coordinated Research Project on Women in Agriculture, PG&RC, Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, Telangana, India - 500 030.

Every day, millions of plastic products are used once then discarded. From water bottles and grocery bags to food packaging and disposable cutlery, single-use plastics have become deeply embedded in modern life. Their convenience, low cost, and versatility have made them ubiquitous. Yet behind this convenience lies a mounting environmental crisis — a plastic pandemic that is altering ecosystems, threatening wildlife, and even influencing human health.

In this article, we explore the challenges posed by single-use plastics and the innovative solutions emerging worldwide to reduce this waste.

The Plastic Explosion

Since the 1950s, global plastic production has skyrocketed. What began as a useful material for medical devices and durable goods soon expanded into packaging and disposable products. Today, annual plastic production exceeds 400 million tonnes, nearly half of which is designed for single use. Most of this waste ends up in landfills, incinerators, or the natural environment. Only a small fraction is recycled effectively, and even then, the quality of recycled plastic often diminishes with each cycle.

Plastics are durable by design — an advantage for products but a serious problem for waste. Materials like polyethylene and polypropylene can persist in the environment for hundreds to thousands of years. Over time, larger plastic items fragment into microplastics — tiny particles less than 5 millimeters in size — which infiltrate soils, waterways, and oceans.

Global Impact on Ecosystems

The impact of plastic waste on ecosystems is severe and widespread:

1. Marine life: Millions of tons of plastic enter the oceans each year. Sea turtles, seabirds, and marine mammals often ingest plastic debris or become entangled, leading to injury, starvation, or death.

2. Food webs: Microplastics accumulate in plankton and small fish, moving up the food chain and ultimately reaching humans through seafood.

3. Soil and freshwater systems: Microplastics have been detected in agricultural soils and freshwater bodies, affecting soil structure, nutrient cycling, and aquatic organisms.

The environmental persistence of plastics means that even if production were halted today, the legacy of past use would continue to affect ecosystems for generations.

Human Health Concerns

Plastic pollution isn't just an environmental issue — it's a human health concern too. Microplastics have been found in drinking water, table salt, indoor dust, and even human tissues. While research is still emerging, studies suggest potential health effects related to:

1. Chemical exposure: Plastics often contain additives such as phthalates and bisphenol A (BPA), known to disrupt endocrine function.

2. Inflammation and toxicity: Ingested microplastics can trigger inflammation or carry toxic chemicals from the environment into the body.

Although the full impact on human health remains under study, the ubiquity of plastics in our food, water, and air underscores the urgency of addressing this problem.

Barriers to Reducing Single-Use Plastics

Efforts to reduce plastic waste face several key challenges:

1. Consumer Habits: Convenience drives the use of single-use plastics. Changing behavior — such as using reusable bags, bottles, and utensils — requires sustained education and incentives.

2. Economic Factors: Plastic production is cheap due to inexpensive fossil fuel feedstocks. Alternatives like biodegradable materials or reusable systems often cost more, limiting adoption without subsidies or regulation.

3. Recycling Limitations: Not all plastics are recyclable. Even when they are, contamination and inadequate infrastructure reduce recycling rates dramatically. Downcycling — converting plastic into lower-quality products — further reduces material value.

4. Policy Gaps: Globally, policies addressing plastic waste vary widely. While some nations have banned specific single-use items (like plastic bags or straws), others lack enforcement or comprehensive waste management systems.

Innovations Leading the Way

Despite these challenges, scientists, engineers, policymakers, and communities are developing creative solutions to curb single-use waste:

1. Biodegradable and Compostable Materials: Researchers are developing plastics derived from renewable sources such as corn starch, sugarcane, or algae. These materials can break down under specific conditions, reducing long-term pollution. Some are fully compostable in industrial facilities, while others biodegrade in natural environments.

However, these alternatives are not a panacea — they often require specific conditions to degrade and can contaminate recycling streams if not properly sorted.

2. Chemical Recycling: Unlike mechanical recycling, which grinds plastics into lower-grade products, chemical recycling breaks polymers down into their chemical building blocks. These can be reused to produce new, high-quality plastics. Although still emerging at scale, chemical recycling offers a way to reclaim materials previously considered unrecyclable.

3. Reuse and Refill Systems: Many businesses are adopting reuse models that reduce packaging waste. For example, refill stations for cleaning products, beverages, and personal care items allow consumers to bring containers back for refilling. Retailers and startups are experimenting with reverse vending machines and deposit systems that reward returning containers.

4. Extended Producer Responsibility (EPR): EPR policies require manufacturers to take responsibility for the end-of-life management of their products. This can include financing recycling programs, designing more recyclable products, and reducing packaging material. Countries with strong EPR frameworks often see higher recycling rates and lower waste generation.

5. Public Awareness and Education: Public campaigns that highlight the impacts of plastic waste help shift behavior. From beach cleanups to social media movements, education empowers individuals to make sustainable choices and pressure businesses and policymakers to act.

Success Stories Around the World

Several regions have demonstrated meaningful progress:

1. European Union: The EU's Single-Use Plastics Directive bans certain disposable items and sets ambitious recycling targets.

2. Kenya: One of the world's strictest bans on plastic bags has significantly reduced their use.

3. Japan and South Korea: Advanced waste management systems and high recycling rates showcase how infrastructure and policy can work together.

These examples illustrate that with political will and innovation, reducing plastic waste is achievable.

The Road Ahead

The fight against single-use plastic waste is not simple — nor is it quick. It requires systemic change across production, consumption, and waste management. Effective solutions will combine technological innovation with strong policies, economic incentives, and cultural shifts.

No single strategy will solve the plastic pandemic alone. Instead, a **multipronged approach** — reducing consumption, redesigning materials, strengthening recycling, and fostering global collaboration — offers the best path forward.

As consumers, producers, and citizens of the planet, we each have a role to play. Reducing single-use waste not only protects ecosystems and wildlife but also safeguards human health and opens the door to sustainable, circular economies.

References

1. Geyer, R., Jambeck, J.R., & Law, K.L. (2017). *Production, use, and fate of all plastics ever made*. Science Advances, 3(7), e1700782.
2. Thompson, R.C., et al. (2009). *Plastics, the environment and human health: current consensus and future trends*. Philosophical Transactions of the Royal Society B.
3. Jambeck, J.R., et al. (2015). *Plastic waste inputs from land into the ocean*. Science, 347(6223), 768–771.

4. Ellen MacArthur Foundation. (2016). *The New Plastics Economy: Rethinking the Future of Plastics.*
5. Lebreton, L., & Andrady, A. (2019). *Future scenarios of global plastic waste generation and disposal.* Palgrave Communications.
6. Hopewell, J., Dvorak, R., & Kosior, E. (2009). *Plastics recycling: challenges and opportunities.* Philosophical Transactions of the Royal Society B.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

History of Induced Breeding of Fish: An Overview

Article ID: 72780

Prem Kumar[1], Safal Shandilya[1], Kedar Nath Mohanta[1]
[1]ICAR-Central Institute of Fisheries Education, Panch Marg, Off Yari Road, Versova, Andheri (W), Mumbai-400061.

Aschheim and Zondek (1927), reported that when pituitary is implanted in female mice it accelerated its sexual development, which paves the bedrock of induced breeding in current scenarios to produce and increase large number of larvae for sustainable aquaculture.

Argentina

Houssay (1931) of Argentina used pituitary extracted from *Prochilodus platensis* to induce gonadal maturity and spawning in a small viviparous catfish, *Cresterodondecam maculatus* which marked a turning point in hypophysation technology.

Brazil

The hypophysation technology was further refined by Von Ihering for breeding of locally available fish by administration of suspension of pituitary glands (Cardoso, 1934; Von Ihering, 1937). Therefore, Brazil is said to be the first country to introduce hypophysation technique.

Russia

Anadromous sturgeons (*Acipenser stellatus*) were induced to spawn via hypophysation technique by Russian scientist (Gerbil'skii, 1938).

USA

The rainbow trout (*Oncorhynchus mykiss*) in the United States were successfully induced to spawn by injecting pituitary extract from carps (Hasler et al., 1939).

Japan

Fujita et al. (1946) effectively induced spawning in loach by giving pituitary hormones, resulting in the production of fish seed under controlled conditions in Japan.

India

Khan (1938) in India made the first attempt to stimulate spawning in *Cirrhinus mrigala* (Hamilton) in India by injecting mammalian pituitary extract. In the 1950s, pituitary extract injection was used to successfully induce breeding in carp minnows (*Esomus danricus*) and catfish (*Pseudotropius atherinoides*) (Chaudhuri, 1955). Pituitary hormones extract was used to breed singhi (*Heteropneustes fossilis*) (Ramaswamy and Sundararaj, 1956, 1957). In 1957, at CIFRI, Cuttack the hypophysation of Indian main carps, including *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*, was accomplished with remarkable and historic success (Chaudhuri and Alikunhi, 1957). Alikunhi et. al., (1963), successfully bred the exotic Chinese carps – *Hypophthalmichthys molitrix* & *Ctenopharyngodon idella*.

China

In 1958, China with its extensive history of fish culture, employs hypophysation technique to generate fish seed of rapidly developing carps, including silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthys nobilis*), for aquaculture purposes (Bhowmick, 2018). Also, in 1960 artificial propagation of grass carp (*Ctenopharyngodon idella*) was succeeded by using pituitary gland of common carp (Sah, 2017).

Malaysia

In Malaysia, Chen et al. (1969) induced spawning in silver carp, grass carp, and bighead carp by combining a little amount of common carp pituitary with Synohorin, a preparation of H.C.G. (Human chorionic gonadotropin).

Present

Lin-Pe Method was developed by Lin and Peter (Lin et. al., 1988). In this method, combination of gonadotropin-releasing hormone analogue (GnRH-a) and a dopamine antagonist is used for induce breeding of fish. Currently most of the commercial hormones used available for fish breeding is based on this method.

References

1. Alikunhi, K. H., Sukumaran, K. K., and Parameswaran, S. (1963). Induced spawning of the Chinese carps, *Ctenopharyngodon idella* (C. & V.) and *Hypophthalmichthys molitrix* (C. & V.) in the ponds at Cuttack, India. *Current Science*, *32*(3), 103-106.
2. Aschheim, S., and Zondek, B. (1927). *Klinische Wochenschrift*, *28*.
3. Cardoso, D. M. (1934). Relations entre 1'hypophyse et les organes sexuels chez les poissons. *Compt. Rend. Soc. Biol.*, *115*, 1347-1349.
4. Chaudhuri, H. (1955). Successful spawning of the carp minnow, *Esomus danricus* by pituitary gland injection. University of Calcutta, Calcutta. (PhD thesis)
5. Chaudhuri, H., and Alikunhi, K. H. (1957). Observations on the spawning of Indian carps by hormone injection. *Current Science*, *26*(12), 381-382.
6. Chen, F.Y., Chow, M. and Sim, B.K. (1969). Induced spawning of the major Chinese carps in Mdacca, Malaysia. *Malay. Agric. J.* (Malaysia), *47*, 24-38.
7. Fujita, T., Uno, K., Yatsunagi, K., and Kobuta, Z. (1946). On the artificial taking of eggs of loach by injection of Pituitary Hormone. *Contr. Cent. Fish Stn. Jap.*, *44*, 254-258.
8. Gerbil'skii, N. L. (1938). Expedition for the study of the Physiology of Spawning. *Rybonoe khoziaistvo*, *18*(10), 33-36.
9. Hasler, A. D., Meyer, R. K., and Field, H. M. (1939). Spawning induced prematurely in trout with the aid of pituitary glands of the carp. *Endocrinology*, *25*, 978-983.
10. Houssay, B. A. (1931). Action sexuelle de I' hypophyse Sur les poissons etles reptiles. *Comptes Rendus de la Société de Biologie et de ses Filiales*, *106*, 377- 378.
11. Khan, H. (1938). Ovulation in fish (Effect of administrating of anterior lobe of mammalian pituitary gland). *Current Science*, *7*(5), 233-234.
12. Lin, H. R., VanderKraak, G., Zhou, X. J., Liang, J. Y. , Peter, R. E., Rivier, J. E., Vale, W. W. (1988). Effects of [DArg6, Trp7, Leu8, Pro9NEt]-luteinizing hormone-releasing hormone (sGnRH-A) and [D-Ala6, Pro9NEt]-luteinizing hormone-releasing hormone (LHRH-A), in combination with pimozide or domperidone, on 102 gonadotropin release and ovulation in the Chinese loach and common carp. General and *Comparative Endocrinology*, *69*(1), 31-40.
13. Ramaswamy, L. S., & Sundararaj, B. I. (1957). Inducing spawning in the Indian catfish Heteropneustes with pituitary injections. *Cells Tissues Organs*, *31*(4), 551-562.
14. Ramaswamy, L. S., and Sundararaj, B. J. (1956). Inducing spawning in the Indian cat fish. *Science*, *123*(326), 1080.
15. Sah, R. (2017). *Effect of Ovulin on Induced Breeding in Rohu (Labeo rohita,* Hamilton, 1822*) and Naini (Cirrhinus mrigala,* Hamilton, 1822*)* at *Fish Development and Training Centre, Janakpur Nepal* (Doctoral dissertation, Department of Zoology).
16. Von Ihering, R. (1937). A method for inducing fish to spawn. *The Progressive Fish-Culturist*, *4*(34), 15-16.



Fig. Administration of hormone through intramuscular injection (I/M)

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Breeding Better Pulses: Seeds of India's Protein Revolution

Article ID: 72781

S. Suganthi[1], S. Vennila[2]
[1]Assistant Professor (Plant Breeding and Genetics),
[2]Assistant Professor (*Forestry*),
Agricultural College and Research Institute, Tamil Nadu Agricultural University, Vazhavachanur, Tiruvannamalai.

Summary
Pulses, despite their diminutive size, possess considerable importance in nutrition and agriculture, particularly in India, where they serve as a principal source of plant-based protein. India is the foremost global producer of pulses, yielding 244.93 lakh tonnes in FY 2024, essential for food security and land fertility. Notwithstanding their significance, pulse yields frequently remain low because to drought, pests, and climate change. Plant breeding is essential for improving pulse cultivars to achieve higher yields and increased resistance. Success narratives encompass disease-resistant chickpeas and high-yield pigeonpea hybrids. Contemporary breeding involves farmer engagement and sophisticated technology such as CRISPR, with the objective of developing climate-resilient and nutrient-dense cultivars. Given that pulses enhance nutritional security and promote sustainable agriculture, India's current breeding initiatives aim to amplify these advantages, thereby facilitating a Protein Revolution for healthier populations and resilient farms.

Introduction
Small Seeds, Big Impact: Pulses may be small, however their significance in our lives is substantial. The edible seeds of leguminous plants, including chickpea, lentil, pigeonpea, and mung bean, have sustained Indian cuisine for ages. The Food and Agriculture Organization (FAO) identifies pulses as one of the most significant sources of plant-based protein globally (FAO, 2016). Pulses are distinguished by their elevated protein content, which ranges from 20 to 25 percent—nearly double that of wheat and thrice that of rice (Jukanti *et al.*, 2012). Pulses are the essential foundation of daily nourishment for millions of Indians, particularly vegetarians.

In India: The Global Pulse Leader
India stands tall as the **largest producer of pulses globally**, growing nearly all major pulse crops, including chickpea, pigeonpea, mung bean, urad bean, lentil, field pea, and cowpea (Government of India, 2024). In FY 2024 alone, India produced **244.93 lakh tonnes of pulses**, reflecting their growing importance in national food security.

Different pulses flourish in different regions:

a. Chickpea in central India
b. Pigeonpea in southern states
c. Green gram and black gram in rice fallows
d. Lentil in northern India.

Beyond food, pulses improve soil fertility by fixing atmospheric nitrogen, reducing the need for chemical fertilizers and making farming more sustainable (FAO, 2016; ICAR, 2018).

Why Do We Need Better Pulses?
Notwithstanding their significance, pulse yields frequently remain suboptimal. Agriculturists encounter persistent adversities like drought, pests, diseases, and suboptimal soil conditions. Climate change has exacerbated these issues (Singh *et al.*, 2016). Plant breeding is essential in this context.

The Science Behind Stronger Pulses
Plant breeding is the process of choosing superior plants and combining their advantageous traits. Scientists enhance pulse variations by hybridizing high-yielding strains with drought- or disease-resistant types, resulting in greater performance in agricultural settings (Upadhyaya *et al.*, 2011). Creating a new variety requires years of meticulous testing across several places and seasons. Only those that continuously exhibit high performance are approved for cultivation, guaranteeing reliability for farmers.

Success Stories from Indian Fields
The effects of pulse breeding are already evident throughout India. Varieties of chickpeas, including JG 11 and KAK 2, have resistance to wilt disease and demonstrate high yields in arid regions. The pigeonpea hybrids ICPH 2671 and ICPH 2740 have surpassed yield limitations, providing farmers with increased profitability (Varshney *et al.*, 2018). In rice-

based systems, early-maturing mung bean varieties such as VBN 3 and CO 8 enable farmers to cultivate an additional crop utilizing residual soil moisture. Simultaneously, biofortified pulses fortified with iron and zinc are addressing hidden hunger and enhancing nutritional health (Bohra *et al.*, 2020). These improvements are changing lives—one field at a time.

Breeding for a Changing Climate

Increasing temperatures and erratic precipitation necessitate more intelligent solutions. Contemporary breeders employ advanced technologies like genetic markers and genomics to more swiftly and precisely identify climate-resilient plants (Varshney *et al.,* 2018). The objective is clear yet impactful: develop pulse types that use less water, withstand heat, and fight emerging pests—guaranteeing consistent yields despite unpredictable weather conditions.

Farmers and Scientists: A Shared Journey

Modern breeding is no longer confined to laboratories. Through **participatory plant breeding**, farmers work alongside scientists to select varieties that suit local conditions. This approach improves adoption and ensures that research truly benefits those on the ground (Chaturvedi *et al.*, 2014).

The Road Ahead

The future of pulse improvement lies in combining tradition with technology. Advanced tools like **CRISPR gene editing, artificial intelligence, and digital field monitoring** promise faster and smarter breeding (Varshney et al., 2018). Equally important is bringing pulses back into crop rotations, where they restore soil health, reduce fertilizer costs, and strengthen sustainable agriculture (FAO, 2016).

A Seed of Hope

Pulses are more than just food—they are a solution to nutritional insecurity, climate challenges, and soil degradation. Thanks to the dedication of plant breeders and farmers, India is steadily moving toward a **Protein Revolution**. Every improved pulse variety is a **seed of hope**—for healthier families, stronger farms, and a resilient agricultural future.

Conclusion

Pulses may be small in size, but their importance to India's food system, nutrition, and sustainability is immense. As a rich and affordable source of protein, they form the backbone of diets for millions while also improving soil health and reducing dependence on chemical fertilizers. In the face of climate change, shrinking resources, and rising nutritional needs, pulses offer a smart and sustainable solution.

Through continuous efforts in plant breeding—blending traditional wisdom with modern science—India is strengthening its pulse sector with high-yielding, climate-resilient, and nutrient-rich varieties. These improved pulses are not only enhancing farm productivity and incomes but also contributing to better health and food security. Every new pulse variety released is more than a scientific achievement; it is a promise of healthier people, resilient farms, and a sustainable agricultural future. In nurturing these tiny seeds, India is truly sowing the foundations of a lasting Protein Revolution.

References

1. Bohra, A., Jha, U. C., Adhimoolam, P., Bisht, D., & Singh, N. P. (2020). Biofortification in pulses: A sustainable approach for nutritional security. *Frontiers in Plant Science, 11*, 1–15. https://doi.org/10.3389/fpls.2020.01268
2. Chaturvedi, S. K., Ali, M., & Kumar, S. (2014). Participatory varietal selection in pulses for enhancing adoption and productivity. *Indian Journal of Agricultural Sciences, 84*(7), 839–845.
3. Food and Agriculture Organization of the United Nations (FAO). (2016). *Pulses: Nutritious seeds for a sustainable future*.
4. Government of India. (2024). *Agricultural statistics at a glance*. Ministry of Agriculture & Farmers Welfare, New Delhi.
5. Indian Council of Agricultural Research (ICAR). (2018). *Vision 2030: Indian Institute of Pulses Research*. ICAR-IIPR, Kanpur.
6. Jukanti, A. K., Gaur, P. M., Gowda, C. L. L., & Chibbar, R. N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.). *British Journal of Nutrition, 108*(S1), S11–S26. https://doi.org/10.1017/S0007114512000797
7. Singh, N. P., Kumar, R., & Chauhan, J. S. (2016). Pulses production in India: Present status, bottleneck and way forward. *Journal of AgriSearch, 3*(2), 75–83.
8. Upadhyaya, H. D., Dwivedi, S. L., Ambrose, M., Ellis, N., Berger, J., Smýkal, P., & Debouck, D. (2011). Legume genetic resources: Management, diversity assessment, and utilization in crop improvement. *Euphytica, 180*(1), 27–47.

9. Varshney, R. K., Thudi, M., Roorkiwal, M., He, W., Upadhyaya, H. D., & Gaur, P. M. (2018). Legume genomics and breeding for climate change adaptation. *New Phytologist, 217*(1), 13–18. https://doi.org/10.1111/nph.14874.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Paecilomyces lilacinus: An Effective Biological Control Agent for the Management of Plant-Parasitic Nematodes

Article ID: 72782

K. S. Jotangiya[1], Vaishali Dangar[2], Payal J. Kodavala[3]
[1]Agri. Officer, NAU, Navsari.
[2]M.Sc. student, Department of Plant breeding and Genetics, NAU, Navsari.
[3]Ph.D. Scholar, Department of Plant Pathology, JAU, Junagadh.

Abstract
Plant-parasitic nematodes are among the most destructive soil-borne pests, causing significant yield losses in agricultural crops worldwide. The extensive use of chemical nematicides has raised serious concerns related to environmental pollution, human health hazards, and soil biodiversity loss. In this context, biological control has emerged as a sustainable and eco-friendly alternative. *Paecilomyces lilacinus* (recently reclassified as *Purpureocillium lilacinum*) is a well-known egg-parasitic fungus that has demonstrated high efficacy against major plant-parasitic nematodes, particularly root-knot nematodes (*Meloidogyne* spp.). This article reviews the taxonomy, morphology, mode of action, target nematodes, methods of application, advantages, and limitations of *P. lilacinus*, highlighting its importance in integrated nematode management and sustainable agriculture.

Keywords: *Paecilomyces lilacinus* (*Purpureocillium lilacinum*), biological control, plant-parasitic nematodes, root-knot nematode, sustainable agriculture.

Introduction
Plant-parasitic nematodes represent a major constraint to global agricultural productivity, inflicting heavy economic losses on a wide range of crops. Among them, root-knot nematodes (*Meloidogyne* spp.), cyst nematodes (*Heterodera* and *Globodera* spp.), and reniform nematodes (*Rotylenchulus reniformis*) are of particular importance. Traditionally, nematode management has relied heavily on chemical nematicides; however, their adverse effects on the environment, non-target organisms, and human health have necessitated the development of safer alternatives.



Figure 1. Microscopic and Cultural Characteristics of *Paecilomyces lilacinus*: Conidiophores with Chains of Conidia and Lilac-Coloured Colony Growth on Potato Dextrose Agar (PDA)

Biological control using antagonistic microorganisms has gained prominence as a sustainable approach to nematode management. Among fungal bioagents, *Paecilomyces lilacinus* has been extensively studied and commercially exploited due to its strong egg-parasitic activity against several economically important nematodes. Its ability to survive in soil, colonize the rhizosphere, and significantly reduce nematode reproduction makes it a valuable component of integrated nematode management strategies.

Taxonomy and Classification
1. Kingdom: Fungi
2. Phylum: Ascomycota
3. Class: Sordariomycetes
4. Order: Hypocreales

5. Genus: Purpureocillium
6. Species: *Paecilomyces lilacinus*

The reclassification of *P. lilacinus* into the genus *Purpureocillium* was based on molecular and phylogenetic studies, although the former name is still widely used in agricultural literature.

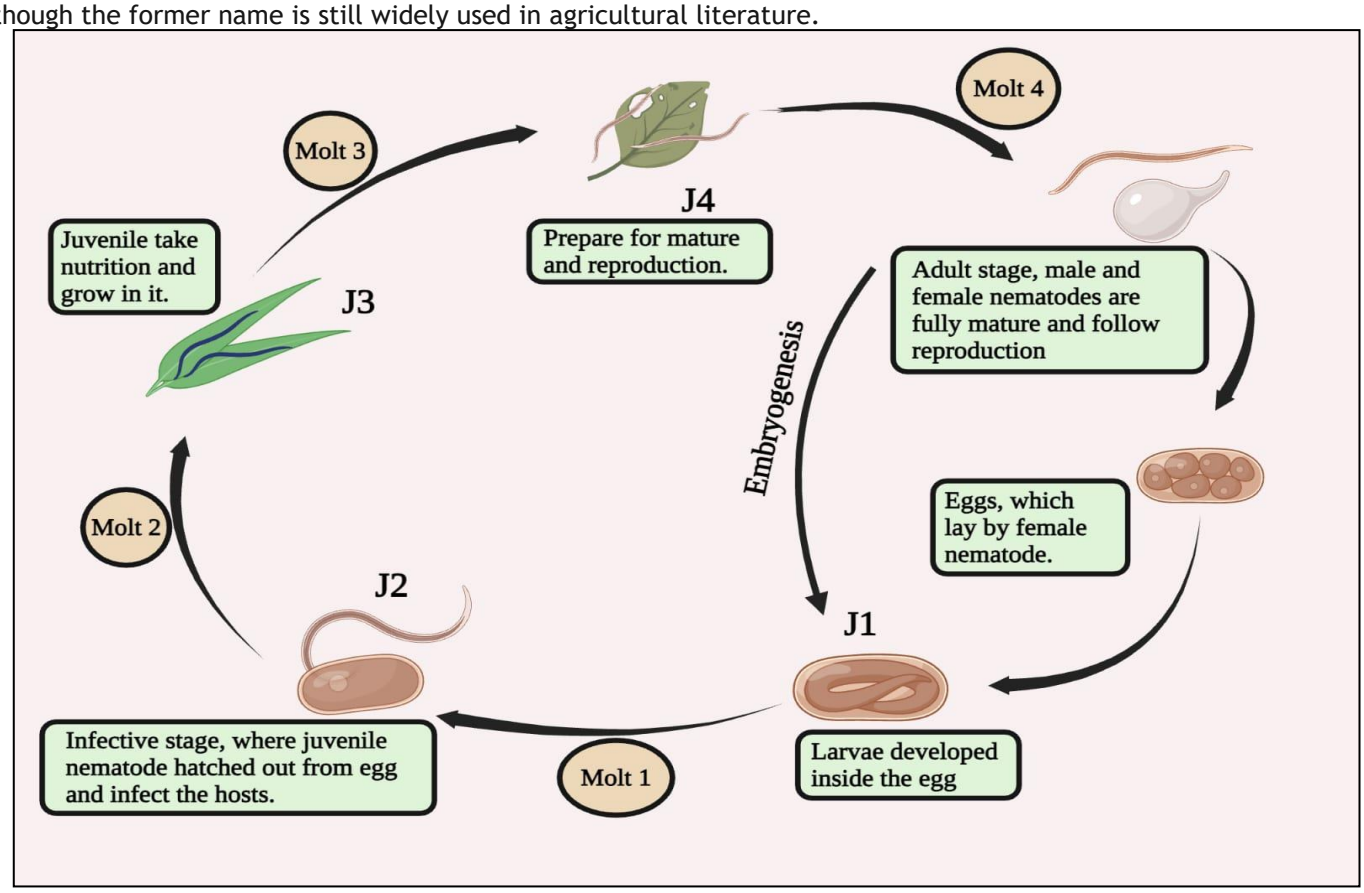


Figure 2. General Life Cycle of Plant Parasitic Nematode

Morphological Characteristics

Paecilomyces lilacinus produces fast-growing colonies that range in color from lilac to violet on Potato Dextrose Agar (PDA). The mycelium is hyaline and septate. Conidiophores are branched and bear phialides that produce chains of oval to ellipsoidal conidia. The fungus sporulates profusely, contributing to its persistence and effectiveness in soil environments.

Target Plant-Parasitic Nematodes

Paecilomyces lilacinus is effective against a wide range of nematodes, including:

1. *Meloidogyne* spp. (root-knot nematodes)
2. *Heterodera* spp. (cyst nematodes)
3. *Globodera* spp.
4. *Rotylenchulus reniformis* (reniform nematode)

Its highest efficacy has been reported against the **egg stage** of root-knot nematodes.

Mode of Action

The biocontrol activity of *Paecilomyces lilacinus* is primarily attributed to the following mechanisms:

Egg Parasitism: The fungus penetrates the nematode egg shell by producing lytic enzymes such as chitinases and proteases, leading to destruction of the embryo and inhibition of egg hatching.

Juvenile Infection: In addition to eggs, the fungus can infect second-stage juveniles (J2), causing mortality and reduced infectivity.

Reduction in Nematode Reproduction: By destroying egg masses and reducing egg viability, *P. lilacinus* significantly suppresses nematode population buildup in soil.

Rhizosphere Competence: The fungus colonizes the rhizosphere effectively, maintaining prolonged antagonistic activity against nematodes.

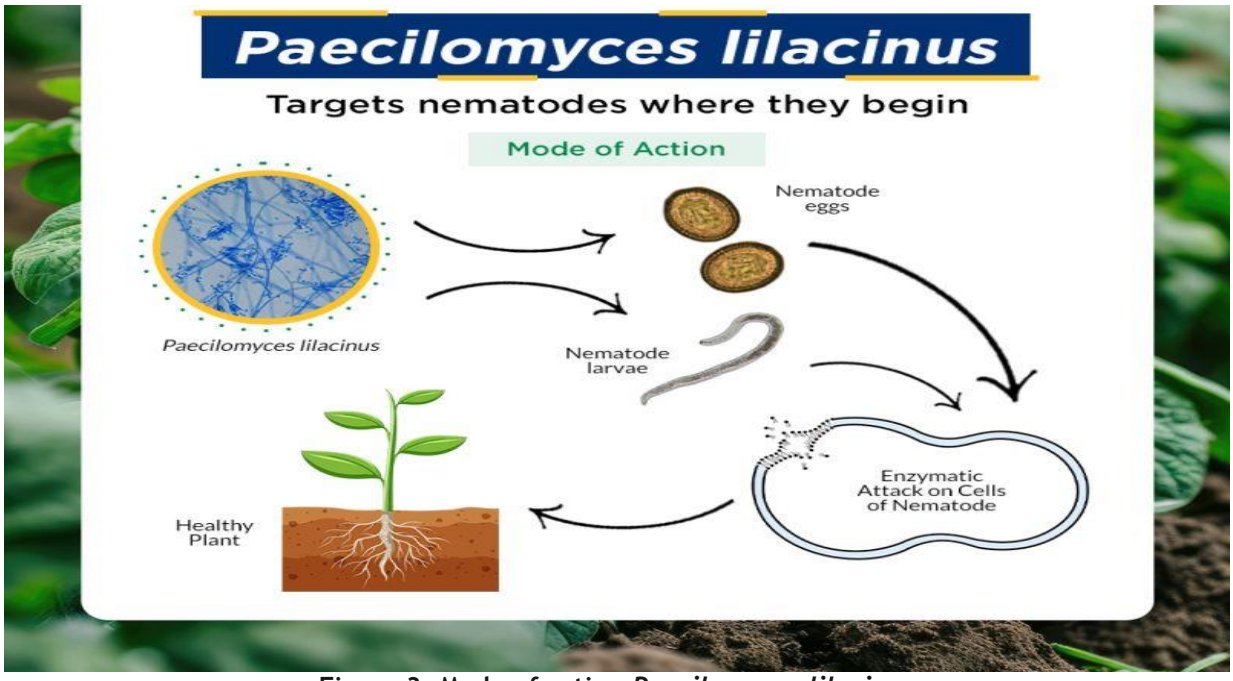


Figure 3. Mode of action *Paecilomyces lilacinus*

Methods of Application

Soil Application: Carrier-based formulations of *P. lilacinus* are applied at 2-5 kg/ha, often mixed with farmyard manure or compost.

Nursery Bed Treatment: Application at 50-100 g/m² helps reduce nematode infestation at the seedling stage.

Seed Treatment: Seeds are treated with 5-10 g/kg seed to protect seedlings during early growth.

Root Dip Treatment: Seedlings are dipped in a spore suspension before transplanting to ensure early root colonization.

Advantages

1. Eco-friendly and biodegradable
2. Safe to humans, animals, and beneficial soil organisms
3. Compatible with organic and integrated farming systems
4. Reduces dependence on chemical nematicides
5. Long-term suppression of nematode populations.

Limitations

1. Slower action compared to chemical nematicides
2. Effectiveness influenced by soil moisture and temperature
3. Requires proper formulation and application techniques.

Role in Integrated Nematode Management

Paecilomyces lilacinus performs best when integrated with other management practices such as crop rotation, organic amendments (neem cake), resistant varieties, and other biocontrol agents. Such integrated approaches enhance nematode suppression and ensure sustainable crop production.

Conclusion

Paecilomyces lilacinus is one of the most promising fungal bioagents for the biological management of plant-parasitic nematodes. Its strong egg-parasitic activity, ecological adaptability, and environmental safety make it an essential tool in sustainable agriculture. Wider adoption of *P. lilacinus* as part of integrated nematode management strategies can significantly reduce crop losses while minimizing the environmental footprint of agriculture.

References

1. Stirling, G.R. (1991). Biological Control of Plant Parasitic Nematodes. CAB International, Wallingford, UK.
2. Siddiqui, Z.A., & Mahmood, I. (1996). Biological control of plant parasitic nematodes by fungi: A review. Bioresource Technology, 58, 229–239.

3. Kerry, B.R. (2000). Rhizosphere interactions and the exploitation of microbial agents for the biological control of plant-parasitic nematodes. Annual Review of Phytopathology, 38, 423–441.
4. Khan, M.R., & Saxena, S.K. (1997). Effect of *Paecilomyces lilacinus* on root-knot nematode infecting tomato. Nematologia Mediterranea, 25, 31–35.
5. Kumar, S., et al. (2012). Management of root-knot nematode using *Paecilomyces lilacinus*. Indian Journal of Nematology, 42, 1–8.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Pseudomonas putida: A Versatile Plant-Associated Bacterium for Sustainable Agriculture and Environmental Applications

Article ID: 72783

K. S. Jotangiya[1], Payal J. Kodavala[2], Vaishali Dangar[3]
[1]Agri. Officer, NAU, Navsari.
[2]Ph.D. Scholar, Department of Plant Pathology, JAU, Junagadh.
[3]M.Sc. student, Department of Plant breeding and Genetics, NAU, Navsari.

Summary
Pseudomonas putida is a Gram-negative, aerobic, rod-shaped bacterium widely distributed in soil, rhizosphere, and plant-associated environments. It is well recognized for its remarkable metabolic versatility, ecological adaptability, and beneficial interactions with plants. This bacterium plays an important role in sustainable agriculture through plant growth promotion, suppression of phytopathogens, and enhancement of plant tolerance to abiotic stresses. In addition, *P. putida* is extensively studied for its capacity in bioremediation due to its ability to degrade a wide range of organic pollutants. Its multifunctional nature, environmental safety, and adaptability make *Pseudomonas putida* a promising bioinoculant and biotechnological tool for eco-friendly agricultural and environmental management systems.

Introduction
Soil and plant-associated bacteria form complex interactions with plants, influencing their growth, health, and productivity. Among these beneficial microorganisms, species belonging to the genus *Pseudomonas* have gained considerable attention due to their ecological significance and functional diversity. *Pseudomonas putida* is a non-pathogenic, free-living bacterium commonly found in agricultural soils, rhizosphere, and occasionally in endophytic habitats of plants.

The success of *P. putida* in diverse environments is largely attributed to its broad metabolic capabilities, enabling it to utilize a wide range of organic compounds as carbon and energy sources. This metabolic flexibility allows the bacterium to survive under nutrient-limited and stress-prone conditions commonly encountered in soil and plant-associated niches. In the rhizosphere, root exudates rich in sugars, amino acids, and organic acids serve as substrates that support the colonization and persistence of *P. putida*.

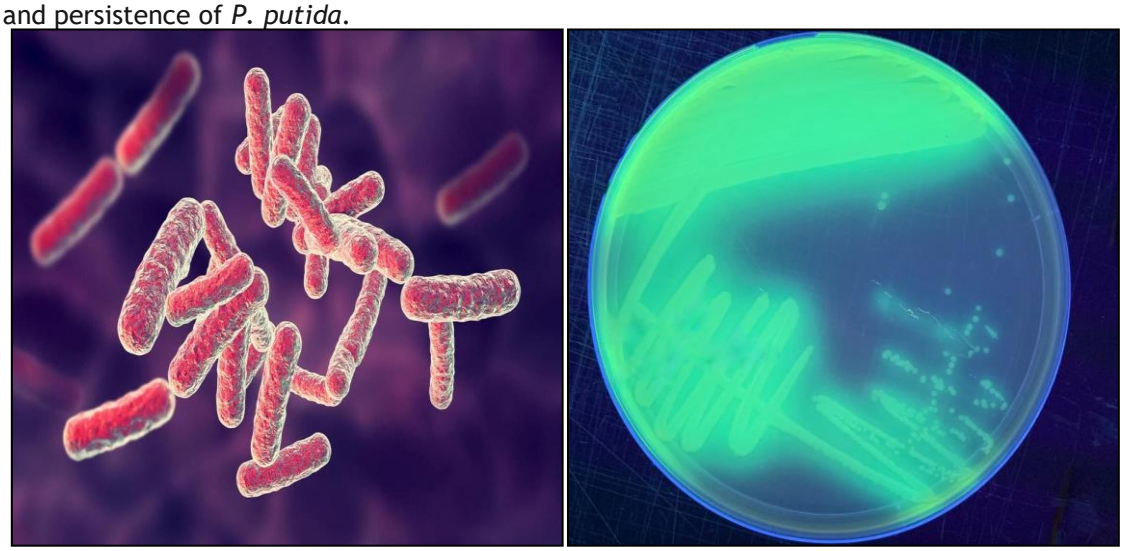


Figure 1. Morphology and Cultural Characteristics of *Pseudomonas putida*: Rod-Shaped Bacterial Cells and Fluorescent Pigment Production on Medium

Beyond survival, *Pseudomonas putida* establishes beneficial associations with plants by promoting growth, improving nutrient uptake, and protecting plants against pathogens and environmental stresses. Due to these traits, *P. putida* is increasingly explored as a biofertilizer, biocontrol agent, and an integral component of sustainable agriculture.

Characteristics of the Genus Pseudomonas with Special Reference to *Pseudomonas putida*
Pseudomonas putida belongs to the family Pseudomonadaceae and exhibits several distinctive morphological, physiological, and biochemical characteristics:
1. Cells are Gram-negative, rod-shaped, and non-spore forming
2. Aerobic in nature with oxidative metabolism

3. Motile, possessing one or more polar flagella
4. Colonies are generally smooth, circular, and creamy to pale yellow on nutrient agar
5. Capable of utilizing a wide range of organic compounds, including aromatic hydrocarbons
6. Produces siderophores that enhance iron acquisition
7. Exhibits strong rhizosphere competence
8. Non-pathogenic and considered biosafe for agricultural applications
9. Well-adapted to stress conditions, including salinity, drought, and presence of toxic compounds
10. *Pseudomonas putida* KT2440 is a well-characterized model strain frequently used in genetic, ecological, and biotechnological studies.

Plant-*Pseudomonas putida* Interaction

Pseudomonas putida interacts with plants primarily in the rhizosphere, where it colonizes root surfaces and utilizes root exudates. This interaction results in multiple direct and indirect benefits to plants.

Plant Growth Promotion Mechanisms

1. Production of indole-3-acetic acid (IAA), enhancing root elongation and branching
2. Solubilization of phosphates, improving nutrient availability
3. Synthesis of siderophores, facilitating iron uptake
4. Enhancement of nitrogen use efficiency
5. Improvement in root architecture and nutrient absorption.

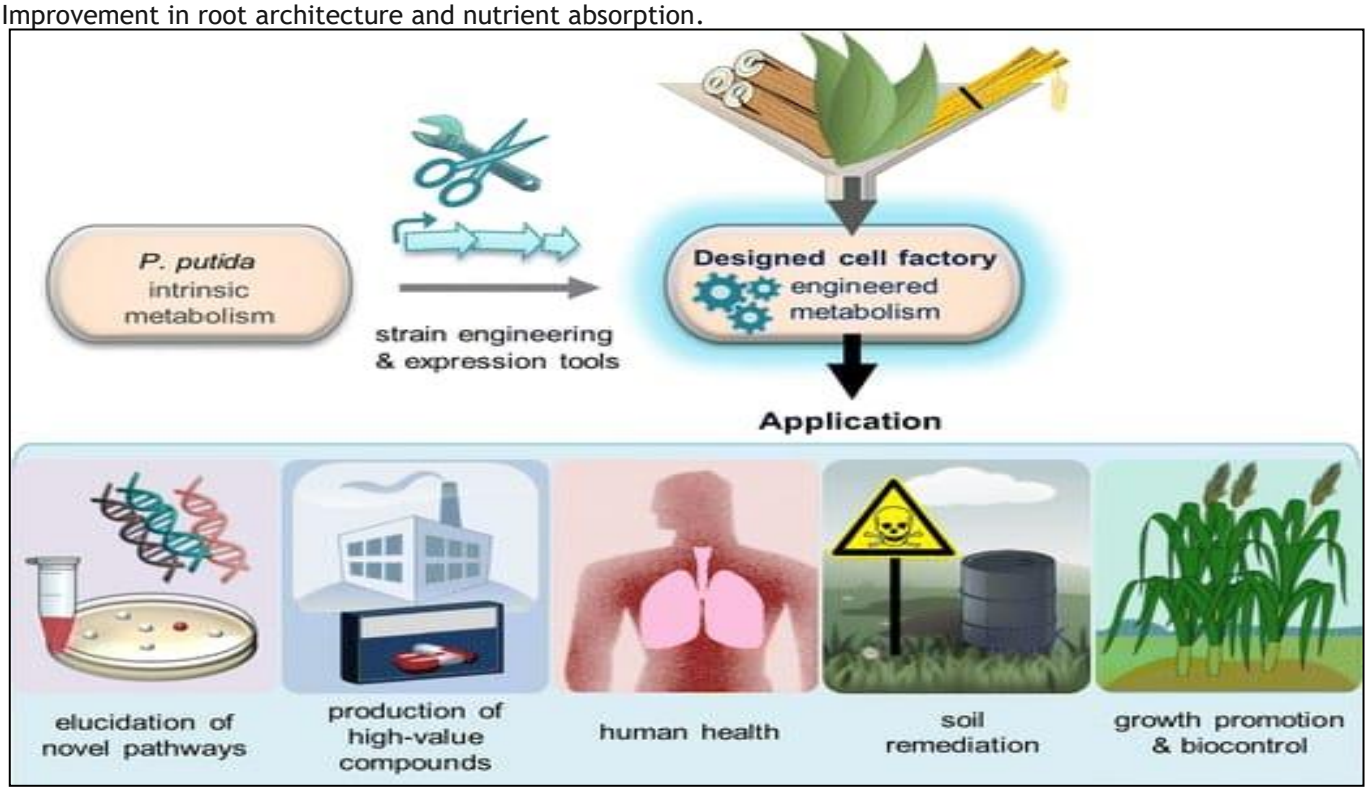


Figure 2. Engineering *Pseudomonas putida* as a Designed Cell Factory for Metabolic Innovation, Bioremediation, and Agricultural Applications

Role in Biocontrol of Plant Pathogens

1. *Pseudomonas putida* suppresses phytopathogens through several antagonistic mechanisms:
2. Production of antibiotics and antimicrobial metabolites
3. Competition for nutrients and ecological niches in the rhizosphere
4. Siderophore-mediated iron deprivation of pathogens
5. Induction of systemic resistance (ISR) in host plants
6. Biofilm formation on root surfaces, preventing pathogen establishment
7. These traits make *P. putida* an effective biocontrol agent against soil-borne pathogens such as Fusarium, Rhizoctonia, and Pythium species.

Role in Abiotic Stress Tolerance

1. *Pseudomonas putida* enhances plant tolerance to various abiotic stresses:
2. Improves plant performance under drought and salinity stress
3. Reduces oxidative stress by enhancing antioxidant enzyme activity
4. Produces ACC deaminase, lowering stress-induced ethylene levels
5. Enhances water-use efficiency and nutrient uptake under adverse conditions.

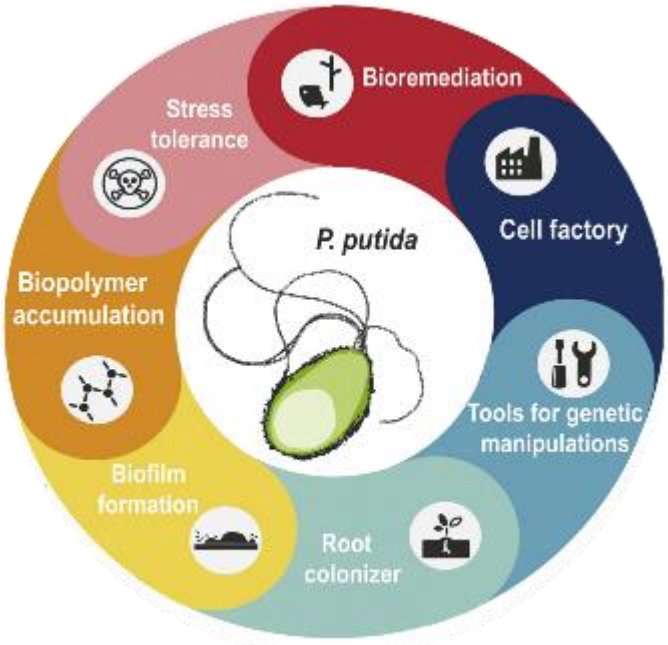


Figure 3. Multifunctional Roles of *Pseudomonas putida* in Plant Growth Promotion, Stress Tolerance, Bioremediation, and Biotechnological Applications

Environmental and Biotechnological Applications

1. Apart from agriculture, *Pseudomonas putida* is extensively utilized in environmental biotechnology:
2. Degradation of aromatic hydrocarbons and xenobiotic compounds
3. Application in bioremediation of contaminated soils and water
4. Used as a host for genetic engineering and metabolic pathway studies
5. Important role in sustainable waste management.

Methods of Application of *Pseudomonas putida*

Seed Treatment: Seeds coated with bacterial suspension improve germination and early seedling vigor.

Seedling Root Dip: Enhances root establishment and survival after transplanting.

Soil Application: Applied through soil drenching or mixed with compost or organic manure.

Bioformulation-Based Application: Used as liquid or carrier-based biofertilizer formulations for better shelf life and field performance.

Conclusion

Pseudomonas putida is a multifunctional, plant-beneficial bacterium with immense potential in sustainable agriculture and environmental management. Its ability to promote plant growth, suppress pathogens, enhance abiotic stress tolerance, and degrade environmental pollutants highlights its ecological and biotechnological significance. The integration of *P. putida*-based bioinoculants into modern agricultural practices can reduce dependency on chemical fertilizers and pesticides while improving crop productivity and environmental health. Further research on strain-specific interactions and formulation strategies will strengthen its practical applications under field conditions.

References

1. Weller, D.M. (2007). Pseudomonas biocontrol agents of soilborne pathogens: Looking back over 30 years. Phytopathology, 97, 250–256.
2. Lugtenberg, B., & Kamilova, F. (2009). Plant-growth-promoting rhizobacteria. Annual Review of Microbiology, 63, 541–556.

3. Ramos, J.L., et al. (2002). The versatility of Pseudomonas putida in environmental biotechnology. Environmental Microbiology, 4, 1–9.
4. Nelson, K.E., et al. (2002). Complete genome sequence and comparative analysis of the metabolically versatile Pseudomonas putida KT2440. Environmental Microbiology, 4, 799–808.
5. Glick, B.R. (2012). Plant growth-promoting bacteria: Mechanisms and applications. Scientifica, 2012, 1–15.
6. Haas, D., & Défago, G. (2005). Biological control of soil-borne pathogens by fluorescent pseudomonads. Nature Reviews Microbiology, 3, 307–319.
7. Mercado-Blanco, J., & Bakker, P.A.H.M. (2007). Interactions between plants and beneficial Pseudomonas spp. Molecular Plant–Microbe Interactions, 20, 699–709.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Ganoderma lucidum: The "Reishi" Mushroom - A Comprehensive Review of its Pharmacological Potential and Biotechnological Applications

Article ID: 72784

Payal J. Kodavala[1], K. S. Jotangiya[2], Vaishali Dangar[3]
[1]Ph.D. Scholar, Department of Plant Pathology, JAU, Junagadh.
[2]Agri. Officer, NAU, Navsari.
[3]M.Sc. student, Department of Plant breeding and Genetics, NAU, Navsari.

Abstract

Ganoderma lucidum, commonly known as Reishi or Lingzhi, is a medicinal mushroom widely recognized for its therapeutic properties. This fungus has been used in traditional medicine for over 2,000 years, especially in China and Japan. Modern scientific research has validated its health benefits, including immunomodulatory, anti-inflammatory, antioxidant, anticancer, hepatoprotective, antidiabetic, and neuroprotective effects. These effects are primarily attributed to bioactive compounds such as polysaccharides, triterpenoids, sterols, peptides, and phenolics. This review summarizes current knowledge on *Ganoderma lucidum*, including its taxonomy, morphology, bioactive compounds, mechanisms of action, clinical applications, cultivation techniques, and future research prospects. The article also highlights biotechnological advancements in enhancing yield and potency, as well as challenges and safety considerations.

Keywords: *Ganoderma lucidum*, Reishi, medicinal mushroom, polysaccharides, triterpenoids, immunomodulation, anticancer, biotechnology.

Introduction

Ganoderma lucidum is a woody fungus belonging to the family *Ganodermataceae*. It has a long history of use in traditional Asian medicine and is known as the "mushroom of immortality" due to its reputed health benefits. The mushroom grows on decaying hardwood trees and is characterized by its reddish-brown glossy cap and kidney-shaped fruiting body.

In modern times, *G. lucidum* has attracted global attention because of its wide range of bioactive compounds. Its extracts are widely used in dietary supplements, herbal medicines, and functional foods. Research indicates that it possesses strong pharmacological properties that could help manage various diseases, including cancer, diabetes, cardiovascular diseases, and neurodegenerative disorders.



Figure 1. Fruiting body of *Ganoderma lucidum* (Reishi mushroom) growing on wood (left) and its processed dried basidiocarp powder with whole fruiting bodies (right).

Taxonomy and Morphology

1. Kingdom: Fungi
2. Phylum: Basidiomycota
3. Class: Agaricomycetes
4. Order: Polyporales
5. Family: Ganodermataceae
6. Genus: Ganoderma

7. Species: *Ganoderma lucidum*.

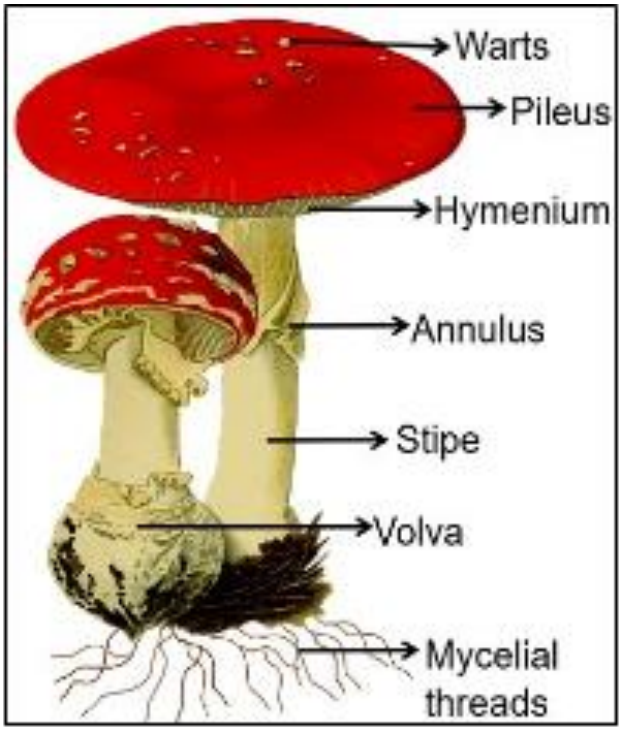


Figure 2. Generalized structure of a mushroom showing major morphological parts, including pileus, hymenium, annulus, stipe, volva, mycelial threads, and surface warts.

Morphology:

a. Cap: Reddish-brown, varnished appearance, kidney-shaped.
b. Texture: Hard, woody, and tough.
c. Pores: White pores on the underside; turns brown with age.
d. Spore: Double-walled with a unique ornamentation.

Bioactive Compounds

Ganoderma lucidum is rich in multiple bioactive substances, which are responsible for its medicinal effects:

1. Polysaccharides:

a. Major active components.
b. Include ß-glucans, heteropolysaccharides.
c. Known for immunomodulatory and antioxidant activities.

2. Triterpenoids:

a. Over 150 triterpenoids identified.
b. Responsible for anti-inflammatory, hepatoprotective, and anticancer effects.

3. Sterols:

a. Ergosterol and derivatives.
b. Help in cholesterol regulation and antioxidant activity.

4. Proteins & Peptides: Lectins and peptides with immunomodulatory properties.

5. Phenolics & Flavonoids: Provide antioxidant and anti-inflammatory benefits.

Pharmacological Properties

1. Immunomodulatory Activity: *Ganoderma lucidum* polysaccharides stimulate immune cells like macrophages, natural killer (NK) cells, and T lymphocytes. They enhance cytokine production (IL-2, IL-6, TNF-α), promoting immune defense against infections and tumors.

2. Anticancer Activity: Both polysaccharides and triterpenoids show anticancer potential through:

a. Inhibition of tumor growth
b. Induction of apoptosis (cell death)
c. Prevention of metastasis
d. Enhancement of immune response against tumor cells.

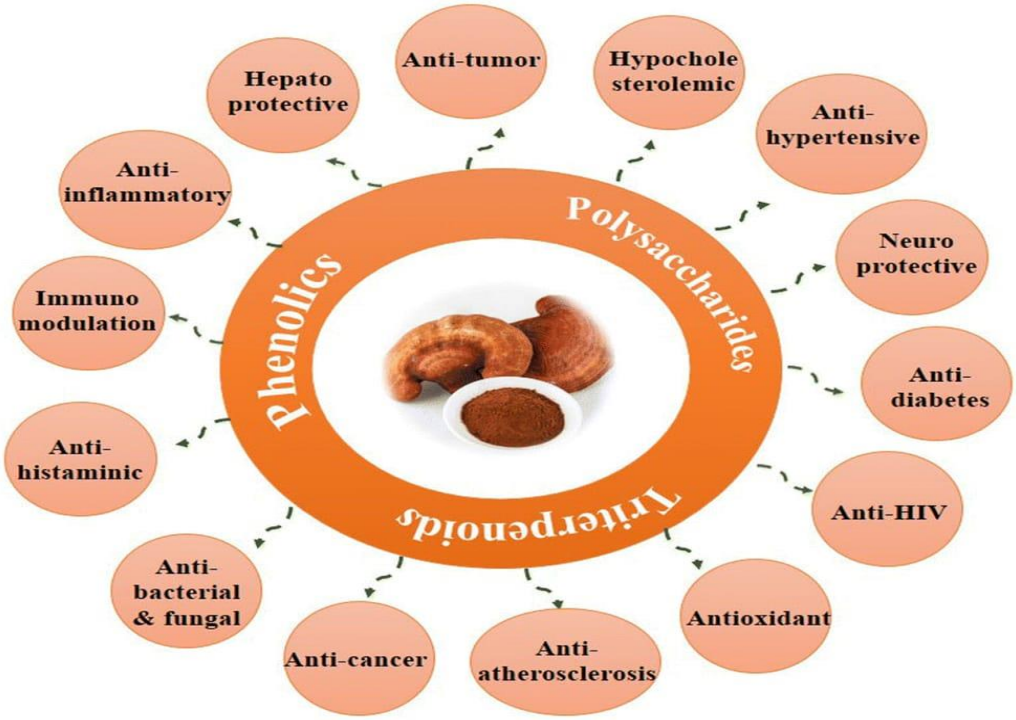


Figure 3.Bioactive compounds of Ganoderma lucidum and their pharmacological activities.

3. Antioxidant Activity: The mushroom contains powerful antioxidants that reduce oxidative stress by scavenging free radicals and enhancing antioxidant enzymes like SOD and catalase.

4. Anti-inflammatory Activity: Triterpenoids reduce inflammation by suppressing pro-inflammatory cytokines and inhibiting inflammatory pathways.

5. Hepatoprotective Effects: *Ganoderma lucidum* protects liver cells from toxins and promotes regeneration. It helps in reducing liver enzymes and improving liver functions.

6. Antidiabetic Effects: The polysaccharides improve insulin sensitivity, reduce blood glucose levels, and regulate lipid profiles.

7. Neuroprotective Effects: It protects nerve cells from damage, improves cognitive functions, and may help in neurodegenerative disorders like Alzheimer's disease.

Mechanism of Action

1. The therapeutic effects of *G. lucidum* involve multiple molecular pathways:
2. Activation of immune cells and cytokines
3. Inhibition of inflammatory pathways (NF-κB, COX-2)
4. Induction of apoptosis in cancer cells via mitochondrial pathway
5. Regulation of oxidative stress through antioxidant enzymes
6. Modulation of insulin signaling pathways.

Cultivation and Biotechnological Advances

1. *Ganoderma lucidum* is cultivated using:
2. Solid-state fermentation (SSF)
3. Submerged fermentation (SmF).

Substrate Optimization: Common substrates include:

a. Sawdust
b. Rice bran
c. Wheat straw
d. Cottonseed hulls.

Biotechnological Approaches:

a. Tissue culture for disease-free spawn
b. Genetic engineering for enhanced bioactive production

c. Elicitation using methyl jasmonate and other stimulants
d. Nanotechnology for better delivery of bioactives.

Commercial Applications

1. Nutraceuticals and dietary supplements
2. Herbal teas and capsules
3. Functional foods and beverages
4. Cosmetic products (anti-aging creams).

Safety and Toxicity

1. *Ganoderma lucidum* is generally safe for human consumption. However, high doses may cause:
2. Digestive upset
3. Allergic reactions
4. Interaction with blood thinners (warfarin).

Caution: Pregnant women and patients with bleeding disorders should consult doctors before using.

Future Prospects

1. Future research may focus on:
2. Clinical trials for standardized dosing
3. Identification of novel bioactive compounds
4. Advanced cultivation methods for higher yield
5. Genomic and metabolomic studies
6. Development of new formulations for better bioavailability.

Conclusion

Ganoderma lucidum is a promising medicinal mushroom with diverse therapeutic properties. Its bioactive compounds offer potential in treating chronic diseases and improving human health. With modern biotechnology, its production and potency can be enhanced, making it a valuable resource in pharmaceuticals and nutraceuticals. Future clinical research will further validate its benefits and help in developing safe and effective therapeutic products.

References

1. Wasser, S. P. (2011). Current findings, future trends, and unsolved problems in studies of medicinal mushrooms. Applied Microbiology and Biotechnology, 89(5), 1323-1332.
2. Paterson, R. R. M. (2006). Ganoderma—a therapeutic fungal biofactory. Phytochemistry, 67(18), 1985-2001.
3. Boh, B., Berovic, M., Zhang, J., & Zhi-Bin, L. (2007). Ganoderma lucidum and its pharmaceutically active compounds. Biotechnology Annual Review, 13, 265-301.
4. Sanodiya, B. S., Thakur, G. S., Baghel, R. K., Prasad, G. B. K. S., & Bisen, P. S. (2009). Ganoderma lucidum: a potent pharmacological macrofungus. Current Pharmaceutical Biotechnology, 10(8), 717-742.
5. Liu, J., Shimizu, K., & Kim, S. (2013). The bioactive components and health benefits of Ganoderma lucidum. Journal of Food Science, 78(8), R1244-R1250.
6. Lin, Z. B. (2005). Cellular and molecular mechanisms of immuno-modulation by Ganoderma lucidum. Journal of Pharmacological Sciences, 99(2), 144-153.
7. Fang, H., Wang, Q., & Li, J. (2014). Ganoderma lucidum polysaccharides: immunomodulation and potential anti-cancer activities. Journal of Ethnopharmacology, 154(1), 1-14.
8. Zeng, J., & Zhang, X. (2018). Ganoderma lucidum triterpenoids: bioactivities and potential health benefits. Frontiers in Pharmacology, 9, 1259.
9. Liu, Y., & Zhang, L. (2020). Advances in Ganoderma lucidum cultivation and biotechnology. Mycological Research, 124(10), 1140-1153.
10. Chen, H., Zhang, W., & Yu, Q. (2019). Ganoderma lucidum in modern medicine: therapeutic potential and clinical applications. Journal of Integrative Medicine, 17(2), 93-100.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

The Volatile Frontier: Harnessing Microbial Scents for Sustainable Pest Management

Article ID: 72785

Sameena[1], Sankari Meena K[2]
[1]Department of Plant Pathology, College of Agriculture, PJTAU, Rajendranagar, Hyderabad.
[2]Crop Protection Division, ICAR-Indian Institute of Oilseeds Research (IIOR), Rajendranagar, Hyderabad.

Summary
There is a gradual shift toward an "atmospheric" model of crop protection that utilizes microbial Volatile Organic Compounds (VOCs), aka the secondary metabolites that diffuse rapidly through soil and air due to their high vapor pressure. Unlike traditional biocontrol agents that require direct physical contact , VOCs offer long-distance efficacy and residue-free protection, making them highly effective for both field-scale and post-harvest disease management. These compounds function through dual physiological channels: direct pathogen antagonism and Induced Systemic Resistance (ISR). In practical application, innovative technologies are bringing these laboratory findings to the field, including bio-capsule technology for sustained release in rhizospheres and Electronic Noses (E-noses), which can "smell" pre-symptomatic volatile fingerprints to detect diseases.

Introduction
In the microscopic world of plant-microbe interactions, communication is rarely visual but frequently chemical. Volatile Organic Compounds (VOCs) are low-molecular-weight metabolites (< 300 Da) with high vapor pressure that facilitate rapid diffusion through soil pores and the phyllosphere. As the management of plant diseases is moving beyond traditional liquid-phase biocontrol, the trend to assess volatilome i.e., the collective gaseous signals produced by beneficial microbes such as *Bacillus*, *Pseudomonas*, and *Trichoderma* offers a revolutionary, non-contact approach to managing destructive crop diseases.

Why VOCs for Pest Management?
Traditional biocontrol agents (BCAs) often require direct physical contact with the pathogen or the plant surface to be effective. However, VOCs offer several unique advantages:

1. Long-Distance Efficacy: Due to their gaseous nature, they can travel over centimeters which is a vast distance in the microbial world, allowing them to counteract pathogens hidden in soil crevices or dense canopies.

2. Residue-Free Protection: VOCs evaporate readily, leaving no harmful residues on the final produce, making them ideal for post-harvest disease management.

3. Multi-Functional Roles: A single volatile compound can simultaneously inhibit fungal growth, repel insect vectors, and stimulate plant growth through hormonal modulation. This aspect of VOCs acts as a single strategic agent with multi-modal disease management.

Mode of Action of VOCs
Microbial volatiles exert their influence through two primary physiological channels:

1. Direct Pathogen Antagonism: VOCs like hydrogen cyanide (HCN) and sulfur-containing compounds (e.g., Dimethyl disulfide) penetrate the lipid bilayer of fungal hyphae and spores. This leads to cytoplasmic leakage, inhibition of mitochondrial respiration, and eventual cell death.

2. Induced Systemic Resistance (ISR): Volatiles act as signaling ligands perceived by the plant. This triggers the activation of the Jasmonic Acid (JA) and Ethylene (ET) pathways, leading to callose deposition and the accumulation of Pathogenesis-Related (PR) proteins, priming the plant against future infections.

VOCs in Today's Plant Disease Management: From Lab to Field
Transitioning VOCs from laboratory "*In-vitro* plate" assays to field-scale efficacy is the current frontier of research in India. This involves sophisticated delivery systems and diagnostic tools. Noteworthy work is being conducted within the country borders.

1. Bio-Capsule Technology: In the spice-growing regions of Kerala, ICAR-IISR has pioneered "Bio-capsule" technology. These gelatinous capsules encapsulate VOC-producing *Trichoderma* and *Bacillus* strains, ensuring a sustained release of antifungal volatiles in the ginger rhizosphere to manage soft rot under tropical conditions.

2. Enriched Amendments and Fertigation: In the pomegranate orchards of Maharashtra, *Trichoderma*-enriched organic amendments are integrated into irrigation systems. The *in situ* generation of 6-pentyl-alpha-pyrone (6-PP) volatiles provides a gaseous protective barrier against soil-borne wilt pathogens.

3. Electronic Noses (E-noses) for disease detection: E-nose diagnostic arrays are being used to "smell" early-stage volatiles associated with diseases. Several trained devices exist that specifically differentiate diseases. For instance, advanced devices (PEN 3/MSEM 160) successfully detected diseases such as mango twig tip dieback and Panama disease in bananas. These chemical sensors detect pre-symptomatic volatile fingerprints, allowing for precision bio-fumigation before fruit quality degrades.

4. E-noses for insect pest detection: An e-nose system was designed to detect VOC biomarkers, linalool and carveol, which were released by tomato plants during early-stage aphid stress. The system achieved an 86.7% classification accuracy, providing a non-invasive tool for greenhouse monitoring.

Table 1: Examples of Microbial VOCs and their Pathogen Targets:

Biocontrol Agent	Major Volatile Compound	Target Pathogen	Reference
Trichoderma harzianum	6-pentyl-alpha-pyrone	*Alternaria brassicola*	Kottb *et. al.*, (2015)
Bacillus wiedmannii	Proteases	*Meloidogyne arenaria*	Fallahzadeh-Mamaghani *et. al.*, (2023)
Bacillus subtilis	Acetoin & 2,3-butanediol	*Erwinia carotovora* subsp. *carotovora*	Ryu *et. al.*, (2004)

Conclusion

Volatile organic compounds represent a paradigm shift in plant pathology, moving us toward an "atmospheric" model of crop protection. By integrating advanced delivery systems like bio-encapsulation with real-time diagnostic tools like E-noses, we can harness the silent language of microbes for a more sustainable agricultural future.

References

1. Cui, S., Inocente, E.A.A., Acosta, N., Keener, H.M., Zhu, H. and Ling, P.P., (2019). Development of fast e-nose system for early-stage diagnosis of aphid-stressed tomato plants. *Sensors*. 19(16):3480.
2. Fallahzadeh-Mamaghani, V., Shahbazi-Ezmareh, R., Shirzad, A. and Moslehi, S., (2023). Possible mechanisms of action of *Bacillus wiedmannii* AzBw1, a biocontrol agent of the root-knot nematode, *Meloidogyne arenaria*. *Egyptian Journal of Biological Pest Control*. 33(1): 28.
3. Kottb, M., Gigolashvili, T., Großkinsky, D.K. and Piechulla, B., (2015). *Trichoderma* volatiles effecting *Arabidopsis*: from inhibition to protection against phytopathogenic fungi. *Frontiers in microbiology*. 6:995.
4. Li, N., Kim, K.T., Schlagnhaufer, C. and Kang, S., (2024). Multifaceted effects of volatile organic compounds released by *Fusarium oxysporum* on *Trichoderma* biocontrol agents. *Biological Control*. 191:105473.
5. Ratnayake, W., Bellgard, S.E., Wang, H. and Murthy, V., (2024). Electronic Nose and GC-MS Analysis to Detect Mango Twig Tip Dieback in Mango (*Mangifera indica*) and Panama Disease (TR4) in Banana (*Musa acuminata*). *Chemosensors*. 12(7): 117.
6. Ryu, C.M., Farag, M.A., Hu, C.H., Reddy, M.S., Kloepper, J.W. and Paré, P.W., (2004). Bacterial volatiles induce systemic resistance in *Arabidopsis*. *Plant physiology*. 134(3):1017-1026.
7. Suseela Bhai, R., (2020). Preservation and long-term storage of *Trichoderma* spp. by sodium alginate encapsulation. *Journal of Plantation Crops*. 48(1):36-44.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Nematodes as Nutrition for Higher Trophic Levels

Article ID: 72786

Sankari Meena K[1], Sameena[2]
[1]Crop Protection Division, ICAR-Indian Institute of Oilseeds Research, Hyderabad, Telangana, India.
[2]Department of Plant Pathology, College of Agriculture, PJTAU, Rajendranagar, Hyderabad.

Summary
Nematodes form a crucial component of terrestrial food webs, serving as both nutrient mobilizers and prey for higher trophic levels. Their role in providing essential polyunsaturated fatty acids (PUFAs), particularly long-chain omega-3 fatty acids, highlights their nutritional significance for predators such as collembolans and mites. Molecular gut content analysis and novel DNA markers have revealed nematodes as frequent prey of soil microarthropods, reshaping our understanding of soil food web complexity. Environmental factors such as nitrogen enrichment and elevation strongly influence nematode community structure, with implications for energy flow and ecosystem functioning. This review highlights recent insights into nematodes as a nutritional bridge between microbes and higher-level consumers.

Introduction
Nematodes are abundant and diverse in soil, with densities reaching millions per square meter and communities often containing over 100 species (Yeates *et al.*, 2010). Their feeding strategies range from bacterivory and fungivory to plant parasitism and predation (Yeates *et. al.*, 1993). As consumers of microbes and organic matter, nematodes contribute to nutrient mineralization and cycling. At the same time, they serve as prey for soil microarthropods, forming a key link between microbial processes and higher trophic levels (Scheu *et. al.*, 2005).

Recent advances in stable isotope studies, lipid tracing, and molecular gut content analysis have shown that nematodes are an overlooked but important food source for collembolans, mites, and other predators (Heidemann *et. al.*, 2014). This dual role as nutrient processors and prey underscores their importance in sustaining soil biodiversity and food web stability.

Nutritional Importance of Nematodes in Soil Food Webs
A unique feature of nematodes is their ability to synthesize long-chain omega-3 (ω3) polyunsaturated fatty acids (PUFAs), such as eicosapentaenoic acid (EPA), through desaturases absent in vertebrates (Menzel *et. al.*, 2018). These fatty acids are vital for growth, reproduction, and neural development of higher animals but are generally scarce in terrestrial ecosystems compared to aquatic ones.

Laboratory feeding experiments with *Caenorhabditis elegans* and collembolans (*Folsomia candida*, *Protaphorura fimata*) demonstrated that nematode-derived PUFAs enhance growth and reproduction of consumers. Even when fed PUFA-poor nematodes, collembolans retained stable PUFA levels in phospholipids, suggesting a combination of dietary assimilation and endogenous synthesis. This evidence positions nematodes as a significant terrestrial source of essential fatty acids, challenging the view that aquatic ecosystems dominate ω3 PUFA supply.

Environmental Drivers Affecting Nematode Communities
Nitrogen enrichment: Global studies indicate that increasing nitrogen inputs alter nematode diversity and abundance (Xing *et. al.*, 2022). Nematode richness generally declines with high nitrogen, particularly in arid and cool regions, while humid or warm regions sometimes show increased abundance. Higher trophic-level nematodes, such as omnivores and carnivores, are more sensitive to nitrogen enrichment than lower-level feeders. These shifts, linked to soil acidification and reduced microbial diversity, may weaken nematodes' ecological role in nutrient cycling and predator–prey dynamics.

Elevation gradients: Nematode biomass distribution also varies with elevation. Studies from the Tibetan Plateau reveal that trophic groups, rather than body size, determine responses to climatic and edaphic factors (Li *et. al.*, 2023). Higher trophic groups respond more strongly to environmental changes, suggesting that ecosystem alterations disproportionately affect predatory nematodes and their ecological functions.

Nematodes as prey for higher soil fauna: Contrary to earlier assumptions that microarthropods rely mainly on litter and fungal resources, recent molecular analyses reveal that nematodes form a consistent part of their diet (Heidemann *et. al.*, 2014). Bacterivorous nematodes, in particular, are consumed by collembolans and oribatid mites, which in turn transfer energy to larger predators such as centipedes. The frequent detection of nematode DNA in diverse predators highlights their underestimated role as basal prey in decomposer food webs. This suggests a more complex trophic structure, where nematodes act as an energy and nutrient gateway linking microbial productivity to higher trophic levels.

Conclusion

Nematodes serve as essential intermediaries in soil food webs, both by processing microbial biomass and by supplying nutritional compounds to higher trophic levels. Their ability to produce long-chain ω3 fatty acids enhances the nutritional quality of soil prey, benefiting consumers like collembolans and mites. Environmental pressures such as nitrogen enrichment and climate-driven changes in elevation significantly affect nematode communities, with cascading impacts on soil food web stability. Future research should integrate molecular tools with field studies to clarify predator–prey interactions, quantify nematode contributions to consumer nutrition, and predict ecosystem responses under global change scenarios. Recognizing nematodes as both nutrient cyclers and nutritional resources is key to understanding and conserving soil biodiversity.

References

1. Heidemann, K., Hennies, A., Schakowske, J., Blumenberg, L., Ruess, L., Scheu, S. and Maraun, M., (2014). Free-living nematodes as prey for higher trophic levels of forest soil food webs. *Oikos*. 123(10):1199-1211.
2. Li, G., Wilschut, R.A., Luo, S., Chen, H., Wang, X., Du, G. and Geisen, S., (2023). Nematode biomass changes along an elevational gradient are trophic group dependent but independent of body size. *Global Change Biology*. 29(17):4898-4909.
3. Menzel, R., Geweiler, D., Sass, A., Simsek, D. and Ruess, L., (2018). Nematodes as important source for omega-3 long-chain fatty acids in the soil food web and the impact in nutrition for higher trophic levels. *Frontiers in Ecology and Evolution*. 6:96.
4. Scheu, S., Ruess, L. and Bonkowski, M., (2005). Interactions between microorganisms and soil micro-and mesofauna. *In Microorganisms in soils: roles in genesis and functions*. 253-275. Berlin, Heidelberg: Springer Berlin Heidelberg.
5. Xing, W., Lu, X., Niu, S., Chen, D., Wang, J., Liu, Y., Wang, B., Zhang, S., Li, Z., Yao, X. and Yu, Q., (2022). Global patterns and drivers of soil nematodes in response to nitrogen enrichment. *Catena*. 213:106235.
6. Yeates, G.W., Bongers, T., De Goede, R.G., Freckman, D.W. and Georgieva, S., (1993). Feeding habits in soil nematode families and genera—an outline for soil ecologists. *Journal of Nematology*. 25(3):315.
7. Yeates, G.W., (2010). Nematodes in ecological webs. *Encyclopedia of Life Sciences*. John. wiley & Sons Ltd.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Management of N Fertilizer in Rice Field: A Review

Article ID: 72787

S. Madhu Vini[1], P. Ilanthamil[1], R. Karpagavalli[1]
[1]UG Student B.Sc. (Hons.) Agriculture, S. Thangapazham Agricultural College (Affiliated to Tamil Nadu Agricultural University), Vasudevanallur, Tenkasi -627758, Tamil Nadu, India.

Abstract
Rice is one of the most important cereal crops in the world and a staple food for more than half of the global population, especially in Asia. Rice production in the world was more than 800 million tonnes (Mt) in 2023. Rice belongs to the genus *Oryza*, with *Oryza sativa* being the most widely cultivated species. It is mainly grown in warm and humid climates and requires plenty of water, which is why it is commonly cultivated in flooded fields called Paddy Fields. One of the most prevalent issues with rice in Asia is nitrogen deficiency which is common rice growing soils where modern varieties of rice are cultivated without sufficient mineral nitrogen fertilizer. So it is necessary to implement management practices in order to reduce nitrogen losses and increase the nitrogen use efficiency (NUE) in rice production.

Introduction
Nitrogen is essential to crops especially for rice. To increase rice yield and maintain the health of the soil nitrogen application is most important. To prevent N loses from soil proper application techniques and strategies to be followed in rice field. Plant uptake N in various forms like Ammonia, Nitrate, Nitrite. N was applied to the soil through organic and inorganic manner. Organic like FYM and inorganic like Urea. Proper management of nitrogen in rice fields involves the right source, right rate, right time and right method of application. Some symptoms are acquired like old rice leaves and stems become light green under nitrogen stress and the base of the leaf sheath becomes white under severe nitrogen deficiency. Excess nitrogen application can lead to soil deterioration and acidification, chalkiness and poor appearance quality of rice. Excess nitrogen also causes “luxuriant growth”. Nitrogen also losses from soil as ammonium volatilization, Leaching, Denitrification etc,. Effective nitrogen management not only increases rice yield and quality but also reduces production costs and minimizes environmental pollution. Managing N fertilizer is essential for sustainable rice cultivation.

Advantages of N Fertilizer in Rice Field
Promote Vegetative Growth - N encourages vigorous growth of leaves and stems, resulting in healthy plants.

Improves grain Quality – N helps in protein synthesis, improving the nutritional quality of rice grains.

Improves Grain yield – Proper application of Nitrogenous fertilizers significantly increases panicle number, grain size, and grain weight.

Efficient Nutrient Uptake – N enhances the uptake and utilization of other nutrients like P and K.

Increases Tillering – Adequate nitrogen supply increases the number of productive tillers, which directly contributes to higher grain yield.

Losses of N In Rice Field
Leaching: Leaching losses of N from rice fields are harmful to surface and groundwater quality. N leaching in rice fields is the downward movement of nitrogen, primarily as Nitrate and Ammonium through the soil with percolating water, leading to N loss, contamination of groundwater, and reduce fertilizer efficiency, particularly in sandy soils or with heavy rainfall and flood irrigation.

Ammonium Volatilization: Ammonium volatilization in rice fields refers to the loss of applied nitrogen as ammonia gas, mainly after surface application of urea in flooded or puddled paddy soils. If N containing fertilizer like Urea is broadcast on standing water in paddy field. Urea is rapidly hydrolysed by urease enzyme. This forms Ammonium and increases pH of floodwater and at high pH, ammonium converts to ammonia. This forms of ammonia escapes into atmosphere – leads to N loss.

Nitrification – Denitrification: Nitrification is the biological oxidation of Ammonium to Nitrate by aerobic microorganisms like Nitrosomonas and Nitrobacter. It supplies nitrate to rice roots and provides substrate for denitrification. Denitrification is the reduction of nitrate to gaseous nitrogen forms, causing N loss. Denitrification was done by the microbes like *Pseudomonas spp* , *Bacillus spp*.

Management of N in the Field of Rice

The Core principle to manage N is Right Source, Right Rate, Right Time, Right Place, it is the fundamental framework for efficient N management. Choosing Right Fertilizer like Urea, Ammonium sulphate, Coated Urea which containing N content and increase the yield of rice. Right Rate means applying fertilizer at the recommended dose based on soil and crop need, in rice apply N based on the soil test recommendation, use LCC (Leaf Colour Chart). Right Place refers to applying fertilizer at the correct location where roots can easily absorb nutrients, in rice deep placement of Urea, place Urea near root zone. Right Time means to applying fertilizer at the right growth stage of the crop, in rice apply N in split doses like Basal, Active tillering, Panicle initiation. Also managing N through real time N management like LCC, SPAD Chlorophyll Meter and optical sensors like Green Seeker. The principle of real-time N management was Nitrogen is applied only when the crop shows deficiency and decisions are made using plant-based tools. Through LCC, for transplanted rice, LCC less than or equal to 4 and for direct-seeded rice, threshold level (35-38). There is also limitations in real-time based management requires regular field monitoring, less effective under severe pest or disease stress, needs trained farmer.

Conclusion

Effective management of nitrogenous fertilizer in rice is crucial for achieving higher yield, better nitrogen use efficiency, and environmental sustainability. Because rice fields experience flooded, aerobic, and anaerobic conditions, nitrogen losses through volatilisation, leaching, nitrification, and denitrification are common if fertilizers are not properly managed. Adopting scientific practices such as the 4R, split application, deep placement of urea, and real-time nitrogen management using LCC or SPAD meter helps to synchronize nitrogen supply with crop demand. The use of coated fertilizers, inhibitors, and integrated nutrient management further reduces losses. Overall, proper nitrogen management in rice fields enhances fertilizer efficiency, reduces production costs, increases grain yield, and minimizes environmental pollution, making rice cultivation more productive and sustainable.

References

1. Abd El-Maksoud, M. E. (2008) Effect of levels and splitting of N-fertilization on growth, yield components, yield and grain quality of some rice cultivars. Research J. of Agric. and biological Sci.4(5):392-398.
2. Amit Kumar, Singh, S.K., Rohtas Kumar, Shabnam., Priyanka Sanwal, and Gautam, S.K, (2022).Effect of Different Nitrogen Sources on Growth and Yield of Rice (*Oryza sativa*).International J. of Plant & Soil Sci.34(24):430-439.
3. Dashrath Singh, and Anil Kumar. (2014). Effect of sources of Nitrogen on Growth yield and uptake of Nutrients in Rice. Annals of Plant and Soil Res. 16(4):359-361.
4. Rakesh Maurya, Thokchom Dorenchand Singh, Hubert Jones Shullai, Saphina Mary Kurkalang, and Tonya G Momin. (2020) Effect of Nitrogen Fertilization on Rice: A Review. J. of Pharmacognosy and Phytochemistry.9(3):2127-2130.
5. Priyanka Yengkokpam, Purnima Kumari,Vyomendra Kumar Singh, Keithellakpam
6. Chanu Ningthi, Sunidhi Dhiman, Manthan Chaudhary, and Rakshita Sharma.(2024).Application and Management of Nitrogenous Fertilizer in Rice Field: A Review. Asian J. of Soil Science and Plant Nutrition.10(2):64-71.
7. Sharma,A.R, and Mittra,B.N. (1991). Effect of Different Rates Of Application of Organic and Nitrogen Fertilizers in a Rice-Based Cropping System. J. of Agri. Sci., Cambridge. 117:313-318.
8. Wenlu Guan., Xiaohou Shao., and Yuanyuan Li. (2020). Effects of Irrigation and Nitrogen Management on the Growth and Nitrogen Concentration of Paddy Soil and Rice Plant. Pol. J. Environ. Stud. 29(6):4053-4063.
9. TNAU. Nutrient Management: Rice; 2016. Available:https://agritech.tnau.ac.in/agriculture/agri_nutrientmgt_rice
10. Wang Y, Shi PH, Ji RT, Min J, Shi WM, Wang DJ. Development of a model using the nitrogen nutrition index to estimate in season rice nitrogen requirement. Field Crops Res. 2020;245: 107664.
11. Savant NK and De Datta SK (1982). Nitrogen transformations in wetland rice soils. Advances in Agronomy 35:241-302.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

ENSO-IOD Coupling and Monsoon Response in the Indian Ocean Basin During 2014-2025

Article ID: 72788

Ragul Gowtham H[1], Ramachandran J[2]
[1]Undergraduate Student in Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.
[2]Teaching Assistant in Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Abstract
This study examines the coupled evolution of the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) and their combined influence on Indian Ocean climate and South Asian monsoon variability during 2014–2025. Using Niño-3.4 (ONI), Dipole Mode Index (DMI), satellite-derived sea-surface temperatures, and observed monsoon departures, we show that recent extremes were frequently associated with compound ENSO–IOD states. The record positive IOD of 2019 offset El Niño-induced drying and enhanced rainfall, while the concurrent strong El Niño and positive IOD in 2023 produced marked circulation reorganization during unprecedented ocean warming. In contrast, La Niña combined with negative IOD amplified wet anomalies in 2016 and 2022. Results demonstrate that the IOD phase critically modulates ENSO teleconnections, underscoring the need for integrated Indo-Pacific monitoring to improve seasonal monsoon prediction.

Keywords: Climate Teleconnections; El Niño–Southern Oscillation (ENSO); Indian Ocean Dipole (IOD); Indo-Pacific Variability; Sea Surface Temperature (SST); South Asian Monsoon.

Introduction
The El Niño–Southern Oscillation (ENSO) is the dominant driver of interannual climate variability, yet its influence on the Indian Ocean and South Asian monsoon remains incompletely understood because it is strongly modulated by regional ocean–atmosphere processes, particularly the Indian Ocean Dipole (IOD), which alters zonal sea-surface temperature (SST) gradients and atmospheric circulation, often amplifying or counteracting canonical ENSO teleconnections. During 2014–2024, the climate system experienced a sequence of extreme events—including the strong El Niño of 2015–16, the prolonged La Niña of 2020–22, and the record El Niño of 2023—frequently coincident with anomalous IOD phases, producing nonlinear atmospheric responses and rainfall anomalies that diverge from traditional ENSO-monsoon relationships (Power et al., 2021; Andrian et al., 2024; Park et al., 2025). Notably, the extreme positive IOD of 2019 suppressed El Niño–induced drying and resulted in above-normal Indian monsoon rainfall (Nyadjro, 2021), while the strong positive IOD of 2023 substantially reorganized Indo-Pacific circulation during one of the warmest global SST years on record (Luo et al., 2025). Addressing this gap, this study synthesizes ENSO–IOD phase evolution from 2014–2024 and quantifies their combined influence on Indian Ocean SSTs, atmospheric circulation, and South Asian monsoon rainfall using Niño-3.4 indices, the Dipole Mode Index (DMI), satellite observations, and documented monsoon anomalies, thereby advancing physical understanding of Indo-Pacific climate variability and strengthening the basis for seasonal monsoon prediction and climate risk assessment in a warming ocean system.

Discussion
ENSO Phase Evolution (2014–2024):

1. 2014–2016 (Strong El Niño→La Niña): A highly anticipated El Niño began in late 2014 but "failed" due to persistent easterly equatorial winds, trapping warm water subsurface (Pacific Marine Environmental Laboratory). In 2015, this subsurface warm pool, combined with strong westerly wind bursts, produced one of the strongest El Niños on record. NOAA CPC data show Niño-3.4 anomalies rising from approximately +0.5°C in mid-2014 to a peak ONI ≈ of approximately +2.8°C in November/December 2015 (Climate Prediction Center). Ocean–atmosphere coupling led to global SSTs ~+2°C above normal in the tropical Pacific by late 2015. The event transitioned to La Niña by mid-2016 (Niño-3.4 ≈ −0.6°C by Jul–Sep 2016) as easterly winds re-established, plunging the Pacific into a moderate cold phase (Pacific Marine Environmental Laboratory) (Climate Prediction Center).

2. 2017–2019 (Neutral to Weak El Niño with Extreme Positive IOD): Following the strong 2015–16 El Niño, Pacific conditions remained largely neutral during 2017–2018, with weak ocean–atmosphere coupling and modest Niño-3.4 variability. CPC data indicate slightly negative anomalies through late 2017 (OND 2017 ≈ −0.9°C) and a brief warm pulse in late 2018, when a weak El Niño emerged by boreal fall (OND 2018 ≈ +1.0°C) but rapidly decayed (Climate Prediction Center). In contrast, 2019 featured a weak El Niño developing by late year (OND 2019 ≈ +0.7°C) concurrent with an extreme positive IOD. The Dipole Mode Index peaked near +1.8°C in October–November 2019, representing the strongest

positive IOD of the century (Climate Prediction Center). Despite El Niño conditions, the Indian summer monsoon was exceptionally strong, with rainfall reaching ~110% of normal (IMD, 2020), as the positive IOD overwhelmed Pacific forcing and promoted enhanced convection over the western Indian Ocean and India (Nyadjro, 2021).

3. 2020-2021 (Moderate-Strong La Niña): The strong La Niña of 2020–21 followed, with Niño-3.4 anomalies reaching ~−1.2°C by NDJ 2020–21 (Climate Prediction Center). Concurrently, the IOD was briefly positive in mid-2020 (DMI ≈+0.6°C in Jun–Jul), then faded. India's monsoon was above normal: IMD reports 2020 monsoon rainfall ≈109% of LPA (India Meteorological Department. (2021, January 4). By late 2021, La Niña waned (OND 2021 ≈ −0.9°C (Climate Prediction Center)), and Indian Ocean SSTs returned toward neutral. No strong IOD event occurred in 2021.

4. 2022-2023 (Late La Niña to Strong El Niño with Extreme IOD): The Pacific remained weakly cool through mid-2022, with persistent La Niña conditions (ONI ≈ −0.8°C; OND 2021–22 ≈ −0.7°C) accompanied by a strong negative IOD that reached ≈ −1.17°C in August 2022 (Climate Prediction Center). These conditions supported a robust Indian summer monsoon, with rainfall near 106% of normal. Rapid Pacific warming followed, and by November–December 2022 the ONI had risen to +2.1°C, marking the onset of El Niño conditions. In 2023, this transition culminated in a very strong El Niño coinciding with a strong positive IOD. Niño-3.4 anomalies again reached ~+2.1°C by NDJ 2023–24, while the DMI peaked near +1.5°C in November 2023—the second-highest IOD on record (Luo et al., 2025). Record-high SSTs spanned the tropical Pacific, Indian, and Atlantic Oceans. Despite El Niño suppression, the 2023 Indian monsoon reached 94% of normal (IMD, 2023), reflecting Walker circulation reorganization and enhanced west–east Indian Ocean convection driven by the positive IOD (Nyadjro, 2021; Andrian et al., 2024).

5. 2024-2025 (Neutral to Weak La Niña with Weak/Neutral IOD): Following the peak of the 2023 El Niño, the tropical Pacific transitioned to near-neutral conditions in early 2024, with Niño-3.4 anomalies weakening and intermittently approaching weak La Niña thresholds later in 2024 and through 2025 (Climate Prediction Center [CPC], n.d.). Concurrently, the Indian Ocean exhibited weak negative to neutral IOD conditions, with DMI values generally remaining within −0.2 to +0.4 °C, indicating the absence of a sustained zonal SST gradient (CPC, n.d.). The resulting reduction in Pacific forcing and muted IOD activity led to relatively weak large-scale circulation anomalies across the Indo-Pacific. Despite this, Indian summer monsoon rainfall was above normal in both years (India Meteorological Department [IMD], 2024, 2025), reflecting enhanced moisture availability over the Arabian Sea and the increasing role of regional Indian Ocean warming. These conditions exemplify a decoupled ENSO–IOD regime in which basin-scale thermodynamic forcing and Indian Ocean variability exert greater control on monsoon precipitation than canonical ENSO teleconnections.

Indian Ocean Dipole Variability

ENSO is often linked to the Indian Ocean Dipole (IOD). This table summarizes key IOD phase indices:

Table 1: IOD phase indices:

Year	ENSO Phase	Niño-3.4 (ONI, °C)	IOD Phase (peak DMI, °C)	SW Monsoon Rainfall (% of LPA)
2014	Neutral	≈+0.8 (NDJ)	Weak negative (Dec ≈−0.21)	≈82% (deficit)
2015	El Niño	≈+2.8 (Nov)	Positive (Sep +0.72)	86% (below average)
2016	La Niña	≈−0.6 (MAM)	Negative (Jul −1.08)	97% (nearly normal)
2017	Neutral	≈−0.9 (NDJ)	Positive (Aug +0.72)	98% (near normal)
2018	Mild El Niño	≈+1.0 (OND)	Positive (Sep +0.67)	91% (deficit)
2019	Mod. El Niño	≈+0.7 (NDJ)	Extreme positive (Oct/Nov +1.78)	110% (above avg)
2020	La Niña	≈−1.2 (OND)	Positive (Jun +0.57)	109% (above avg)
2021	Neutral/La Niña	≈−0.9 (NDJ)	Weak positive (Apr +0.28)	99% (near avg)
2022	La Niña	≈−0.7 (OND)	Strong negative (Aug −1.17)	106% (above avg)
2023	El Niño	≈+2.1 (NDJ)	Strong positive (Nov +1.50)	94% (below avg)
2024	ENSO Neutral/La Niña-like	Neutral to weak La Niña *≈−0.3 to −0.6*	Weak negative to neutral *≈−0.2 to 0.0*	Above normal (≈105-108%) *observed/estimated*
2025	ENSO Neutral/Weak La Niña	Neutral to weak La Niña (≈−0.2 to −0.5)	Neutral to weak negative (≈−0.1 to −0.4)	≈108% (above avg) *observed*

The Dipole Mode Index (DMI) reflects IOD strength: values >+0.4°C indicate positive IOD, <−0.4°C negative. CPC data show record DMI ≈+1.78°C (Oct/Nov 2019) (Climate Prediction Center) and +1.50°C in late 2023 (Climate Prediction Center), versus −1.17°C in Aug 2022 (Climate Prediction Center). Positive IOD events (warm western Indian Ocean) in 2019 and 2023 coincided with El Niños; negative IODs occurred in 2016 and 2022 during La Niña

or neutral Pacific conditions. The IOD modulates local monsoon: e.g., the 2019 positive IOD brought anomalously heavy rain to western India (monsoon +10% of normal) despite concurrent El Niño (Nyadjro, E. S. (2021)) (India Meteorological Department, 2020, January 6).

Conclusion

This study demonstrates that ENSO impacts on the Indian Ocean and South Asian monsoon during 2014–2024 cannot be interpreted independently of the Indian Ocean Dipole (IOD). Analysis of Niño-3.4 (ONI), Dipole Mode Index (DMI), satellite-derived SSTs, and observed monsoon anomalies shows that extreme and prolonged ENSO events were frequently accompanied by strong IOD phases, producing nonlinear atmospheric responses. The record-positive IOD of 2019 suppressed canonical El Niño–induced drying and yielded above-normal monsoon rainfall, while the concurrent strong El Niño–positive IOD configuration in 2023 reorganized Indo-Pacific circulation during a year of unprecedented global ocean warming. In contrast, La Niña–negative IOD conditions in 2016 and 2022 highlight the asymmetric nature of ENSO–IOD coupling, confirming that positive IODs more effectively modulate ENSO teleconnections than negative IODs amplify La Niña signals. Together, these results provide a physically consistent framework for interpreting recent hydroclimatic extremes and demonstrate that improved monsoon predictability depends on accounting for the joint evolution of ENSO and IOD, particularly under ongoing ocean warming that increases the likelihood of compound climate events.

Abbreviation

ENSO	**El Niño-Southern Oscillation**
IOD	Indian Ocean Dipole
ONI	Oceanic Niño Index
DMI	Dipole Mode Index
SST	Sea Surface Temperature
Niño-3.4	Niño-3.4 Sea Surface Temperature Index
CPC	Climate Prediction Center
NOAA	National Oceanic and Atmospheric Administration
IMD	India Meteorological Department
LPA	Long Period Average
SW	Southwest (as in Southwest Monsoon)
NDJ	November–December–January
OND	October–November–December
MAM	March–April–May
Jul–Sep	July–September
Jun–Jul	June–July
SSTs	Sea Surface Temperatures
Indo-Pacific	Indian Ocean–Pacific Ocean System
PMEL	Pacific Marine Environmental Laboratory

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Indigenous Technical Knowledge (ITK) for Pest Control

Article ID: 72789

Esther Gnana Packiya V[1]
[1]UG student, B.Sc. (Hons.) Agriculture, S. Thangapazham Agricultural College (Affiliated to Tamil Nadu Agricultural University), Vasudevanallur, Tenkasi – 627 760.

Abstract
Agriculture has immense potential as it has survived through ages without modern techniques and has kept so many generations alive. The knowledge base has been gained through continuous experience which is unmatched at all extents. Modern technologies need some break during these times of change and turmoil. Almost all ITKs are environmentally friendly and can be easily adapted by farmers in large scale. This article discusses about the different ITKs used for pest control in and around Southern districts of Tamil Nadu.

Introduction
At present farmers are very much involved in usage of chemicals and also other novel technologies for pest control and other problems. The large-scale cultivation has pushed farmers to get highly toxic and virulent pesticides for more yield and profit making has become the ultimate goal of present-day farming. Even though majority of farmers are involved in such modern farming tactics some farmers still adopt their age old practices which is beneficial for organic farmers as well as consumers. As of the characteristics of ITK they are location specific and varies from place to place and region to region.

ITKs for Pest Control
Some common Indigenous Technical Knowledge for pest control used by farmers are,
1. Neem oil, neem cake, neem leaves as well as neem seed kernels.
2. Buttermilk- asafoetida spray
3. Panchagavya containing 5 products from cows namely, ghee, buttermilk, cow urine, curd and cow dung.
4. Usage of loamy sand soil from riverbeds for controlling of beetles in coconuts.
5. Dusting ash in crops that are affected by pests as they are believed to increase disease resistance.

Case Study
Toads and their control measures: Farmers notice a drop in yield and quality of nuts when population of toads increase in orchards. The symptoms mentioned by farmers are deformation of coconuts, reduced availability of water content in coconuts and reduced yield. Toads reduce yield in coconut by eating most beneficial insects like predators and parasitoids along with harmful insects which increases the overall toad populations in field. During such situations farmers cut the toads in half and tie them to tree trunks. This the farmers suggest as a threatening mechanism which scares away other toads. More scientific details can be uncovered from this if research is done in this subject. These toads are known to release alarm pheromones when undergoing injuries and threats. The alarm pheromones are also released from predatory animals as stated in review articles.

Conclusion
The ITKs practiced by most farmers are proven worthy by time as farmers have been using them so far for so many years. ITKs have played a huge role in controlling pest and diseases and so scientists can research in such topics to uncover the hidden scientific principles. Recording of ITKs should also be encouraged so that farmers might preserve these practices and will continue to practice it.

References
1. Sow, S., Ranjan, S.(2021). Indigenous Technical Knowledge (ITK) for Sustainable
2. Agriculture in India .Agriculture and Food e- newsletter. 3(1). 31-35.
3. Gowda,M.G., Sadare,R., Chandana,S.G., Prasad, V.G.T., Kumar,G.R. (2025).Role of Indigenous Technological Knowledge (ITK) in Organic Farming. Agri Articles. 5(3). 1055-1057.
4. Shahane, A.A., Shivay, Y.S. (2024). Significance of Indigenous Technical Knowledge (ITK) in Agriculture. Just Agriculture. 4(8). 278-284.
5. Rixon, M., Pappuswamy, M., Chaudhary, A., Ansar, S.S.,(2025). The puzzle of pheromones in nature and their mysterious influence: a comprehensive review . Journal of Applied Biology & Biotechnology. 13(1). 24- 36.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Urban Heat Island Effect and Rising City Temperatures

Article ID: 72790

Sourabhi S[1]
[1]Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, India.

Abstract
Urban areas across the globe are experiencing a rapid increase in ambient and surface temperatures, a trend driven by accelerated urbanization, land-use change, and climate change. This localized warming phenomenon, commonly referred to as the Urban Heat Island (UHI) effect, results in cities being significantly warmer than their surrounding rural environments. Rising city temperatures have profound implications for human health, energy consumption, environmental quality, and socio-economic equity. The replacement of natural landscapes with impervious surfaces, loss of vegetation, increased anthropogenic heat emissions, and altered urban geometry are key contributors to urban heat accumulation. Climate change further amplifies these impacts by increasing baseline temperatures and the frequency of extreme heat events. This article presents a comprehensive examination of the Urban Heat Island effect, detailing its causes, spatial and temporal characteristics, impacts on health and ecosystems, and the role of urban planning and policy in mitigation. Emphasis is placed on integrated, climate-responsive strategies essential for developing heat-resilient and sustainable cities.

Keywords: Urban Heat Island; Rising City Temperatures; Urbanization; Climate Change; Heat Stress; Urban Sustainability.

Introduction
Urbanization has transformed cities into centers of economic growth, innovation, and population concentration. However, this rapid development has also resulted in significant environmental challenges, among which rising urban temperatures are increasingly critical. Cities often experience higher temperatures than surrounding rural areas due to extensive land modification and concentrated human activities. This urban warming poses serious risks to human health, infrastructure, and environmental sustainability. The Urban Heat Island effect has gained renewed attention as heatwaves become more frequent and intense. In many cities, elevated nighttime temperatures reduce physiological recovery from daytime heat, increasing health risks. Addressing urban heat is now a priority within the broader context of climate adaptation and sustainable urban development.

Urban Heat Island Effect: Concept and Mechanisms
1. The Urban Heat Island effect refers to the systematic temperature difference between urban and rural areas, where cities exhibit higher air and surface temperatures. This phenomenon arises due to changes in surface energy balance caused by urban development.

2. Materials commonly used in cities such as concrete, asphalt, and bricks have high heat storage capacity and low reflectivity, enabling them to absorb large amounts of solar radiation.

3. At night, this stored heat is slowly released, maintaining elevated temperatures. Additionally, reduced vegetation limits evapotranspiration, a natural cooling process, while dense building structures restrict airflow. These mechanisms collectively contribute to sustained urban warming, particularly during calm and clear weather conditions.

Key Drivers of Rising Urban Temperatures
Several interconnected factors drive rising temperatures in cities. The most prominent include land-use change, increased impervious surfaces, reduced albedo, loss of green cover, and anthropogenic heat emissions. Urban activities such as transportation, industrial operations, air conditioning, and power generation release substantial amounts of waste heat into the urban atmosphere. Population growth and economic activity further intensify energy consumption, reinforcing heat accumulation. These drivers interact in complex ways, creating localized microclimates that significantly elevate urban temperatures compared to surrounding regions.

Role of Urbanization and Built Environment
Urbanization fundamentally alters the physical landscape by replacing natural land covers with buildings, roads, and paved surfaces. These changes reduce the capacity of the land to absorb rainfall and dissipate heat, leading to increased surface temperatures. High-density development often prioritizes space efficiency over climatic considerations, resulting in compact urban forms that trap heat. Building height, street orientation, and spacing influence wind flow and solar exposure. Poorly designed urban layouts can restrict ventilation and enhance heat retention, intensifying the Urban Heat Island effect.

Decline of Urban Green and Blue Spaces

Urban green spaces such as parks, trees, and green belts play a crucial role in moderating city temperatures through shading and evapotranspiration. However, rapid urban expansion often leads to the reduction or fragmentation of these spaces. The loss of vegetation diminishes natural cooling and increases surface temperatures. Similarly, blue spaces like rivers, lakes, ponds, and wetlands—provide cooling through evaporation and influence local microclimates. Their degradation or encroachment further exacerbates urban heat, particularly in densely built environments.

Anthropogenic Heat and Energy Use

Anthropogenic heat emissions are a significant but often underestimated contributor to urban warming. Energy consumed for cooling, heating, transportation, and industrial activities is ultimately released as heat into the urban environment. In hot climates, increased air-conditioning use creates a feedback loop: higher temperatures increase cooling demand, which in turn releases more heat.In densely populated cities, anthropogenic heat can significantly elevate nighttime temperatures, reducing thermal comfort and increasing heat-related health risks.

Spatial and Temporal Characteristics of UHI

The intensity of the Urban Heat Island effect varies across space and time. Spatially, city centers, industrial zones, and densely built areas often act as heat hotspots, while parks and water bodies function as cooler zones. Temporally, UHI intensity is usually greatest during nighttime, when rural areas cool more rapidly than cities. Seasonal variations also influence urban heat, with stronger effects observed during summer months. Understanding these patterns is essential for targeted heat mitigation and urban design interventions.

Impacts on Human Health and Energy Demand

Rising urban temperatures pose serious threats to human health, increasing the incidence of heat-related illnesses such as heat exhaustion, heatstroke, and cardiovascular stress. Vulnerable populations including the elderly, children, outdoor workers, and economically disadvantaged communities are disproportionately affected. From an energy perspective, higher temperatures lead to increased electricity demand for cooling, placing stress on power grids and increasing the risk of outages. This also contributes to higher greenhouse gas emissions, reinforcing climate change.

Mitigation and Adaptation Strategies

Mitigation strategies focus on reducing heat absorption and enhancing natural cooling. Increasing urban green cover, promoting green roofs and walls, restoring water bodies, and using reflective materials are effective approaches. Adaptation measures such as heat action plans, early warning systems, and public awareness campaigns help reduce heat-related risks, particularly during extreme events.

Urban planning plays a central role in addressing urban heat. Climate-sensitive design, protection of green and blue spaces, and incorporation of heat mitigation into building codes and zoning regulations are essential. Policy integration across urban development, energy, health, and environmental sectors is critical for long-term resilience and effective implementation.

Conclusion

The Urban Heat Island effect is a growing challenge intensified by urbanization and climate change. Rising city temperatures threaten public health, energy systems, and environmental sustainability. Addressing this issue requires integrated, science-based approaches that combine urban planning, technological innovation, and policy support. Developing heat-resilient cities is essential for ensuring livable, sustainable urban environments in the future.

References

1. Oke, T. R. (1982). The energetic basis of the urban heat island. Quarterly Journal of the Royal Meteorological Society, 108(455), 1–24.
2. Santamouris, M. (2015). Regulating the damaged thermostat of the cities—Status, impacts and mitigation challenges. Energy and Buildings, 91, 43–56.
3. IPCC (2021). Climate Change 2021: The Physical Science Basis. Cambridge University Press.
4. Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. Remote Sensing of Environment, 86(3), 370–384.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Hydroponics: An Intensified Agriculture Practice to Improve Food Production

Article ID: 72791

Sandhiya J[1]
[1]Undergraduate Student, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Introduction

The world today is facing a serious challenge—how to produce enough food for a rapidly growing population with limited land and water resources. Climate change, urbanization, soil degradation, and shrinking agricultural land have made traditional farming increasingly difficult. In this situation, modern and innovative farming methods are gaining importance. One such promising method is hydroponics, an intensified agriculture practice that can significantly improve food production.

Hydroponics is a method of growing plants without soil, where roots are supplied with water mixed with essential nutrients. This system allows crops to grow faster, healthier, and with better yields compared to conventional soil-based farming. Because of its efficient use of space, water, and nutrients, hydroponics is emerging as a sustainable solution for future food security.

What is Hydroponics?

The term hydroponics comes from the Greek words “hydro” meaning water and “ponos” meaning labor, which together mean “working with water.” In hydroponic farming, plants grow in a nutrient-rich water solution instead of soil. The roots are either directly immersed in water or supported by inert materials such as cocopeat, perlite, or rock wool. Plants do not actually need soil to grow; they need water, nutrients, oxygen, and light. Hydroponics provides these requirements in a controlled manner, allowing plants to grow efficiently. This method is part of Controlled Environment Agriculture (CEA), where temperature, humidity, light, and nutrient levels are carefully managed.



Fig. 1. Hydroponics

Types of Hydroponic Systems

There are several types of hydroponic systems, each designed to suit different crops and conditions:

1. Nutrient Film Technique (NFT): In this system, a thin film of nutrient solution continuously flows over the roots. It is ideal for leafy vegetables like lettuce and spinach.

2. Deep Water Culture: Plants float on nutrient-rich water, and oxygen is supplied using air pumps. This system is simple and effective for small-scale farming.

3. Ebb and Flow System: The plant roots are periodically flooded with nutrient solution and then drained. It supports a wide variety of crops.

4. Drip System: Nutrient solution is slowly dripped onto the base of each plant. This system is commonly used in commercial hydroponic farms.

5. Wick System: A simple, low-cost system where nutrients are drawn to the roots through a wick. It is suitable for small plants and home gardening.

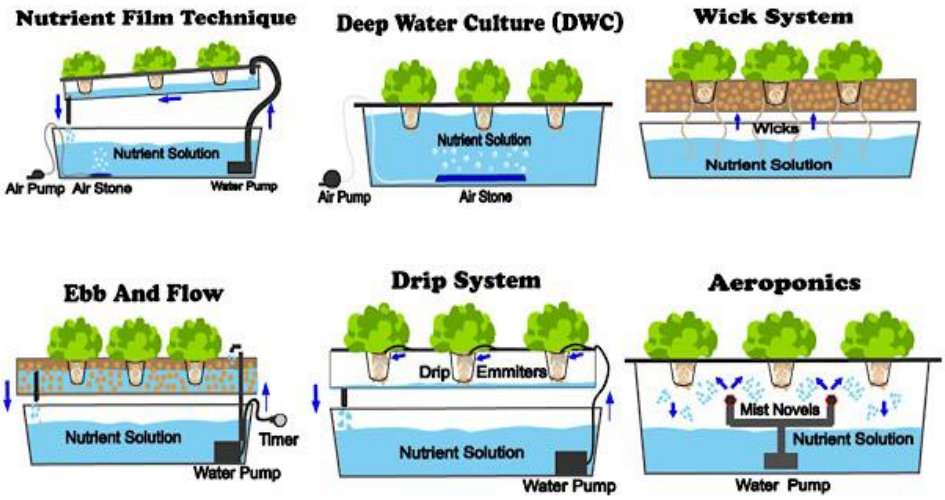


Fig. 2. Types of Hydroponics

Hydroponics as an Intensified Agriculture Practice

Hydroponics is considered an intensified farming system because it produces more food using fewer resources. Crops grow faster because nutrients are directly available to the roots, and there is no competition with weeds. The growing conditions are optimized, which leads to: Higher productivity Shorter crop cycles Better quality produce Year-round cultivation Hydroponics can be combined with vertical farming, where crops are grown in stacked layers. This further increases production per unit area, making it highly suitable for urban agriculture.

Benefits of Hydroponics in Food Production

Efficient Use of Water: Water is continuously recycled in hydroponic systems, reducing wastage. This is especially important in water-scarce regions.

Higher Yield and Faster Growth: Plants grow 30–50% faster than in soil due to efficient nutrient uptake.

Space Saving: Hydroponics requires less land and can be practiced vertically or indoors.

Reduced Use of Pesticides: Since there is no soil, the risk of soil-borne pests and diseases is minimized.

Climate-Resilient Farming: Hydroponics protects crops from extreme weather conditions such as droughts and floods.

Improved Nutritional Quality: Precise nutrient management allows biofortification of crops with iron, zinc, and other essential minerals.

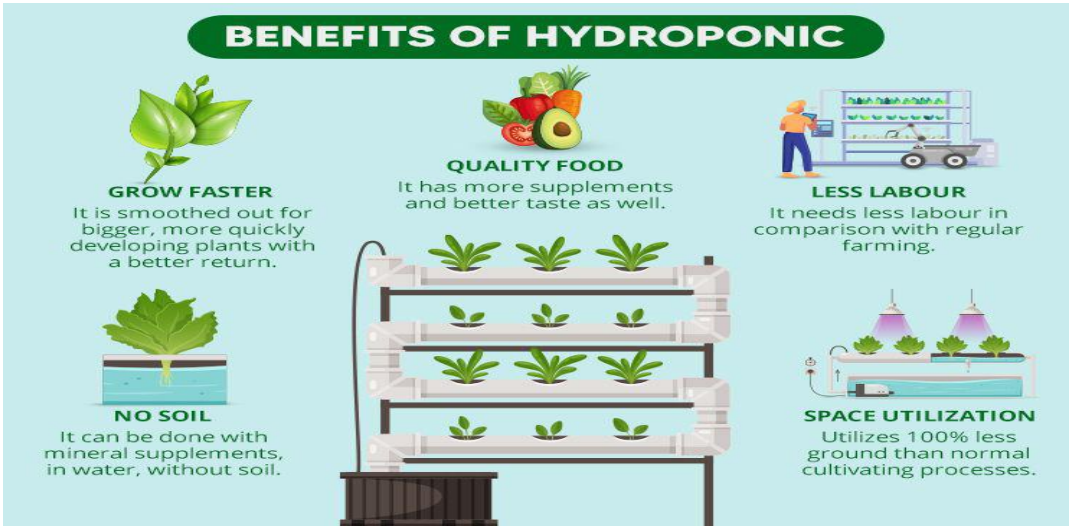


Fig. 3. Benefits of Hydroponics In Foodinroduction

Role in Urban and Sustainable Agriculture

With rapid urbanization, cities are expanding while agricultural land is shrinking. Hydroponics provides an opportunity to grow fresh vegetables near consumers, reducing transportation costs and post-harvest losses. Rooftop gardens, container farming, and indoor hydroponic units can supply fresh, pesticide-free vegetables to urban populations.

Hydroponics also supports sustainable development goals by conserving water, reducing land use, and lowering the environmental footprint of food production.

Challenges in Hydroponics

Despite its advantages, hydroponics has some challenges: High initial investment cost, Need for technical knowledge, Risk of rapid spread of water-borne diseases, Requirement of continuous monitoring of pH and nutrients Dependence on electricity However, with technological advancements such as IoT, automation, renewable energy, and smart sensors, many of these challenges are being addressed.

Conclusion

Hydroponics is an intensified and innovative agricultural practice that offers a practical solution to modern food production challenges. By using water, nutrients, and space efficiently, it enables higher yields, better quality crops, and year-round production. Although there are challenges, continuous research and technological advancements are making hydroponics more accessible and sustainable. In the coming years, hydroponics has the potential to transform agriculture and contribute significantly to global food security, especially in urban and resource-limited environments.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Quantum Dots in Agriculture: A Tiny Technology Transforming Farming

Article ID: 72792

Maheswari C[1], Ramachandran J[2]

[1]Undergraduate Student, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

[2]Teaching Assistant, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Introduction

Agriculture today faces serious challenges such as climate change, declining soil fertility, excessive use of chemical fertilizers and pesticides, and the need to feed a rapidly growing population. To overcome these problems, scientists are exploring advanced technologies that can improve crop productivity while protecting the environment. One such promising innovation is quantum dots (QDs).

Quantum dots are extremely small particles—thousands of times smaller than the width of a human hair. Because of their tiny size, they show special optical and electronic properties that are not seen in ordinary materials. Originally developed for electronics and medical imaging, quantum dots are now emerging as powerful tools in modern and sustainable agriculture.

What Are Quantum Dots?

Quantum dots are nanoscale particles, usually between 1 and 10 nanometers in size. At this scale, electrons inside the material behave differently due to a phenomenon called quantum confinement. As a result, quantum dots can absorb light and re-emit it in different colors depending on their size.

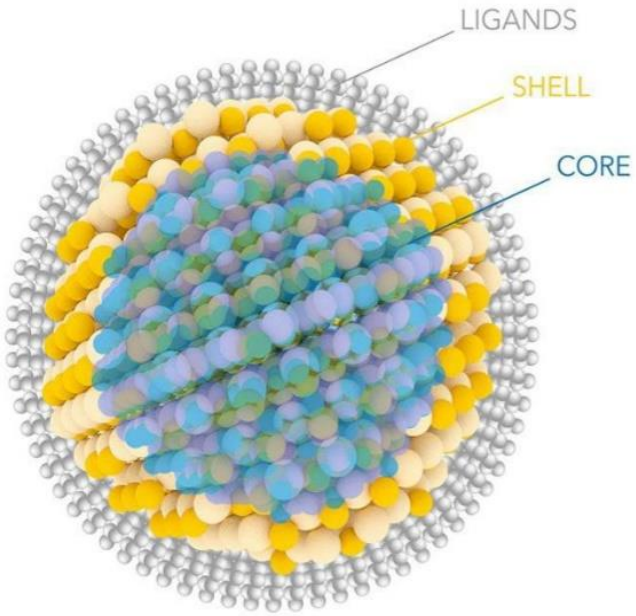


Fig. 1. Quantum Dot

There are different types of quantum dots used in agriculture, such as semiconductor quantum dots (e.g., CdSe, ZnS), carbon quantum dots (CQDs), graphene quantum dots (GQDs), and silicon quantum dots. Among these, carbon-based quantum dots are preferred for agricultural use because they are less toxic, more eco-friendly, water-soluble, and biocompatible.

Why Quantum Dots are Important for Agriculture?

Quantum dots have unique properties that make them useful in farming, including strong and stable fluorescence, the ability to convert light into useful wavelengths, a high surface area for interaction with plant cells, and the capability to carry nutrients and active molecules. These features allow quantum dots to support plant growth, improve photosynthesis, detect harmful chemicals, and reduce environmental damage.

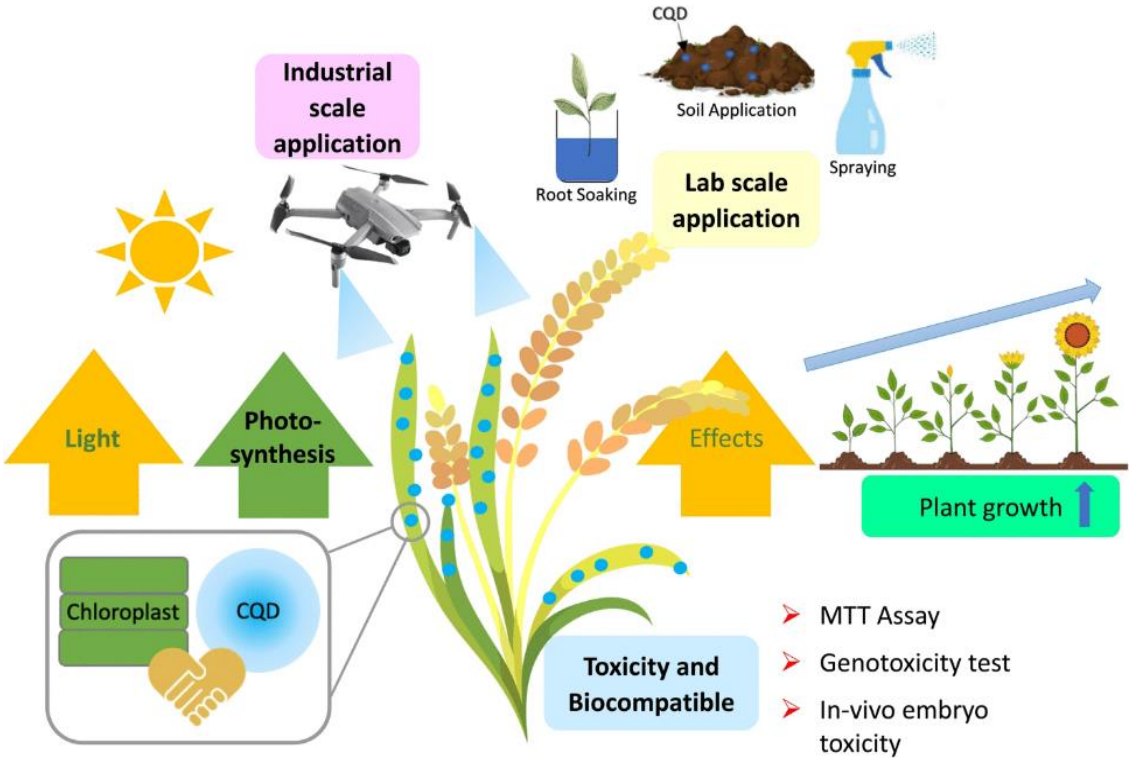


Fig. 2. Applications for Quantum Dots in Agriculture

Enhancing Photosynthesis Using Quantum Dots

Photosynthesis is the process by which plants convert sunlight into food. However, plants cannot use all wavelengths of sunlight efficiently. Quantum dots act as artificial light harvesters by absorbing unused light, such as ultraviolet light, and converting it into wavelengths that plants can use.

Studies show that when quantum dots are applied to plants, photosynthetic efficiency increases significantly, chlorophyll content improves, carbon dioxide assimilation is enhanced, and crop growth becomes faster and healthier. In some experiments, crop yields increased by 15–40%, and photosynthesis efficiency improved by more than 50%.

Quantum Dots as Nano Fertilizers

Traditional fertilizers often suffer from low efficiency because nutrients are lost through leaching and runoff. Quantum dots can function as smart Nano fertilizers by delivering nutrients directly to plant cells, reducing nutrient wastage, and improving the absorption of minerals such as iron, zinc, calcium, and magnesium. Carbon quantum dots with functional groups such as –OH and –COOH help bind nutrients and release them slowly, ensuring better plant uptake and reduced environmental pollution.

Seed Priming and Early Plant Growth

Seed priming is a technique used to improve germination and early seedling growth. Quantum dots have shown excellent results in this area. When seeds are treated with carbon quantum dots, germination rates increase, root and shoot growth improves, and seedlings become stronger and healthier. This happens because quantum dots enhance water absorption and activate early metabolic processes in seeds.

Improving Stress Tolerance in Crops

Plants frequently face stress from drought, salinity, heavy metals, and pathogens. Quantum dots help plants tolerate these stresses by reducing oxidative damage, enhancing antioxidant enzymes such as catalase and superoxide dismutase, and improving water retention and root development. As a result, crops become more resilient under harsh environmental conditions, supporting climate-resilient agriculture.

Detection of Pesticides and Pollutants

Excessive pesticide use has serious impacts on soil, water, and human health. Quantum dots are highly sensitive and can be used as nanosensors to detect pesticide residues in soil and water, herbicides and insecticides, and heavy metal contamination. Because quantum dots change their fluorescence when they interact with harmful chemicals, they allow quick, accurate, and low-cost detection compared to traditional laboratory methods.

Synthesis of Quantum Dots for Agriculture

Quantum dots can be synthesized using two main approaches: top-down methods, which involve breaking down bulk materials, and bottom-up methods, which involve building dots from small molecules. For agriculture, green synthesis methods are preferred. These methods use plant extracts, agricultural waste, and biomass such as fruit peels and leaves to produce carbon quantum dots. This approach is environmentally friendly, cost-effective, and safe for plants and soil. Hydrothermal and microwave-assisted methods are commonly used for producing agricultural carbon quantum dots.

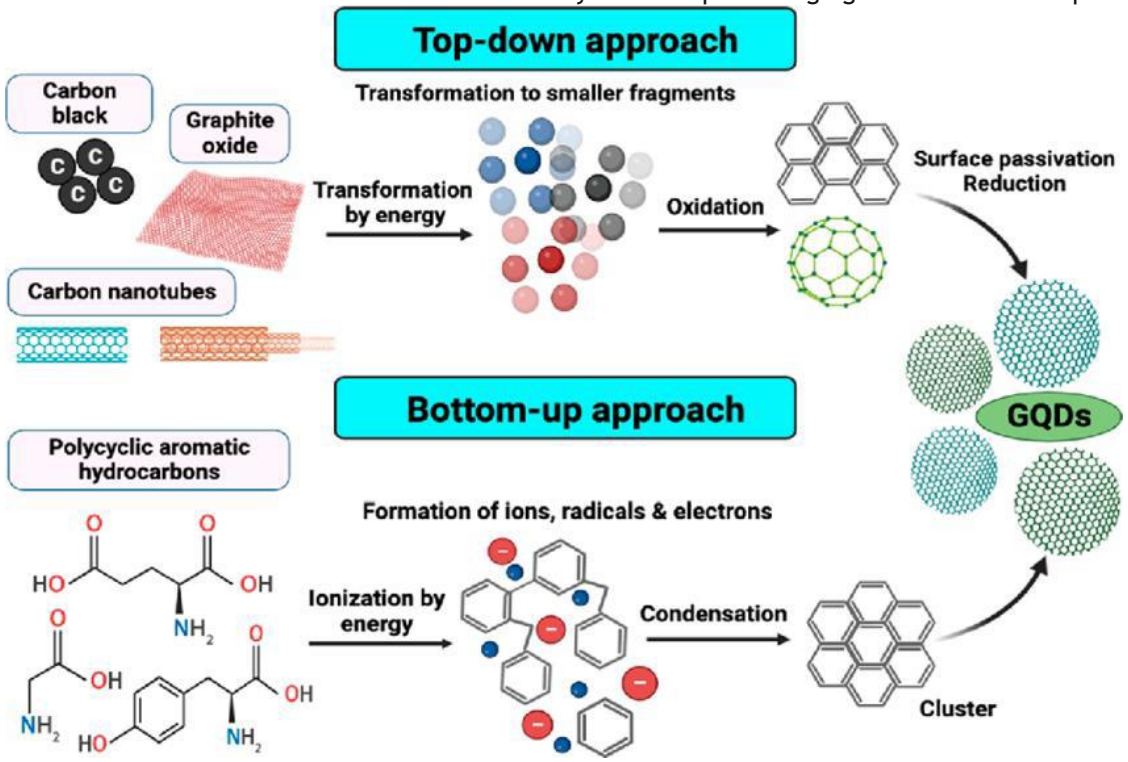


Fig. 3. Synthesis of Quantum Dots

Environmental and Safety Considerations

While quantum dots offer many benefits, safety is an important concern. Semiconductor quantum dots containing heavy metals may pose toxicity risks if not properly controlled. Therefore, carbon-based and silicon quantum dots are preferred, dosage and exposure levels must be carefully regulated, and long-term environmental studies are still needed. Responsible use and proper regulation are essential for sustainable adoption.

Conclusion

Quantum dots represent a powerful example of how nanotechnology can revolutionize agriculture. From enhancing photosynthesis and nutrient delivery to detecting pollutants and improving stress tolerance, these tiny particles offer big solutions. Among them, carbon quantum dots stand out as safe, sustainable, and effective tools for modern farming. As agriculture moves toward sustainability and efficiency, quantum dots may play a crucial role in feeding the world responsibly.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Cleaner Shipping and Coral Bleaching: An Unintended Climate Impact

Article ID: 72793

Hiranya R[1], Ramachandran J[2]
[1]Undergraduate Student, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.
[2]Teaching Assistant, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Introduction

The Great Barrier Reef is one of the most important marine ecosystems from an ecological perspective. Over the past few decades, the reef has suffered from repeated coral bleaching events, largely as a result of increased sea surface temperatures due to global climate change. Bleaching of corals occurs whenever there is prolonged thermal stress that leads to the expulsion of symbiotic algae essential for survival. Although climate change is considered to be the dominant cause of bleaching, recent studies have suggested that some environmental regulations might have inadvertently enhanced heat stress in reef ecosystems. These include a variety of international regulations, such as the global reduction in sulphur emissions from vessels. This policy, created to enhance the quality of air and reduce the amount of other dangerous types of pollution, has generated unforeseen atmospheric effects that may have contributed to increased coral bleaching at the Great Barrier Reef.



Fig. 1. The Great Barrier Reef, Coral Sea, Australia

Sulphur Emissions from Shipping and Atmospheric Effects

Until recently, ships traditionally burned high-sulphur fuels, emitting sulphur dioxide into the atmosphere. This gas reacts to form sulphate aerosols that scatter incoming solar radiation and enhance cloud reflectivity. The resulting cooling effect on the Earth's surface is short-term and particular to major shipping routes. In 2020, the IMO implemented regulations to limit the sulphur content of marine fuels. Although this drastically reduced air pollution and related health impacts, it had an unintended consequence: a severe decline in sulphate aerosol concentrations over the oceans. A decline in atmospheric reflectivity resulted, allowing more solar radiation to reach the ocean surface.

Connection Between Cleaner Shipping and Coral Bleaching

Current study finds that the drop in sulphate aerosols further increased the intensity of surface waters due to increased solar heating of surface waters during extreme heat waves within the Great Barrier Reef region. In the recent heat waves witnessed within the Great Barrier Reef waters during the 2022 heat wave, the increased intensity of surface waters due to increased heat caused corals to exceed their heat tolerance levels, resulting in bleaching. Interestingly, it was also identified that the bleaching occurred during a La Niña period when it should have been cooler. This indicates that changes in atmospheric conditions caused by mitigation of shipping activities in combination with long-term increased ocean temperatures have increased heat stress levels experienced by the corals.



Fig. 2. Coral Bleaching

Implications for Environmental and Climate Policy

The relationship between clean shipping and coral bleaching notwithstanding, there are complexities in dealing with climatic and environmental systems. Accordingly, although aerosols have the cooling effect, these aerosols are the leading source of air pollution, acid rain, and diseases. Therefore, reduction in sulphur emission is good news for the environment. Nevertheless, the essence of an integrated policy response is underlined in this case. Sulphate aerosols have a residence time in the atmosphere for a very short period, compared to greenhouse gases such as carbon dioxide, whose residence time is scheduled for centuries. A proper mitigation response for saving coral reefs will require a concurrent reduction in greenhouse emissions and an evaluation of secondary environmental effects.

Conclusion

Cleaner shipping has undoubtedly yielded huge benefits to air quality and human health, but it has also uncovered some less welcome surprise impacts on marine ecosystems. For example, increased coral bleaching in the Great Barrier Reef highlights that atmospheric processes and ocean systems are all linked. To protect coral reefs, climate policies have a duty to respond simultaneously to air pollution and global warming. Unless greenhouse gas emissions decline quickly and persistently, the incidence and intensity of coral bleaching will probably increase in coming decades.

References

1. Hughes, T. P., Kerry, J. T., Álvarez-Noriega, M., et al. (2017). Global warming and recurrent mass bleaching of corals. Nature, 543(7645), 373–377.
2. Hoegh-Guldberg, O., Poloczanska, E. S., Skirving, W., & Dove, S. (2017). Coral reef ecosystems under climate change and ocean acidification. Frontiers in Marine Science, 4, 158.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Mapping the Raptors of Tamil Nadu Marks a Statewide Effort to Conserve the Region's Top Predators

Article ID: 72794

Dharani G[1], Ramachandran J[2]

[1]Undergraduate Student, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

[2]Teaching Assistant, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Introduction

Tamil Nadu will soon conduct its first-ever statewide survey of raptors or prey birds. The two-day survey will be held on January 31 and February 1, 2026. It aims to create the first scientific baseline in the country on raptors are found and how many exist.

The survey is being organised by the Tamil Nadu Forest Department along with the Advanced Institute for Wildlife Conservation (AIWC) and the Tamil Nadu Raptor Research Foundation (TNRRF). It will cover many habitats including the Western Ghats, coastal areas, farmlands and cities. The TNRRF established in July 2025 focuses only on the research and conservation of raptors and their habitats.



Mapping the Birds of Prey

Raptors such as hawks, eagles, kites, falcons and owls are top predators. They help control prey populations and clean up dead animals, which keeps ecosystems healthy. Because of this, changes in their numbers can shows the environment health.

Tamil Nadu is home to more than 65 raptor species which includes the Brahminy Kite, Crested Goshawk, Shikra, Changeable Hawk-Eagle and Egyptian Vulture. Most of the birds face threats like loss of habitat, electric shock from power lines, pesticide poisoning, and lack of food. A senior Forest Department official said that the decline of raptors is a warning sign of larger environmental problems.

Design and Methodology of the Survey

The first-ever state-wide raptor survey in Tamil Nadu will use a grid-based method, dividing the state into 4,068 blocks, which covers 32 square kilometres. In this, 411 sample grids will be closely monitored by trained teams using binoculars, GPS tools and field data sheets to record bird sightings.

The survey will include two phases. One phase is nocturnal count on January 31, held under the full moon to record owls and nightjars. Another phase is daytime survey on February 1 for eagles, kites and other diurnal raptors. Teams will move through selected grids on foot and vehicle patrols to ensure maximum coverage.

"This is not just a one-time count but a baseline for long-term monitoring," said Dr. K. Karthikeyan, Director of the Animal and Environment Welfare Council (AIWC). "Before we can protect these birds, we need to understand their current status and distribution."

From Data to Conservation Policy

The results of the survey will help to identify the key areas and species that need urgent protection. These findings will guide actions such as habitat restoration, reducing pesticide use and making power lines safer for birds. Officials also hope this project will become a model for a nationwide raptor monitoring program. This is similar to bird surveys in Europe and Africa.

India has already seen what happens when monitoring is neglected. Vulture populations collapsed in the 1990s after the use of the veterinary drug diclofenac, serving as a warning for other raptor species. Scientists says that without regular surveys, many birds of prey could decline, which are unnoticed. “Raptors often disappear quietly,” said a researcher from the Tamil Nadu Raptor Research Foundation. “By the time we realize they’re gone, it’s already too late.”

Conclusion

The Tamil Nadu raptor survey is an important step in understanding and protecting the state’s birds of prey. By combining science with public participation, it lays the foundation for strong, data-based conservation. The survey will help guide actions on habitat protection, pesticide control, and biodiversity planning. As the survey moves forward, it brings hope that the skies of Tamil Nadu will continue to be home to owls, kites and eagles for generations to come.

References

1. The New Indian Express (2026, Jan 21): “Tamil Nadu to conduct first statewide raptor assessment to map distribution of birds of prey.”
2. The Hindu (2026, Jan 20): “First State-wide raptor assessment to be held in Tamil Nadu.”
3. Advanced Institute for Wildlife Conservation (AIWC), Chennai — internal communication and project brief (2025–26).

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Innovative Strategies for Utilising Farm Residue to Drive Yield Gains in 2026

Article ID: 72795

Dr Lakshmi Challa[1], Dr R. Neela Rani[1], Dr Jessie Suneetha. W[1], Dr Swetha Kodali[1], Dr Swarupa Rani[1]
[1]Scientist (CT), Principal Scientist (EXTN), Scientist (FN), Scientist (FRM), Scientist (CD)
AICRP on Women in Agriculture, PJTAU, Rajendranagar, Hyderabad- 500 030.

Abstract
The paper presents the prospects of using farm residues in agricultural activities. Utilising agricultural waste as an organic amendment or biofertilizer is a primary strategy for increasing crop yields by improving soil fertility, structure, and microbial health. Modern agricultural practices for 2026 emphasise a circular economy where residues are repurposed into high-value inputs like nano fertilisers and biochar to reduce reliance on synthetic fertilisers.

Introduction
The farm sector generates considerable waste, much of which is not used productively and poses significant health and environmental risks worldwide (Bala, S. *et al.*, 2023). Farm residue, also known as agricultural residue or agro waste, refers to the non-edible plant biomass and by-products generated before, during, and after the harvesting and processing of crops. The promising relevance of farm residues in the agro-food-pharma-cosmetic industry, and the different possibilities for bioproducts through valorisation techniques, can be realised. In 2026, it is increasingly viewed as a valuable natural resource for a circular bio-economy rather than mere waste. As of 2026, the global agricultural sector is undergoing a massive shift from viewing farm residue as a disposal headache to recognising it as "green gold." Under intense regulatory pressure over air pollution, farmers are increasingly adopting innovative, high-tech strategies to turn leftover stalks, husks, and manure into powerful yield boosters. Disposal of farm waste is a global concern and poses a significant challenge for prospective farmers.

Duque-Acevedo *et al*. (2020) conducted a review of the evolution, approaches, and perspectives on alternative uses. The use of agri-waste is highly dependent on identification, classification, evolution, and approaches and trends in its use and transformation. Agricultural production has increased more than threefold over the last 50 years, with biomass production reaching its highest levels as an essential input for the upcoming bioeconomy.

Types of Farm Residue
Residues are primarily classified by where they are generated:

Field (Primary) Residues: Materials left directly in the field or orchard after harvest.
Examples: Stalks, stubble (stems), leaves, and seed pods.
Management: These are typically left as mulch, incorporated into the soil to boost fertility, or baled for off-site use.

Process (Secondary) Residues: By-products created during the transformation of crops into usable resources.
Examples: Husks, seeds, bagasse (sugarcane fibre), molasses, roots, and shells.
Management: These are often concentrated at processing facilities and used for animal fodder, bio-oil, or manufacturing.

Composition and Value
Farm residue is primarily lignocellulosic biomass, consisting of cellulose (35–55%), hemicellulose (25–40%), and lignin (15–25%).

Economic Worth: As of 2026, the estimated global economic value of these residues is significant, with potential industrial applications ranging from biofuels and bio-plastics to construction materials.

Nutrient Content: Residues contain essential macronutrients (Nitrogen, Phosphorus, Potassium, Sulfur) and organic carbon. For example, rice straw is roughly 1.05% nitrogen and 1.50% potassium.



Figure 1: Farm waste in the field

Prusty, J. K. *et al* (2016) review the potential of agrowaste use in the construction industry. Agro waste can be used as an alternative to cement, fine & coarse aggregates, and reinforcing materials. It has been observed that the agro-waste concrete containing groundnut shell, oyster shell, cork, rice husk ash, and tobacco waste showed better workability than its counterparts. Agro-waste concrete containing bagasse ash, sawdust ash and oyster shell achieved their required strength by 20% of replacement as fine aggregate, which was the maximum among all agro-waste type concrete.



Fig 2: Different forms of Farm waste and their recycled usage options

Yaashikaa *et al* (2022) analysed that energy recovery from waste resources is a promising approach to addressing environmental concerns. In the prospect of environmental sustainability, utilisation of agro-industrial waste residues as feedstock for biorefinery processes has gained widespread attention.

Modern Applications for Farm Waste (2026 Perspective)

Beyond traditional use as animal bedding or fuel, innovative strategies now prioritize:

Bio-Energy: Conversion into biogas, bioethanol, and briquettes for power generation.

Biochar Production: Pyrolyzing residues to create soil amendments that improve water retention and sequester carbon.

Advanced Materials: Using fibers for high-quality textiles, biodegradable packaging, and even as fillers in automotive polymers.

Integration Strategies for Farmers

1. Integrated Farming Systems (IFS): Promoting zero-waste models where waste from one sector (e.g., crop residues) serves as input for another (e.g., livestock feed or biogas), creating a sustainable loop.

2. Information Hubs: Establishing coordination between vegetable and dairy farmers to exchange waste products (e.g., manure for compost and straw for feed) ensures resources are not wasted in the field.

3. 4R Nutrient Stewardship: Applying processed waste using the **Right Source, Right Rate, Right Time, and Right Place** ensures maximum nutrient use efficiency and yield.

The Biochar Breakthrough: Locking in Fertility

One of the most transformative technologies currently scaling in 2026 is **biochar**—a carbon-rich soil amendment produced by heating crop residues like rice husks or corn stover in a low-oxygen environment (pyrolysis).

1. Yield Impact: Applying biochar to fields can increase crop productivity by improving soil nutrient retention and water-holding capacity.

2. Climate Bonus: Biochar acts as a permanent carbon sink, sequestering carbon in the soil for hundreds of years.

3. New for 2026: Emerging **nano biochar** (synthesised through mechanical ball-milling) is now being used as a high-efficiency additive. In recent maize trials, nano biochar mixed with vermicompost increased shoot dry matter yield by up to **32%** while slashing ammonia emissions by 43%.

Vermicomposting 2.0: The "Worm Wealth" Economy

Vermicomposting—using specialised earthworms like *Eisenia fetida* to digest waste—is no longer just for small organic plots. In 2026, it is a key industrial-scale strategy.

1. The Power of Vermicast: Earthworm castings (vermicast) are rich in nitrogen, phosphorus, and potassium (NPK). Recent greenhouse studies on sweet peppers showed that replacing standard compost with 100% vermicompost increased total yields by more than **30%**.

2. Synergistic Mixes: Combining biochar with vermicompost is proving to be a "super-strategy." This combination enhances soil microbial diversity, which helps plants resist diseases and better absorb nutrients.

Nano Fertilizers: Precision Nutrition from Waste

The use of **nano-enabled agrochemicals** is a cornerstone of 2026 precision farming.

1. Sustainable Sourcing: Innovators are now extracting cellulose and nutrients from waste products like sugarcane bagasse and fruit peels to create nano fertilizers.

2. Efficiency Gains: Unlike traditional fertilisers that often wash away, these nanostructured inputs release nutrients slowly in response to environmental triggers. This targeted delivery can significantly increase nutrient use efficiency (NUE) by up to **35%**, leading to higher yields with less total fertiliser application.

From Farm to Infrastructure: Circular Revenue

2026 marks the rise of "waste-to-wealth" industrial applications that provide farmers with secondary income streams.

1. Bio-Bitumen: New technology has begun repurposing crop stubble into materials for road construction, effectively ending the need for field burning in regions like North India while reducing road-building costs.

2. Eco-Construction: Residues like rice husks and wheat straw are being converted into insulating building panels that can save up to **69%** of energy in rural housing.

Targeted Research (Niche Focused)

1. Beyond Mulching: Advanced Thermochemical and Biological Treatments of Waste for Yield Acceleration.

2. Phytoremediation and Productivity: Using Agricultural Waste to Restore Degraded Land for Increased Output.

3. Smallholder Success: Low-Cost Waste Conversion Technologies for Increasing Local Crop Yields.

Conclusion

The Bottom Line for 2026: Utilising farm residue is no longer just an environmental choice; it's an economic imperative. By integrating technologies like pyrolysis for biochar, advanced vermicomposting, and nanotechnology, modern farms are closing the nutrient loop, slashing input costs by up to **20%**, and achieving record-breaking sustainable yields.

References

1. Bala, S., Garg, D., Sridhar, K., Inbaraj, B. S., Singh, R., Kamma, S., Tripathi, M., & Sharma, M. (2023). Transformation of Agro-Waste into Value-Added Bioproducts and Bioactive Compounds: Micro/Nano Formulations and Application in the Agri-Food-Pharma Sector. In *Bioengineering* (Vol. 10, Issue 2). https://doi.org/10.3390/bioengineering10020152
2. Duque-Acevedo, M., Belmonte-Ureña, L. J., Cortés-García, F. J., & Camacho-Ferre, F. (2020). Agricultural waste: Review of the evolution, approaches and perspectives on alternative uses. *Global Ecology and Conservation*, 22, e00902. https://doi.org/10.1016/J.GECCO.2020.E00902
3. Phiri, Resego, M. R., Sanjay, Siengchin, Suchart, Marinkovic, Dragan, 2023. Agro-waste natural fiber sample preparation techniques for bio-composites development: methodological insights. Acta universitatis Series: Mechanical Engineering, 21(4):631 - 656 https://doi.org/10.22190/FUME230905046P

4. Prusty, J. K., Patro, S. K., & Basarkar, S. S. (2016). Concrete using agro-waste as fine aggregate for sustainable built environment – A review. In *International Journal of Sustainable Built Environment* (Vol. 5, Issue 2). https://doi.org/10.1016/j.ijsbe.2016.06.003
5. Yaashikaa, P. R., Senthil Kumar, P., & Varjani, S. (2022). Valorization of agro-industrial wastes for biorefinery process and circular bioeconomy: A critical review. *Bioresource Technology*, *343*. https://doi.org/10.1016/j.biortech.2021.126126.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

A Success Story on Postpartum Anestrus Management and Sustainable Dairy Farming

Article ID: 72796

Mehrajuddin Naikoo[1], Manzoor Ahmad Yatoo[2]
[1]Associate Professor, Division of ARGO, FVSc. & AH, Shuhama (SKUAST-K).
[2]Associate Professor, MLRI- Manasbal (SKUAST-K).

Introduction

Postpartum anestrus is a key contributor to extended calving intervals and reduced reproductive rhythm in dairy cattle. Cows with smooth, inactive ovaries often fail to recommence cyclicity despite of adequate nutrition and normal body condition. Hormonal induction protocols such as Ovsynch have been developed to induce ovulation and permit fixed-time artificial insemination without reliance on behavioural estrus detection (Pursley *et al.*, 1995). At times there are constraints on movement of animals due to non-availability of animal handler/labour, vehicle, and limited Veterinary access, which poses challenges to routine reproductive breeding programmes, mostly Artificial Insemination (AI), increasing the importance of fixed-time breeding approaches. This short success story highlights the response to the Ovsynch protocol in postpartum anestrus cows with smooth ovaries managed under field conditions.

Rationale

Livestock rearing particularly dairy farming is nowadays a good source of income not only for the rural but for many urban people as well. In addition to providing employment opportunities to youth the sector has facilitated in achieving self-reliance and sustainable dairy entrepreneurship. It has a vast scope to expand at significantly higher growth rates compared to other farm sectors, provided the constraints opposing the dairy sector are carefully dealt with. It offers immense potential for expansion, with the capacity to achieve comparably higher growth rates than other agricultural sub-sectors, provided its few prevailing limitations are effectively addressed. This high-value segment of agriculture also holds considerable promise for generating employment amongst unemployed youth and women. This story reveals the successful use of Ovsynch protocol in postpartum anestrus dairy cows as a boost to reproductive health management and sustainable dairy enterprise.

Brief Summary

The current story evaluated the success of the Ovsynch protocol for estrus induction and fertility in postpartum anestrus cows under field and farm conditions. On Gynaeco-clinical examinations, 24 postpartum anestrus cows with normal body condition but smooth ovaries, without any gross uterine or ovarian pathology, with anestrus for more than four months after calving, were selected for the Ovsynch protocol. Six cows were kept as untreated anestrus control and six cows as normal cyclic control. The estrus response was observed in 18 out of 24 cows (75.00%) based on estrus signs, mostly internal signs of estrus were present. Out of the 18 animals inseminated, 11 conceived, resulting in a conception rate of 61.11% among estrus-induced cows and an overall conception rate of 45.83% (11 out of 24 cows). Further, there was a conception rate of 66.66% in normal cyclic cows subjected to routine AI (four out of the six cows conceived). On the other hand, no animal showed estrus out of the six anestrus control animals. The results revealed effective estrus induction associated with acceptable conception rates in postpartum anestrus cows subjected to Ovsynch protocol.

Methodology

The study was carried out using a total of 30 postpartum anestrus cows that had failed to exhibit estrus for more than four months after calving. All cows had normal body condition and smooth, inactive ovaries on per rectal palpation, with no gross uterine abnormalities. The Ovsynch protocol was applied to 24 anestrus cows, each comprising of 20µg GnRH administration on day 0, 500 µg of $PGF_2\alpha$ on day 7, and a 10µg of second GnRH on day 9, followed by fixed-time artificial insemination on day 10. Estrus response was assessed based on the presence of external and/or internal signs, and pregnancy diagnosis was carried out 2 months after AI by palpation per rectum. Six anestrus cows were kept as untreated control and no treatment was given to them except for the placebo using Normal saline. Six normal cyclic cows routinely bred with AI were also kept as normal cyclic control.

Results/ Outcome

Following treatment, 18 out of 24 cows (75.00%) exhibited estrus. Fixed-time AI resulted in a conception in 11 out of the 18 inseminated cows, giving a conception rate of 61.11% among estrus-induced cows and an overall conception rate of 45.83%. This conception rate is quite satisfactory and contrary to that of the normal cyclic group and agreeably higher compared to the anestrus control group. The observed estrus induction rate indicates that the Ovsynch protocol was effective in initiating ovarian activity in postpartum anestrus cows with smooth ovaries. Similar estrus response and

conception rates have been reported in earlier studies using Ovsynch in anestrus and cyclic cows (Pursley *et al.*, 1997; Thatcher *et al.*, 2001). In normal cyclic cows, subjected to routine AI, 66.66% (four out of six cows) Conceived. On the other hand, no animal showed estrus out of the six anestrus control animals. The ability to inseminate cows at a fixed time without the need for estrus detection represents a major advantage under some conditions like constraints on animal movement, non-availability of animal handler, automobile for transport, and at times limited Veterinary access, which challenges routine Artificial Insemination (AI) in animals.

Conclusion

The Ovsynch protocol was effective in inducing estrus and attaining satisfactory conception rates in postpartum anestrus cows with smooth ovaries. The protocol offers a real and reliable reproductive management tool, particularly during periods of limited farm access and reduced estrus detection efficiency. Postpartum anestrus management is a key factor for profitable dairy farming because, it reduces costly inter-calving intervals and helps in maintaining inexhaustible reproductive rhythm in animals.

References

1. Pursley, J.R., Mee, M.O. and Wiltbank, M.C. (1995). Synchronisation of ovulation in dairy cows using $PGF_2\alpha$ and GnRH. *Theriogenology*, 44: 915–923.
2. Pursley, J.R., Wiltbank, M.C., Stevenson, J.S., Ottobre, J.S., Garverick, H.A. and Anderson, L.L. (1997). Pregnancy rates per artificial insemination for cows and heifers inseminated at a synchronised ovulation or synchronised estrus. *Journal of Dairy Science*, 80: 295–300.
3. Thatcher, W.W., Moreira, F., Pancarci, S.M., Bartolome, J.A. and Santos, J.E.P. (2001). Strategies to optimise reproductive efficiency by regulation of ovarian function. *Domestic Animal Endocrinology*, 23: 243–254.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

A Success Story on Profitable Dairy Farming Through Postpartum Anestrus Management in Dairy Cattle

Article ID: 72797

Mehrajuddin Naikoo[1], Manzoor Ahmad Yatoo[2]
[1]Associate Professor, Division of ARGO, FVSc. & AH, Shuhama (SKUAST-K).
[2]Associate Professor, MLRI- Manasbal (SKUAST-K).

Introduction

Postpartum anestrus is a principal contributor to prolonged inter-calving interval and decreased reproductive functionality in dairy cows. It is also one of the important criteria for sustainable dairy industry and economy of farmers. Animals with smooth, inactive ovaries frequently fail to resume ovarian rebound, despite of appropriate nutrition and normal body condition. The Cosynch protocol is a kind of modified Ovsynch protocol that has been developed to induce ovulation and allow fixed-time artificial insemination (FTAI) in cattle without dependence on behavioural estrus detection. In the Cosynch protocol, the first gonadotropin-releasing hormone (GnRH) injection is followed by a $PGF_2\alpha$ injection to induce luteolysis 7 days later, and a second GnRH injection is administered concurrently with TAI to synchronize ovulation at a predetermined time, eliminating the need for estrus detection.

The estrus induction response with Cosynch was 66.66 and the conception rates at induced estrus 50.00. In normal cyclic control group, the conception rate at first cycle was 33.33%. It was concluded that Cosynch protocol was better for estrus induction and conception rate in anestrus and subestrus suckled Kankrej cows (Naikoo *et al.*, 2021). Difficulties in arranging labour, transport, and timely contact with Veterinary Artificial insemination service personnel often delay breeding of some animals. To overcome such problems, fixed-time breeding offers a practical solution. This brief script describes the successful use of the Cosynch protocol in postpartum anestrus cows managed in the field and farm cows.

Summary

The Cosynch protocol for estrus induction and fertility in postpartum anestrus cows under field and farm conditions was used in this study programme. On thorough Gynaecological examination, 26 postpartum anestrus cows with optimum body weight, having normal sized but smooth ovaries, with no gross uterine or ovarian pathology, but showing no signs of estrus from more than four months postpartum were selected for Cosynch protocol. Eight cows were kept as untreated anestrus control and eight cows with regular estrus cyclicity were also kept as normal control. The estrus response was observed in 19 out of 26 cows (73.07%), typically internal signs of estrus were present in maximum animals. After AI was performed 11 Out of the 19 animals conceived, ensuing in a conception rate of 57.89% among estrus-induced cows and an overall conception rate of 42.30% (11 out of 26 cows). Moreover, there was a conception rate of 62.50% in normal cyclic cows subjected to routine AI (five out of eight cows). However, only one animal showed estrus out of the six anestrus control animals. It was observed that there was a good estrus induction associated with satisfactory conception rates in postpartum anestrus cows by using Cosynch protocol.

Materials and Methods

The study was conducted in 34 postpartum anestrus cows that had failed to display estrus for more than four months after parturition. The cows had normal body weight but smooth, inactive ovaries were observed on examination per-rectum, without any gross uterine abnormalities. The Cosynch protocol was used to 26 anestrus cows, each comprising of 20µg GnRH administration on day 0, 500 µg of $PGF_2\alpha$ on day 7, and a 10µg of second GnRH on day 9, followed by fixed-time artificial insemination on the same day 9. Estrus response was measured based on the presence of external and/or internal signs, and pregnancy diagnosis was carried after 2 months of AI by examination per rectum. A total of eight anestrus cows were kept as untreated control and no treatment was given to them but only the placebo using Normal saline. Eight normal cows routinely bred with AI were also kept as normal cyclic control.

Outcomes/ Results

After the treatment, 19 out of 26 cows (73.07%) exhibited estrus. Fixed-time AI resulted in a conception in 11 out of the 19 inseminated cows, giving a conception rate of 57.89% among estrus-induced cows and an overall conception rate of 42.30% (11 out of 26 cows). This conception rate is fairly suitable and almost similar to that of the normal cyclic group but pleasantly higher compared to the anestrus control group. The observed estrus induction rate indicates that the Cosynch protocol was very good in initiating ovarian activity in postpartum anestrus cows with smooth ovaries. Similar estrus response and conception rates have been reported in earlier studies using Cosynch in anestrus and cyclic cows (Naikoo *et al.*, 2021). In normal cyclic cows, subjected to routine AI, 66.66% (four out of six cows) Conceived. On the other hand, one animal showed estrus out of the six anestrus control animals but did not conceive. The capability to inseminate cows at a fixed time without the necessity for estrus detection and in addition to that similar day for AI and

last GnRH signifies a key advantage under some circumstances viz. arranging labour, transport, and timely contact with Veterinary Artificial insemination service personnel often delay breeding of some animals.

Conclusion

The protocol namely Cosynch was very useful in inducing estrus and attaining acceptable conception rates in postpartum anestrus cows with smooth ovaries. The protocol proposed a truly reliable reproductive management means, particularly during periods of limited farm access and decreased estrus detection effectiveness. The management of Postpartum anestrus cattle is a prime key factor for moneymaking dairy farming because, it lessens the costly calving interval and aids in maintaining regular reproductive cyclicity in dairy animals.

Reference

Naikoo, M., Dhami, A.J. and Parmar, B.C. 2021. Monitoring Plasma Metabolic Profile and Fertility in Normal and Estrus Synchronized Suckled Kankrej Cows. *Indian Journal of Animal Research*. DOI: 10.18805/IJAR.B-4220.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Plastic-Degrading Bacteria in Mangrove Ecosystems: A Natural Approach to Microplastic Pollution

Article ID: 72798

Devatharshini S[1], Ramachandran J[2]

Introduction

Plastic pollution has emerged as a major environmental concern due to the widespread use of synthetic polymers such as polyethylene terephthalate (PET), polystyrene (PS), polyethylene (PE), polypropylene (PP), and low-density polyethylene (LDPE). These materials are highly resistant to natural degradation and therefore persist in the environment for long periods. Mangrove ecosystems receive significant amounts of plastic waste through river discharge and tidal action. The continuous accumulation of plastic debris negatively affects biodiversity, sediment quality, and overall ecosystem health. Recent research has revealed that native microorganisms in mangrove environments possess the ability to degrade plastics naturally.

Plastic Pollution in Mangrove Ecosystems

Mangroves function as natural sinks for plastic debris because of their complex root systems and low water flow. Plastic waste entering coastal zones becomes trapped in mangrove sediments and gradually fragments into microplastics. These microplastics accumulate in both soil and water and are often ingested by aquatic organisms, leading to ecological disturbances and potential health hazards. As a result, mangrove ecosystems have become critical hotspots for plastic pollution.

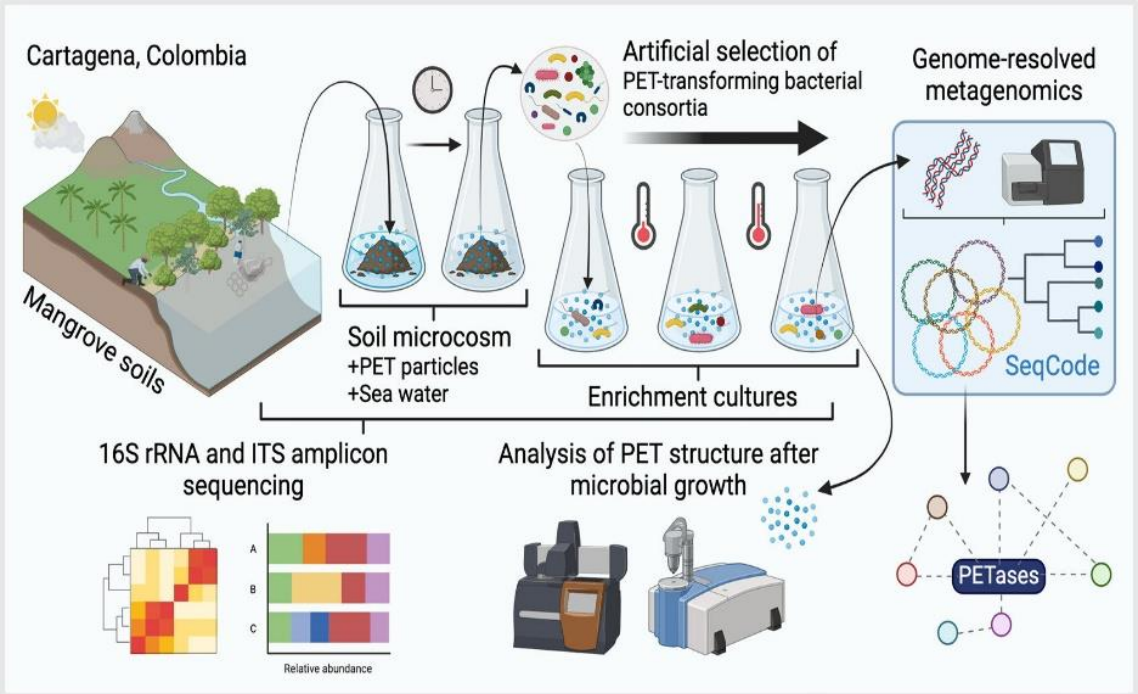


Fig. 1: Mangrove microorganisms showing potential for plastic degradation

Indigenous Plastic-Degrading Bacteria

Mangrove soils and waters support diverse microbial communities that are well adapted to fluctuating salinity, temperature, and nutrient conditions. Certain indigenous bacteria can attach to plastic surfaces and form biofilms. These bacteria secrete enzymes capable of breaking down plastic polymers into simpler compounds. Bacterial genera such as Bacillus, Brevibacillus, Lysinibacillus, Stenotrophomonas, and Pseudochrobactrum have been frequently reported for their plastic-degrading abilities. These microorganisms utilize plastic-derived compounds as supplementary carbon sources.

In-Situ Bioremediation of Microplastics

In-situ bioremediation refers to the treatment of contaminated environments using native microorganisms directly at the affected site. In mangrove ecosystems, microbial consortia have demonstrated the capacity to degrade PET and PS microplastics under natural conditions. An increase in microbial activity has been observed in the presence of

microplastics, indicating microbial adaptation. Extended exposure results in measurable reductions in microplastic mass, confirming the effectiveness of natural biodegradation processes.

Mechanism of Plastic Degradation

The degradation of plastics begins with surface deterioration caused by environmental factors such as sunlight, moisture, and salinity. Microorganisms then adhere to the plastic surface and form biofilms. These microbes release extracellular enzymes, including lipases and hydrocarbon-degrading enzymes, which break long polymer chains into smaller molecules. The resulting compounds are further metabolized and assimilated by the microbes.

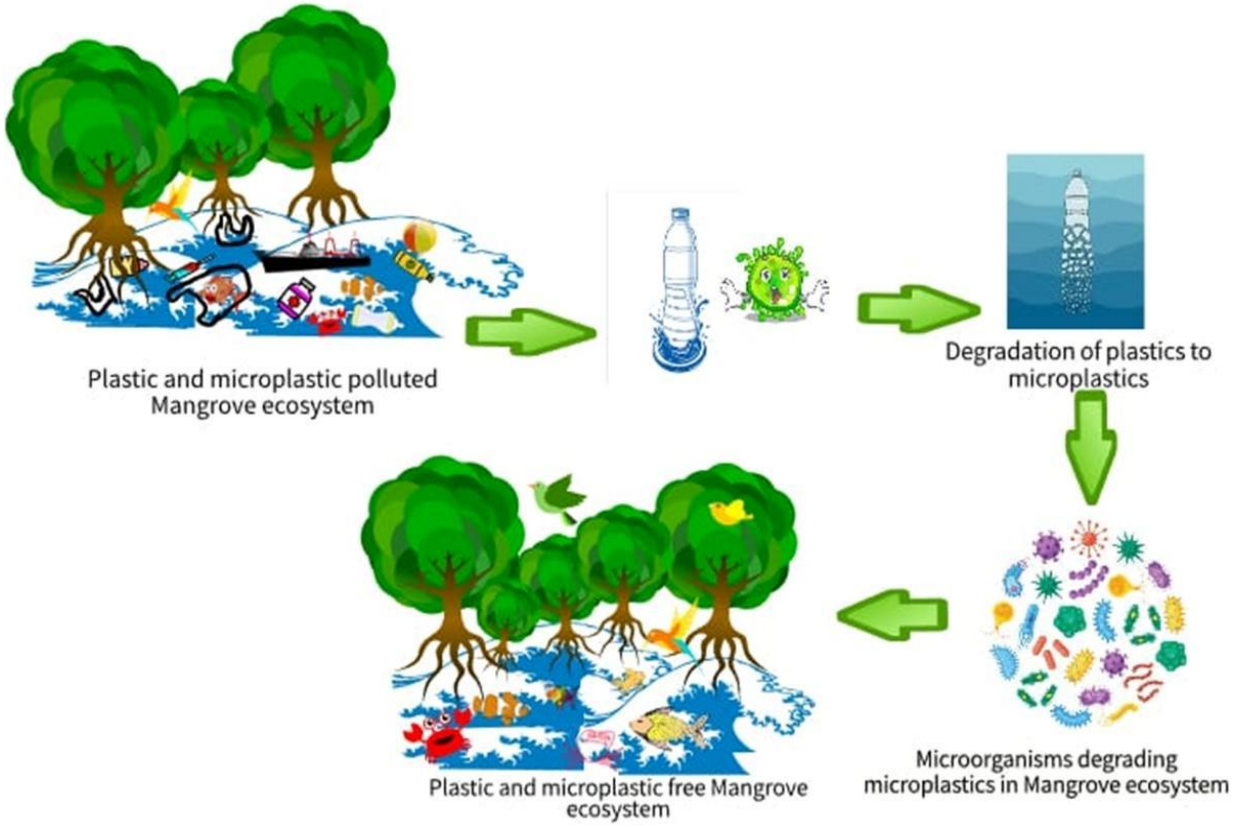


Fig. 2: Presence of microplastics in mangrove ecosystems and the potential for biodegradation

Structural and Chemical Changes in Plastics

Microbial degradation leads to noticeable alterations in the physical and chemical properties of plastics. Scanning electron microscopy reveals surface cracks, pits, and erosion. Energy-dispersive spectroscopy shows a decline in carbon and oxygen content, while Fourier transform infrared spectroscopy indicates the weakening or loss of polymer functional groups. These observations provide clear evidence of microbial-mediated plastic degradation.

Influence of Environmental Factors

Environmental conditions play a crucial role in determining the efficiency of plastic biodegradation. Factors such as pH, salinity, nutrient availability, and exposure duration significantly influence microbial growth and enzymatic activity. The dynamic nature of mangrove ecosystems enhances microbial adaptability, while high organic matter content supports continuous microbial processes. These conditions collectively promote effective plastic degradation.

Environmental Importance

Plastic-degrading bacteria contribute to reducing plastic persistence in mangrove sediments, thereby protecting aquatic life and maintaining ecological balance. Natural bioremediation is environmentally friendly and does not produce secondary pollutants. This process also supports sustainable coastal ecosystem management, highlighting the important role of mangroves in combating plastic pollution.

Conclusion

Mangrove ecosystems host diverse indigenous bacteria capable of degrading plastics and microplastics. Through biofilm formation and enzymatic activity, these microorganisms break down polymer materials such as PET, PS, PE, PP, and LDPE under natural conditions. In-situ bioremediation using mangrove-associated microbes is a cost-effective,

sustainable, and eco-friendly strategy. This natural approach offers a promising solution for mitigating plastic pollution in coastal environments.

References

1. Li, Z., Wang, Y., & Chen, L. (2018). Plastics in mangrove ecosystems: abundance, fate and removal pathways. Marine Pollution Bulletin, 135, 363–374.
2. Singh, A., et al. (2024). Bacterial degradation of polyethylene and polypropylene microplastics in a mangrove ecosystem. Chemosphere, 369, 143908.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

PM2.5 Air Pollution in India: Trends, Urban Dynamics, and Environmental Agricultural Impacts

Article ID: 72799

Atchaya. M[1]
[1]Undergraduate Student, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Abstract
Fine particulate matter (PM2.5) is one of the most dangerous air pollutants affecting India today. Because these particles are extremely small, they can enter deep into the human lungs and bloodstream, causing serious health problems. PM2.5 also affects the environment and agriculture by reducing soil quality, crop productivity, and ecosystem stability. This popular science article explains PM2.5 pollution in India using scientific evidence and real-world observations, focusing on major cities such as New Delhi,

Mumbai, Chennai, Bengaluru, Hyderabad, Kolkata, and Coimbatore. It also highlights environmental and agricultural impacts and discusses solutions for deaner air.

Keywords: PM2.5, air quality, agriculture, environment, AQI, India.

Introduction
Air pollution has become one of India's most serious environmental challenges. Rapid urbanization, population growth, increased vehicle use, industrial expansion, and

agricultural activities have led to a sharp rise in PM2.5 levels. Unlike visible dust, PM2.5 particles remain suspended in the air for long periods and travel large distances. As a result, both cities and rural areas experience harmful Pollution.

The Indo-Gangetic Plain, especially northern India, experiences extreme pollution

during winter due to weather conditions that trap pollutants close to the ground. Southern cities generally have lower levels, but pollution is steadily increasing due to urban growth.

What is PM2.5 and where does it Come From?
PM2.5 refers to particulate matter with a diameter of 2.5 micrometers or smaller. These particles come from direct emissions such as vehicle exhaust and factory smoke, and from chemical. reactions in the atmosphere involving gases like sulfur dioxide and nitrogen
oxides.

In cities, major sources include vehicles, industries, construction dust, and household fuel use. In rural areas, crop residue buming, fertilizer use, and dust from farming activities play a significant role Agricultural emissions, especially stubble burning, strongly affect regional air quality.

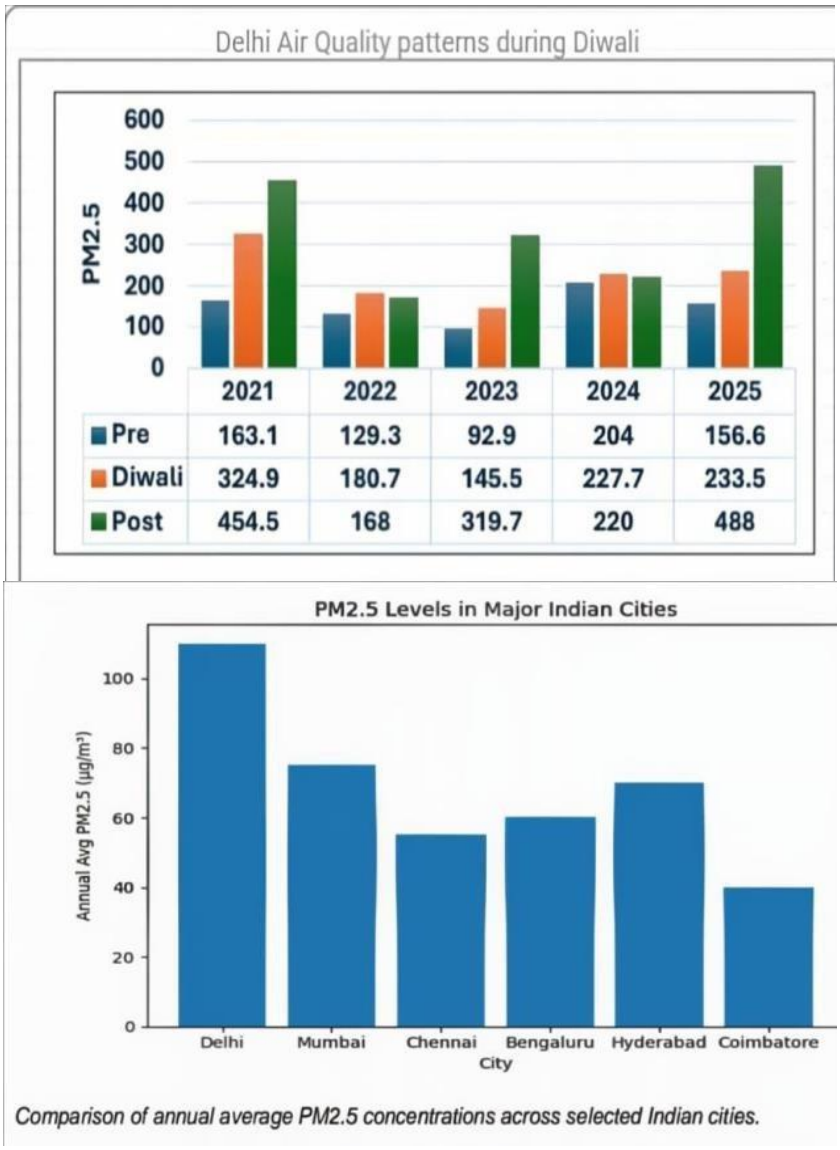
PM2.5 Trends Across India
Monitoring data show that PM2.5 pollution remains high across most Indian cities. Levels peak during winter when wind speeds are low and temperatures trap pollutants. During the monsoon, rainfall helps clean the air.

Studies also show that PM2.5 pollution has a "memory effect," meaning pollution episodes can last longer and repeat if strong action is not taken.

PM2.5 in Major Indian Cities
New Delhi frequently records PM2.5 levels several times higher than safety limits, especially in winter. Causes include vehicles, industries, construction, and smoke from crop burning in nearby states.

Mumbai and Chennai show moderate to high pollution due to traffic and industrial activity, while coastal winds help reduce pollution at times. Kolkata struggles with old vehicles and high population density. Bengaluru and Hyderabad face rising pollution from construction and rapid urban growth.

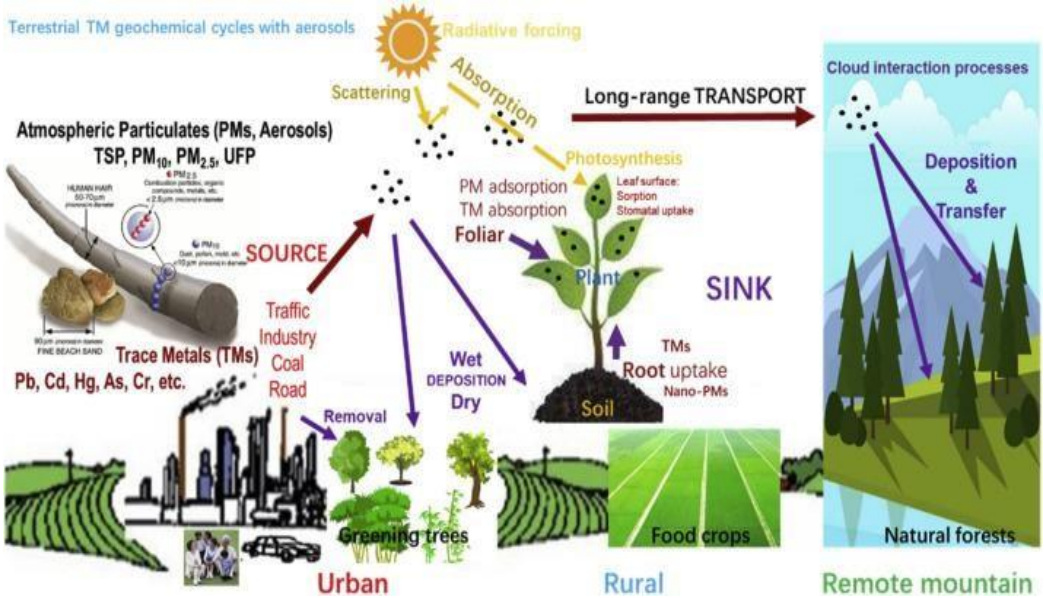
Coimbatore generally has better air quality, helped by favorable winds and its location near the Western Ghats. However, increasing vehicles and industrial growth pose future risks.



Comparison of annual average PM2.5 concentrations across selected Indian cities.

Environmental and Agricultural Impacts

PM2.5 reduces visibility, affects climate by altering sunlight absorption, and damages ecosystems. When particles settle on soil and water bodies, they change chemical properties and reduce biodiversity.



For agriculture, PM2.5 reduces crop productivity by blocking sunlight on leaves and damaging plant tissues Long-term exposure leads to lower yields in crops like rice and wheat. Soil quality is also affected due to acidic and metal-containing particles.

Solutions and Policy Measures

India's National Clean Air Programme (NCAP) aims to reduce particulate pollution through better monitoring, cleaner fuels, electric mobility, and improved waste and crop residue management. Long-term success depends on strong enforcement, public awareness, and region-specific solutions.

Conclusion

PM2.5 pollution is a major threat to health, the environment, and agriculture in India. While some cities face severe pollution, others still have time to act. Strong scientific evidence shows that sustained and coordinated action can significantly improve air quality and protect future generations.

References

1. Guttikunda, S. K., C Jawahar, P. (2018). Atmospheric emissions and pollution from the coal-fired thermal power plants in India. Atmospheric Environment, 92, 449–460.
2. Health Effects Institute. (2020). State of global air 2020. Boston, MA: HEI.
3. Lelieveld, J., Evans, J. S., Fnais, M., Giannadaki, D., C Pozzer, A. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature, 525(7569), 367–371.
4. Sharma, S., Zhang, M., Anshika, Gao, J., Zhang, H., C Kota, S. H. (2020). Effect of restricted emissions during COVID-19 on air quality in India. Science of the Total Environment, 728.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Chakhao Black Rice of Manipur: From Cultural Heritage to Emerging Livelihood Opportunity

Article ID: 72800

Sai Santak Pattanaik[1], Lakshmi Dhar Hatai[1], Girija Prasad Patnaik[2]
[1]Department of Agricultural Economics, COA, Central Agricultural University, Imphal, Manipur, India.
[2]Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India.

Summary of Article

Chakhao, the traditional black scented rice of Manipur, has historically been cultivated for household consumption, cultural rituals and festive occasions rather than for commercial purposes. In recent years, scientific studies have highlighted its exceptional nutritional qualities, particularly its high antioxidant content, which distinguishes it from conventional white rice (Asem *et al.*, 2015). This nutritional recognition, combined with its Geographical Indication (GI) status, has repositioned Chakhao as a premium rice variety with increasing demand in health-conscious domestic and niche markets (Banerjee *et al.*, 2019; Thongam and Pathak, 2023).

Economic studies indicate that Chakhao often fetches market prices several times higher than ordinary rice, offering scope for higher farm returns even under low-input cultivation systems (Nandini Devi *et al.*, 2019). However, farmers continue to face challenges such as low yield potential of traditional varieties, limited access to processing and storage facilities, and unequal distribution of value along the supply chain, where a large share of profits is captured beyond the farm level. This article traces Chakhao's transition from a culturally significant grain to an emerging livelihood opportunity and discusses how scientific improvement, value addition and institutional support can enable more inclusive and sustainable rural development in Manipur.

Introduction

Agriculture in the North-Eastern region of India is predominantly practised under small and fragmented landholdings, with limited mechanisation and strong reliance on traditional crop systems. In such regions, indigenous crops with high market value play a crucial role in enhancing farm income while simultaneously conserving local biodiversity and cultural heritage. Chakhao, the black scented rice traditionally cultivated in Manipur, represents one such indigenous crop that has gained renewed attention in recent years.

Traditionally, Chakhao was grown mainly for household consumption and ceremonial purposes. Farmers consciously selected and conserved this rice for its distinctive colour, aroma, stickiness and taste, rather than for high yield. Consequently, Chakhao remained outside formal rice improvement and commercialisation programmes for a long period. With changing food habits and increasing consumer interest in nutritionally rich and functional foods, this traditional grain has gradually moved beyond local kitchens to wider markets (Banerjee *et al.*, 2019).

Scientific investigations have revealed that Chakhao is rich in natural antioxidants associated with its dark pericarp, making it nutritionally superior to common white rice varieties (Asem *et al.*, 2015). This scientific validation, along with its cultural identity and geographical specificity, has transformed Chakhao from a subsistence grain into a premium rice with growing demand in health-oriented domestic and niche markets. As a result, Chakhao is increasingly being viewed not only as a traditional food but also as a potential contributor to sustainable rural livelihoods in Manipur.

Economic Importance of Chakhao

Chakhao is recognised as a high-value rice due to the premium prices it commands in local and niche markets. Studies have reported that, despite lower yields compared to modern rice varieties, Chakhao cultivation can generate higher gross returns per unit area because of its superior market price (Nandini Devi *et al.*, 2019). This price advantage makes Chakhao a viable option for income diversification, particularly for small and marginal farmers operating under rainfed conditions.

However, the economic benefits of Chakhao are not evenly distributed along the marketing chain. Although consumers pay high prices, farmers often receive only a modest share of the final value. Limited access to storage, milling and processing facilities forces many farmers to sell the grain immediately after harvest. As a result, activities that generate higher value—such as cleaning, packaging and product preparation—are largely undertaken by traders and processors, leading to unequal distribution of income across the value chain (Thongam and Pathak, 2023).

Role of Science and Improved Varieties

Low yield potential and vulnerability to lodging have long been major limitations in the cultivation of traditional Chakhao varieties. To address these challenges, recent scientific efforts have focused on developing improved Chakhao lines that maintain their characteristic colour, aroma and nutritional quality while offering greater yield stability. These improved

varieties exhibit stronger plant architecture, better field performance and wider adaptability under local growing conditions.

The adoption of such varieties reduces production risk and improves the overall economic viability of Chakhao cultivation. When supported by suitable agronomic practices and organic nutrient management, improved Chakhao varieties can deliver higher and more stable returns while maintaining soil health and environmental sustainability (Mahanta *et al.*, 2021). This integration of traditional quality traits with scientific improvement strengthens Chakhao's potential as a reliable income-generating crop for farmers.

Value Addition and Market Opportunities

The greatest economic opportunity for Chakhao lies beyond the sale of raw grain. Products such as traditional sweets, bakery items and ready-to-cook preparations made from black rice command much higher prices in the market than unprocessed rice. Establishing small-scale processing units at the village level can generate additional employment, particularly for women and rural youth, while allowing farmers to capture a larger share of consumer expenditure.

The Geographical Indication (GI) status of Chakhao further enhances its identity and credibility in the marketplace by linking quality with its place of origin. However, the economic advantages of GI recognition can be fully realised only when farmers are organised into groups and supported with appropriate infrastructure, certification mechanisms and market linkages. Such collective efforts can strengthen branding, improve market access and ensure that the benefits of premium pricing reach the producer level (FAO, 2017).

Personal Opinion

Chakhao should be viewed not only as a speciality rice but as a practical instrument for rural development. Organising farmers into functional groups, encouraging village-level processing and actively involving rural youth can convert Chakhao cultivation into a stable and sustainable livelihood option. With appropriate institutional backing in the form of credit, infrastructure and market support, this traditional grain has the potential to enhance farm incomes while simultaneously safeguarding the cultural identity and farming heritage of Manipur.

Conclusion

Chakhao black rice exemplifies how traditional crops can gain new relevance when culture, nutrition and economics come together. Its gradual transition from a ritual grain to a premium food product demonstrates the untapped potential of indigenous crops in contemporary agricultural systems. By combining scientific improvement with local value addition and supportive institutional policies, Chakhao can evolve into a reliable source of income and employment. Such an approach not only strengthens rural livelihoods but also ensures the conservation of cultural heritage and agrobiodiversity in Manipur and other comparable regions.

References

1. Asem I.D., Imotomba R.K., Mazumder P.B. and Laishram J.M., (2015). Anthocyanin content in black scented rice (Chakhao). Journal of Food Science and Nutrition. 3: 1–7.
2. Banerjee R., Chakraborty A., Chowdhury S. and Ganguly S., (2019). Medico-nutritional value and profitability of black rice: The new black gold of Indian agriculture. Science for Agriculture and Allied Sector. 3(6): 11–16.
3. Nandini Devi K., Athokpam F.D., Chongtham S.K. and Singh N.G., (2019). Production economics and yield performance of traditional black scented rice (Chakhao) under rainfed conditions of Manipur. Journal of Crop and Weed. 15(2): 123–129.
4. Thongam K.D. and Pathak H., (2023). Economics of Chakhao cultivation in Manipur. Economic Affairs. 68: 523–532.
5. Mahanta B.S., Abraham T. and Singh V., (2021). Effect of organic nutrient management on growth, yield and economics of black rice. Journal of Pharmacognosy and Phytochemistry. 10: 218–221.
6. FAO, (2017). Geographical Indications for Sustainable Development. Food and Agriculture Organization of the United Nations, Rome.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Panicle-Level Grain Distribution in Paddy: A Quantitative Approach

Article ID: 72801

Dr. R. Sugunthakunthalambigai[1], Dr. R. Brimapureeswaran[2], Dr. M. Radha[3]
[1]Assistant Professor, Agricultural College and Research Institute, TNAU, Kumulur, Tiruchirappalli – 620 027.
[2]Assistant Professor, College of Fish Nutrition and Food Technology, TNJFU, Chennai - 600 051.
[3]Assistant Professor Department of Agricultural Economics, ADAC & RI, TNAU, Tiruchirappalli – 620 027.

Introduction

Paddy (*Oryza sativa* L.) is a major staple food crop, and its productivity depends on several yield components such as number of tillers, panicle length, spikelet fertility, and grain distribution along the panicle. Among these, panicle-level grain distribution plays a vital role in determining both yield and grain quality. The rice panicle is a branched structure bearing spikelets at different positions. These spikelets do not contribute equally to grain formation. Generally, grains located in the upper portion of the panicle are better filled and more numerous compared to those in the lower portion. This positional variation is influenced by flowering sequence, nutrient translocation, and assimilates availability.

Understanding how grains are distributed along the panicle through a **quantitative approach** helps in better yield estimation and provides insights useful for crop improvement programmes.

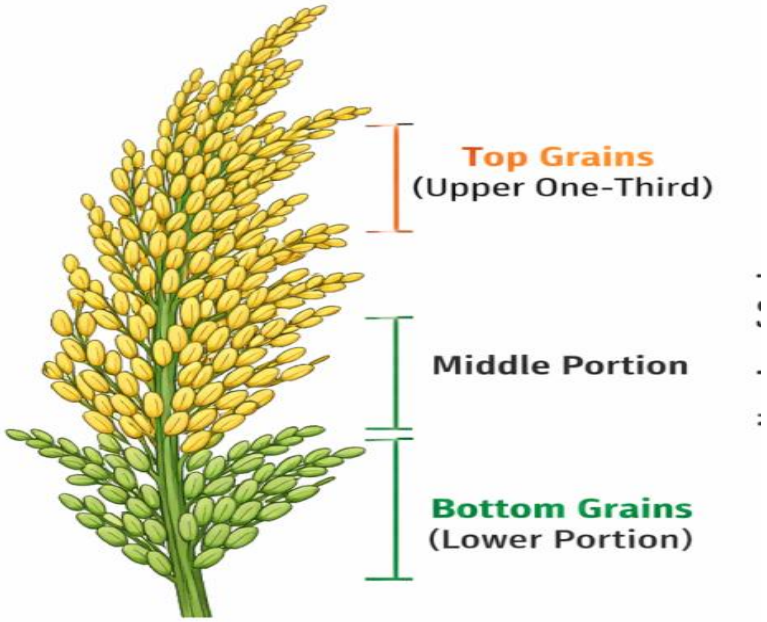


Figure 1. *Schematic representation of a paddy panicle showing top and bottom grain regions.*

Objectives

1. To study grain distribution at different positions along the paddy panicle
2. To quantify grain numbers in the top, middle, and bottom portions
3. To compare grain distribution patterns using numerical data
4. To analyze field-level observations from AEC&RI, Kumulur.

Source of Data

The data for this study were collected from paddy plants grown at the Agricultural Engineering College and Research Institute (AEC&RI), Kumulur, Tamil Nadu. Fully matured and healthy plants were selected at the time of harvest.

Materials and Methodology

Selection of Panicles: Twelve healthy and mature paddy plants were randomly selected from the experimental fields of AEC&RI, Kumulur. One representative panicle from each plant was used for the study.

Grain Counting Procedure: Spikelets from each portion were carefully separated. Only fully developed grains were counted manually. Grain counts from the top and bottom portions of the same panicle were treated as paired observations for quantitative analysis.

Sample Data Collected:

Plant No.	Top Grains	Bottom Grains	Plant No.	Top Grains	Bottom Grains
1	45	55	7	80	85
2	55	65	8	85	70
3	60	60	9	45	65
4	50	49	10	60	65
5	70	75	11	80	65
6	70	80	12	90	85

Results and Discussion

The grain counts from twelve paddy panicles showed noticeable variation between the top and bottom portions. The mean number of grains in the top portion was 65.8**,** while the bottom portion recorded a slightly higher mean of 68.3 **grains.**

The mean difference between top and bottom grain counts was -2.42 **grains**, indicating a marginal numerical advantage for the bottom portion. The standard deviation of the differences was 10.36, reflecting considerable variability among individual plants. The standard error (SE) of the mean difference was calculated as:

$$SE = \frac{S_d}{\sqrt{n}} = \frac{10.36}{\sqrt{12}} = 2.99$$

Since the mean difference (-2.42) was smaller than the standard error (2.99), the observed variation falls within sampling variability. The calculated t-value (**0.81**) was much lower than the critical value at the 1% level of significance (3.106)**,** indicating that the difference between top and bottom grain counts was **not statistically significant**.

Biologically, the observed variation may be attributed to differences in flowering sequence, panicle architecture, assimilate partitioning, and micro-environmental conditions within the crop canopy. Although individual panicles showed positional differences, no consistent dominance of either portion was evident across all plants.

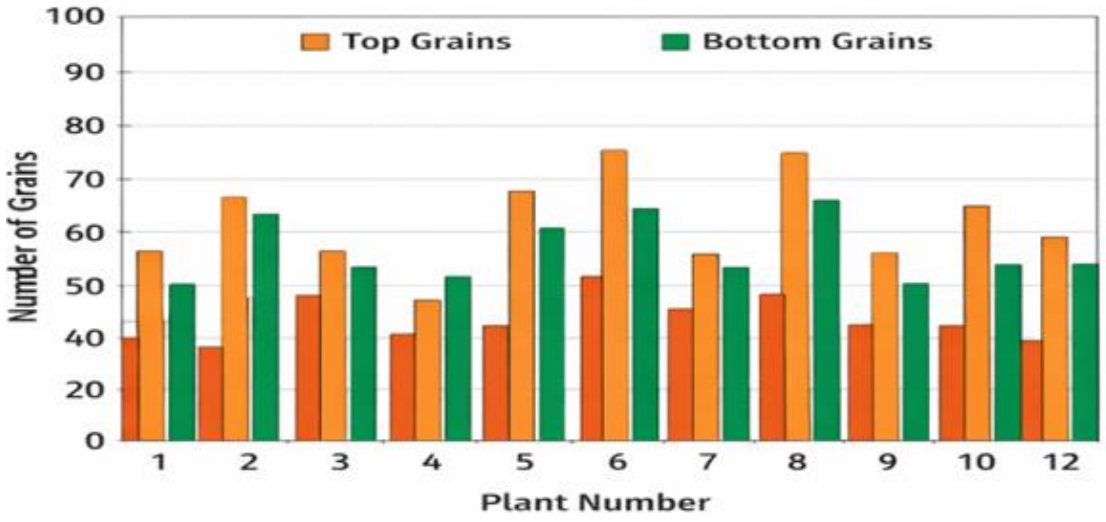


Figure 2. *Comparison of top and bottom grain counts in selected paddy plants.*

Conclusion

The present study demonstrates that grain distribution along the paddy panicle exhibits natural positional variation; however, the difference between the top and bottom portions is not statistically significant at the 1% level, as evidenced by the small mean difference relative to its standard error. Both portions of the panicle contribute nearly equally to total grain number. The findings indicate that grain formation in paddy is influenced by multiple interacting biological and environmental factors rather than panicle position alone. This panicle-level quantitative approach provides useful insights for students, farmers, and researchers in understanding yield components and improving paddy productivity.

References

1. Yoshida, S. (1981). *Fundamentals of Rice Crop Science*. International Rice Research Institute, Philippines.
2. Gomez, K. A., & Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research*. Wiley.
3. Matsushima, S. (1964). Yield-determining factors in rice. *National Institute of Agricultural Sciences*, Japan.
4. IRRI Rice Knowledge Bank. Panicle structure and grain formation in rice.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Advances in Drying Technologies

Article ID: 72802

P. R. Davara[1], B. M. Devani[1]
[1]Dept. of Processing and Food Engineering, College of Agril. Engg. & Technology, Junagadh Agricultural University, Junagadh - 362001.

Introduction

Drying, the process of removing moisture from materials to preserve them or to prepare them for further processing, is among humanity's oldest preservation techniques. Traditional methods like sun-drying or air-drying have been used for centuries for foods, and other perishable items. However, traditional drying has limitations such as long processing times, dependency on weather conditions, contamination risk, and uneven drying. These constraints stimulated the development of artificial drying technologies, which allowed more controlled, faster drying at industrial scales.

Conventional Artificial Drying and Its Limitations

Conventional artificial drying, primarily hot-air convection drying, offered significant improvements over sun-drying: reduced time, improved control, and scalability. However, despite these advantages, conventional drying methods have persistent drawbacks:

1. High energy consumption: heating large volumes of air and maintaining airflow is energy intensive.

2. Quality degradation: prolonged exposure to heat can degrade nutritional content (in food), bioactive compounds (in pharmaceuticals or nutraceuticals), and sensory or structural qualities (colour, flavour, texture).

3. Uneven drying or over-drying: surface moisture may evaporate faster than internal moisture, causing crusting, shrinkage, case hardening, or uneven final moisture content.

Because of these limitations, research and industrial practice gradually moved toward alternative and improved drying techniques.

Modern Drying Technologies: Principles and Advancements

Advances in engineering, materials science, process control, and energy technologies have led to a variety of modern drying methods. These aim to improve drying speed/efficiency, preserve product quality (especially for heat-sensitive materials), and reduce energy and environmental costs.

1. Spray Drying & Nano-Spray Drying:

a. Spray drying involves atomizing a liquid into a hot gas stream. The droplets dry rapidly, yielding fine powders. This technique is widely used in food processing, pharmaceuticals, and industrial materials.

b. A recent advancement is nano-spray drying, which enables significantly smaller particle sizes, higher yields, and even small sample volumes.

c. These innovations owe to improvements in spray-head technology (piezoelectric vibrating mesh), laminar-flow heating systems, and advanced particle collectors (e.g., electrostatic collectors instead of traditional cyclones).

d. Nano-spray drying expands applications, for example in pharmaceuticals (fine powders for inhalation, amorphous dispersions) and nanomaterials, that were previously limited.

2. Freeze-Drying (Lyophilization):

a. Freeze-drying removes moisture by sublimation under low temperature and vacuum, beneficial for heat-sensitive materials

b. However, conventional freeze-drying is energy- and time-intensive (taking many hours or even days), which restricts throughput and increases cost.

c. To address these, modern variants such as microwave-assisted freeze-drying have emerged. In this technique, microwave energy supplies heat for sublimation, enabling volumetric heating inside the material, thereby accelerating drying and improving uniformity.

3. Microwave, Infrared, Radiofrequency, Vacuum-Microwave & Dielectric Drying:

a. Microwave drying uses electromagnetic radiation (commonly 915 or 2450 MHz) to heat water molecules volumetrically inside the material via dipolar rotation and ionic conduction.

b. Because heating is volumetric, drying is faster and more energy-efficient than surface-heating methods, which helps to reduce damage in heat-sensitive products.

c. Vacuum-microwave drying (VMD) combines vacuum with microwave heating. The lower pressure reduces the boiling point of water and allows moisture removal at lower temperatures; the microwave ensures rapid internal

heating. This combination yields rapid drying, good energy efficiency, and better retention of quality (nutrients, colour, aroma) in foods and biomaterials.

d. Infrared (IR) drying transfers radiant energy directly to the product, bypassing ambient air heating, enabling high heat and mass transfer rates, hence rapid surface moisture removal. IR drying is particularly useful for heat-sensitive bioactive-rich foods, as it can help preserve phytochemicals, antioxidants, and vitamins compared to conventional hot-air drying.

e. Radiofrequency (RF) drying and other dielectric heating techniques are also being researched; their volumetric heating and faster moisture removal can lead to reduced thermal degradation and improved product quality.

4. Hybrid and Process-Intensified Drying Systems:

a. Modern drying research emphasizes hybrid drying systems, combining two or more drying techniques (e.g., convective air + microwave, vacuum + microwave, infrared + convection). Such hybridization aims to leverage the strengths of each technique while minimizing weaknesses.

b. Examples include microwave-vacuum drying, microwave-assisted freeze-drying, infrared + convective drying, and convective-radiation drying.

c. Process intensification via hybrid methods can drastically reduce drying time, energy consumption, and damage to product quality, critical for heat-sensitive products such as functional foods, nutraceuticals, pharmaceuticals, and biopharmaceuticals.

d. Moreover, modern computational and modelling tools, such as computational fluid dynamics (CFD), population balance models, pore-network models, and even machine learning based models, are increasingly used to simulate, optimize, and scale drying processes. For instance, recent work uses physics-informed machine learning (PIML) to capture microscale cellular changes during drying of plant-based foods, offering deeper insights and more accurate predictions of drying behaviour at microstructural levels.

Impact of Modern Drying Technologies: Benefits and Challenges

1. Benefits:

a. Improved product quality: Modern drying methods, especially when applied to foods, biomaterials, pharmaceuticals, and functional foods, help to retain nutritional value, bioactive compounds, volatile flavour/aroma compounds, colour, texture, and structural integrity.

b. Faster processing and higher throughput: Techniques like spray-drying, microwave-vacuum drying, and hybrid methods significantly reduce drying time compared to conventional hot-air drying or traditional methods.

c. Energy efficiency and sustainability: Hybrid and optimized drying systems can lower energy consumption substantially. Studies report reductions in energy use and carbon footprint compared to conventional systems.

d. Scalability and flexibility: With advances in modelling, control systems, and hybridization, modern drying technologies can be tailored for a wide range of materials, from agricultural products (grains, fruits, vegetables) to pharmaceuticals, biomaterials, and industrial compounds.

2. Challenges & Limitations:

a. Cost and capital investment: Advanced dryers, especially those using vacuum, microwave, or hybrid systems, often require more complex equipment, higher upfront investment, and specialized maintenance. This can hinder adoption in small-scale or resource-limited settings.

b. Uniformity and control issues: Some methods, especially microwave-based, face challenges like non-uniform heating, creation of hot spots, or uneven moisture removal, which can affect product quality.

c. Scale-up difficulties: Methods proven at lab or pilot scale (e.g., microwave-assisted freeze-drying, vacuum-microwave drying) may encounter difficulties when scaled up to industrial volumes, due to limitations in equipment, energy supply, and process control.

d. Optimization complexity: Determining optimal parameters (temperature, pressure, radiation intensity, airflow, moisture content, etc.) for each material is non-trivial and often requires detailed modelling, experimentation, and process control systems.

Emerging Trends and Future Directions

In recent years, drying-technology research has increasingly focused on sustainability, quality retention, flexibility, and smart control. Some key emerging directions:

1. Hybrid & multi-stage drying systems: Combining multiple drying techniques (e.g., microwave-vacuum + hot air; infrared + convective; freeze-dry + vacuum-microwave) to optimize energy use, time, and product quality.

2. Integration with advanced computational modelling and AI: Use of CFD, pore-network modelling, and data-driven / physics-informed machine learning (PIML) to predict drying behaviour at microstructural levels, optimize process parameters, and accelerate design.

3. Focus on bioactive and sensitive materials: As interest in functional foods, nutraceuticals, biopharmaceuticals, and high-value biomaterials rises, drying methods that preserve delicate compounds (vitamins, antioxidants, proteins) while ensuring stability and shelf life are increasingly important.

4. Energy-efficient & environmentally friendly drying: Adoption of renewable energy sources (e.g., solar-energy-integrated drying), energy recovery systems, heat pumps; hybrid designs that minimize waste and emissions.

5. Modular and flexible drying systems: Research into modular drying plants that can be optimized for different products, volumes, and operational conditions, facilitating adaptation to evolving industrial or agricultural needs.

Conclusion

The journey of drying technologies from passive sun or air-drying to advanced, hybrid, and intelligently controlled systems reflects broader trends in industrialization, materials science, energy efficiency, and quality-sensitive processing. Modern drying technologies, such as spray/nano-spray drying, microwave-vacuum drying, infrared/radiofrequency drying, freeze-drying (and its microwave-assisted variant), and hybrid systems, offer significant advantages in speed, energy use, product quality, and flexibility. At the same time, challenges remain: cost, scale-up, uniformity, and optimization. The future of drying technology likely lies in the integration of hybrid drying, smart control systems, renewable energy, and data-driven modelling and optimization, enabling efficient, high-quality, and sustainable drying tailored to a wide range of materials (foods, biomaterials, pharmaceuticals, industrial materials).

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

9 Perennial Flowers that can take the Heat

Article ID: 72803

Navya Swetha[1]
[1]Assistant Professor, SKLTGHU, College of Horticulture, Dep: Floriculture and Landscaping.

Knowing the difference between heat-tough perennials and heat-wimpy ones is becoming more and more of an issue as our summers are getting hotter for longer.

Black-Eyed Susan (*Rudbeckia*)

This long-time favorite native produces showy, golden flower petals around a central dark cone and also blooms for up to two months in mid-summer. 'American Gold Rush' is hard to beat for flower power and disease-resistance. It grows two feet tall.



Blanket Flower (*Gaillardia*)

Another U.S. native, blanket flower is one of the longest-blooming perennials, producing red, gold, or red/gold daisy-like flowers most of the summer – especially when spent blooms are dead-headed. 'Fanfare' and 'Goblin' are two good 18-inchers.



Hardy Hibiscus

Our native hardy hibiscus is a big, head-turning, shrub-like perennial that can grow four feet tall and wide with huge, dessert-plate-size flowers of red, pink, or white in July. The whole Summerific series is excellent, and 'Midnight Marvel' offers bright red flowers set on a dark-leaf background.



Coreopsis

Coreopsis or “tickseed” is another heat-tough native and one that produces coin-sized gold, yellow, or red daisy-like flowers in early summer. When cut back after bloom, most of the thread-leaf types will bloom again in late summer.



Coneflower

A top native choice for pollinators, coneflowers are heat-lovers that traditionally bloom in purple-pink in mid-summer. New varieties come in many other colors as well, including light and dark pink, white, red, and orange. It’s hard to go wrong with any variety you’ll find.



Salvia

One of the few flowers that deer will hardly ever even sample, salvia is a reliable perennial that produces spikes of purple, blue-purple, and sometimes pink. May is the main bloom month, but after a cutback, most salvias will bloom again in late summer.



Sedum

This cold-hardy succulent comes in groundcover forms, but for the perennial garden, bushy two-foot types that bloom pink in late summer are solid, heat-tough, drought-tough choices.

Good varieties include 'Neon,' 'Brilliant,' 'Autumn Fire,' and the dark-leafed Rock 'n Grow 'Back in Black.'



Daylily

It's hard to kill a daylily, even after deer repeatedly eat them and the increasingly problematic leaf-streak disease turns them brown soon after blooming.

When all goes right, though, daylilies produce lots of trumpet-shaped flowers in all sorts of colors and color blends. Many of them rebloom.



Russian Sage

This one's been catching on lately because of its heat- and drought-toughness and new, compact varieties, which make Russian sage garden-friendlier than older, floppier three- and four-footers.

Plants produce purple to blue-purple spikes for weeks. Compact two-foot versions include ‘Denim ‘n Lace,’ Lacey Blue, and the even shorter Little Lace.



AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Seaweed A Crop for Future: Blue Transformation in Action

Article ID: 72804

Puneet Kumar Patel[1], Shashank Singh[1], Dinesh Kumar[1], Ajay Yadav[1]
[1]Department of Aquaculture, College of Fisheries, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya 224229, Uttar Pradesh, India.

Abstract

Seaweeds, the marine macro-algae, have emerged as a strategic resource for sustainable aquaculture, blue economy development, and climate-resilient coastal livelihoods. Globally, seaweed cultivation has expanded rapidly since the mid-20th century, contributing nearly 30% of total aquaculture production, with Asian countries dominating both production and technological advancement. Seaweed plays a multifaceted role in marine ecosystems through carbon sequestration, nutrient cycling, biodiversity support, and coastal protection, while also contributing significantly to food security and industrial development.

This report provides a comprehensive overview of the global and Indian scenario of seaweed production, species diversity, and major cultivable groups, along with historical production trends and species-wise contributions. It further outlines site selection criteria, cultivation techniques, planting and harvesting practices, and highlights the seaweed value chain with emphasis on industrial products such as agar, alginate, and carrageenan.

The status of seaweed farming in India is discussed in the context of recent policy initiatives, particularly the PMMSY. Key challenges related to labour availability, market uncertainty, seed quality, environmental concerns, and offshore cultivation constraints are critically examined. The presentation concludes by identifying future priorities for strengthening seaweed farming through capacity building, promotion of indigenous species, industry support, and sustainable expansion, positioning seaweed as a vital component of blue transformation and sustainable development.

Keywords: Seaweed, value-chain, cultivation, industrial product, issue and challenges.

Introduction

Seaweeds are marine macroalgae commonly found in coastal and shallow marine environments, where they grow attached to rocks and other hard substrata. They are broadly classified into green (Chlorophyta), brown (Phaeophyta), and red (Rhodophyta) algae, and play a crucial ecological role as primary producers, nutrient cyclers, and habitat providers in marine ecosystems (Duarte *et al.*, 2017; UN, 2016).

Owing to their rich biochemical composition and presence of bioactive compounds, seaweeds have gained recognition as the "medical food of the 21st century" and are widely utilized in food, pharmaceutical, nutraceutical, cosmetic, and agricultural industries (FAO, 2018; PIB-GoI, 2025).

In recent decades, seaweed cultivation has emerged as a sustainable and climate-smart aquaculture practice in response to increasing pressure on terrestrial agriculture, declining capture fisheries, and global climate change concerns. Globally, seaweed farming has expanded rapidly since the mid-20th century, contributing nearly 30 % of total aquaculture production and supporting ecosystem services such as carbon sequestration, nutrient bio-extraction, coastal protection, and livelihood generation (FAO, 2024; State of the World's Seaweeds, 2025).

Although India possesses rich seaweed biodiversity along its mainland and island coasts, commercial cultivation remains at a nascent stage. Recent policy interventions, particularly the Pradhan Mantri Matsya Sampada Yojana (PMMSY), aim to promote seaweed farming as a key component of blue transformation, sustainable aquaculture development, and coastal livelihood enhancement (DoF-GoI, 2024; NITI Aayog, 2024).

Estimated area of vegetated marine ecosystems		
Seaweed	75%	6.06 m km^2
Sea-grasses	20%	1.65 m km^2
Coral reefs	3.4%	0.28 m km^2
Mangroves	1.8%	0.15 m km^2
Saltmarshes	0.8%	0.06 m km^2

Source: State of the world's seaweeds (2025), Duarte *et al.* (2022)



Fig.1 Estimated area of Vegetated marine ecosystem

Objectives

1. To provide an overview of seaweeds as an important marine bio-resource and to distinguish them from sea-grasses based on biological, ecological, and functional characteristics (Duarte *et al.*, 2017; UN, 2016).

2. To examine the global scenario and historical trends of seaweed production, with emphasis on major producing countries and species groups (FAO, 2024; State of the World's Seaweeds, 2025).

3. To assess the current status, cultivable species, and production potential of seaweeds in India in the context of recent policy initiatives and government support (DoF-GoI, 2024; NITI Aayog, 2024).

4. To describe standard seaweed cultivation practices, including site selection, farming methods, planting, and harvesting techniques (FAO, 2021).

5. To highlight the seaweed value chain and industrial applications, particularly the production and utilization of agar, alginate, and carrageenan (FAO, 2018).

6. To identify key issues, constraints, and challenges in seaweed farming and to outline future strategies for sustainable expansion and blue transformation (State of the World's Seaweeds, 2025; NITI Aayog, 2024).

Key Differences Between Seaweed and Seagrass

1. Biological nature: Seaweeds are marine macroalgae, whereas seagrasses are true flowering plants (angiosperms) adapted to marine environments (UN, 2016; Duarte *et al.*, 2017).

2. Attachment and habitat: Seaweeds are generally attached to rocks or other hard substrata using a holdfast, while seagrasses are rooted in soft sediments of shallow coastal and estuarine waters (FAO, 2018).

3. Morphology: Seaweeds lack true roots, stems, leaves, vascular tissues, flowers, and seeds; in contrast, seagrasses possess well-developed roots, rhizomes, leaves, flowers, and seeds (Duarte *et al.*, 2017).

4. Reproductive strategy: Seaweeds reproduce mainly through spores, vegetative fragmentation, or alternation of generations, whereas seagrasses reproduce sexually through flowering and seed formation and also vegetatively via rhizomes (UN, 2016).

5. Ecological function: Seaweeds contribute significantly to primary production, nutrient cycling, and carbon sequestration, while seagrasses play a vital role in sediment stabilization, shoreline protection, and providing nursery habitats for marine organisms (FAO, 2018; State of the World's Seaweeds, 2025).

6. Utilization: Seaweeds are widely cultivated and exploited for food, phycocolloids (agar, alginate, carrageenan), pharmaceuticals, and biofertilizers, whereas seagrasses are not commercially cultivated and are primarily valued for their ecosystem services (FAO, 2018; UN, 2016).

Global Scenario of Seaweed Production

Global seaweed production has shown a remarkable increase since the 1950s, largely driven by the rapid expansion of aquaculture. Initially, seaweed supply was dominated by wild harvesting; however, by the early 1970s, cultivated production surpassed wild collection, marking a major transition in the global seaweed sector (FAO, 2021; SOFIA, 2024).

This shift was primarily influenced by technological advancements in hatchery-based seed production and long-line cultivation systems, particularly in East Asia.

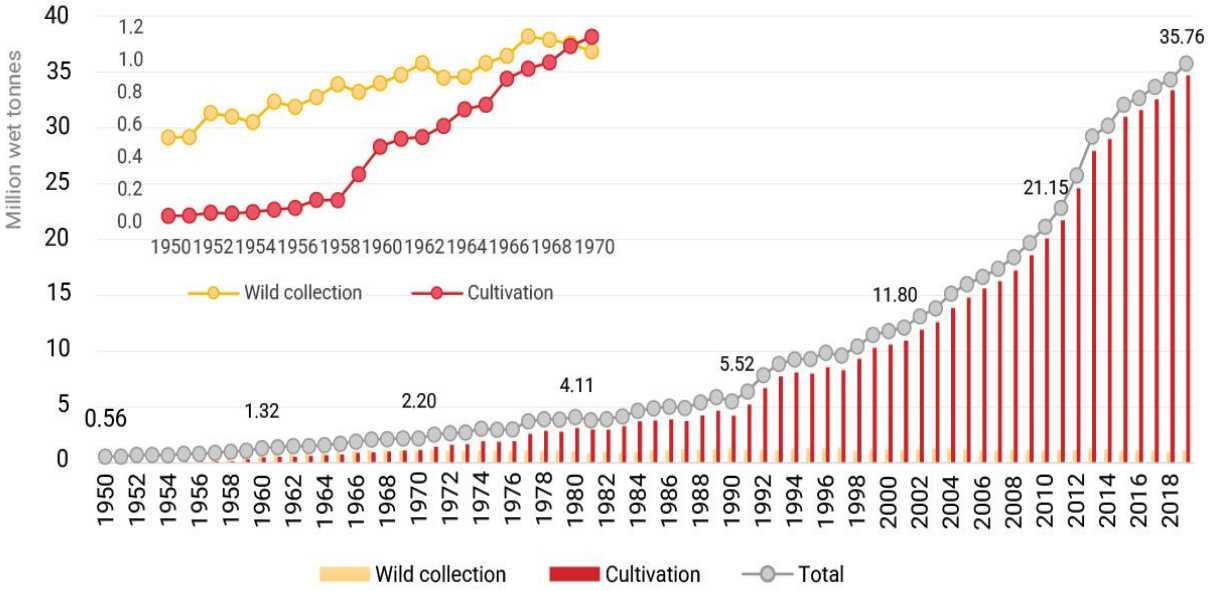


Fig. 2 Global seaweed production trends since 1950

From the 1970s onwards, global seaweed production increased more than 30-fold, with China emerging as the leading producer, largely due to the large-scale cultivation of kelp species such as *Laminaria (Saccharina) japonica*. Government-led initiatives to combat iodine deficiency and ensure food security further accelerated kelp farming in China, making it the backbone of global seaweed production during this period (FAO, 2021; SOFIA, 2024).

During the period 1970–1990, often referred to as the "kelp revolution," production of kelp (*Laminaria* spp.) continued to dominate global output. At the same time, cultivation of red seaweeds such as *Porphyra* and *Undaria* expanded, mainly for direct human consumption. In parallel, the farming of carrageenan-yielding tropical red seaweeds, particularly *Kappaphycus alvarezii*, increased from negligible levels to several hundred thousand tonnes, especially in the Philippines and Indonesia, driven by growing industrial demand (FAO, 2021).

Between 1990 and 2019, global seaweed aquaculture diversified further. While kelp species (*Laminaria*/*Saccharina*) remained dominant, contributing over 12 million tonnes annually, *Kappaphycus* and *Eucheuma* emerged as fast-growing tropical species, challenging the dominance of temperate kelps. Favorable climatic conditions, availability of suitable farming sites, and low-cost labor supported the rapid expansion of tropical seaweed farming in Southeast Asia (FAO, 2021).

As per recent estimates, global seaweed production 37.8 million tonnes, with nearly 97% originating from aquaculture, and production remains heavily concentrated in East and Southeast Asia, accounting for more than 95% of global output (FAO, 2024; State of the World's Seaweeds, 2025). Species-wise, brown seaweeds (mainly kelps) dominate global biomass, followed by red seaweeds used for agar and carrageenan extraction, while green seaweeds contribute a comparatively smaller share (Guiry & Guiry, 2025; FAO, 2021).

Dominant Seaweed Species Groups Globally

a. **Brown seaweeds**: *Laminaria* / *Saccharina*, *Undaria* – dominant in global biomass
b. **Red seaweeds**: *Kappaphycus*, *Eucheuma*, *Gracilaria*, *Porphyra* – important for food and hydrocolloids
c. **Green seaweeds**: *Ulva*, *Caulerpa* – minor share but increasing interest

Status of Seaweed in India

India is endowed with a long coastline of approximately 7,500 km, encompassing mainland states and island territories, which supports a diverse range of marine macroalgae species. The country hosts over 800 species of seaweed, including significant red, brown, and green algal groups, with brown and red algae dominating the cultivable biomass (Mantri *et al.*, 2020; NITI Aayog, 2024). Despite this biodiversity and favorable coastal environments, seaweed cultivation in India remains underdeveloped compared to major Asian producers such as China and Indonesia (FAO, 2024; DoF-GoI, 2024). Traditional wild harvest persists in some regions, but organized farming systems are limited and localized.

Recent policy initiatives under the Pradhan Mantri Matsya Sampada Yojana (PMMSY) have placed renewed emphasis on the expansion of seaweed farming, value chain development, and coastal livelihood enhancement. These interventions aim to facilitate infrastructure support, capacity building, processing facilities, and private sector participation, thereby enhancing production, market access, and export potential (DoF-GoI, 2024; NITI Aayog, 2024). Encouragingly, several

pilot projects and community-based farming models have demonstrated improved yields and socioeconomic benefits, particularly for coastal women and youth, although scalability and sustained technical support remain key challenges (DoF-GoI, 2024; Mantri *et al.*, 2020).

Seaweed Cultivation Techniques

Successful seaweed cultivation depends on appropriate site selection, suitable farming methods, proper planting, and timely harvesting. Selection of an ideal site is a crucial prerequisite for seaweed farming. Cultivation areas should have **moderate water movement (20-40 m min^{-1})** to ensure nutrient exchange but must be sheltered from strong waves, currents, and winds. Sites near river mouths or areas with heavy freshwater runoff should be avoided due to fluctuations in salinity. Optimal water temperature for most tropical seaweeds ranges between **25-30 °C,** with water depth not less than **2 feet during low tide and more than 7 feet during high tide.** The farm bottom should be sandy or rocky and stable enough to support stakes or bamboo structures (FAO, 2021).

Several cultivation methods are practiced depending on site conditions and target species. The **line method** involves tying knotted ropes or twines between two mangrove stakes placed approximately **12 meters apart**, on which test crops are planted at uniform intervals for growth assessment. This method is simple and widely adopted in sheltered coastal waters (FAO, 2021).

The **floating bamboo raft method** consists of bamboo frames (usually **2.5 × 5 m**) tied together to form floating rafts, over which net webbing is fixed. Seaweed seedlings are attached at uniform distances on the net, allowing efficient water circulation and sunlight exposure. This method is commonly used for farming *Kappaphycus* and *Eucheuma* species (FAO, 2021).

The **net method**, originally adapted for *Eucheuma* culture, uses rectangular nets (**2.5 × 5 m**) with diagonal meshwork having a bar length of about **25 cm**. Nets are installed horizontally and secured at the corners to stakes or wires. Seedlings are tied using soft plastic ties, allowing a higher number of plants per unit area and better yield efficiency (FAO, 2021).

The **bottom monoline method** is considered cost-effective and less prone to surface weather disturbances. It consists of multiple modules, each having **28 monolines of about 30 feet length,** suspended **20-25 cm above the sea bottom**. Approximately **36 plants** can be tied per monoline, making it suitable for shallow and calm waters (FAO, 2021).

Planting involves cleaning healthy seedlings thoroughly to remove dirt, epiphytes, and other adhering materials. Seedlings weighing **80-100 g** are tied to knots at **20-25 cm intervals** in line and net methods, while **50-150 g seedlings** are used in bottom monoline systems. Harvesting is usually carried out when plants attain a weight of **750-850 g**, either partially or completely, leaving about **200 g** on each plant to allow regeneration. Harvesting is done carefully using stainless steel knives, and harvested biomass is collected using scoop nets (FAO, 2021).

Seaweed Value Chain



Fig. 3 Seaweed value chain | Source: NITI Aayog (2024)

The seaweed value chain begins with the **selection and cultivation of suitable seaweed species,** followed by harvesting, primary processing, extraction of bioactive compounds, and conversion into industrial and consumer products. The efficiency of the value chain determines the economic viability and sustainability of seaweed farming.

At the production level, **specific seaweed species are cultivated based on their end-use potential.** Red seaweeds such as *Gelidium* spp. and *Gracilaria* spp. serve as the primary and widely cultivated sources of **agar**, while *Kappaphycus alvarezii* and *Eucheuma denticulatum* are major sources of **carrageenan*. Brown seaweeds including *Laminaria*, *Sargassum*, and *Macrocystis* are utilized mainly for **alginate extraction** (FAO, 2018; Mantri *et al*., 2020).

Following harvesting, fresh seaweeds undergo **primary processing**, which includes washing to remove sand and epiphytes, followed by drying using sun-drying or solar-assisted techniques to reduce moisture content and improve shelf life. Dried seaweed biomass is then supplied to processing industries or aggregators, forming a critical link between farmers and industrial units (FAO, 2018).

The next stage involves **secondary processing and extraction**, where dried seaweeds are processed to extract phycocolloids such as agar, alginate, and carrageenan through physical and chemical methods. Agar extracted from *Gelidium* and *Gracilaria* is widely used in food, pharmaceutical, and microbiological applications. Alginate extracted from brown seaweeds is used as a thickener, stabilizer, and emulsifier, while carrageenan from *Kappaphycus* and *Eucheuma* is extensively used in dairy, food, and pharmaceutical industries (FAO, 2018; Permata *et al*., 2025).

The final stage of the value chain includes the **manufacture of finished products**, distribution, and marketing. Seaweed-derived products are used across multiple sectors, including food, pharmaceuticals, nutraceuticals, cosmetics, agriculture (biofertilizers and soil conditioners), animal feed, textiles, and emerging sectors such as bioplastics and biofuels. Efficient integration of farming, processing, and market access enhances value addition, income generation, and employment opportunities, particularly for coastal communities and women entrepreneurs (NITI Aayog, 2024; DoF-GoI, 2024).

Issues, Constraints and Challenges in Seaweed Farming

Seaweed farming faces several socio-economic, technical, and environmental challenges that limit its large-scale expansion and sustainability. One of the major constraints is the **shortage of skilled and seasonal labor**, particularly during peak planting and harvesting periods. Seaweed cultivation is labor-intensive, requiring a large workforce over short durations, which makes it difficult for farmers to offer stable wages. In many regions, industrial development and alternative employment opportunities have drawn younger generations away from seaweed farming, reducing labor availability (Valderrama *et al.*, 2013; Davis, 2021).

Another significant challenge is the **uncertain and fluctuating demand for seaweed products**, especially in regions outside East Asia where consumer exposure to seaweed-based foods is limited. **Food safety concerns**, including contamination and quality assurance, further restrict market expansion. Although seaweeds have promising applications in pharmaceuticals, nutraceuticals, cosmetics, animal feed, biofertilizers, bio-packaging, textiles, and biofuels, these non-food sectors face **technical, economic, and market-related constraints**, limiting large-scale commercialization (Aher *et al.*, 2021; Cai *et al.*, 2021).

The **limited availability of suitable near-shore farming sites** poses another constraint, as coastal areas are increasingly subjected to competition from urban development, tourism, recreation, and capture fisheries. Conflicts over coastal space restrict expansion of traditional farming areas. While **offshore seaweed cultivation** has the potential to overcome space limitations, it presents challenges related to **technical feasibility, high investment costs, operational risks, and economic viability** (Burg *et al.*, 2016; Liu *et al.*, 2019).

Biological and technical issues also affect productivity. **Low or declining seed quality** remains a persistent problem, often resulting from repeated vegetative propagation and the use of inbred stocks. This can lead to **trait degeneration**, reduced growth rates, inferior product quality, and increased susceptibility to diseases, ultimately affecting farm profitability and sustainability (Loureiro *et al.*, 2015). Addressing these issues requires improved seed management, genetic diversification, and strengthened hatchery systems.

Way Forward in Seaweed Farming

To ensure sustainable growth and maximize the potential of seaweed cultivation, several strategic actions are recommended:

1. Popularization of Seaweed-Based Products: Promote awareness and consumption of seaweed-derived foods, nutraceuticals, and industrial products to create stable markets and consumer demand.

2. Environmental Protection Measures: Implement practices to safeguard seaweed farms from pollution, sedimentation, and other environmental stresses, ensuring long-term sustainability.

3. Support to Industries: Encourage investment in processing, extraction, and value-addition facilities for agar, carrageenan, alginate, and other seaweed-based products (NITI Aayog, 2024).

4. Development in Island Territories: Expand cultivation programs in island regions such as Lakshadweep and Andaman & Nicobar to leverage untapped marine resources and promote local livelihoods.

5. Enhancing Seed Availability: Strengthen hatcheries and nursery systems to provide high-quality seedlings, reduce dependence on wild stocks, and improve farm productivity.

6. Promotion of Indigenous Species: Encourage cultivation of locally adapted seaweed species to ensure ecological compatibility, higher growth rates, and resilience against diseases (State of the World's Seaweeds, 2025).

7. Training and Capacity Building: Provide technical training to farmers, entrepreneurs, and stakeholders in modern cultivation, harvesting, and post-harvest processing techniques.

8. Entrepreneurship Development: Facilitate women-led and community-based seaweed enterprises to generate income, employment, and equitable economic benefits for coastal populations (DoF-GoI, 2024).

Recent FAO Publications on Seaweed

Year of publication	Title	Notes
2025	Seaweed for the future: public policy recommendations towards a blue transformation	FAO policy report on seaweed-based blue economy development.
2025	Edible seaweed food guide	FAO manual on nutritional value, food safety and utilization of edible seaweeds.
2025	Aquaculture development – 10. Responsible investment for sustainable aquaculture	FAO policy guideline including algal aquaculture context.
2024	The State of World Fisheries and Aquaculture 2024	FAO flagship publication including updated seaweed and microalgae production statistics.
2023	FAO Aquaculture News – No. 67 (June 2023)	Includes updates on seaweed and microalgae developments.
2022	Report of the Expert Meeting on Food Safety for Seaweed – Current status and future perspectives	FAO-WHO joint expert report on seaweed food safety hazards.
2021	Seaweeds and microalgae: an overview for unlocking their potential in global aquaculture development	FAO Fisheries and Aquaculture Circular No. 1229 (i.e. the current document).
2021	Global seaweeds and microalgae production, 1950–2019	World Aquaculture Performance Indicators (WAPI) factsheet. www.fao.org/3/cb4579en/cb4579en.pdf
2021	Seaweed revolution: where is the next milestone?	WAPI policy brief. www.fao.org/3/cb4850en/cb4850en.pdf#page=13
2018	The global status of seaweed production, trade and utilization	FAO Globefish Research Programme, Vol. 124. www.fao.org/3/CA1121EN/ca1121en.pdf
2013	Seaweed for a better life	RFLP Report. www.fao.org/3/a-ar486e.pdf

Table: 1 Recent FAO publications on seaweed

Conclusion

Seaweed cultivation represents a **sustainable, climate-smart, and economically viable aquaculture practice** with significant potential for global and Indian marine sectors. It contributes to **carbon sequestration, nutrient cycling, coastal protection, and biodiversity support,** while providing raw materials for food, pharmaceuticals, and industrial products. Despite challenges such as labor shortages, limited seed quality, market uncertainty, and competition for coastal space, strategic interventions including **policy support under PMMSY, technological advancements, capacity building, and value chain development** can enhance production, profitability, and livelihoods. Promoting indigenous species, improving seed availability, supporting women-led and community-based enterprises, and expanding cultivation in island territories will strengthen the seaweed sector, making it a **key driver of blue transformation and sustainable development.**

References

1. Aher, S. B., et al. (2021). Seaweed-based bioproducts: Emerging applications and future prospects. *Journal of Applied Phycology, 33*(4), 2567–2585. https://doi.org/10.1007/s10811-021-02410-5.
2. Burg, S. W. K., et al. (2016). Optimizing offshore seaweed cultivation for bioenergy production. *Ocean & Coastal Management, 121*, 50–57.
3. Cai, J., Lovatelli, A., Aguilar-Manjarrez, J., Cornish, L., Dabbadie, L., Desrochers, A., … Yuan, X. (2021). Seaweeds and microalgae: An overview for unlocking their potential in global aquaculture development. *FAO Fisheries and Aquaculture Circular No. 1229*. FAO.

4. Davis, J. (2021). Labour dynamics and livelihood challenges in seaweed farming systems. *Marine Policy, 132*, 104683. https://doi.org/10.1016/j.marpol.2021.104683
5. Department of Fisheries, Government of India (DoF-GoI). (2024). Pradhan Mantri Matsya Sampada Yojana (PMMSY): Guidelines and progress report. Ministry of Fisheries, Animal Husbandry & Dairying, New Delhi.
6. Duarte, C. M., Wu, J., Xiao, X., Bruhn, A., & Krause-Jensen, D. (2017). Can seaweed farming play a role in climate change mitigation and adaptation? *Frontiers in Marine Science, 4*, 100. https://doi.org/10.3389/fmars.2017.00100
7. Duarte, C. M., et al. (2022). Global estimates of vegetated marine ecosystems. *Nature Climate Change, 12*, 123–130. https://doi.org/10.1038/s41558-021-01258-9
8. Food and Agriculture Organization of the United Nations (FAO). (2018). Seaweed utilization and value chains. FAO Fisheries and Aquaculture Technical Paper No. 624. Rome.
9. Food and Agriculture Organization of the United Nations (FAO). (2021). Global status of seaweed production and farming technologies. FAO Fisheries and Aquaculture Circular. Rome.
10. Food and Agriculture Organization of the United Nations (FAO). (2024). The State of World Fisheries and Aquaculture 2024 (SOFIA). FAO. Rome.
11. Guiry, M. D., & Guiry, G. M. (2025). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. https://www.algaebase.org
12. Liu, F., et al. (2019). Engineering challenges in offshore seaweed aquaculture. *Renewable & Sustainable Energy Reviews, 104*, 112–121. https://doi.org/10.1016/j.rser.2019.01.028
13. Loureiro, R. R., et al. (2015). Genetic degeneration in vegetatively propagated seaweeds. *Journal of Applied Phycology, 27*, 2037–2045. https://doi.org/10.1007/s10811-014-0477-4
14. Mantri, V. A., et al. (2020). Seaweed resources of India: Current status and future perspectives. *Journal of the Indian Society of Coastal Agricultural Research, 38*(1), 1–12.
15. NITI Aayog. (2024). Strategy for sustainable development of the seaweed sector in India. Government of India, New Delhi.
16. Permata, D. A., et al. (2025). Recent advances in carrageenan extraction and applications. *Carbohydrate Polymers, 305*, 120535. https://doi.org/10.1016/j.carbpol.2024.120535
17. Press Information Bureau, Government of India (PIB-GoI). (2025). Seaweed farming initiatives under blue economy framework. Ministry of Fisheries, Animal Husbandry & Dairying.
18. State of the World's Seaweeds. (2025). Seaweeds as a nature-based solution for sustainable development. Global Seaweed Coalition Report.
19. United Nations. (2016). World Ocean Assessment I. United Nations Division for Ocean Affairs and the Law of the Sea, New York.
20. Valderrama, D., Cai, J., Hishamunda, N., & Ridler, N. (2013). Social and economic dimensions of carrageenan seaweed farming. *FAO Fisheries and Aquaculture Technical Paper No. 580*. FAO.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Novel Technologies for Quality and Safe Food: Strengthening the Food System from Farm to Fork

Article ID: 72805

B. M. Devani[1], P. R. Davara[1]

[1]Dept. of Processing and Food Engineering, College of Agril. Engg. & Technology, Junagadh Agricultural University, Junagadh - 362001.

Food is the most fundamental requirement for human survival, health, and well-being. However, in today's rapidly evolving food system, merely producing sufficient food is no longer adequate. Ensuring food safety and quality has become equally important due to rising population, globalization of food trade, changing consumer preferences, and increasing awareness about health and nutrition. Unsafe or poor-quality food not only threatens public health but also undermines consumer confidence, causes economic losses, and weakens food supply chains.

Historically, food processing and preservation relied mainly on thermal treatments and natural methods to enhance shelf life and safety. While these methods have served humanity well for centuries, modern challenges demand innovative and technologically advanced **solutions** that can deliver safe food without compromising nutritional and sensory quality. In this context, novel food processing and supply-chain technologies have emerged as powerful tools to ensure food safety and quality throughout the value chain.

Traditional Food Processing Technologies: Strengths and Limitations

Traditional food processing techniques such as cooking, boiling, pasteurization, sterilization, canning, drying, dehydration, fermentation, and smoking have been widely practiced across cultures. These methods primarily depend on the application of heat or reduction of moisture to inactivate microorganisms and enzymes responsible for spoilage.

Thermal processing methods like pasteurization and sterilization are highly effective in reducing pathogenic microorganisms and ensuring microbiological safety. Canning, for instance, involves sealing food in airtight containers followed by heat treatment, which significantly extends shelf life and prevents microbial growth. Similarly, fermentation employs beneficial microorganisms to improve food safety while enhancing flavor, texture, and nutritional value, as seen in products like yogurt, cheese, and fermented vegetables.

Despite their effectiveness, thermal processing methods have notable drawbacks. High temperatures can lead to degradation of heat-sensitive nutrients such as vitamins, antioxidants, and bioactive compounds. Additionally, excessive heating may adversely affect color, flavor, texture, and overall acceptability of food products. These quality losses have encouraged researchers and the food industry to explore alternative approaches that can ensure safety while preserving freshness and nutritional value.

Emergence of Novel Non-Thermal Food Processing Technologies

Novel food processing technologies, particularly non-thermal methods, have gained significant attention over the past two decades. These technologies aim to inactivate microorganisms and enzymes without the severe application of heat, thereby minimizing quality deterioration. Some of the most promising non-thermal technologies include:

1. High Hydrostatic Pressure (HHP)
2. Pulsed Electric Fields (PEF)
3. Ultrasound (US)
4. Pulsed Light (PL)
5. Ultraviolet (UV) radiation
6. Cold Plasma (CP)

Each of these technologies has a distinct mechanism of action, such as disrupting microbial cell membranes, damaging DNA, or generating reactive species that inactivate pathogens. Their effectiveness depends on processing parameters like pressure, electric field strength, exposure time, frequency, and the nature of the food matrix.

Non-Thermal Technologies Offer Several Advantages

1. Improved retention of nutrients, color, and flavor
2. Enhanced sensory quality
3. Reduced processing time
4. Potential for energy efficiency

These methods can be used independently or in combination with mild heat treatments, offering promising alternatives to conventional thermal pasteurization and sterilization. However, challenges such as process optimization, equipment cost, and large-scale commercialization still need to be addressed.

Role of Novel Technologies across the Food Value Chain

Food safety and quality are influenced not only by processing but also by handling, storage, transportation, and distribution. Recent technological advancements have transformed the entire food value chain, ensuring transparency, traceability, and real-time monitoring.

Blockchain Technology in Food Supply Chains

Blockchain technology has emerged as a revolutionary tool for enhancing traceability and transparency in the food supply chain. It operates as a decentralized and immutable digital ledger, recording every transaction and movement of food products from farm to consumer.

Key benefits of blockchain include:

1. Real-time traceability of food products
2. Rapid identification and isolation of contaminated batches
3. Enhanced trust among consumers through verifiable information

Major food companies have already adopted blockchain solutions. For example, Walmart and IBM Food Trust have significantly reduced the time required to trace foodborne contamination sources, while Nestlé uses blockchain to allow consumers to track products such as coffee and dairy back to their origin.

Sensor Technologies and Internet of Things (IoT)

Sensor-based technologies, integrated with the Internet of Things (IoT), play a critical role in real-time monitoring of food quality and safety. Sensors can continuously track parameters such as temperature, humidity, gas composition, and microbial activity during storage and transportation.

Advantages of Sensor Technologies Include

1. Prevention of spoilage through timely intervention
2. Improved cold-chain management
3. Reduction of post-harvest losses

Innovative systems like wireless temperature sensors and freshness indicators are increasingly used in perishable food supply chains, especially for fruits, vegetables, meat, and dairy products.

Artificial Intelligence in Food Safety and Quality Management

Artificial Intelligence (AI), particularly machine learning, is transforming food safety management by enabling predictive and data-driven decision-making. AI systems analyze vast datasets from sensors, inspections, laboratory results, and even social media to identify potential risks before they escalate. Applications of AI include:

1. Predicting food safety hazards
2. Automated quality inspection
3. Optimization of processing and logistics

AI-based platforms have demonstrated their ability to enhance accuracy, reduce human error, and improve efficiency in quality control and risk assessment processes.

Nanotechnology Applications in Food Systems

Nanotechnology offers innovative solutions for food safety, quality, and packaging. Nano-sensors can detect contaminants, pathogens, or toxins at extremely low concentrations, enabling early intervention. Nanomaterials incorporated into packaging can act as antimicrobial barriers, extending shelf life and maintaining product quality. While nanotechnology holds immense promise, careful evaluation of its safety, regulatory acceptance, and consumer perception is essential before widespread adoption.

Regulatory Considerations and Challenges

Regulatory frameworks play a vital role in ensuring that novel technologies are safely and effectively implemented. Governments and international organizations focus on risk-based approaches, preventive controls, traceability, and transparency. However, several challenges persist such as rapid technological advancements outpacing regulations, resource and infrastructure constraints, globalization of food trade and need for harmonization of international standards

Adaptive and science-based regulatory systems, strengthened international collaboration, and enhanced public awareness are crucial to overcoming these challenges.

Future Outlook and Societal Implications

The future of food safety and quality lies in the integration of advanced technologies such as blockchain, AI, IoT, smart packaging, and augmented reality. These technologies will not only improve safety but also empower consumers with information, strengthen supply-chain resilience, and enhance global trade competitiveness. However, technological advancements also bring societal and economic implications, including implementation costs, data security concerns, workforce skill requirements, and ethical considerations. A balanced and inclusive approach involving governments, industry, academia, and consumers is essential to ensure equitable benefits.

Conclusion

Novel technologies are redefining how food safety and quality are managed across the entire food value chain. From non-thermal processing methods that preserve nutritional and sensory attributes to digital tools that enhance traceability, transparency, and predictive analysis, these innovations are creating a more secure and efficient food system. The successful adoption of these technologies will play a crucial role in protecting public health, strengthening consumer trust, and building a resilient and sustainable global food supply. With continued research, regulatory support, and stakeholder collaboration, novel technologies hold immense potential to shape the future of food.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Green Technology Innovations that Could Save the Planet

Article ID: 72806

Shajitha S[1]
[1]Undergraduate Student, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Abstract
Green technology plays a crucial role in addressing the growing environmental challenges faced by the planet, such as climate change, pollution, and the depletion of natural resources. This popular article focuses on key green technology innovations that aim to protect the environment while supporting sustainable development. It highlights advancements in renewable energy, green transportation, sustainable agriculture, waste management, green buildings, and water conservation technologies. The article also emphasizes the role of modern digital tools in improving the efficiency and adoption of these technologies. By encouraging the use of eco-friendly solutions at both individual and societal levels, green technology helps reduce environmental damage and promotes a cleaner, healthier future. The article concludes that adopting green technological innovations is essential for safeguarding the planet for present and future generations.

Keywords: Green Technology, Sustainability, Renewable Energy, Environmental Protection, Climate Change Mitigation, Eco-friendly Innovations.

Introduction
The planet is facing serious environmental challenges such as climate change, air and water pollution, depletion of natural resources, and loss of biodiversity. Rapid industrialization of green technology innovations is renewable energy. Unlike fossil fuels, renewable energy sources such as solar, wind, hydro, geothermal, and biomass produce little or no greenhouse gas emissions. Solar energy has become increasingly popular due to advancements in photovoltaic cells, which are now more efficient and affordable. Rooftop solar panels and large solar farms are helping countries reduce their dependence on coal and oil.

Renewable Energy Technologies
One of the most impactful green technology innovations is renewable energy. Unlike fossil fuels, renewable energy sources such as solar, wind, hydro, geothermal, and biomass produce little or no greenhouse gas emissions. Solar energy has become increasingly popular due to advancements in photovoltaic cells, which are now more efficient and affordable. Rooftop solar panels and large solar farms are helping countries reduce their dependence on coal and oil.

Wind energy is another fast-growing renewable source. Modern wind turbines can generate electricity even at low wind speeds, making them suitable for many regions. Offshore wind farms are especially promising as they can produce large amounts of clean energy without occupying land. Hydropower, of the oldest renewable sources, continues to play a major role in clean energy generation, while new small-scale hydro projects minimize environmental impacts. Together, renewable energy technologies are essential for reducing carbon emissions and slowing climate change.



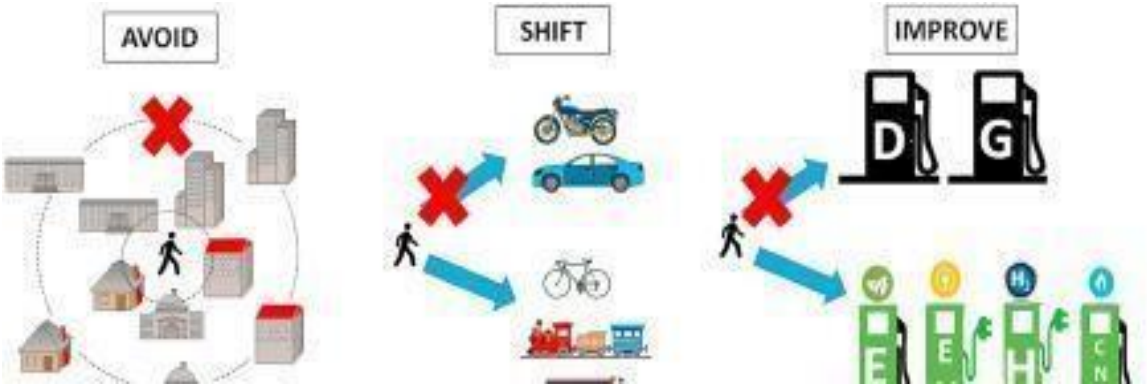
Energy Storage and Smart Grids
While renewable energy is clean, it is often intermittent, meaning energy is not always available when needed. Energy storage technologies such as advanced batteries help solve this problem. Lithium-ion batteries, solid-state batteries,

and emerging technologies like flow batteries store excess energy and release it during peak demand. These innovations make renewable energy more reliable and efficient.

Smart grids are another important development. A smart grid uses digital technology to monitor and manage electricity supply and demand in real time. It reduces energy loss, improves efficiency, and integrates renewable energy sources smoothly into the power system. By combining energy storage with smart grids, countries can build a resilient and sustainable energy infrastructure.

Green Transportation Technologies

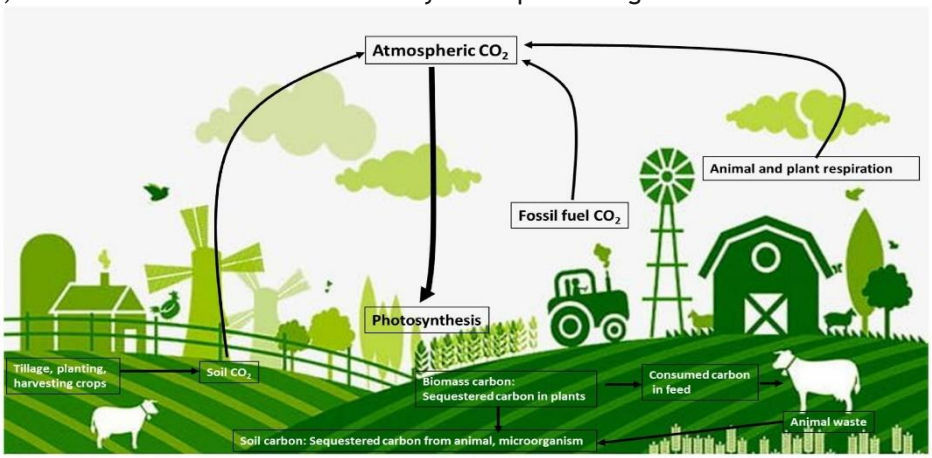
Transportation is a major contributor to air pollution and greenhouse gas emissions. Green transportation technologies aim to reduce these impacts. Electric vehicles (EVs) are leading to this transformation. EVs produce zero tailpipe emissions and are becoming more affordable due to improvements in battery technology. Charging infrastructure is also expanding, making EVs more practical for everyday use. In addition to electric cars, green innovations include electric buses, trains, and two-wheelers. Hydrogen fuel cell vehicles are another promising option, especially for heavy transport. These vehicles use hydrogen to produce electricity, emitting only water vapor as a byproduct. Sustainable public transport systems and shared mobility solutions further reduce traffic congestion and pollution, making cities cleaner and healthier.



Sustainable Agriculture and Food Technologies

Agriculture plays a vital role in human survival but also contributes to deforestation, water pollution, and greenhouse gas emissions. Green technology innovations in agriculture focus on sustainability and efficiency. Precision farming uses sensors, drones, and data analytics to optimize the use of water, fertilizers, and pesticides. This reduces waste and protects soil and water resources.

Vertical farming and hydroponics allow crops to be grown in controlled environments using less land and water. These methods are especially useful in urban areas where space is limited. Alternative protein technologies, such as plant-based meat and lab-grown meat, reduce the environmental impact of livestock farming. By adopting sustainable agricultural practices, the world can ensure food security while protecting the environment.



Waste Management and Recycling Innovations

Waste generation is a growing environmental problem, especially in urban areas. Green technology offers innovative solutions for waste management and recycling. Advanced recycling technologies can process plastics that were previously difficult to recycle, turning waste into valuable resources. Waste-to-energy plants convert non-recyclable waste into electricity and heat, reducing landfill use.

Biodegradable and compostable materials are replacing single-use plastics, reducing pollution in oceans and on land. Smart waste management systems use sensors to optimize waste collection, saving fuel and reducing emissions. These innovations help create a circular economy where resources are reused and waste is minimized.

Green Buildings and Sustainable Architecture

Buildings consume large amounts of energy and resources. Green building technologies aim to reduce this environmental impact. Energy-efficient designs, improved insulation, and smart lighting systems reduce energy consumption. Green buildings often use renewable energy sources such as solar panels and incorporate rainwater harvesting systems.

Innovative materials like green concrete, recycled steel, and bamboo reduce the carbon footprint of construction. Green roofs and vertical gardens improve air quality, reduce urban heat, and enhance biodiversity. Sustainable architecture not only protects the environment but also provides healthier living spaces for people.

Water Conservation and Purification Technologies

Freshwater scarcity is a major global concern. Green technologies for water conservation and purification play a crucial role in addressing this issue. Desalination technologies powered by renewable energy provide clean drinking water in water-scarce regions.

Advanced filtration and membrane technologies remove pollutants from wastewater, making it safe for reuse. Rainwater harvesting systems and smart irrigation technologies reduce water wastage in agriculture and urban areas. By improving water efficiency and quality, these innovations help ensure access to clean water for future generations.

Role of Artificial Intelligence and Digital Technologies

Artificial intelligence (AI) and digital technologies support green innovations by improving efficiency and decision-making. AI is used to optimize energy use, predict weather patterns, and manage renewable energy systems. In agriculture, AI helps farmers monitor crop health and improve yields with minimal environmental impact.

Digital platforms promote sharing economies, reducing resource consumption. Smart city technologies improve traffic management, energy use, and waste management. When combined with green technologies, digital innovations accelerate the transition to sustainability.

Conclusion

Green technology innovations offer hope for a sustainable future. From renewable energy and green transportation to sustainable agriculture and waste management, these technologies address some of the planet's most pressing environmental challenges. While technology alone cannot solve all problems, it plays a critical role when supported by strong policies, public awareness, and responsible consumption. By investing in and adopting green technologies, societies can reduce environmental damage, protect natural resources, and ensure a healthy planet for future generations. Green technology is not just an option; it is a necessity for saving the planet.

References

1. United Nations Environment Programme (UNEP). (2022). Green Technology and Sustainable Development. United Nations, New York.
2. International Energy Agency (IEA). (2023). Renewable Energy Market Update. IEA Publications, Paris.
3. World Economic Forum. (2021). Top 10 Emerging Technologies for Sustainability. World Economic Forum, Geneva.
4. Food and Agriculture Organization (FAO). (2021). Sustainable Agriculture and Innovative Farming Technologies. FAO, Rome.
5. International Renewable Energy Agency (IRENA). (2022). Innovation Landscape for Renewable Energy. IRENA Publications, Abu Dhabi.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Reducing Drudgery: Solar Technology Impact on Rural Women Time

Article ID: 72807

Dr. Swetha Kodali[1], Dr. R. NeelaRani[2], Dr. Jessie Suneetha.W[3], Dr. Lakshmi Challa[4], Dr. Swarupa Rani[5]

[1]Scientist (FRM), [2] Principal Scientist (EXTN), [3]Scientist (FN), [4]Scientist (CT) and [5]Scientist (CD)
AICRP on Women in Agriculture, PJTAU, Rajendranagar, Hyderabad-30.

In countless rural communities across the globe, the day begins before sunrise and ends long after dark for women who bear the primary responsibility for household and agricultural labour. This work is often physically exhausting, repetitive and mechanized defines what is known as "drudgery." Tasks like walking miles to collect heavy bundles of firewood, spending hours hunching over manual grain mills, and constant exposure to the toxic smoke of biomass cooking fires not only consume every waking hour but also lead to chronic health issues, from severe respiratory diseases to musculoskeletal disorders. This cycle of exhaustion traps women in poverty and limits the potential of their families and communities.

However, a silent revolution is underway, powered by the sun. Solar energy is emerging not merely as a clean power source but as a profound tool for social change and gender equality. The widespread adoption of affordable, targeted solar technologies directly addresses the core causes of female drudgery in rural communities, fundamentally freeing up invaluable time and energy that women can redirect toward economic empowerment, better health and improved quality of life.

Extending Productive Hours

For generations, the workday in off-grid rural homes ended with the sunset. The introduction of solar home lighting systems fundamentally changes this reality. Bright, reliable LED lights replace dangerous kerosene lamps, providing a safer environment and extending productive hours into the evening.

This Simple Shift has a Dramatic Impact

1. Efficient Chores: Evening household chores can be completed faster and more safely.

2. Income Generation: Women engaged in home-based micro-enterprises like tailoring, craft production, or food processing can continue working after dark, significantly boosting their output and income.

3. Education: Children, particularly girls who often share the burden of daytime chores, gain crucial hours for studying, improving educational outcomes and future prospects.

Powering Livelihoods: Drudgery-Reducing Appliances

The true power of solar technology lies in its ability to mechanize tasks that have historically relied on manual force. This innovation directly alleviates the most demanding physical labour.

1. Solar Water Pumps: Transportation of water is a daily chore that consumes hours. Solar pumps automate irrigation and household water supply, drastically reducing physical exertion and ensuring a reliable water source close to home.

2. Solar-Powered Agro-Processing: Machines like solar-powered flour mills, grain threshers, and silk-reeling machines replace agonizing manual labor. A case study on solar-powered silk reeling in India showed women could produce up to three times more yarn per day than with manual methods, simultaneously improving the quality of the product and eliminating unhygienic traditional practices.

3. Solar Dryers and Cold Storage: Post-harvest activities often involve intense labor to preserve produce. Solar dryers efficiently remove moisture from fruits and vegetables, reducing losses and saving the time previously spent constantly monitoring crops in traditional sun-drying methods. On-farm, solar-powered cold storage units allow women to preserve perishable goods, reducing food waste and increasing their ability to sell produce when market prices are favorable.

The Current Effect: Health, Income, and Empowerment

The time and health benefits gained from solar technology create an impact in every aspect of a woman's wok life.
Improved Health: Switching from biomass fuels to clean solar energy eliminates deadly indoor air pollution, drastically reducing the incidence of respiratory diseases, eye ailments, and burns. Avoiding the physical strain of carrying heavy loads and constant manual labor alleviates chronic back pain and fatigue.

Economic Independence: The time saved directly translates into economic opportunities. Women can engage in new income-generating activities, access training programs, and dedicate more time to their existing enterprises. Studies have shown significant income boosts for women who adopt these technologies, leading to greater financial

independence and decision-making power within their households and communities. This newfound confidence enhances their status and respect.

Conclusion

Solar technology is a profound catalyst for gender equality and sustainable development in rural areas. By specifically targeting the daily drudgery faced by millions of women, these innovations offer an escape from a life dominated by relentless, exhausting labor.

The transition from hours spent collecting fuel to hours spent generating income, from smoky kitchens to clean air, and from exhaustion to empowerment is more than just a technological upgrade—it is a fundamental restructuring of opportunity. To truly unlock this potential, a concerted effort is needed from policymakers, NGOs, and the private sector to bridge the gap between awareness and access through accessible finance, robust training, and supportive policy frameworks. By empowering rural women with solar energy, we are not just lighting up homes; we are igniting progress for entire communities.

References

1. Bera. R, Mishra, P and Patnaik, P. 2024. Renewable energy for women empowerment: Experiences from rural West Bengal. *Renewable and Sustainable Energy Reviews*. 198:1144-46.
2. Jennifer. B, Halimatou. A, Rosamond, N, Douglas. T. 2017. Impact of a rural solar electrification project on the level and structure of women's empowerment. Environ. Res. Lett. *12: 095007*.
3. https://sun-connect.org/empowering-women-and-transforming-lives-with-solar-energy/#:~:text=Empowering%20Women%20Through%20Education%20and,transforming%20lives%20in%20remarkable%20ways.
4. https://nenow.in/north-east-news/assam/solar-powered-looms-boost-income-and-safety-for-indias-silkweavers.html#:~:text=Before%20she%20made%20the%20switch,longer%20 exper iences%20injuries%20or%20pain.
5. https://www.ceew.in/sites/default/files/CEEW-PL-Impact-Factsheet-Solar-Silk-Reeling-15 May23.pdf
6. https://www.ceew.in/blogs/how-rural-indian-women-are-using-clean-energy-dre-powered-appliances-to-improve-incomes#:~:text=Solarising%20refrigerators%20to%20improve%20 the,the%20country%2C%E2%80%9D%20she%20says.
7. https://climatepromise.undp.org/news-and-stories/solar-energy-changing-womens-lives-and-transforming-rural-communities-bolivia#:~:text=For%20example%2C%20in%20Yapacan %C3%AD%2C%20the, reduced%20their%20impact%20on%20deforestation.
8. https://www.nrdc.org/stories/rural-india-women-take-charge-renewable-power

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Chronic Stress and Physiological Consequences Among Secondary School Students

Article ID: 72808

Dr. G. Swarupa Rani[1], Dr. Jessie Suneetha W[2], Dr. R. Neela Rani[3], Dr. Swetha Kodali[4], Dr. Laksmi Challa[5]

[1]Scientist (CD), at AICRP on Women in Agriculture, PJAU, Rajendranagar, Hyderabad-30.
[3]Scientist (FN), at AICRP on Women in Agriculture, PJAU, Rajendranagar, Hyderabad-30.
[2]Principal Scientist (EXN), at AICRP on Women in Agriculture, PJAU, Rajendranagar, Hyderabad-30.
[4]Scientist (FRM) at AICRP on Women in Agriculture, PJAU, Rajendranagar, Hyderabad-30.
[5]Scientist (TC) at AICRP on Women in Agriculture, PJAU, Rajendranagar, Hyderabad-30.

Abstract

Secondary school students are increasingly exposed to chronic stress due to academic demands, competitive environments, parental expectations, peer pressure, and digital influences. When stress becomes persistent, it triggers prolonged activation of the body's stress-response systems, leading to physiological changes that affect growth, immunity, sleep, and overall health. Chronic stress elevates cortisol and disrupts normal functioning of the cardiovascular, endocrine, immune, and digestive systems. Over time, these physiological disturbances may contribute to headaches, fatigue, weakened immunity, metabolic imbalance, and increased vulnerability to long-term health problems. This article examines the biological mechanisms underlying chronic stress in secondary school students and highlights the importance of early identification and supportive interventions to safeguard adolescent physical health.

Introduction

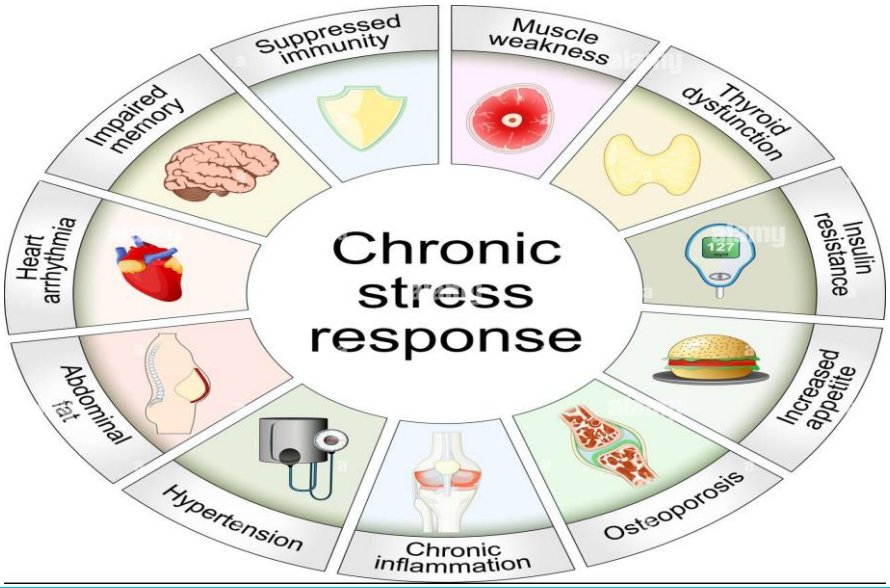
Secondary school years represent a crucial developmental stage marked by rapid physical growth, hormonal changes, and increasing academic responsibilities. While moderate stress can motivate learning and performance, chronic stress places a heavy burden on the developing body. Continuous exposure to stressors such as examinations, academic competition, parental pressure, social comparison, and reduced leisure time can disrupt normal physiological balance. Unlike short-term stress, chronic stress keeps the body in a constant state of alert, gradually impairing vital biological systems. Understanding the physiological consequences of chronic stress among secondary school students is essential for promoting holistic health and preventing long-term disease risks.

Physiological Mechanisms of Chronic Stress

1. Activation of the Stress Response System: Chronic stress continuously activates the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic nervous system. This leads to sustained release of cortisol and adrenaline. While these hormones are adaptive in short bursts, prolonged exposure disturbs homeostasis and places excessive strain on the body's organs and systems.

Major Physiological Consequences of Chronic Stress.

2. Effects on the Cardiovascular System: Persistent stress increases heart rate and blood pressure. Secondary school students experiencing chronic stress may show early signs of hypertension, palpitations, and increased cardiovascular reactivity. Over time, these changes raise the risk of cardiovascular disorders later in life.



3. Impact on the Immune System: Elevated cortisol suppresses immune functioning, reducing the body's ability to fight infections. Chronically stressed students often experience frequent colds, delayed wound healing, and general susceptibility to illness. This weakened immunity can interfere with school attendance and academic performance.

4. Sleep Disturbances and Fatigue: Stress disrupts normal sleep–wake cycles, leading to insomnia, poor sleep quality, and daytime fatigue. Inadequate sleep further worsens hormonal imbalance, concentration difficulties, and physical exhaustion, creating a vicious cycle of stress and health decline.

5. Gastrointestinal and Digestive Problems: Chronic stress affects gut functioning by altering digestion and gut motility. Secondary school students may experience stomach pain, nausea, indigestion, constipation, or irritable bowel symptoms. These psychosomatic complaints are common physical expressions of unresolved stress.

6. Hormonal and Metabolic Imbalance: Prolonged stress interferes with growth hormones, insulin regulation, and metabolic processes. This may contribute to weight gain or loss, delayed puberty, menstrual irregularities in girls, and reduced energy levels. Such disruptions can affect normal adolescent development.

7. Musculoskeletal Pain and Physical Discomfort: Stress often manifests physically as tension headaches, neck pain, back pain, and muscle stiffness. Poor posture, excessive screen use, and academic workload further intensify stress-related musculoskeletal problems among secondary school students.

Long-Term Health Implications

If chronic stress remains unaddressed during secondary school years, physiological consequences may persist into adulthood. Long-term risks include cardiovascular disease, metabolic disorders, weakened immunity, chronic fatigue, and stress-related psychosomatic illnesses. Early adolescence is a sensitive period; therefore, prolonged stress can "program" the body toward vulnerability to future health problems.

Preventive and Supportive Strategies

School-Level Strategies:

a. Balanced academic workload and realistic expectations
b. Incorporation of physical education and relaxation activities
c. Stress-awareness and life-skills education

Family-Level Support:

a. Emotional support and open communication
b. Encouraging healthy routines and adequate rest
c. Avoiding excessive academic pressure

Individual Coping Strategies:

a. Regular physical activity
b. Mindfulness, breathing exercises, and relaxation techniques
c. Adequate sleep and healthy nutrition

Professional Support:

a. School counsellors and mental health professionals
b. Early screening for stress-related health complaints

Conclusion

Chronic stress among secondary school students is not merely a psychological issue but a significant physiological concern. Continuous activation of stress-response systems disrupts cardiovascular, immune, digestive, and hormonal functioning, threatening both immediate and long-term health. Addressing stress during secondary school years through supportive environments, healthy lifestyles, and timely interventions is essential for promoting physical well-being and ensuring healthy development into adulthood.

References

1. Blakemore, S. J and Choudhury, S. 2016. Development of the adolescent brain: Implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry*. 47(3-4): 296-312.
2. https://doi.org/10.1111/j.1469-7610.2006.01611.
3. Compas, B. E., Jaser, S. S., Bettis, A. H., Watson, K. H., Gruhn, M. A., Dunbar, J. P., Williams, E and Thigpen, J. C. 2017. Coping, emotion regulation, and psychopathology in childhood and adolescence: A meta-analysis and narrative review. *Psychological Bulletin*. 143(9): 939-991. https://doi.org/10.1037/bul0000110
4. Gunnar, M. R and Quevedo, K. 2007. The neurobiology of stress and development. *Annual Review of Psychology*. *58*: 145-173. https://doi.org/10.1146/annurev.psych.58.110405.085605

5. Lee, J. E., Pope, Z and Gao, Z. 2019. The role of physical activity in stress management among adolescents. *International Journal of Environmental Research and Public Health, 16*(10):1870. https://doi.org/10.3390/ijerph16101870
6. Liston, C., McEwen, B. S and Casey, B. J. 2009. Psychosocial stress reversibly disrupts prefrontal processing and attentional control. *Proceedings of the National Academy of Sciences*. 106(3): 912–917. https://doi.org/10.1073/pnas.0807041106
7. Lupien, S. J., McEwen, B. S., Gunnar, M. R and Heim, C. 2019. Effects of stress throughout the lifespan on the brain, behaviour, and cognition. *Nature Reviews Neuroscience*. 10(6): 434–445. https://doi.org/10.1038/nrn2639
8. McEwen, B. S. 2017. Brain on stress: How the social environment gets under the skin. *Proceedings of the National Academy of Sciences*. 109(2): 17180–17185. https://doi.org/10.1073/pnas.1121254109
9. Romeo, R. D. 2017. The impact of stress on the structure of the adolescent brain: Implications for adolescent mental health. *Brain Research*. 1654: 185–191. https://doi.org/10.1016/j.brainres.2016.03.021
10. Tottenham, N and Galvan, A. 2016. Stress and the adolescent brain: Amygdala–prefrontal cortex circuitry and ventral striatum as developmental targets. *Neuroscience & Biobehavioural Reviews*. 70: 217–227. https://doi.org/10.1016/j.neubiorev.2016.07.030
11. Zoogman, S., Goldberg, S. B., Hoyt, W. T and Miller, L. 2015. Mindfulness interventions with youth: A meta-analysis. *Mindfulness. 6*(2): 290–302. https://doi.org/10.1007/s12671-013-0260-4

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Onion Cultivation: A Profitable Crop for Farmers in Angul District, Odisha

Article ID: 72809

Abhishek Govind Rao[1], Ranjit Kumar Das[1], Dr. Satyendra Singh[1]
[1]National Horticultural Research and Development Foundation, Regional Research Station, Paljhar, Boudh, Odisha, 762026.

Angul district, primarily known for paddy cultivation, has been witnessing and increasing shift towards onion cultivation, as farmers search for high value crops that ensure better returns. Onion has emerged as a promising vegetable crop in the district due to its wide consumer demand. According to state horticulture statistics, Odisha had about 31,7190 ha. Under cultivation in 2023-24 with a total production of around 3.69 lakh tonnes and an average productivity of nearly 11.6 t/ha. Angul contributes significantly to this acreage, with farmers adopting both rabi and Kharif onion cultivation. With increasing market demand and improved farming practices, onion area in Angul is gradually expanding, especially in Athmalik, Kishorenagar and Angul block.

Keywords: Onion cultivation, Angul district, Onion cultivation, NHRDF.

Angul district is under the Mid-Central Table Land agro climatic zone, with a cropping intensity of about 168-175%. The district's major cropping pattern is dominated by Rice-Pulse, Rice-Oilseed and in irrigated areas intensive sequence like rice-vegetables-vegetables. This diversified system provides scope for onion crop to emerge as a profitable enterprise. Onion has emerged as one of the most important commercial vegetable crops in Angul district. Farmers, who were earlier dependent mainly on paddy cultivation, are now shifting toward onion due to its high market demand and better profitability.

The efforts of the National Horticultural Research and Development Foundation (NHRDF), Boudh have been instrumental in popularising onion cultivation in the district through quality seed distribution, technical guidance and training programmes, NHRDF has enabled farmers to adopt improved varieties such as Agrifound Dark Red and NHRDF K-883 for Kharif and late Kharif and Agrifound Light Red, NHRDF Red-4, NHRDF Red-3, NHOR-920 and NHRDF Fursungi for rabi season which perform well under this climatic condition. By adopting recommended agronomic practices, including NPK (100:50:50 kg/ha) with sulphur (40 kg/ha) and specific spacing, farmers are achieving yields of 12-17 tonnes/ ha. Along with this, improved storage and market linkage have insured reduced post-harvest losses and better price realisation.

Angul district has been blessed with various agro climatic condition suited for the production of variety of crops. Angul enjoys south-east monsoon with average rainfall between 1400-1600 mm over the year. During the Rabi season, Angul district experiences a cool and dry climate with average temperature ranging from 12-15-degree centigrade minimum to 28-30 C maximum, which is congenial for onion bulb development. The low humidity and clear sunshine hours during this period reduce the incidence of foliar disease and favour better bulb quality. Irrigation facilities are essential for successful Rabi onion cultivation. These climatic conditions make onion a promising crop for diversification in the district' Rabi cropping system.

Challenges

Challenges in rabi onion cultivation in Angul despite favourable climatic condition, onion cultivation in Angul faces several challenges. The erratic winter rainfall and dependence on assured irrigation often limit the area under onion. Farmers usually prioritize paddy, leaving limited recourses for onion production. High labour costs and scarcity during peak operations such as transplanting and harvesting further add to production constraints. The crop is also vulnerable to biotic stresses like purple blotch, Stemphyllium blight, anthracnose and thrips infestation, which can significantly reduce yield and quality. Moreover, lack of storage and market infrastructure often forces farmers to sell their produce immediately after harvest at low prices, restricting profitability.

Economics

Comparative economics of Paddy and Onion Cultivation in Angul district is as below:

Particulars	Paddy (Rs/ha)	Onion (Rs/ha)
Land preparation	6000-8000	8000-10000
Seed cost	2000-3000	20000-22000
Manure & Fertilizer	12000-15000	25000-30000
Transplanting	20000-22000	20000-22000
Plant protection	4000-5000	6000-8000
Irrigation charges	5000-6000	3000-4000
Labours (wedding, harvesting, sorting grading, etc.)	10000-12000	25000-30000

Total cost of cultivation	59500-71000	107000- 126000
Avg. Yield	40-45 q/ha	200-250 q/ha
Gross Return	94760-106605	300000-375000
B:C Ratio	1.64-1.50	2.80-2.97

Summary

In Angul district, where paddy is the dominant crop, onion cultivation during rabi season has shown considerable promise. A detailed comparison of economics reveals that although onion requires a relatively higher cost of cultivation compared to paddy but the gross return from onion is significantly higher. This clearly indicates that onion is more profitable and economically viable than paddy under assured irrigation in Angul district, Odisha. Promoting onion as a diversification option can enhance farmer's income and contribute to a more balanced cropping system in the region.

Scheduling of fertilizer with dose for Onion transplanting (Per acre) as per the recommendation of NHRDF (100:50:50-N:P:K):		
DAP (18:46): MOP: Urea		
At basal dose	DAP: MOP	44 Kg: 34 Kg
20 DAT	Urea	35 Kg.
40 DAT	Urea	35 Kg.
NPK (12:32:16) : Urea : MOP		
At basal dose	NPK & MOP	62 kg :17 kg
20 DAT	Urea	35 Kg
40 DAT	Urea	35 Kg
SSP: Urea: MOP		
At basal dose	SSP: MOP	125 kg.: 34 kg
20 DAT	Urea	43 Kg
40 DAT	Urea	43 Kg
NPK (10:26:26) : Urea		
At basal dose	10:26:26	76 kg
20 DAT	Urea	35 Kg
40 DAT	Urea	35 Kg
24:24:00: Urea: MOP		
At basal dose	24:24:00 & MOP	83 kg: 34 Kg
20 DAT	Urea	25 Kg
40 DAT	Urea	25 Kg
12:61:00: Urea: MOP		
At basal dose	12:61:00 & MOP	32.6 kg.: 34 Kg
20 DAT	Urea	34 Kg
40 DAT	Urea	34 Kg
14:35:14: Urea: MOP		
At basal dose	14:35:14 & MOP	56.8 kg: 14 Kg
20 DAT	Urea	35 Kg
40 DAT	Urea	35 Kg
20:20:00:13: Urea: MOP		
At basal dose	12:61:00 & MOP	100 kg.: 34 Kg
20 DAT	Urea	21.5 Kg
40 DAT	Urea	21.5 Kg.

Note

Urea should not be applied in onion field after 50 Days of transplanting.



Some glimpse of Onion crop promotion: From seed and seedlings distribution to field cultivation, TDTD programmes and success story of farmers under the guidance and support of NHRDF.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Nanosensors and Nanotechnology in Agriculture: Precision Tools, Sustainable Outcomes, and the Critical Path to Field Implementation

Article ID: 72810

Abinash Sarmah[1], Dr. Gayatree Goswami[2]
[1]B.Sc. (Agriculture) 2nd year student, BSSRV, Golaghat, Assam.
[2]Faculty of Agriculture, B.Sc. Agriculture Programme, BSSRV, Golaghat, Assam.

Introduction: The Rationale for Nanotechnology in Modern Agriculture

Global agriculture is facing twin challenges of enhancing productivity for a growing population, while at the same time reducing resource depletion and environmental degradation caused by conventional agricultural practices. The transition towards resource-efficient, targeted management is the basis for modern Agriculture

Nanotechnology, processing materials at 1-100 nm, provides enabling tools for this transformation. These nanomaterials, with unique electronic and chemical properties, create high precision monitoring and delivery systems. Nanosensors enable real-time, nondestructive monitoring of biological and environmental conditions.

Further, nanotechnology helps build climate resilience: precision sensing enables adaptive management, while nano-enabled inputs enhance plant physiology for improved the water use efficiency and tolerance to abiotic stresses like drought and salinity.

Nanomaterials: Building Blocks for Smart Agro-Systems

Agricultural nanomaterials include metal oxides (e.g., Zinc Oxide), carbon-based nanomaterials, and organic nanoparticles, all engineered for stability and antimicrobial activity.

Carbon Nanomaterials and Plant Interactions

Carbon-based nanomaterials, in particular carbon nanotubes are prized for their optical and electrical properties. It has been reported that carbon nanomaterials can enhance seed germination, plant growth, and nutrient uptake and decrease pesticide accumulation in plants.

Performance, however, is highly variable depending on plant species, CNM type, concentration, and growth medium. This variability limits scalability and standardization for widespread agricultural use.

Mitigation of Abiotic Stress

Engineered nanoparticles improve resilience in plants under stress conditions.

Silicon Dioxide, Nanoparticles improve plant defenses against salt stress, enhancing transpiration and Water use efficiency for crops such as Cucurbita pepo.

Metallic nanoparticles-for example, Gold Nanoparticles-may work as "nano-enzymes" to mimic the functions of antioxidant enzymes and mitigate the oxidative stress brought about by drought and the temperature irregularities.

Nanosensors: Mechanisms for Real-Time, Sub-Symptomatic Monitoring

Nanosensors provide high-resolution, real-time data, thus acting as highly accurate tools for the modern smart agriculture.

The Nano-Internet of Things Paradigm

Nanosensors work as low-cost, distributed nodes within the Nano-internet of things, bridging nanoscale data to centralized AI and GPS systems. They enable continuous monitoring of soil moisture, pH, and nutrient status through mobile applications, thus turning management practices from reactive to predictive.

Environmental Monitoring and In Plant Diagnostics

1. Graphene-enhanced electrochemical nanosensors have the capacity to detect heavy metal ions and essential nutrients, such as nitrogen and phosphorus, at very low levels.

2. Paper-based lab-on-a-chip sensors provide low-cost, accurate analysis of the soil.

3. Inductive coupling and Radio Frequency Identification -based nanosensors measure deep soil moisture with high accuracy, with extended read ranges greater than 1 meter.

Among optical nanosensors, Forster Resonance Energy Transfer-based systems are applied in plants for the non-destructive observation of internal biochemical events, including protein-protein interactions and stress signaling.

Single walled carbon nanotube-based biomarker nanosensors can identify molecules such as water and nitric oxide before the symptoms of any disease become visually apparent, thus allowing for early management of the disease, such as Tobacco Mosaic Virus.

Despite the potentials, cost, complexity of data processing, and power requirements are significant barriers to large-scale deployment of nanosensor networks.

Nanotechnology in Precision Input Management: Targeted Delivery

Nanotechnology allows the controlled and directed delivery of agricultural inputs, improving efficiency while reducing the environmental impact.

Controlled Release Mechanisms and Nano-Inputs

Nanocarriers encapsulate fertilizers and pesticides, providing controlled release that can optimize both biological effectiveness and prevent over-application.

Other benefits include the following:

a. 20–30% reduction in water use.
b. 10–20% reduction in fertilizer consumption.
c. Up to 30% increase in crop yield.
d. Up to 70 percent reduction in pesticide use.

This method protects the groundwater, increases nutrient uptake, and allows for the better management of resources in a sustainable way.

Nanocarriers for Advanced Genetic Engineering

Nanoparticles can deliver biomolecules, including DNA, RNA, or Clustered regularly interspaced short palindromicrepeats components, directly into plant cells without tissue culture. Their tunable properties enable penetration through plant cell walls for efficient gene editing.

Such systems accelerate genetic modification in crops like wheat and barley, supporting rapid deployment of desirable traits.

However, the toxicokinetic trade-off-enhanced bioavailability vs. environmental persistence-is of critical importance and requires thorough consideration to ensure ecosystem and non-target species safety.

The Critical Path: Scalability, Cost-Benefit, and Field Readiness

The global agricultural nanotechnology market is projected to cross beyond USD 900 billion by 2032. Farmers take up a share of about 42.7% for cost reduction and improvement in yield.

Key challenges include:

a. High manufacturing costs of special nanomaterials.
b. Need for flexible synthesis techniques, and
c. Integration of reliable data and power systems for the field operations.

Whereas various technology maturity and deployment potential assessment frameworks, like the Agricultural Nanosensor Readiness Levels, have been proposed to facilitate adoption.

Risk Assessment, Environmental Fate, and Regulatory Challenges

Ecotoxicology and Biosafety: Certain nanomaterials can pose risks to soil ecosystems:

a. Carbon nanotubes could pose a toxic threat to soil organisms.
    i. Future nano-agricultural products should be developed with a great emphasis on biodegradability and biocompatibility to avoid potential long-term environmental risks.
    ii. In addition, occupational safety for agricultural workers involves clear protocols of risk management and the obligation of using personal protective equipment.

The Evolving Regulatory Landscape: Regulatory approaches vary worldwide:

a. Nanomaterials produced in the United States are under the purview of the Environmental protection agency through Toxic substances control Act, that requires notifications on production and control of exposures.
b. The approach followed, and supported through the European food safety authority, allows the European Union to consider an “integrated, safe, and responsible” approach, by defining and assessing the role of engineered nanomaterials for agri-food use.

However, the lack of consensus regarding engineered nanomaterials definitions and testing protocols serves as a continuing obstacle to international trade and innovation.

Ethical Implications and Societal Acceptance

Public acceptance will be a important component of nano-agriculture. The debate over Genetically modified crops shows that transparency, communication, and trust in emerging technologies are crucial for their acceptance.

Additionally, the high price of nano-enabled inputs creates equity and accessibility problems, whereby small-scale farmers may not be able to acquire the technology. Inclusiveness is important so as not to widen existing socio-economic disparities.

Conclusions and Recommendations

Nanotechnology offers a set of powerful tools that can help advance the cause of sustainable intensification and precision management in agriculture. Nevertheless, achieving wide diffusion necessitates the resolution of a number of interlinked challenges, including

1. **Scientific Priorities:**
    a. Long-term ecotoxicological studies
    b. Development of biodegradable and biocompatible nanocarriers.
2. **Translational Goals:**
    a. Establishment of field-deployment standards, such as Agricultural nanosensor readiness levels.
    b. Investment in robust energy and data infrastructure for nanosensing.
3. **Regulatory Frameworks:**
    a. Global harmonization of the definitions and safety protocols concerning ENMs.
    b. Policies that balance innovation with environmental and ethical safeguards.

Coordinated efforts in research, regulation, and industry would make nanotechnology a cornerstone of sustainable agriculture in the 21st century.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Transfer of Technology Through Seed Production Program's at KVK Farm, Amroha: Case Study

Article ID: 72811

Amit Tomar[1]
[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, Amroha
Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.).

Details of Seed Production Program

Seed production of Pearl millet variety Pusa Composite-701 were conducted at Krishi Vigyan Kendra, Gajraula, Amroha during kharif, 2025. The performance of Pearl millet variety Pusa Composite-701 were good in terms of plant population, panicles development and maturity, etc. Seed production of Maize variety Pusa Composite-05 were conducted at Krishi Vigyan Kendra, Gajraula, Amroha during Kharif, 2025. The performance of Bajra & Maize variety were good in terms of plant population, cob/panicles development and maturity, etc. The detail of seed production crop variety are given below:

Table-1: Detail of Bajra & Maize variety under seed production program:

S.No.	Name of crop	Name of variety	Season & year	Area (ha.)
1.	Pearl millet	Pusa Composite-701	Kharif, 2025	08
2.	Maize	Pusa Composite-05	Kharif, 2025	1.5

Seed production of Wheat variety HD-3086 & Mustard variety PM-30 were conducted at Krishi Vigyan Kendra, Gajraula, Amroha during rabi, 2025-26. The performance of Wheat & Mustard variety were good in terms of plant population, spikelet / Siliqua development and maturity, etc. The detail of seed production crop variety are given below:

Table-2: Detail of Wheat variety under seed production program:

S.No.	Name of crop	Name of variety	Season & year	Area (ha.)
1.	Wheat	HD-3086	Rabi, 2025-26	05
2.	Mustard	PM-30	Rabi, 2025-26	04

Monitoring the sowing of Wheat variety HD-3385 under seed production program during Rabi, 30th November, 2025-26 in at Krishi Vigyan Kendra, Gajraula, Amroha.





Dr. Gyanendra Singh In-charge Seed Production Unit, IARI, New Delhi visited the NS-BS Seed production of Wheat variety HD-3086 and Mustard variety BS-CS seed during 10th January, 2026 at Krishi Vigyan Kendra, Gajraula, Amroha.

ISSN: 2581 - 8317





AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Transfer of Technology Through Extension Functionaries Training Program for Extension Workers/FPO's/SHG's/Progressive Farmers/Social Worker's

Article ID: 72812

Amit Tomar[1]
[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, Amroha.

Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), India.

Extension Functionaries Training Detail

Organized an Extension Functionaries training under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **"Varietal diversification, characteristics, seed production technology and entrepreneurship development in Basmati Rice" during 25/04/2025 at State Seed Godown, Varshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety for Basmati Rice transplanting.

Extension Functionaries Training Detail

Organized an Extension Functionaries training under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **"Varietal diversification, characteristics, seed production technology and entrepreneurship development in Millets" during 30/04/2025 at State Seed Godown, Varshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Mustard in their cultivation practices.





Extension Functionaries Training Detail

Organized an Extension Functionaries training under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **"Uses, quality, varietal diversification and production technology of Millets in Western Uttar Pradesh region" during 27/08/2025 January, 2025 at State Seed Godown, Varshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Linseed in their cultivation practices.





Extension Functionaries Training Detail

Organized an Extension Functionaries training under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **"Varietal diversification, characteristics, seed production technology and entrepreneurship development in Sugarcane for Western Uttar Pradesh region" during 30/08/2025 January, 2025 at State Seed Godown, Varshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Linseed in their cultivation practices.

Extension Functionaries Training Detail

Organized an Extension Functionaries training under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **Organized Extension Functionaries training program on "Varietal diversification, characteristics, seed production technology and entrepreneurship development in Bio-fortified wheat for Western Uttar Pradesh region" during 22/12/2025 December, 2025 at State Seed Godown, Varshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Linseed in their cultivation practices.



Extension Functionaries Training Detail

Organized an Extension Functionaries training under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **Organized Extension Functionaries training program on "Varietal diversification, characteristics, seed production technology and entrepreneurship development in Berseem for Western Uttar Pradesh region" during 29/12/2025 December, 2025 at State Seed Godown, Varshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Linseed in their cultivation practices.



AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Popularization of Groundnut Variety GG-34 Among Farmers Under Cluster Frontline Demonstrations (CFLDs): Success Story

Article ID: 72813

Amit Tomar[1]
[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, Amroha (U.P.).

Background Information About Farmer Field

Shri Ramratan Singh ji of Amroha district after completion his education up to B.A. degree, engaged himself in agriculture in his own land for running his family. He possesses 4.5 ha of land, out of which he cultivates Cereal and oilseed Crop in 3.00 ha and 1.5 ha under vegetable cultivation. But income generated from his farm was not enough for smooth running of his family. Later on he formed a farmers group along with few youths.

Details of Technology Demonstrated

1. High yielding Oil Seed Crop Groundnut GG-34
2. Seed inoculation with Biofertilizer
3. Vermicompost @ 2.5 q/ha
4. 50 % recommended dose of N and full dose of P, K, Sulphur fertilizer

Institutional Involvement

KVK Amroha has demonstrated the high yielding Groundnut variety GG-34 along with other technology mentioned above during Kharif, 2025 under CFLD on Oilseed Crop.

Success Point

They wanted to grow Oil Seed Crop were remain fallow during Kharif season. Shri Ramratan Singh Ji along with his group came to KVK Amroha and they expressed their willingness to utilize that area for crop production. Then a team of scientists from KVK, Amroha visited the area and after discussion with the farmers and necessary survey, conducted a training program for them. Later on, they were provided with seeds of high yielding Oil Seed Crop Groundnut variety GG-34 and other necessary inputs for demonstration. The crop was sown during July, 2025 and harvested during November, 2025. They have harvested a very good crop (Yield: 22.85 q/ha) and earned a very good income (Net income Rs. 86,399 /ha).

Farmers Feedback

After successful implementation of the technology, farmers in the village were highly impressed and motivated by the performance of the new variety (Groundnut variety GG-34) of with improved cultivation practices due to its higher net income. He is now a role model not only in his village but also for the entire farming community of the nearby villages. Farmers from other villages are motivated by the success of this farmer and showing keen interest to implement pulses production program with proven HYV seeds in their villages. These interventions have the potential to create positive impact on Oil Seed production in Amroha district which will benefit the farmers at large.

Outcome from Technology

Demonstration	**22.85**	**District average (Previous year)**	**14.08**
Potential yield of variety/ technology	25.00	State average (Previous year)	12.56

Performance of Technology Vis-À-Vis Local Check (Increase in Productivity and Returns)

Specific Technology	Yield (q/ha)	Gross cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha	B:C ratio
Farmer practices	17.45	75890	126740	50850	**1.67**
Demonstration	**22.85**	79560	165959	86399	**2.08**
% Increase	**23.63**	-	-	-	-

Farmers Training & Distribution of Groundnut variety GG-34 seeds to the farmers under Cluster Front Line Demonstrations (CFLDs) on Oilseeds during 30th June, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.



Organized field day on CFLD on Oilseeds (Groundnut) variety GG-34 in the Village- Toniya Mafi, Dhanuara, Amroha during 15th September 2025.



Demonstration Plot of Groundnut variety GG-34 at farmers field during Kharif, 2025

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Technology Transfer through Vocational Training Program for Un-Employment Rural Youth/Farm Women's

Article ID: 72814

Amit Tomar[1]
[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, (Amroha).

Vocational Training Detail

Organized an Vocational training for Rural Youth under Plant Breeding. Total 10 farmers were attended the training program. During the training program scientists were discussed about **on "New high yielding varieties of Mustard, their characteristics, production technology and entrepreneurship development" during 13th to 17th February, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Mustard in their cultivation practices.





Vocational Training for Rural Youth Training Detail

Organized a Vocational training for Rural Youth under Plant Breeding. Total 10 farmers **on "New high yielding varieties of Basmati Rice, their characteristics, production technology and entrepreneurship development" during 13th to 17th May, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Mustard in their cultivation practices.





Vocational Training Detail

Organized an Vocational training for Rural Youth under Plant Breeding. Total 10 farmers **New high yielding varieties of Millets, their characteristics, production technology and entrepreneurship development" during 15th to 19th September, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology and seed/ variety of Mustard in their cultivation practices.


कृषि विज्ञान केन्द्र गजरौला, अमरोहा


कृषि विज्ञान केन्द्र गजरौला, अमरोहा
प्रशिक्षण ग्रामीण बेरोजगार
युवक/युवतियां


कृषि विज्ञान केन्द्र गजरौला, अमरोहा




कृषि विज्ञान केन्द्र गजरौला, अमरोहा
प्रशिक्षण ग्रामीण बेरोजगार
युवक/युवतियां


कृषि विज्ञान केन्द्र गजरौला, अमरोहा

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Impact Assessment of New High Yielding Variety of Basmati Rice Pusa Basmati-1847 Under Front Line Demonstrations in District Amroha of Western Uttar Region: Case Study

Article ID: 72815

Amit Tomar[1]
[1]ICAR-Krishi Vigyan Kendra, Gajraula, Amroha (Directorate of Extension), Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P.

Details of Frontline Demonstrations (FLD's)

Front Line Demonstrations (FLDs) on Basmati Rice was conducted during Kharif, 2025. The high yielding varieties/hybrids namely; Pusa Basmati-1947 was used for distribution of seed under FLDs on Basmati Rice during Kharif-2025 in Western Uttar Pradesh region. The average yield of these varieties/hybrids are 47.25 q/ha. and mature in medium duration.

Table-01: Details of Frontline Demonstrations during Kharif, 2025:

Name of KVK	**KVK, Amroha**
Crop and variety name	Basmati Rice variety Pusa Basmati-1947
Background information about farmer field	Using old variety
Details of technology demonstrated	Replacement of Local variety of Basmati Rice by PB-1121 with use of IDM & IPM.
Institutional involvement	Technical guidance & Monitoring
Success point	Use of Sulphur, timely sowing, timely practices & low incidence of Insect-pests & diseases.
Farmer feedback	(i) Grain yield has been increased due to selection of high yielding variety PB-1947. (ii) Uniform maturity and bold grain. (iii) Farmer are convinced to grow quality of seed & low incidence of Insect-pest & diseases.
Yield (q/ha)	
- Demonstration	47.25
- Potential yield of variety/technology	36.95

Performance of Technology Vis-A-Vis Local Check (Increase in Productivity and Returns):

Specific Technology	Yield (q/ha)	Gross cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B:C ratio
Farmer practices	47.25	42540	87158	44658	2-05
Demonstration	36.50	36650	112880	76230	3-08
% Increase	**22.75 %**	-	-	-	-

Distribution of Basmati Rice varieties Pusa Basmati-1847 at farmers field during Kharif, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.





Organized field day for monitoring the performance of Basmati Rice variety Pusa Basmati-1847 under Front Line Demonstrations (FLDs) during Kharif, 2025 in the Village- Barshabad, Gajraula, Amroha on 28th August, 2025.



Performance of Basmati Rice variety PB-1947 under FLD's during Kharif, 2025.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Technology Transfer Through On & Off Campus Farmers & Farm Women Training Program

Article ID: 72816

Amit Tomar[1]
[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, Amroha.
Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), India

On-Campus Farmers Training Detail

Organized an on-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **"New high yielding varieties of Basmati Rice and quality seed production technologies" during 01st to 02st May, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



On-Campus Farmers Training Detail

Organized an on-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **"New high yielding varieties of Millets and quality seed production technologies" during 05tht to 06th May, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



On-Campus Farmers Training Detail

Organized an on-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **"New high yielding varieties, their characteristics and quality seed production techniques of Millets" during 24th to 25th July, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.




On-Campus Farmers Training Detail

Organized an on-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **"New high yielding varieties of Basmati Rice and their production techniques for Western Uttar Pradesh Region" during 07th to 08th August, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.




On-Campus Farmers Training Detail

Organized an on-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **"New high yielding varieties of late sown wheat and their production techniques for Western Uttar Pradesh Region" during 08th to 9th October, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.**

Farmers were Highly Satisfied with the Training Program and also Implicated Technology





Off-Campus Farmers Training Detail

Organized an off-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **on "New high yielding varieties of Basmati Rice and their production techniques for Western Uttar Pradesh Region" during 04/04/2025 at Village-Kumrala, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



Off-Campus Farmers Training Detail

Organized an off-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about **"Varietal diversification and production techniques of new high yielding Millets varieties for Western Uttar Pradesh region" during 24/04/2025 at Village- Barshabad, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



Off-Campus Farmers Training Detail

Organized an off-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about on **"New high yielding varieties of Yellow Sarson and their production techniques for Western Uttar Pradesh Region" during 06th October, 2025 at Village- Banseli, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



Off-Campus Farmers Training Detail

Organized an off-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about on **"New high yielding varieties of Bio-fortified Wheat and their production techniques for Western Uttar Pradesh Region" during 12th December, 2025 at Village- Kumrala, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



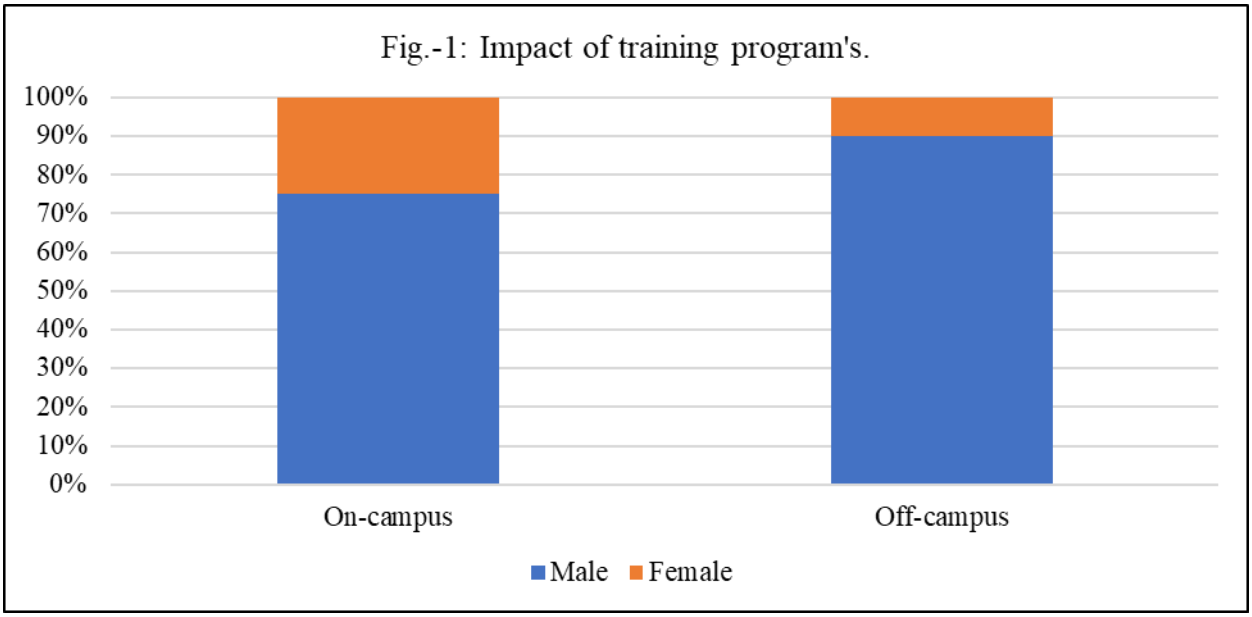
Off-Campus Farmers Training Detail

Organized an off-campus farmers training under Plant Breeding. Total 20 farmers attended the training program. During the training program scientists were discussed about on **"New high yielding varieties of late sown wheat and their production techniques for Western Uttar Pradesh Region" during 20th December, 2025 at Village- Chakanwala, Gajraula, Amroha.** Farmers were highly satisfied from the training program and also implicated the technology.



Impact of Training Program's

Training's	Male	Female
On-campus	15	05
Off-campus	18	02



AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Impact Assessment of New High Yielding Variety of Basmati Rice Pusa Basmati-1885 Under Front Line Demonstrations in District Amroha of Western Uttar Region: Case Study

Article ID: 72817

Amit Tomar[1]
[1]ICAR-Krishi Vigyan Kendra, Gajraula, Amroha (Directorate of Extension), Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P.

Details of Frontline Demonstrations (FLD's)

Front Line Demonstrations (FLDs) on Basmati Rice was conducted during Kharif, 2025. The high yielding varieties/hybrids namely; Pusa Basmati-1885 was used for distribution of seed under FLDs on Basmati Rice during Kharif-2025 in Western Uttar Pradesh region. The average yield of these varieties/hybrids are 45.85 q/ha. and mature in medium duration.

Table-01: Details of Frontline Demonstrations during Kharif, 2025:

Name of KVK	**KVK, Amroha**
Crop and variety name	Basmati Rice variety Pusa Basmati-1885
Background information about farmer field	Using old variety
Details of technology demonstrated	Replacement of Local variety of Basmati Rice by PB-1121 with use of IDM & IPM.
Institutional involvement	Technical guidance & Monitoring
Success point	Use of Sulphur, timely sowing, timely practices & low incidence of Insect-pests & diseases.
Farmer feedback	(i) Grain yield has been increased due to selection of high yielding variety PB-1885. (ii) Uniform maturity and bold grain. (iii) Farmer are convinced to grow quality of seed & low incidence of Insect-pest & diseases.
Yield (q/ha)	
- Demonstration	45.85
- Potential yield of variety/technology	38.65

Performance of Technology Vis-A-Vis Local Check (Increase in Productivity and Returns)

Specific Technology	**Yield (q/ha)**	**Gross cost (Rs/ha)**	**Gross income (Rs/ha)**	**Net income (Rs/ha)**	**B:C ratio**
Farmer practices	36.50	42540	87198	44658	2.0
Demonstration	45.85	35650	109536	73886	3.07
% Increase	**20.39 %**	-	-	-	-

Organized field day for monitoring the performance of Basmati Rice variety Pusa Basmati-1885 under Front Line Demonstrations (FLDs) during Kharif, 2025 in the Village- Toniya Mafi, Dhanuara, Amroha on 15th September, 2025.



Performance of Basmati Rice variety PB-1885 under FLD's during Kharif, 2025.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Fermented Organic Manure (FOM): Benefits and Applications

Article ID: 72818

Amit Tomar[1], Mahak Singh[2]
[1]Subject Matter Specialist (Plant Breeding), ICAR- KVK, Gajraula (Amroha), SVPUA&T, Meerut.
[2]Professor (Genetics & Plant Breeding), Dept. of Genetics & Plant Breeding, College of Agriculture, CSAUA&T, Kanpur.

What is Fermented Organic Manure (FOM) and its benefit?

Fermented organic manure (FOM) is **a type of organic fertilizer produced through a controlled fermentation process of organic materials like manure, crop residues, and compost**. This process enhances nutrient availability and releases beneficial microorganisms that improve soil health and plant growth.

What is it?



1. FOM is essentially a by-product of biogas plants or compressed biogas (CBG) plants, where organic waste is used to produce biogas.

2. It involves a controlled fermentation of organic matter to break down complex compounds into simpler, more readily available forms.

3. This process also releases beneficial microorganisms like bacteria and fungi that improve soil health.

How is it Made?

1. Organic materials like animal manure, crop residues, and kitchen scraps are combined with water and allowed to ferment in a controlled environment.

2. The fermentation process breaks down the organic matter, releasing nutrients and beneficial microorganisms.

3. FOM is a by-product derived by the fermentation of plant residue, animal manure, and organic waste after biogas production.

4. Eco-friendly manure: FOM promotes sustainable farming practices by improving soil physical and microbial properties. It enhances soil nutrients, improves soil structure and moisture retention, leading to favourable soil conditions.

5. Boosts crop productivity and quality: Regular application of FOM results in healthier crops, increased yields, and improved crop quality, making it particularly beneficial for organic and sustainable farming systems.

6. Long-term soil benefits: It acts as a carbon enhancer and promotes healthier soil ecosystem. Further, FOM enhances soil fertility and resilience, contributing to sustainable agricultural productivity over time.

7. Soil Enrichment: FOM is used to improve soil fertility by adding essential nutrients, organic matter, and beneficial microorganisms. It enhances soil structure, water retention, and nutrient availability to plants.

8. Crop Nutrient Supply: FOM provides a source of essential nutrients like nitrogen, phosphorus, and potassium, as well as secondary and micronutrients to support plant growth. It acts as a natural and slow-release fertilizer.

9. Reducing Chemical Fertilizer Dependency: FOM can partially or wholly replace synthetic chemical fertilizers, reducing the environmental impact and costs associated with chemical fertilization.

10. Enhanced Plant Growth: Application of FOM promotes healthier and more vigorous plant growth, leading to increased crop yields and improved quality of fruits, vegetables, and other agricultural products.

11. Waste Management: FOM is an effective way to recycle and utilize organic waste materials, such as crop residues, kitchen scraps, and animal manure, reducing the need for landfill disposal.

12. Reduced Soil Erosion: By enhancing soil structure and root development, FOM helps reduce soil erosion, particularly in areas prone to erosion.

In which Crops, FOM can be Applied

Application of FOM is recommended in the following crops: Wheat, Rice, Maize, Babycorn, Pea, Okra, Spinach, Mustard, Vegetable cowpea and Sugarcane.

POP FOM/LFOM

Under the Government of India's GOBAR **D**han scheme, ICAR has developed organic fertilizer (FOM/LFOM)-based cropping systems for major crops. This report includes fertilizer management practices recommended by various ICAR institutes for different crops. The objective is to promote environmentally friendly and sustainable agriculture.

Crop Wise Recommendations of FOM/LFOM

Crop	FOM/LFOM usage
Maize	Application of FOM @ 4 to 6 t/ha is recommended along with 80% of recommended dose of fertilizer (150 kg N/ha, 60 kg P2O5/ha, 30 kg K2O/ha) for optimum productivity.
Rice(Paddy)	In transplanted puddled rice crop, application of FOM (Bio-slurry enriched and stabilized to 2.1% N) @ 2.5 t/ha during nursery preparation and @1.25 t/ha after transplanting is recommended along with the recommended dose of fertilizer (RDF) (120 kg N/ha, 60 kg P2O5/ha, 60 kg K2O/ha). In direct seeded rice, the liquid FOM is recommended @ 1.25 t/ha along with the RDF. LFOM should be used @ 500 Liter per ha for 2 to 3 times.
Wheat	In wheat, soil application of FOM (dried bio-slurry) @ 6-8 t/ha, 10 days before sowing is recommended along with recommended dose of fertilizer (120 kg N/ha, 60 kg P2O5/ha, 60 kg K2O/ha) for sustainable productivity. FOM should be applied before last plough and ploughed into the soil.
Sugarcane	Apply FOM @ 5-6 t/ha with C:N ratio less than 20 before last ploughing and apply FOM @ 5 t/ha after 90 days of planting and do earthing up. Along with, apply RDF (200 kg/N, 60 kg P2O5/ha and 100 kg K2O/ha) for optimum yield.

Important Note

1. Don't apply FOM / LFOM as foliar spray. Use this along with recommended dose of fertilizers for each crop.
2. FOM should be applied 7-15 days before sowing in all the crops.
3. pH of FOM should be in between 6.5 to 7.5.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Green Hydrogen Gas and Dispensing Stations: Uses and Applications

Article ID: 72819

Amit Tomar[1], Mahak Singh[2]
[1]Subject Matter Specialist (Plant Breeding), ICAR- KVK, Gajraula (Amroha), SVPUA&T, Meerut
[2]Professor (Genetics & Plant Breeding), Dept. of Genetics & Plant Breeding, College of Agriculture, CSAUA&T, Kanpur Green Hydrogen.

Green Hydrogen Gas

Green Hydrogen is produced through water treatment, electrolysis, gas purification, drying and compression of hydrogen of not more than 2 kg CO2 equivalent / kg H2.

Uses

Clean Energy Source: Green hydrogen can be used as a clean source of energy for various applications, including electricity generation, heating, and transportation.



Electricity Generation: Hydrogen can be used in fuel cells to generate electricity. This is particularly valuable for providing backup power and grid stability, especially in regions with intermittent renewable energy sources like wind and solar.

Powering Fuel Cells: Green hydrogen is used for fueling fuel cells in various sectors, including stationary power generation, vehicles, and portable devices, providing a reliable and clean power source.

Transportation Fuel: Green hydrogen can be used as a clean fuel for hydrogen fuel cell vehicles. It offers longer ranges and shorter refueling times compared to electric batteries.

Decarbonizing Industrial Processes: Green hydrogen can replace fossil fuels in various industrial applications, such as ammonia and methanol production, reducing carbon emissions from these processes.

Steel Production: In the steel industry, hydrogen can be used to replace coke in the iron ore reduction process, leading to lower carbon emissions in steel production.

Dispensing Stations: Franchisee for a comprehensive destination offering petrol, diesel, E100 fuel, Bio CNG, CBG, EV charging, battery swapping, and essential retail services.

Uses

Vehicle Refueling: The primary purpose of fuel dispensing stations is to provide a convenient location for drivers to fill their vehicles with fuel.



Variety of Fuel Types: Offers a wide range of fuel types, catering to different vehicles and their specific fuel requirements, including petrol, diesel, E 100 Fuel, Bio CBG, and EV Charging Points.

Convenience Store and Amenities: Our Fuel Stations include convenience stores, restrooms, and other amenities for customers to enhance their experience and meet additional needs.

Vehicle Maintenance and Services: Fuel stations offer basic vehicle maintenance and services, such as oil changes, tire inflation, and car wash facilities.

Emergency Fuel Supply: Fuel stations can serve as sources of emergency fuel during natural disasters or power outages, ensuring that vehicles can continue to operate.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Climate Smart Agriculture: Opportunities and Challenges

Article ID: 72820

Amit Tomar[1], P.K. Singh[2]

[1]Subject Matter Specialist (Plant Breeding), ICAR- Krishi Vigyan Kendraa, Gajraula, Amrohaa, SVPUA&T, Meerut (U.P.).

[2]Professor (Agronomy), Directorate of Extension, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.).

Climate Smart Agriculture

Climate-smart agriculture (CSA) is an approach that helps guide actions to transform agri-food systems towards green and climate resilient practices. CSA supports reaching internationally agreed goals such as the SDGs and the Paris Agreement. It aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible. CSA supports the FAO Strategic Framework 2022-2031 based on the Four Betters: better production, better nutrition, a better environment and a better life for all, leaving no one behind. What constitutes a CSA practice is context-specific, depending on local socio-economic, environmental and climate change factors. FAO recommends the approach is implemented through five actions points: expanding the evidence base for CSA, supporting enabling policy frameworks, strengthening national and local institutions, enhancing funding, and financing options, and implementing CSA practices at field level.

Climate-smart agriculture (CSA) (or **climate resilient agriculture**) is a set of farming methods that has three main objectives with regards to climate change. Firstly, they use adaptation methods to respond to the effects of climate change on agriculture (this also builds resilience to climate change). Secondly, they aim to increase agricultural productivity and to ensure food security for a growing world population. Thirdly, they try to reduce greenhouse gas emissions from agriculture as much as possible (for example by following carbon farming approaches). Climate-smart agriculture works as an integrated approach to managing land. This approach helps farmers to adapt their agricultural methods (for raising livestock and crops) to the effects of climate change. The most effective approach to enhancing climate-smart agriculture (CSA) is to involve the relevant organizations and government. This will demonstrate the duties and responsibilities of the government and the supporting institutions in facilitating the advancement of CSA practices. Assessing risks necessitates contemplating climate-smart agriculture. The CSA can assist in the research of the introduction of new crop varieties to address the changing climate. There are different actions to adapt to the future challenges for crops and livestock. For example, with regard to rising temperatures and heat stress, CSA can include the planting of heat tolerant crop varieties, mulching, boundary trees, and appropriate housing and spacing for cattle. There are attempts to mainstream CSA into core government policies and planning frameworks. In order for CSA policies to be effective, they must contribute to broader economic growth and poverty reduction.

Definition

The term *climate-smart agriculture* has been criticized as a form of greenwashing for big businesses. The World Bank described climate-smart agriculture (CSA) as follows: "CSA is a set of agricultural practices and technologies which simultaneously boost productivity, enhance resilience and reduce GHG emissions." and "CSA is an integrated approach to managing landscapes—cropland, livestock, forests and fisheries--that address the interlinked challenges of food security and climate change." FAO's definition is: "CSA is an approach that helps guide actions to transform agri-food systems towards green and climate resilient practices."

Key Objectives of Climate-Smart Agriculture

CSA has the following three objectives: "sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions". Others describe the objectives as follows: mitigate the adverse impacts of climate change on agriculture, stabilize crop production, maximize food security.

1. Sustainably Increase Productivity and Incomes: CSA seeks to improve agricultural yields and incomes in a way that is environmentally sound and socially equitable.

2. Enhance Resilience to Climate Change: This involves adapting agricultural practices to cope with the impacts of climate change, such as droughts, floods, and extreme temperatures.

3. Reduce and/or Remove Greenhouse Gas Emissions: CSA aims to minimize the environmental footprint of agriculture by reducing emissions from agricultural activities and exploring opportunities for carbon sequestration.

Key Principles of Climate-Smart Agriculture

1. Holistic Approach: CSA considers the interconnectedness of agricultural systems with the environment, economy, and society.

2. Context-Specific Solutions: CSA recognizes that the most effective strategies will vary depending on local conditions, such as climate, soil type, and farming practices.

3. Synergies and Trade-offs: CSA aims to identify practices that can achieve multiple objectives simultaneously, while also mitigating potential negative trade-offs.

Strategies

Strategies and methods for CSA should be specific to the local contexts where they are employed. They should include capacity-building for participants in order to offset the higher costs of implementation.

Carbon Farming

Carbon farming is one of the components of climate-smart agriculture and aims at reducing or removing greenhouse gas emissions from agriculture. Carbon farming is a set of agricultural methods that aim to store carbon in the soil, crop roots, wood and leaves. The technical term for this is *carbon sequestration*. The overall goal of carbon farming is to create a net loss of carbon from the atmosphere. This is done by increasing the rate at which carbon is sequestered into soil and plant material. One option is to increase the soil's organic matter content. This can also aid plant growth, improve soil water retention capacity and reduce fertilizer use. Sustainable forest management is another tool that is used in carbon farming. Carbon farming is one component of climate-smart agriculture. It is also one way to remove carbon dioxide from the atmosphere. Agricultural methods for carbon farming include adjusting how tillage and livestock grazing is done, using organic mulch or compost, working with biochar and terra preta, and changing the crop types. Methods used in forestry include reforestation and bamboo farming.

Gender-responsive approach: Woman picking peas in the Mount Kenya region, for the Two Degrees Up project, to look at the effects of climate change on agriculture. To increase the effectiveness and sustainability of CSA interventions, they must be designed to address gender inequalities and discriminations against people at risk. Women farmers are more prone to climate risk than men are. In developing countries, women have less access compared to men to productive resources, financial capital, and advisory services. They often tend to be excluded from decision making which may impact on their adoption of technologies and practices that could help them adapt to climatic conditions. A gender-responsive approach to CSA tries to identify and address the diverse constraints faced by men and women and recognizes their specific capabilities. Climate-smart agriculture presents opportunities for women in agriculture to engage in sustainable production.

Monitoring tools: FAO has identified several tools for countries and individuals to assess, monitor and evaluate integral parts of CSA planning and implementation:

a. Modelling System for Agricultural Impacts of Climate Change (MOSAICC),
b. Global Livestock Environmental Assessment Model (GLEAM),
c. Sustainability Assessment of Food and Agriculture (SAFA) system,
d. Economics and Policy Innovations for Climate-Smart Agriculture (EPIC),
e. Ex-Ante Carbon-balance Tool (EX-ACT),
f. Climate Risk Management (CRM),
g. Gender mainstreaming,
h. Monitoring and Assessment of Greenhouse Gas Emissions and Mitigation Potential in Agriculture (MAGHG) project.

Climate-Resilient Agriculture Index: The Climate-Resilient Agriculture (CRA) Index is a tool designed to assess and improve the resilience of agricultural systems to climate change. Two distinct versions of this index exist, each with a unique purpose and scope:

CRA Index: The CRA Index is aimed at benchmarking national agricultural resilience across countries. It uses nine indicators grouped into three dimensions: agricultural productivity and resource use efficiency, environmental sustainability and climate impact, and socio-economic resilience. It helps categorise nations into four resilience levels: Highly Resilient, Moderately Resilient, Low Resilience, and Very Low Resilience. This index provides policymakers with insights to prioritise interventions and enhance national-level climate adaptation strategies.

CRA Index for India: The CRA Index for India evaluates climate resilience within the country's diverse agro-climatic zones. It employs 26 indicators spanning environmental, technological, socio-economic, and infrastructural dimensions to assess inter- and intra-zone resilience variations. This region-specific framework supports the development of tailored strategies to address local challenges and improve agricultural adaptability to climate change. Both indices offer valuable insights for addressing the impacts of climate change on agriculture. While the global CRA Index focuses on

international benchmarking and national-level strategies, the CRA Index for India targets regional disparities to guide localised interventions.

Major Initiatives

European Green Deal: The EU has promoted the development of climate-smart agriculture and forestry practices as part of the European Green Deal Policy. A critical assessment of progress was carried out using different multi-criteria indices covering socio-economic, technical and environmental factors. The results indicated that the most advanced CSA countries within the EU are Austria, Denmark and the Netherlands. The countries with the lowest levels of CSA penetration are Cyprus, Greece and Portugal. Key factors included labor productivity, female ownership of farmland, level of education, degree of poverty and social exclusion, energy consumption / efficiency and biomass / crop productivity. The Horizon Europe research programme has created a focus on CSA and climate-smart farming within the EU. Projects deal with co-creation among stakeholders to change behavior and understanding within agricultural value chains. Investigative CSA studies on pig, dairy, fruit, vegetable and grain farms have been carried out in Denmark, Germany, Spain, Netherlands and Lithuania, respectively.

Agriculture Innovation Mission for Climate: The Agriculture Innovation Mission for Climate (AIM for Climate/AIM4C) is a 5-year initiative to 2025, organized jointly by the UN, US and UAE. The objective is to rally around climate-smart agriculture and food system innovations. It has attracted some 500 government and non-government organizations around the world and about US$10 billion from governments and US$3 billion from other sources. The initiative was introduced during COP-26 in Glasgow. The CGIAR as part of the AIM4C summit in May 2023 called for a number of actions: Integration of initiatives from the partner organizations, enabling innovative financing, production of radical policy and governance reform based on evidence. And lastly, promotion of project monitoring, evaluation, and learning.

Global Roadmap to 2050 for Food and Agriculture

Global food systems GHG emissions in 2020 for different agriculture sectors in terms of gigatons of CO_2 equivalents. Several actors are involved in creating pathways towards net-zero emissions in global food systems.

Four areas of focus relate to:

a. Lowered GHG-emission practices by increasing production efficiency;
b. Increased sequestration of carbon in croplands and grasslands;
c. Shifting of human diets away from livestock protein;
d. Taking on "new-horizon" technologies within the food systems.

Livestock production (beef, pork, chicken, sheep and milk) alone accounts for 60% of total global food system GHG emissions. Rice, maize and wheat stand for 25% of the global emissions from food systems.

Criticism

The greatest concern with CSA is that no universally acceptable standard exists against which those who call themselves *climate-smart* are actually acting *smart*. Until those certifications are created and met, sceptics are concerned that big businesses will just continue to use the name to greenwash their organizations—or provide a false sense of environmental stewardship. CSA can be seen as a meaningless label that is applicable to virtually anything, and this is deliberate as it is meant to conceal the social, political and environmental implications of the different technology choices. In 2014 *The Guardian* reported that climate-smart agriculture had been criticized as a form of greenwashing. Contradictions surrounding practical value of CSA among consumers and suppliers may be the reason why the European Union is lagging with CSA implementation compared to other areas of the world.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Breeding Approach to Develop Climate Resilient Crops: Current Status and Future Prospects: A Review

Article ID: 72821

Amit Tomar[1], P.K. Singh[2]

[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula (Amroha), SVPUA&T, Meerut.

[2]Professor (Agronomy), Directorate of Extension, SVPUA&T, Meerut.

Introduction

Climate-resilient breeding develops crops that can withstand climate change impacts like drought, heat, floods, and pests, ensuring food security by using advanced techniques (genomics, gene editing) alongside traditional methods (hybridization, selection) to identify and incorporate stress-tolerance genes, creating varieties with stable yields under harsh, erratic conditions, benefiting farmers and global food systems.

Key Goals & Characteristics

Stress Tolerance: Develops plants resistant to drought, heatwaves, waterlogging (floods), high salinity, and new pests/diseases.

Stable Yields: Maintains productivity even with unpredictable weather and extreme events.

Adaptability: Enables crops to thrive in diverse soils and challenging environments.

Examples & Impact

Drought-Tolerant Maize: Widely adopted in Africa, improving yields in dry conditions.

Flood-Tolerant Rice: Showing promise in Southeast Asia, reducing crop loss.

Climate-Resilient Wheat: Focuses on early maturity and plant architecture for heat/drought areas.

Importance

Food Security: Secures food supply for growing populations facing climate threats.

Farmer Livelihoods: Protects farm income by preventing crop failure.

Sustainability: Reduces reliance on water and inputs, promoting sustainable agriculture. Climate-resilient wheat varieties are bred for heat/drought tolerance, better yields under stress, and disease resistance, with key Indian examples including **DBW187, DBW222 (Karan Narendra), DBW303, HD 3385, and WH1270**, developed by ICAR-IIWBR for timely/late sowing, helping farmers adapt to rising temperatures and ensure food security. These varieties, along with others like PBW826 and HI 1633, focus on traits like better grain filling under heat, lodging resistance, and water efficiency, supported by government and research efforts for widespread adoption.

Key Heat-Tolerant Varieties (India):

DBW187 & DBW222 (Karan Narendra): Highly heat-tolerant, showing significant yield gains in warmer conditions, superior to older heat-tolerant types like HD-3086.

HD 3385: Specifically designed for terminal heat (late March spikes), suitable for both timely and late sowing.

DBW303, DBW327, WH1270, PBW872: Also developed for heat stress, often grown with adjusted planting times (mid-November) to avoid peak heat.

Other Resilient & High-Yielding Varieties

Narendra 09: Farmer-developed, high-yielding, water-efficient, thrives in diverse conditions.

HI 1633 (Pusa Wheat 1633): Recommended for better disease/yield.

PBW 826: A top high-yielding choice.

Muktinath 3170 & GW 451: Hard-grain varieties good for milling and processing.

Features of Resilient Wheat

Heat Tolerance: Ability to maintain yield during grain filling when temperatures rise (terminal heat).

Drought Resistance: Better performance in water-scarce regions.

Lodging Resistance: Stronger stems to prevent crop collapse, reducing yield loss.

Disease Tolerance: Resistance to common diseases like rust.

Strategies for Resilience

Breeding: ICAR-IIWBR and international partners (CIMMYT) are developing new gene pools for diverse traits.

Sowing Times: Adjusting planting (e.g., mid-November) to align grain filling with cooler temperatures.

Resource Conservation: Using techniques like Zero Tillage (ZT) and Happy Seeder (HS) for better profitability and efficiency.

What is Climate-Resilient Crop Varieties?

Climate-resilient crop varieties are plants that are adapted to tolerate extreme weather conditions such as: Drought and Heat and Salinity and Flooding.

Pests and Diseases: These varieties are designed to grow and yield optimally despite environmental challenges, using advanced breeding techniques and biotechnology.

The Need for Climate-Resilient Crops

Erratic Weather Patterns: Unpredictable rainfall and temperature fluctuations threaten crop yields.

Increasing Soil Salinity: Rising sea levels and irrigation practices lead to saline soils, making it hard for conventional crops to grow.

Water Scarcity: Droughts are becoming more frequent, reducing water availability for crops.

Pest and Disease Outbreaks: Warmer temperatures can lead to new and more aggressive pests and diseases.

Examples of Climate-Resilient Crops

Drought-Tolerant Maize: Developed using selective breeding and genetic engineering, varieties like *Drought TEGO* in Africa provide stable yields under water-limited conditions.

Salt-Tolerant Rice: In coastal regions, rice varieties like *Swarna Sub1* can survive submergence and high salinity.

Heat-Tolerant Wheat: Researchers have developed wheat strains with a higher temperature threshold for germination and flowering.

Flood-Resistant Sorghum: Sorghum varieties bred to withstand waterlogged soils help mitigate yield losses in flood-prone regions.

Legume Varieties with Pest Resistance: Cowpeas and chickpeas are being developed with natural pest resistance to reduce chemical pesticide dependency.

Breeding Techniques Used

Conventional Breeding: Cross-breeding plants with desired traits over generations to develop climate-resilient varieties.

Marker-Assisted Selection (MAS): Using molecular markers to identify and select plants with stress-tolerant traits more efficiently.

Genetic Modification (GM): Introducing foreign genes into plants to provide resilience against drought, salinity, or pests.

CRISPR Gene Editing: Precise editing of plant DNA to improve resilience traits without introducing foreign genes.

Speed Breeding: Using controlled environments to accelerate the breeding process.

Benefits of Climate-Resilient Crops

Food Security: Ensures stable food production even under extreme conditions.

Reduced Dependency on Pesticides and Water: Enhanced resistance to pests and diseases reduces the need for chemical treatments, and drought tolerance reduces irrigation requirements.

Economic Stability for Farmers: Resilient varieties minimize crop losses and provide consistent incomes.

Biodiversity Preservation: Diverse crop varieties reduce the risk of monoculture-related vulnerabilities.

Challenges in Developing and Adopting Climate-Resilient Crops

Research and Development Costs: Developing new varieties takes time, money, and extensive research.

Regulatory and Ethical Concerns: Some stakeholders have concerns over the safety and environmental impact of genetically modified crops.

Farmer Awareness and Training: Adoption is slow due to limited knowledge or trust in new crop varieties.

Market Access: Small-scale farmers often lack access to improved seeds or financing options.

Future Outlook and Innovations: The future of climate-resilient agriculture lies in embracing technological innovations such as:

AI and Big Data: Using predictive analytics to identify traits that enhance climate resilience.

Blockchain Technology: Ensuring traceability and transparency in the seed supply chain.

Agroecological Practices: Integrating resilient crops with sustainable farming methods for holistic climate adaptation. The future of climate-resilient breeding is shifting from traditional selection to a highly integrated "smart breeding" framework. This approach combines genomic tools, artificial intelligence, and rapid generation advancement to develop crops that can withstand multiple simultaneous stresses like extreme heat, drought, and flooding.

Key Technological Innovations: The integration of these technologies aims to reduce breeding cycles from decades to just a few years:

Precision Gene Editing (CRISPR/Cas): Beyond simple gene knockouts, future applications focus on **multiplex editing** to target multiple genes at once for complex traits. It is also being used for **de novo domestication**, where wild relatives with natural resilience are rapidly "domesticated" by editing key yield-related genes while keeping their native stress tolerance.

Next-Gen Artificial Intelligence (AI): AI and machine learning are becoming central to analysing massive "multi-omics" datasets (genomics, phenomics, enviromics) to predict how specific genotypes will perform in future climate scenarios.

Speed Breeding: By manipulating light and temperature in controlled environments, breeders can now produce up to **6 generations per year** for crops like wheat and barley, drastically accelerating the deployment of new varieties.

High-Throughput Phenomics: Using drones, sensors, and hyperspectral imaging, researchers can non-destructively monitor plant health and root architecture in real-time, allowing for the selection of superior traits that were previously invisible.

Emerging Strategic Priorities Future breeding efforts are expanding beyond single-crop yield to broader ecological resilience:

Exploiting Crop Wild Relatives (CWRs): Gene banks are being "mined" for lost genetic diversity. CWRs and underutilized "orphan crops" (e.g., millets, quinoa) are being prioritized for their inherent survival traits in harsh environments.

Breeding for "Combined Stresses": Future varieties must handle dual threats, such as drought followed by heatwaves, which require a deeper understanding of complex molecular signaling pathways like ROS and calcium waves.

The Holobiont Approach: Breeding is moving toward a "holistic" view that includes the **plant microbiome**. Future strategies may involve selecting for plants that better recruit beneficial soil microbes to enhance nutrient uptake and stress tolerance.

Climate Modeling Integration: Incorporating predictive climate models directly into breeding programs helps identify the specific environmental stressors a region will face 20–30 years in the future.

Current Challenges & Bottlenecks: Despite technological promise, several hurdles remain for widespread adoption:

Regulatory & Social Barriers: Gene-edited crops face complex regulatory frameworks and varying levels of public acceptance across different countries.

G x E Interactions: The "Genotype x Environment" interaction remains a major challenge, as a variety that is resilient in one region may fail in another due to local soil or weather nuances.

Data Standardization: The explosion of "big data" from sensors and sequencing requires new standards to ensure information can be shared and used effectively by breeders worldwide.

Government and Policy Support: Governments and international organizations play a vital role in funding research, streamlining regulatory approvals, and creating incentives for farmers to adopt climate-resilient varieties. Initiatives like the **Global Commission on Adaptation** and **CGIAR's Climate Change Program** are already driving innovation in this field.

Conclusion

Climate-resilient crop varieties offer a promising path toward a sustainable and food-secure future. By investing in research, raising awareness, and promoting equitable access to resilient seeds, we can empower farmers to adapt to changing climates and ensure agricultural stability for generations to come.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Climate Resilient Crop Varieties

Article ID: 72822

Amit Tomar[1], Mahak Singh[2]

[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula (Amroha), SVPUA&T, Meerut, U.P., India.

[2]Professor & Head, Department of Genetics & Plant Breeding, College of Agriculture, CSAUA&T, Kanpur (U.P.), India.

Climate Resilient Crop Varieties

Climate-resilient crop varieties are emerging as one of the most effective solutions to ensure food security in the face of these challenges. These crops are specifically bred or genetically engineered to withstand environmental stresses and provide stable yields under adverse conditions.

What is Climate-Resilient Crop Varieties?

Climate-resilient crop varieties are plants that are adapted to tolerate extreme weather conditions such as:

1. Drought and Heat

2. Salinity and Flooding

3. Pests and Diseases: These varieties are designed to grow and yield optimally despite environmental challenges, using advanced breeding techniques and biotechnology.

The Need for Climate-Resilient Crops

Erratic Weather Patterns: Unpredictable rainfall and temperature fluctuations threaten crop yields.

Increasing Soil Salinity: Rising sea levels and irrigation practices lead to saline soils, making it hard for conventional crops to grow.

Water Scarcity: Droughts are becoming more frequent, reducing water availability for crops.

Pest and Disease Outbreaks: Warmer temperatures can lead to new and more aggressive pests and diseases.

Examples of Climate-Resilient Crops

Drought-Tolerant Maize: Developed using selective breeding and genetic engineering, varieties like *Drought TEGO* in Africa provide stable yields under water-limited conditions.

Salt-Tolerant Rice: In coastal regions, rice varieties like *Swarna Sub1* can survive submergence and high salinity.

Heat-Tolerant Wheat: Researchers have developed wheat strains with a higher temperature threshold for germination and flowering.

Flood-Resistant Sorghum: Sorghum varieties bred to withstand waterlogged soils help mitigate yield losses in flood-prone regions.

Legume Varieties with Pest Resistance: Cowpeas and chickpeas are being developed with natural pest resistance to reduce chemical pesticide dependency.

Breeding Techniques Used

Conventional Breeding: Cross-breeding plants with desired traits over generations to develop climate-resilient varieties.

Marker-Assisted Selection (MAS): Using molecular markers to identify and select plants with stress-tolerant traits more efficiently.

Genetic Modification (GM): Introducing foreign genes into plants to provide resilience against drought, salinity, or pests.

CRISPR Gene Editing: Precise editing of plant DNA to improve resilience traits without introducing foreign genes.

Speed Breeding: Using controlled environments to accelerate the breeding process.

Benefits of Climate-Resilient Crops

Food Security: Ensures stable food production even under extreme conditions.

Reduced Dependency on Pesticides and Water: Enhanced resistance to pests and diseases reduces the need for chemical treatments, and drought tolerance reduces irrigation requirements.

Economic Stability for Farmers: Resilient varieties minimize crop losses and provide consistent incomes.

Biodiversity Preservation: Diverse crop varieties reduce the risk of monoculture-related vulnerabilities.

Challenges in Developing and Adopting Climate-Resilient Crops

Research and Development Costs: Developing new varieties takes time, money, and extensive research.

Regulatory and Ethical Concerns: Some stakeholders have concerns over the safety and environmental impact of genetically modified crops.

Farmer Awareness and Training: Adoption is slow due to limited knowledge or trust in new crop varieties.

Market Access: Small-scale farmers often lack access to improved seeds or financing options.

Future Outlook and Innovations The future of climate-resilient agriculture lies in embracing technological innovations such as:

AI and Big Data: Using predictive analytics to identify traits that enhance climate resilience.

Blockchain Technology: Ensuring traceability and transparency in the seed supply chain.

Agroecological Practices: Integrating resilient crops with sustainable farming methods for holistic climate adaptation.

Government and Policy Support Governments and international organizations play a vital role in funding research, streamlining regulatory approvals, and creating incentives for farmers to adopt climate-resilient varieties.

Initiatives like the **Global Commission on Adaptation** and **CGIAR's Climate Change Program** are already driving innovation in this field.

Conclusion

Climate-resilient crop varieties offer a promising path toward a sustainable and food-secure future. By investing in research, raising awareness, and promoting equitable access to resilient seeds, we can empower farmers to adapt to changing climates and ensure agricultural stability for generations to come.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Popularization of Sesame Variety GT-06 Among Farmers Under Cluster Frontline Demonstrations (CFLDs): Success Story

Article ID: 72823

Amit Tomar[1]
[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, Amroha (U.P.).

Background Information About Farmer Field

Shri Hukum Singh ji of Amroha district after completion his education up to M.A. degree, engaged himself in agriculture in his own land for running his family. He possesses 5.5 ha of land, out of which he cultivates Cereal & oilseeds Crop in 4.00 ha and 1.5 ha under vegetable cultivation. But income generated from his farm was not enough for smooth running of his family. Later on, he formed a farmers group along with few youths.

Details of Technology Demonstrated

1. High yielding Oil Seed Crop Sesame GT-06
2. Seed inoculation with Biofertilizer
3. Vermicompost @ 2.5 q/ha
4. 50% recommended dose of N and full dose of P, K, Sulphur fertilizer.

Institutional Involvement

KVK Amroha has demonstrated the high yielding Sesame variety GT-06 along with other technology mentioned above during Kharif, 2025 under CFLD on Oilseed Crop.

Success Point

They wanted to grow Oil Seed Crop remained fallow during Kharif season. Shri Hukum Singh Ji along with his group came to KVK Amroha and they expressed their willingness to utilize that area for crop production. Then a team of scientists from KVK, Amroha visited the area and after discussion with the farmers and necessary survey, conducted a training program for them. Later on, they were provided with seeds of high yielding Oil Seed Crop Sesame variety GT-06 and other necessary inputs for demonstration. The crops were sown during July 2025 and harvested during October, 2025. They have harvested a very good crop (Yield: 10.56 q/ha) and earned a very good income (Net income Rs. 78,079 /ha).

Farmers Feedback

After successful implementation of the technology, farmers in the village were highly impressed and motivated by the performance of the new variety (Sesame variety GT-06) of with improved cultivation practices due to its higher net income. He is now a role model not only in his village but also for the entire farming community of the nearby villages. Farmers from other villages are motivated by the success of this farmer and showing keen interest to implement pulses production program with proven HYV seeds in their villages. These interventions have the potential to create positive impact on Oil Seed production in Amroha district which will benefit the farmers at large.

Outcome from Technology

Demonstration	**10.56 q/ha**	**District average (Previous year)**	**10.25 q/ha**
Potential yield of variety/ technology	12-15 q/ha	State average (Previous year)	09.50 q/ha

Performance of Technology Vis-À-Vis Local Check (Increase in Productivity and Returns)

Specific Technology	**Yield (q/ha)**	**Gross cost (Rs/ha)**	**Gross income (Rs/ha)**	**Net income (Rs/ha**	**B:C ratio**
Farmer practices	7.95	28920	78275	49355	2.70
Demonstration	10.56	25895	103974	78079	4.02
% Increase	24.72	-	-	-	-

Farmers Training & Distribution of Sesame variety GT-06 seeds to the farmers under Cluster Front Line Demonstrations (CFLDs) on Oilseeds during 30th June, 2025 at Krishi Vigyan Kendra, Gajraula, Amroha.



Organized field day on CFLD on Oilseeds (Sesame) variety GT-06 in the Village- Raipur Shumali, Gajraula, Amroha during 15th September, 2025.



Organized field day on CFLD on Oilseeds (Sesame) variety GT-06 in the Village- Toniya Mafi, Dhanuara, Amroha during 15th September, 2025.



Organized field day on CFLD on Oilseeds (Sesame) variety GT-06 in the Village- Fatehpur Shumali, Gajraula, Amroha during 15th September, 2025.



Demonstration Plot of Mustard variety RH-0725 at farmers field during Rabi, 2023-24

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Biofortification: A Long-Term Solution to Improve Global Health

Article ID: 72824

Amit Tomar[1], P.K. Singh[2]

[1]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula (Amroha), SVPUA&T, Meerut.

[2]Professor (Agronomy), Directorate of Extension, SVPUA&T, Meerut.

Introduction

Biofortified crops are staple foods (like rice, wheat, maize, sweet potato) bred to have higher levels of essential vitamins and minerals (iron, zinc, Vitamin A) using traditional breeding or biotechnology, providing a sustainable way to combat "hidden hunger" (micronutrient deficiencies) without changing diets or requiring extra processing, offering a long-term, cost-effective health solution for vulnerable populations. Nutritious diet is vital for proper growth and development in humans. It helps in preventing diseases, besides maintaining the body metabolism for physical- and mental- well-being. Food provides energy, protein, essential fats, vitamins, antioxidants and minerals to meet our daily metabolic requirement. Most of them cannot be synthesized in human body, therefore are to be supplemented through diet. Further, anti-nutritional factors present in edible parts of the food exert adverse effects on human health. Indian Council of Agricultural Research (ICAR) has improved the nutritional quality in high yielding varieties of cereals, pulses, oilseeds, vegetables and fruits using breeding methods. Special efforts were initiated during 12th Plan with the launching of a special project on Consortium Research Platform on Biofortification. Concerted efforts in collaboration with other national and international initiatives has led to the development of 87 varieties of rice (8), wheat (28), maize (14), pearl millet (9), finger millet (3), small millet (1), lentil (2), groundnut (2), linseed (1), mustard (6), soybean (5), cauliflower (1), potato (2), sweet potato (2), greater yam (2) and pomegranate (1). In addition, a large number of advance elite materials are in pipelines and will be released in due course of time. These biofortified varieties assume great significance to achieve nutritional security of the country. Special efforts are being made to popularize these biofortified varieties among masses. Quality seeds of biofortified varieties are being produced and made available for commercial cultivation. Extension Division of ICAR has also launched two special programmes viz. Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA) for up-scaling the biofortified varieties through its Krishi Vigyan Kendra's (KVK's).

Types of Malnutrition

Malnutrition is caused by consumption of unbalanced diet. It affects most of the world's population at some point in their lifecycle during infancy to old age. Every country experience one or the other form of malnutrition. It affects all geographies, age groups and people from rich to poor. Malnutrition exists in different forms:

1. **Undernutrition:** Lack of proper nutrition caused by not having enough food.
2. **Stunting:** Low height as per age in children under five years of age due to limited access to food, health and care.
3. **Wasting:** Thin for their height in children under five years of age because of acute food shortages or disease.
4. **Micronutrient deficiencies:** Suboptimal nutritional status caused by lack of intake, absorption or use of one or more vitamins or minerals.
5. Moderate and severe thinness or underweight.

Global Hunger Index

The Global Hunger Index (GHI) is a tool for comprehensively measuring and tracking hunger at global, regional, and national levels over recent years and decades. GHI score is based on a formula that involves three dimensions of hunger, viz., (i) insufficient caloric intake (undernourishment) in the population, (ii) undernutrition among children, and (iii) child mortality using four indicators:

Undernourishment: Share of the population that is undernourished, reflecting insufficient caloric intake.

Child wasting: Share of children ((<5 years) who possess low weight for height, reflecting acute undernutrition.

Child stunting: Share of children (<5 years) who possess low height for age, reflecting chronic undernutrition.

Status of Malnutrition

Malnutrition contributes to increased morbidity, disability, stunted mental and physical growth, and reduced national socio-economic development. The extent of malnutrition worldwide as well as in India is presented below:

Global scenario:

a. 2.37 billion do not have access to adequate food.
b. 768 million people are undernourished.
c. 118 million more people faced hunger in 2020 in comparison to 2019.
d. 20.5 million new-borns (14.6 % of all live births) have a low weight at birth.
e. 149.2 million (22.0 %) children (12 million avoidable deaths among adults.
f. In Southern Asia, 30.7 % and 14.1 % of the children (<5 years) are stunted and wasted, respectively.

Indian scenario:

a. 15.3 % of the population are undernourished.
b. Neonatal mortality rate (NNMR): 24.9 per 1,000 births.
c. Infant mortality rate (IMR): 35.2 per 1,000 births.
d. Child (< 5 years) mortality rate (U5MR): 41.9 per 1,000 live births.
e. 35.5 % of the children (<5 years) are stunted, 19.3 % wasted and 7.7 % severely wasted.
f. 32.1 % of the children (<5 years) are under-weight.
g. 3.4 % of the children (<5 years) are over-weight.
h. 18.7 % women and 16.2 % men possess BMI below normal (<18.5).
i. 24.0 % of women and 22.9 % of men are overweight or obese (BMI ≥25.0).
j. 67.1 % of the children (6-59 months) are anaemic.
k. 57.2 % of non-pregnant, 52.2 % pregnant and 57.0 % of all women (15-49 years) are anaemic.
l. 59.1 % of all women (15-19 years) are anaemic.
m. 25.0 % of men (15-49 years) are affected due to anaemia.
n. 31.1 % of men (15-19 years) are anaemic.
o. 13.5 % of women and 15.6 % of men possess high or very high blood Sugar.
p. 21.3 % women and 24.0 % men possess elevated blood pressure.
q. India's GHI score is 27.5 (serious category).
r. India ranks 101 among 116 countries in relation to GHI.
s. India loses over US$12 billion in GDP per year to vitamin and mineral deficiency.

Biofortification

Four avenues are generally practiced to alleviate malnutrition:

Food fortification: It is a process of physically adding vital nutrients to the food in order to enrich it. For example, (i) iron, folic acid and vitamin B12 fortified wheat and rice flour, (ii) iron and iodine fortified salts, (iii) vitamin-A and vitamin-D fortified oil and milk, have been permitted by Food Safety and Standards Authority of India (FSSAI), Govt. of India.

Medical supplementation: It is a process of providing vital nutrients through pills. For example, Govt. sponsored programmes:

a. Weekly Iron Folic Acid Supplementation (WIFS) programme for school adolescent boys and girls (10- 19 years) and out of school girls (10-19 years) in urban and rural areas.
b. Vitamin-A Supplementation (VAS) programme for children under five, are in place India.

Dietary diversification: It is a process of including diverse cereals, pulses, oilseeds, vegetables and fruits in the diet in order to enhance the nutritional status.

Crop biofortification: It is a process of enhancing the nutritional quality of edible parts of the plants through genetic approach such as plant breeding. For example, iron and zinc rich wheat grains (ii) protein and zinc rich rice grains, and (iii) vitamin-A rich maize grains.

Merits of Biofortification

1. It is regarded as the most sustainable approach to alleviate malnutrition.
2. It provides nutrients in natural form; thus, nutrients enter the body as part of natural food matrix.
3. People can afford the 'biofortified food' as it does not involve any additional price.
4. 'Biofortified varieties' are as high yielding as 'traditional varieties', thus no loss is incurred to the farmers.
5. It does not require elaborate infrastructure facility as required in 'food fortification'.
6. It does not need elaborate distribution system as required in 'medical supplementation'.
7. It does not involve additional cost on preparing the enriched food grains.

How they Work?

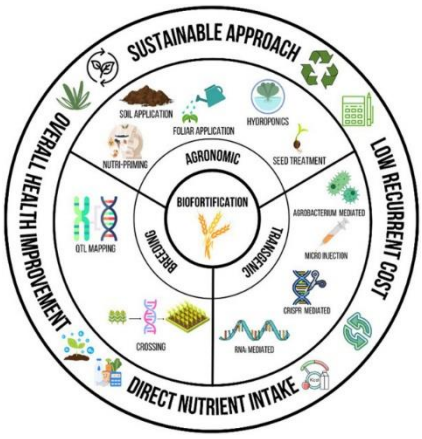
Increased nutrient density: The plants naturally accumulate more micronutrients during growth.

Simple mechanism: Eating more of these nutrient-dense crops means consuming and

absorbing more essential vitamins and minerals.

Key benefits:

Sustainable: A one-time investment in breeding provides continuous nutritional benefits.
Cost-effective: No extra cost for farmers or consumers during cultivation or consumption.
Addresses "hidden hunger": Fights widespread micronutrient deficiencies impacting growth, immunity, and sight.



Common examples:

Vitamin A: Golden Rice, sweet potato, cassava, maize.
Iron: Beans, pearl millet, wheat, rice.
Zinc: Maize, rice, wheat, pearl millet.
Breeding methods of development:
Conventional breeding: Selecting and crossing plants with desired traits.
Genetic engineering/biotechnology: Modifying genes (e.g., CRISPR) for enhanced nutrition.
Agronomic practices: Applying specialized fertilizers (e.g., zinc-enriched).

Why they Matter?

1. Unlike food fortification (adding nutrients during processing), biofortification enriches the food at the source.
2. They reach rural populations who may not access fortified foods, improving public health in resource-limited settings.

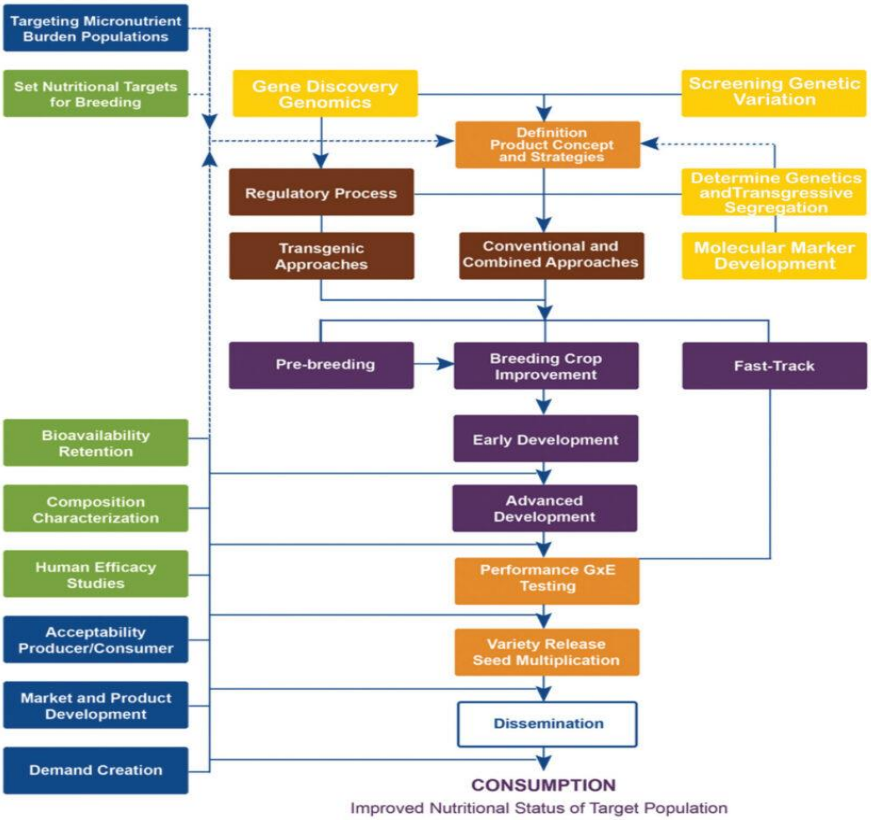


Fig.-1: Crop Development Framework. (Source: Harvest Plus)

Releases of Biofortified Crops

Cumulatively, more than 400 biofortified varieties of 12 crops have been released in more than 40 countries, which includes all varieties facilitated by Harvest Plus plus orange sweet potato varieties developed independently by CIP. Candidate biofortified varieties across 12 crops are being evaluated for release in an additional 20 countries.

Conclusion: Current Successes and Impact

Proven Effectiveness: Randomized controlled trials have confirmed that biofortified crops, such as iron-rich beans in Rwanda and vitamin A-rich orange sweet potatoes in Mozambique, significantly improve nutritional status and cognitive performance in vulnerable populations.

Cost-Effectiveness: Biofortification is a highly economical intervention. Every $1 invested can yield up to $17 in economic benefits. Unlike traditional fortification, which requires recurring costs, biofortification utilizes a one-time investment in seed development that stays "fixed" in the germplasm.

Reach: It uniquely targets underserved rural populations who rely on home-grown staples and lack access to commercial supplements or processed fortified foods.

India's Progress: India has emerged as a leader, developing over 70 nutrition-rich crop cultivars across staples like wheat, rice, maize, and pearl millet.

Future Prospects and Emerging Frontiers

Multi-Nutrient "Stacked" Biofortification: The future is shifting from single-nutrient improvements to "multi-nutrient" or "combinatorial" biofortification. Researchers are using gene-stacking and genetic engineering (e.g., CRISPR-Cas9) to simultaneously increase iron, zinc, and provitamin A in a single variety.

Climate-Smart Traits: To combat declining nutrient densities caused by rising CO2 levels, future varieties are being developed to combine high nutrition with climate-resilient traits like drought and pest resistance.

Precision Agronomy and Nanotechnology: Emerging "Nano-fertilizer-assisted biofortification" offers a way to precisely deliver nutrients to plants, increasing absorption efficiency and reducing environmental runoff compared to traditional fertilizers.

Microbe-Mediated Approaches: The use of beneficial soil microorganisms (like *Bacillus* and *Pseudomonas*) is a growing sustainable frontier to enhance nutrient solubility and uptake in the rhizosphere.

Mainstreaming Goals: A major strategic goal for 2030 is to "mainstream" biofortified traits into all public plant breeding programs, making high mineral and vitamin content a standard requirement for all new variety releases.

Key Challenges for the Future

Consumer Acceptance: Visible traits, like the orange colour in vitamin A-rich maize or rice, require sustained social marketing to gain public trust.

Regulatory Barriers: Transgenic (GM) crops often face strict regulatory hurdles and political opposition, particularly in Europe, despite their potential for higher nutrient densities.

Scaling and Policy: Full impact depends on integrating biofortified crops into government programs like school feeding schemes and public distribution systems (e.g., India's PDS).

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Present Status and Future Planning, Quality Seed Production Technology, Post-Harvest Uses and Uses of Linseed (*Linum usitatissimum*)

Article ID: 72825

Mahak Singh[1], Amit Tomar[2]

[1]Professor and Project Leader (AICRP on R&M), (Section of Oilseeds), Department of Genetics & Plant Breeding, College of Agriculture, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur-208002, Uttar Pradesh, India.

[2]Subject Matter Specialist (Plant Breeding), ICAR- Krishi Vigyan Kendra, Gajraula (Amroha), Uttar Pradesh, India, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India.

Introduction

Linseed (also known as flax) has seen shifts in its status and future planning, moving from a crop primarily focused on fiber to a more versatile crop with potential in food, medicine, and various industries. Current trends show an increased interest in linseed's health benefits, particularly as an immunity booster and for managing menopause symptoms, while also exploring its potential in sustainable agriculture and eco-friendly product development.

Present Status

Global Production: While Russia and Kazakhstan are major producers, China and India also contribute significantly to global linseed production.

Dual-Purpose Varieties: Linseed varieties are being developed for both oil and fiber production, offering farmers more options.

Industrial Applications: Linseed oil is used in paints, varnishes, and other industrial applications, though competition from synthetic materials exists.

Health Benefits: Linseed is gaining recognition for its health benefits, including its high omega-3 content and potential to manage menopause symptoms.

Farming Practices: Linseed is being explored for crop diversification, particularly in regions like the North-Eastern Hill region of India, where it can be grown on rice fallow land.

Future Planning

Increased Productivity: There's a focus on enhancing linseed productivity through the adoption of improved technologies and breeding programs.

Value Addition: Efforts are underway to improve linseed quality and develop value-added products for various industries.

Climate-Resilient Agriculture: Linseed is being explored as a sustainable and climate-resilient crop, offering potential solutions to environmental challenges.

Diversification: The potential for diversifying linseed cultivation into non-traditional seasons and regions is being explored.

Market Expansion: The food, pharmaceutical, and linen sectors are projected to be key growth areas for linseed.

Research and Development: Further research is needed to improve linseed varieties for higher yields, disease resistance, and desirable oil and fiber quality.

Post-harvest uses of linseed: Linseed, also known as flax, offers diverse post-harvest uses, ranging from industrial applications to medicinal purposes and even food. Linseed oil is extracted from the seeds and is a key component in paints, varnishes, and linoleum, and also finds use in the textile and paper industries. The remaining seed cake is a valuable animal feed and organic manure. Additionally, linseed oil is recognized for its medicinal properties, including its use in treating burns and as a laxative.

Industrial Uses

Linseed Oil: A major component in paints, varnishes, and linoleum, linseed oil is also used in oilcloth, printing inks, and various specialty items.

Linseed Cake: A by-product of oil extraction, linseed cake is a valuable animal feed and can also be used as a slow-release organic manure.

Textiles: Linseed straw can be processed to obtain fibers used in textiles, packaging, and insulation.

Paper Industry: Linseed fiber can be used in paper production, including high-grade paper and specialty papers like parchment and safety papers.

Medicinal Uses

Linseed Oil for Burns: A mixture of linseed oil and limewater is an effective application for burns and scalds.

Laxative: Linseed oil can be used as a natural laxative in specific doses.

Other Uses: Linseed oil is also explored for its potential in treating skin disorders, managing hypertension, and other health benefits.

Other Uses

Edible Purposes: A small percentage of linseed is used directly for edible purposes, including salted seeds, chutneys, and baked products.

Cosmetics and Soap: Linseed oil is used in cosmetics and in soap making.

Adhesives and Lubricants: Linseed oil can be used as a base for adhesives and also finds use in lubricants and greases.

Uses of linseed in our daily life: Linseed, also known as flaxseed, has diverse uses ranging from culinary and nutritional to industrial applications. It's a rich source of omega-3 fatty acids, fiber, and lignans, offering various health benefits like improved digestion, heart health, and potential cancer risk reduction. Industrially, linseed oil, extracted from the seeds, is a key ingredient in paints, varnishes, wood finishes, and printing inks.

Culinary and Nutritional

Dietary Supplement: Linseed is consumed as a dietary supplement to improve digestion, potentially reduce constipation, and lower cholesterol levels.

Omega-3 Source: It's a plant-based source of omega-3 fatty acids, particularly alpha-linolenic acid (ALA), which is beneficial for heart health and brain function.

Fiber: Linseed is rich in both soluble and insoluble fiber, aiding in digestion and promoting healthy bowel movements.

Weight Management: The fiber content can contribute to a feeling of fullness, potentially aiding in weight management.

Baking: Ground flaxseed can be added to baked goods like bread or muffins.

Industrial Uses

Paints and Varnishes: Linseed oil is a key ingredient in many paints and varnishes, acting as a binder and providing a smooth, glossy finish to wood and other surfaces.

Wood Finishes: It protects and preserves wood, acting as a sealant against moisture and rot.

Printing Inks: Linseed oil is used as a binder in printing inks, allowing for proper adhesion to paper.

Linoleum: It's a component in the production of linoleum, a flooring material.

Wood Putty: Linseed oil is a key ingredient in traditional wood putty, used to seal and fill gaps in wood and around glass.

Other Applications: It's also used in various other products like oilcloth, concrete surfaces, and even for conditioning pool cues and fretboards of musical instruments.

Health Benefits

Heart Health: The omega-3 fatty acids in linseed can help lower blood pressure and reduce the risk of heart disease.

Cancer Prevention: Some studies suggest that the lignans and fiber in linseed may play a role in cancer prevention, particularly breast and colon cancer.

Skin and Hair Health: Linseed oil can be used externally to improve skin conditions and promote healthy hair.

Anti-inflammatory Properties: The omega-3s and lignans in linseed have anti-inflammatory properties, which can be beneficial for various conditions.

Quality seed production technology of linseed: Linseed is an important oilseed and fiber crop. Among the oilseed crops raised during rabi, linseed is next in importance to rapeseed-mustard in area as well as in production. In technical oil production, it ranks first in the country. It is raised both for its seeds as well as fibre, which is used for the manufacture of linen. Seed contains a good percentage of oil, which varies from 33 to 47% in different varieties. Every part of the linseed plant is utilized commercially, either directly or after processing. On a very small scale, the seed is directly used for edible purposes. About 20% of the total oil produced is used in farmer's homes. About 80% of the oil goes to industries

in various forms, such as boiled oil, borated oil, eposidized oil, aluminated oil, urethane oil, isomerized oil etc. It is utilized in the manufacture of paints, oil cloth, varnish, pad-ink, printed ink, linoleum etc. The stem yields fibre of good quality having high strength and durability. The weather resistant fibre is lustrous and blends very well with wool, silk, cotton etc. Strong twines, canvas, suitings, shirtings and various indispensible products for defence purposes are manufactured from it. Woody matter and short fibres may be used as raw pulp for making paper of quality comparable with that of currency notes. The rough, strong linseed fibre can be effectively used for low-cost roofing tiles based on convertible polymers and for fiber reinforced plastics (FRP) based on unsaturated polyesters.

Land Requirements

Land to be used for linseed seed production shall be free of volunteer plants. In addition the field should be well-drained, free of weeds and the soil should have a good water holding capacity.

Isolation Distance

Linseed is normally a self pollinated crop. Natural cross pollination up to 6.75 per cent mainly due to insects has been recorded. For pure seed production it is advisable to isolate seed fields from the fields of other varieties or same variety of linseed not conforming to varietal purity requirements at least by 50 meter for foundation seed class and 25 meters for certified seed class.

Preparation of Land

Usually one ploughing, two to three harrowing, followed by leveling are sufficient to prepare land to desired tilth.

Time of Sowing

Sowing time varies from the first week of October to mid-November, in various states.

Source of Seed

Obtain nucleus/breeder's/foundation seed from a source approved by a seed certification agency.

Method of Sowing

The seed crop should invariably be sown in rows. Depth of seedling should not be more than 3 cm.

Spacing

Row to row = 22 to 30 cm.
Plant to plant= 5 to 6 cm.

Seed Rate

Seed rate varies considerably in different states. In U.P. recommended seed rate is 30 to 35 kg per hectare.

Fertilization

Apply 50 to 60 kg nitrogen and 40 kg phosphorus per hectare. Nitrogen application should be split in two doses. Half the dose should be provided at the time of sowing Sand the remaining half top-dressed at the time of the first irrigation.

Interculture Operations

One weeding during early stage of crop growth and one after first irrigation is necessary.

Plant Protection

For control of laphigma, semilooper and linseed fly, dust 5 per cent Gammexene (20 kg per hectare), and for control of grassy cutworm dust 2 per cent gamma BHC dust (20 kg per hectare). For control of rust spray Zineb (2 kg in 100 litres of water per hectare), and for powdery mildew spray 0.2 per cent Thiovit solution, or dust the crop with sulphur powder (20 kg per hectare).

Roguing

Rogue out off-type plants and diseased plants affected by wilt from time to time in the field as required.

Harvesting and Threshing

The crop can be soon after the plants are brown and brittle and the seed rattles in the bolls. The crop can be cut with sickles, or the plants may be pulled by hand. The plants are left in the field for one or two days to dry. The threshing can be done by flailing the siliquas with sticks followed by winnowing. Stationery threshers can also be used. The crop can also be combined directly or indirectly. Seed should be dried to seven per cent moisture before storage.

ISSN: 2581 - 8317

Seed Yield

Average seed yield varies from 10 to 19 qtl per hectare.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Present Status, Production Constraints and Future Research Strategies in Oilseed *Brassica* Species

Article ID: 72826

Mahak Singh[1], Amit Tomar[2]

[1]Professor & Head Department of Genetics & Plant Breeding, College of Agriculture, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur-208002, (U.P.), India.

[2]Subject Matter Specialist (Plant Breeding), ICAR-Krishi Vigyan Kendra, Gajraula, Amroha, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, U.P., India.

Introduction

Rapeseed-mustard crops in India comprise traditionally grown indigenous species, namely toria (*Brassica campestris* L. var. toria), brown sarson (*Brassica campestris* L. var. brown sarson), yellow sarson (*Brassica campestris* L. var. yellow sarson), Indian mustard [*Brassica juncea* (L.) Czernj & Cosson], black mustard (*Brassica nigra*) and taramira (*Eruca sativa/vesicaria* Mill.), which have been grown since about 3,500 BC along with non-traditional species like gobhi sarson (*Brassica napus* L.) and Ethiopian mustard or karan rai (*Brassica carinata* A. Braun).

Rapeseed-mustard crops in India are grown in diverse agro-climatic conditions ranging from north-eastern/north-western hills to down south under irrigated/rainfed, timely/late sown, saline soils and mixed cropping. Indian mustard accounts for about 75-80% of the 5.8 million hectare (mha) under these crops in the country during 2009-10. The cultivation of brown sarson which once dominated the entire rapeseed-mustard growing region is now shadowed by Indian mustard. There are two different ecotypes of brown sarson: lotni (self- incompatible) and tora (self-compatible). The 'lotni' is predominantly cultivated in colder regions of the country particularly in Kashmir and Himachal valley. The 'tora' on the other hand is cultivated in limited areas of eastern Uttar Pradesh. Yellow sarson is now mainly grown in Assam, Bihar, north-eastern states, Orissa, eastern Uttar Pradesh and West Bengal. Toria is a short duration crop cultivated largely in Assam, Bihar, Orissa and West Bengal in the east mainly as winter crop. In Haryana, Himachal Pradesh, Madhya Pradesh, Punjab, Uttarakhand and western Uttar Pradesh, it is grown as a catch crop. Taramira is grown in the drier parts of north-west India comprising the states of Rajasthan, Haryana and Uttar Pradesh. Gobhi sarson and karan rai are the new emerging oilseed crops having limited area of cultivation. Gobhi sarson is a long duration crop confined to Haryana, Himachal Pradesh and Punjab. Rapeseed-mustard crops because of their low water requirement fit well in the rainfed cropping system of resource poor farmers.

Important oil seed crop grown in cool season sub tropics, higher elevations and winter crops. Rapeseed oil was produced in the 19th century as a source of a lubricant for steam engines. It was less useful as food for animals or humans because it has a bitter taste due to high levels of glucosinolates. Varieties have now been bred to reduce the content of glucosinolates, yielding a more palatable oil. This has had the side effect that the oil contains much less erucic acid.

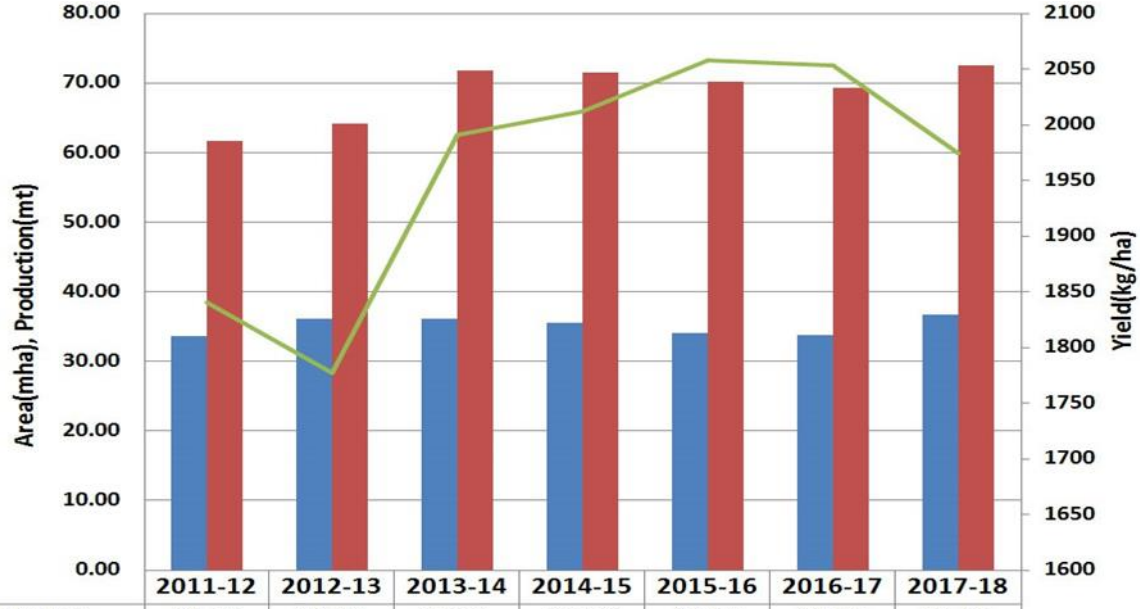
The oil and protein content vary from 37 to 49% and 22-28%, respectively. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout the northern India in cooking and frying purposes. It is also used in the preparation of hair oils and medicines. It is used in soap making, in mixtures with mineral oils for lubrication. Rapeseed oil is used in the manufacture of grease. The oil cake is used as feed and manure. Green stem and leaves are a good source of green fodder for cattle. The leaves of young plants are used as green vegetable as they supply enough sulphur and minerals in the diet. In the tanning industry, mustard oil is used for softening leather.

Rapeseed oil is one of the oldest vegetable oils, but historically was used in limited quantities due to high levels of erucic acid, which is damaging to cardiac muscle of animals, and glucosinolates, which made it less nutritious in animal feed (Sahasrabudhe, 1977). Rapeseed oil can contain up to 54% erucic acid (CFR, 2010). Food-grade canola oil derived from rapeseed cultivars, also known as rapeseed 00 oil, low erucic acid rapeseed oil, LEAR oil, and rapeseed canola-equivalent oil, has been generally recognized as safe by the United States Food and Drug Administration (The Commission of the European Communities, 1980). Canola oil is limited by government regulation to a maximum of 2% erucic acid by weight in the USA and 5% in the EU (Humbert *et al.*, 2001), with special regulations for infant food. These low levels of erucic acid are not believed to cause harm in human neonates.

Rapeseed-mustard oil contains lowest level of saturated fatty acids among all vegetable oil, which is quite desirable for good health. Both the essential fatty acids (EFA) such as linoleic acid (C18:2) and linolenic (C18:3) are present in rapeseed-mustard oil. Rapeseed-mustard oil has high level of antioxidant, which retards growth of free radicals mainly responsible for disease like cancer and ageing. Glucosinolates present in seed meal has shown anticancer properties. *Brassica* species are very rich in phenolic compounds and glucosinolates.

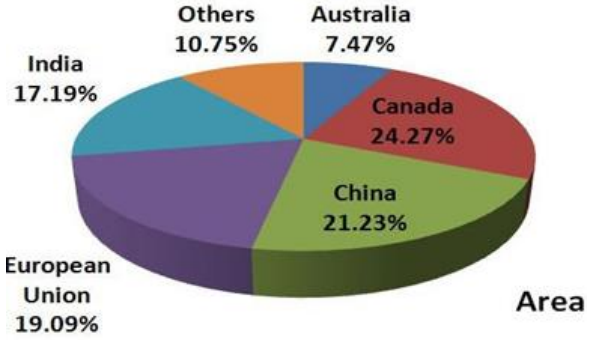
Production Status

The estimated area, production and yield of rapeseed-mustard in the world was 36.68 million hectares (mha), 72.42 million tonnes (mt) and 1974 kg / ha, respectively, during 2017-18 (Fig.1). Globally, India account for 19.8 % and 9.8% of the total acreage and production (USDA 2016-17). During the last seven years, there has been a considerable increase in productivity from 1840 kg/ha in 2010-11 to 1974 kg/ha in 2017-18 and production has also increased from 61.64 m t in 2010-11 to 72.42 m t in 2017-18.

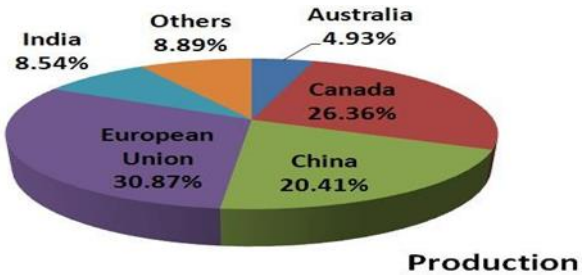


	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Area (mha)	33.51	36.05	36.01	35.52	34.05	33.70	36.68
Production(mt)	61.64	64.06	71.68	71.45	70.05	69.18	72.42
Yield(kg/ha)	1840	1777	1990	2012	2057	2053	1974

Rapeseed-Mustard Production trends in World

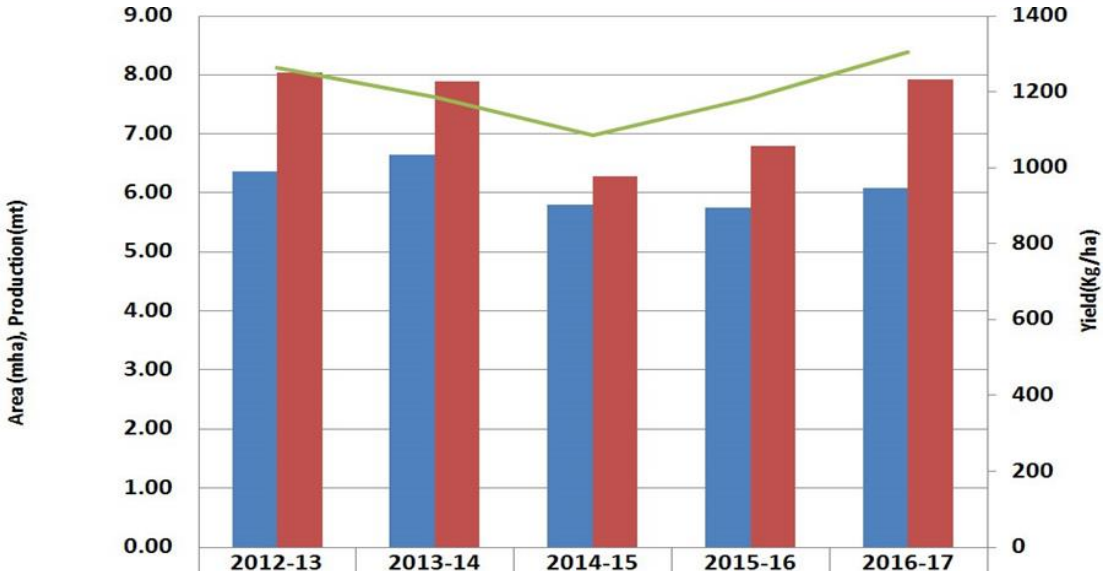


Contribution of different countries in R&M acreage Average (2013-14 to 2017-18)



Contribution of different countries in R&M production Average (2013-14 to 2017-18)

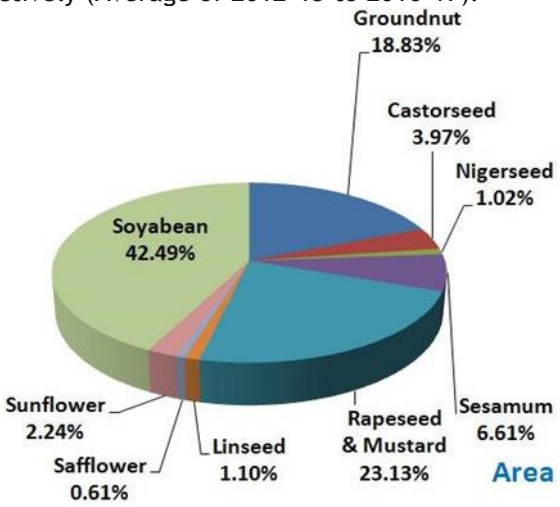
Rapeseed-mustard crops in India are grown in diverse agro climatic conditions ranging from north-eastern / north western hills to down south under irrigated/rainfed, timely/late sown, saline soils and mixed cropping. Indian mustard accounts for about 75-80 % of the 6.07 m ha under these crops in the country during 2016-17 crop season.



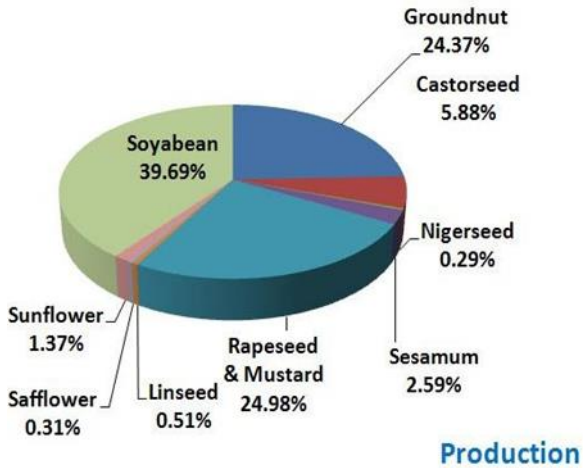
	2012-13	2013-14	2014-15	2015-16	2016-17
Area(mha)	6.36	6.65	5.80	5.75	6.07
Production (mt)	8.03	7.88	6.28	6.80	7.92
Yield(Kg/ha)	1262	1185	1083	1183	1304

Rapeseed-Mustard Production Trends in India

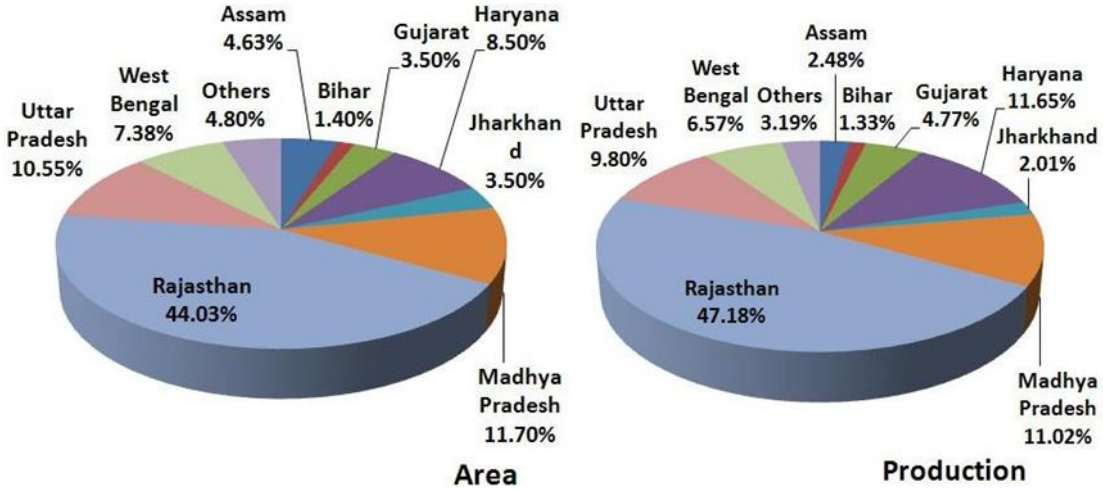
Soybean, groundnut and rapeseed-mustard are the major oilseed crops in India contributing nearly 84% and 88% to its total acreage and production, respectively (Average of 2012-13 to 2016-17).



Contribution of different oilseed crops acreage Average (2013-14 to 2017-18)



Contribution of different crops production Average (2013-14 to 2017-18)



Contribution of different oilseed producing states in total area and production of rapeseed-mustard (Average of 2012-13 to 2016-17)

Constraints in Production

The rapeseed-mustard, which contributes nearly 80% of the total *rabi* oilseed production, is a vital component in edible oil sector. The rapeseed- mustard crops are diverse in their agro-climatic requirements and crop management practices. The production constraints facing each of the crops are also diverse in nature. The objective of raising domestic availability of edible oil can be realized only by increasing the productivity of these oilseed crops. Enhancing the production and productivity of the crop assumes significance; not only from the farmers' viewpoint but also for the edible oil industry and other vertically and horizontally linked enterprises. The major constraints faced by these crops are:

1. Uncertainty of acreage of the crops due to several factors: climatic, biological, natural resources and policy decisions.

2. Low and erratic rainfall leading to continuous moisture stress/ drought over the years. Seedling stage is most sensitive to moisture stress followed by flowering. Farmers are also not well versed with the moisture conservation techniques.

3. Irrigation with saline and alkali-blended water in most of the areas of Rajasthan and parts of UP, Haryana and Punjab resulting in salinity builds up.

4. Mono cropping in most of the major areas has led to soil deficiency for nutrients and built-up of soil borne pathogens.

5. Stress caused by insect, nematodes, fungal, bacterial and viral pathogens, *Orobanche* and weeds collectively result in approximately 45% yield loss annually.

6. High temperature during crop establishment (mid-September to early- November), cold spell, fog and intermittent rains during crop growth cause considerable yield losses by physiological disorder and appearance and proliferation of white rust, downy mildew and *Sclerotinia* stem rot diseases and aphid pest.

7. Farmer's reluctance in using balanced dose of fertilizers, poor adoption of plant protection measures to control pest, diseases and weeds and harvesting at improper time.

Future Research Plans

It would concentrate on the following key researchable areas to achieve quantum jump in production and productivity of rapeseed-mustard:

1. Efficient utilization of rapeseed-mustard genetic resources.

2. Exploitation of available heterosis in mustard and toria for further enhancing the yield potential.

3. Developing high yielding varieties/hybrids with improved oil and seed meal quality for food, feed and industrial uses using conventional as well as biotechnological approaches.

4. Development of thermo and photo - insensitive genotypes for diverse cropping systems under varied agro-ecological situations.

5. Development of cultivars with high water and nutrient use and photosynthetic efficiency for different situations.

6. Development of designer *Brassica* for different fatty acids profile & value- added product.

7. Development of rapeseed mustard genotypes tolerant to various biotic (Alternaria blight, Sclerotinia rot, white rust, *Orobanche*, mustard aphid, painted bug) and abiotic stresses (drought, temperature and salinity).

8. Production technologies for mustard based cropping systems under climate change scenario.

9. Bio-molecules, bio-remediation and bio-fertilization for environmental safety.

10. Survey and surveillance of insect-pests, diseases and weeds under climate change.

11. Remote sensing for energy-water balance, disease and insect-pest surveillance, forewarning and crop modelling.

12. Bio-intensive integrated pest management (IPM) module development for major insect pests and diseases.

13. Host-pathogen interaction and induced resistance for management of diseases.

14. Impact of pesticide residues on the dynamics of soil flora, fauna and environment.

15. Socio-economic, operational and institutional constraints in the transfer of technology, yield gap analysis and farmer's perceptions.

16. Development of information technology (IT) based decision support systems, innovations in knowledge management and technology dissemination.

17. Impact of policies (procurement, price, export-import, storage, incentives etc.) and development programmes on area and production of rapeseed- mustard.

Conclusion

The Vision 2030 on rapeseed-mustard aims not only at sustaining the present level of production but also to improve the productivity and quality in fragile environments across diverse agro-ecological regions. Enhancing the nutritional security of the increasing human population and providing quality feed market for livestock sector are also targeted. It also aims at meeting the industrial requirements and bring about substantial savings of foreign exchange through import substitution and higher export earnings. Timely availability of seeds of improved varieties suitable for the mitigation of these constraints requires out of the box thinking and innovative research strategies. The research approach itself needs an urgent revamp to harness the full potential of rapeseed-mustard crop.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Crop Diversification as a Risk Reduction Strategy in Modern Agronomy

Article ID: 72827

Saurabh Suman[1], Roop Kishore Sharma[1], Yash Nandan[1]
[1]Department of Agriculture, Doon (PG) College of Agriculture Science & Technology, Selaqui, Dehradun [Affiliated to HNBGU, Srinagar].

Abstract
Crop diversification is an effective and resilient measure against the gradually increasing climate changes, market uncertainities and soil degradation. By adopting crop diversification measures instead of monocropping farmers can go for restoring the soil health, reduce input use, utilize their resources better and earn stable incomes. When coupled with good extension services, favorable policies, and access to markets, crop diversification becomes a reliable protective measure against climate and income risks, which is essential for the continuation of farming that is environmentally sound.

Introduction
Modern agriculture is facing far more uncertainities than ever before. With the rise in issues such as unpredictable weather patterns, increase in soil erosion, pests and disease outbreaks farmers today face a lot of challenges to achieve optimum production for the growing population. Monocropping, the practice of growing a single crop on the same piece of land year after year poses widespread risk as it amplifies soil nutrient depletion, reduced biodiversity, buildup of crop-specific pests and diseases resulting in heavy fertilizer and pesticide use. Monocropping is suitable for temporary boost in yield of a particular crop yet it carries larger amounts of risks with it as it can threaten long term yield and sustainability. In such a scenario, crop diversification has emerged has a resilient and practical solution. By growing different crops in combination or in sequence, crop diversification allows for better soil health, reduction in development of crop-specific pests and diseases and at the same time also helps in case one crop fails. It helps farmers get better market prices throughout the year, thus maintaining both environmental and economic sustainability.

What is Crop Diversification?
Crop diversification can be considered as an attempt to increase the diversity of crops through, e.g. crop rotation, multiple cropping or intercropping, compared to specialized farming with the aim to improve the productivity, stability and delivery of ecosystem services (Garbach *et al*. 2017). It is the practice of growing variety of crops in a farm rather than relying on a single crop. It can be one of the most ecologically feasible, cost-effective, and rational ways of reducing uncertainties in agriculture—especially among smallholder farmers. India prominently features two basic types of agricultural diversification: horizontal diversification and vertical diversification. Horizontal diversification involves multiple cropping instead of growing a single crop while vertical diversification includes incorporation of supplemental activities like horticulture, agroforestry, livestock rearing, culture of aromatic crops in addition to multiple cropping (Paroda,2022). Incorporation of multiple crops can be done through measures such as crop rotation, intercropping, mixed cropping, inclusion of legumes, diversification with high value crops etc.

Why Crop Diversification Matters Today?
Crop diversification matters today because of the advantages it has to offer such as:

1. It helps to spread out the risk that is caused by unpredictable market prices. For instance, if vegetables have a bad season and don't sell well, the money made from pulses can help farmers keep going. And when both crops get good prices, the profits can be increased.

2. Practices such as crop rotation, intercropping, multiple cropping etc. helps in saving the soil from nutrient depletion thus reducing reliance on chemical fertilizers.

3. Crop diversification reduces occurrence of crop specific disease and pests thus helping in reduction of pesticide and insecticide usage.

4. Diversifying crops can help decrease the risk of losing an entire crop reason due to extreme weather events.

5. Crop diversification helps fetch better prices in the market from the different crop produces, thus helping in stabilization of farm incomes.

6. Crop diversification overall enhances ecological balance and nutritional security.

Popular Crop Diversification Models in India

1. Cereal-legume systems: It involves growing of cereals like rice, wheat, maize with legumes such as pulses and oilseed legumes. Legumes help in biological nitrogen fixation thus increasing the pool of nitrogen in soil which can be used by cereals for their growth. Thus, it helps in improving soil fertility reducing dependence on external inputs.

2. Oilseed inclusion: It involves incorporation of oilseeds like mustard, soyabean, rapeseed, sunflower etc. in the cropping system thus reducing overdependence on cereals which helps improve sustainability as well as reduces the buildup of pests and diseases and nutrient depletion associated with continuous cereal cultivation.

3. Horticulture-based diversification: It involves changing shifting the traditional farm area to high value horticultural crops like flowers, fruits, vegetables etc. which can make efficient use of land and other resources while adapting to changing market demands and climatic conditions.

4. Millet based systems: Millet based systems refer to the introduction of crops such as pearl millet, sorghum, finger millet etc. into the cropping system. These crops are less input intensive, drought tolerant, can be grown in marginal soils and have a high nutrient content. Owing to the demand for healthier diets among todays generation, this system is becoming increasingly popular in India.

5. Integrated Farming Systems (IFS): This model combines crops with horticulture, livestock (dairy/goat), poultry, fishery, and bio-enterprises on the same farm to spread risk and stabilize income. IFS helps use farm resources more efficiently and generate multiple income streams.

6. Agroforestry system: Agroforestry is any sustainable land-use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time, using management practices that suit the social and cultural characteristics of the local people and the economic and ecological conditions of the area (TNAU Agritech portal, n.d.). It is a popular system now as it can work well in low-input conditions, emphasize on multiple indigenous trees and shrubs as well as less input intensive.

Benefits to Small and Marginal Farmers

1. Acts as a source of income security for small and marginal farmers by stabilizing farm income because different crops will earn them different prices in the market at various times.

2. Crop diversification also generates employment opportunities for small and marginal farmers as diversified systems like high value crops as well as livestock rearing require more on farm labor and year-round work.

3. It also helps them to use their land and resources more efficiently by making better use of soil nutrients and reducing dependence on chemical fertilizers.

Challenges in Adoption

1. Lack of awareness in part of the farmers about what crops are suited in their conditions and what crop combination to go for.

2. Limited market opportunities may also be a cause of farmers not able to adopt crop diversification as they are not sure about whether they will get fair prices for their produces in the market.

3. Farmers might not be very sure about the performance of the new crops as a result of which they might stick to growing of their traditional crops.

4. The farmers might not be able to get access to all the inputs required for crop diversification.

5. Lack of exposure to modern farming techniques may also stand in the way of adoption of crop diversification.

Way Forward

Crop diversification needs to be promoted primarily through extension activities, farmer orientation and training and field demonstrations supported by policies and market linkages. Going ahead, there should be more focus on region specific crop planning, climate-resilient and high- value crops like horticultural crops, integration of livestock. In addition farmers should have more access to credits, inputs, insurances and other resources required for crop diversification. If small and marginal farmers get assured markets, fair prices and timely technical support, they will undoubtedly be able to diversify in a sustainable manner leading to increased incomes, risk reduction and resilient agricultural systems.

Conclusion

Crop diversification acts as a powerful climate and income shield for the farmers as it reduces dependence on a single crop, saving the farmers from both climatic vulnerability and market risks. If crop diversification suited to local agro-climatic conditions is adopted the farmers gets easily protected against extreme weather conditions like droughts, floods and also pest outbreaks which would ensure continuous income generation throughout the year. This strategy would act as a risk aversion technique as it saves the farmers in case one crop fails. And if supported well by extension services,

policies and market access it would help in safeguarding the future of small and marginal farmers in the face of climate change and economic uncertainty.

References

1. Garbach K, Milder JC, DeClerck FAJ, Montenegro de Wit M, Driscoll L, Gemmill-Herren B (2017) Examining multi-functionality for crop yield and ecosystem services in five systems of agroecological intensification. Int J Agric Sustain 15(1):11–28. https://doi.org/10. 1080/14735903.2016.1174810
2. Paroda, R. (2022). Crop diversification for sustainable agriculture. *Ecology, Economy and Society-the INSEE Journal*, *5*(1), 15-21.
3. TNAU Agritech portal (n.d.). Forestry Technologies. https://agritech.tnau.ac.in/forestry/agroforestry_index.html.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Cultivation of Mango (*Mangifera indica* L.)

Article ID: 72828

Tanuja Chaourasiya[1]
[1]B.Sc. (Agriculture) School of Agriculture, Eklavya University Damoh (M.P.).

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruit crops grown worldwide, particularly in South and Southeast Asia, Africa, and Latin America. It belongs to the Anacardiaceae family and is often referred to as the "king of fruits." Mango is highly valued for its delicious taste, attractive aroma, and rich nutritional profile. The fruit is a good source of vitamins A, C, and E, dietary fiber, and minerals such as potassium and magnesium. Its high antioxidant content contributes to human health by supporting immunity and reducing oxidative stress. In addition to its economic and nutritional value, mango has cultural significance, being associated with festivals, traditions, and cuisine across many regions. Its versatility allows it to be consumed fresh, processed into juices, jams, pickles, and dried products, making it a cornerstone of tropical horticulture and food industries.

Origin and Distribution

Mango is believed to have originated in South Asia, particularly in the Indian subcontinent (India–Myanmar region), where it has been cultivated for over 4,000-6,000 years. Ancient texts and archaeological evidence highlight its importance in Indian culture and agriculture. From South Asia, mango spread to Southeast Asia, the Middle East, Africa, and later to the Americas through traders and colonial explorers. Today, mango is widely grown in tropical and subtropical regions of the world, including India, China, Thailand, Indonesia, Pakistan, Mexico, Brazil, Bangladesh, the Philippines, and Nigeria. India is the largest producer of mango, contributing about 40–45% of global production, due to its vast cultivation area, diverse varieties, and suitable climatic conditions.

Climate and Soil Requirements

Mango is a tropical to subtropical fruit crop and grows best under warm climatic conditions. The crop is sensitive to frost and prolonged waterlogging.

Temperature: The ideal temperature range for mango growth is 24–30°C. Cool temperatures (10–15°C) during flower bud differentiation are beneficial for flowering, while temperatures below 5°C or frost can damage flowers and young fruits. Extremely high temperatures during fruit development may cause sunburn and fruit drop.

Rainfall: Mango performs well in areas receiving annual rainfall of about 75–250 cm. Dry weather during flowering and fruit set is essential, whereas heavy rainfall or high humidity during flowering can lead to poor fruit set and increased disease incidence.

Soil: Mango grows well in deep, well-drained loamy to sandy loam soils with good organic matter content. The crop prefers a soil pH of 5.5–7.5. Waterlogged, saline, and highly alkaline soils are unsuitable, as they adversely affect root growth and tree health.



Source: https://www.britannica.com/

Varieties

Classification of Mango Varieties: Mango varieties are mainly classified based on fibre content, taste, fruit size, colour, and purpose of use.

1. Fibre-less (Table Purpose) Varieties: These varieties are preferred for fresh consumption due to their smooth pulp and excellent flavour.

Popular fibre-less varieties include Alphonso, Kesar, Dashehari, Langra, Chausa, and Banganapalli. They are known for their sweetness, aroma, attractive colour, and high market value.

Alphonso (Hapus) – Golden yellow colour, excellent flavour, export quality

Kesar – Saffron-coloured pulp, very sweet, Gujarat region

Dashehari – Long-shaped fruit, North India me popular

Banganapalli (Safeda) – Large size, sweet taste, South India

Langra – Green skin even after ripening, rich

2. Fibre-rich (Processing Purpose) Varieties: These varieties contain more fibre and are suitable for processing into pulp, juice, pickles, and other products.

Common fibre-rich varieties include Totapuri, Neelum, Rumani, and Malgoa. They have good keeping quality and are widely used in the processing industry.

Totapuri – Parrot-beak shape, mildly sour, processing industry me popular

Neelum – Medium size, late-season variety

Rumani – South India me ugayi jaati hai

Malgoa (Mulgoba) – Large fruit, good keeping quality

3. Region-specific Popular Varieties: Different mango varieties perform well in different agro-climatic regions

North India: Dashehari, Langra, Chausa

West India: Alphonso, Kesar, Pairi

South India: Banganapalli, Totapuri, Neelum

East India: Himsagar, Fazli

These varieties are popular due to their high yield, adaptability, and consumer preference.

Land Preparation

Proper land preparation is essential for successful establishment and healthy growth of mango orchards. The land should be deeply ploughed 2–3 times to loosen the soil and improve aeration. All weeds, stubbles, and previous crop residues should be removed to reduce pest and disease incidence. The field should be levelled to facilitate proper layout, irrigation, and drainage. Pits of suitable size (generally 1 × 1 × 1 m) are dug at recommended spacing and left open for weathering. Well-decomposed farmyard manure mixed with topsoil is filled back into the pits before planting. Proper drainage is particularly important, as mango does not tolerate waterlogging.

Sowing (Planting of Mango)

Timely planting is essential for proper establishment and early growth of mango plants. In most parts of India, mango is planted during the monsoon season (July–August) to utilize adequate soil moisture, while in irrigated areas planting can also be done during February–March. Mango is mainly propagated through grafted seedlings, which ensure true-to-type plants and early bearing. Proper spacing is required for good canopy development and light penetration; traditional orchards follow 8 × 8 m or 10 × 10 m spacing, whereas high-density planting uses about 5 × 5 m or closer, depending on variety and management. Grafted plants should be planted at the same depth as in the nursery, keeping the graft union above soil to prevent rotting. Before planting, seedlings should be treated with fungicide or Trichoderma, and well-decomposed FYM should be applied in pits for better root growth.

Nutrient Management

Although mango is a perennial crop, balanced nutrition is essential for healthy growth, flowering, and fruiting. At planting, apply about 100–150 g each of nitrogen, phosphorus (P_2O_5), and potassium (K_2O) per plant, depending on soil fertility, to support root and shoot development. In zinc-deficient soils, apply 5–10 g zinc and 1–2 g boron per plant to improve flowering, fruit set, and reduce fruit drop. In bearing trees, nitrogen should be applied in 2–3 split doses annually, while phosphorus and potassium are applied once or twice a year. Use of biofertilizers like mycorrhiza and nitrogen-fixing bacteria enhances nutrient uptake, soil health, and long-term productivity.

Water Management

Mango is mainly grown under rainfed conditions, but proper irrigation is important, especially during the early years and in dry regions. Critical stages for irrigation include establishment (first 2–3 years), flower bud initiation and flowering, and fruit development and maturation, as moisture stress at these stages reduces fruit set, size, and yield. Young plants require irrigation every 7–10 days during dry periods to support root growth, while mature trees generally need only

supplementary irrigation during prolonged droughts. Waterlogging must be avoided because mango is highly sensitive to excess moisture and poor drainage, which can lead to root rot, reduced growth, and eventual tree decline.

Weed Management

Weeds compete with mango trees for water, nutrients, and light, especially during early orchard stages. Regular hand weeding in the tree basin for the first 3–4 years is effective. Mulching with straw, leaves, or sugarcane trash suppresses weeds and conserves moisture. Mechanical methods like hoeing and mowing help control weeds in inter-row spaces. Chemical control may include pre-emergence herbicides like pendimethalin and post-emergence directed sprays of glyphosate, avoiding trunk contact. Integrated Weed Management (IWM), combining cultural, mechanical, and chemical methods, is most effective. Maintain a weed-free zone of 1–2 m around young trees and manage inter-row weeds in mature orchards to reduce competition and pest habitat.

Plant Protection

Major Insect Pest:

a. Mango Hopper: Mango hopper (*Idioscopus* spp.) is a sap-sucking insect that feeds on the flowers, young leaves and shoots of mango trees. Their feeding causes the flowers and buds to dry up and drop, reducing fruit production. They also produce honeydew, which encourages sooty mould fungus to grow on the tree.

b. Mango Mealy Bug (*Drosicha mangiferae*): These bugs suck sap from inflorescences, tender leaves and shoots, causing drying up of flowers and fruit drop. They produce honeydew that encourages fungal growth.

c. Fruit Flies (Tephritidae family): Adult fruit flies lay eggs in fruit; larvae (maggots) feed inside, causing fruit rot and premature fruit drop. Different species attack mango in various regions.

d. Mango Stone/Nut Weevil (*Sternochetus mangiferae*): Beetle whose larvae develop inside the seed and fruit, leading to spoilage and reduced fruit quality.

e. Bark-Eating Caterpillars *(Indarbela spp.*): Larvae feed on bark and stems, creating holes and weakening branches (damage may not always be easily seen externally).

f. Leaf Webber / Leaf Caterpillars: that chew leaves, sometimes weaving webs; heavy feeding can reduce photosynthesis and tree vigor. Flower Gall Midges (e.g., Procystiphora mangiferae)
Tiny flies whose larvae form galls (swellings) on flowers and buds, affecting fruit set.

Major Disease:

a. Powdery Mildew: White powdery fungal growth appears on leaves, flowers, and young fruits, causing curling, flower drop, poor fruit set, and significant yield reduction in mango orchards.

b. Anthracnose: It causes black spots on leaves, flowers, and fruits with sunken lesions and rotting of young and ripe fruits, severely affecting yield and fruit quality, including post-harvest losses.

c. Bacterial Canker: Water-soaked lesions appear on leaves, stems, and fruits with sticky bacterial ooze, causing leaf and fruit drop, reduced tree vigor, poor fruit quality, and dieback of branches in severe cases.

d. Dieback: It causes wilting and blackening of twigs and shoots with premature leaf fall, leading to progressive drying from branch tips, weakening trees and reducing fruiting.

e. Mango Malformation: It causes abnormal, twisted, and thickened shoots with malformed flowers, leading to poor flowering and severe reduction in fruit yield.

Sooty Mold: Sooty mold develops due to fungi growing on honeydew secreted by sap-sucking insects like mealybugs and hoppers. It appears as a black, powdery coating on leaves and fruits, reducing photosynthesis and affecting fruit appearance. Though mainly a cosmetic problem, it lowers market quality and indicates insect infestation.

Red Rust (Cephaleuros virescens): Red rust is an algal disease producing orange-red, velvety patches on leaves, sometimes causing curling and premature leaf fall. It results in mild to moderate defoliation and reduced photosynthetic area, which may slightly reduce yield but is rarely fatal to mango trees.

Leaf Spot / Black Spot

Causal Agent: *Pseudocercospora purpurea*

Symptoms: Dark brown to black spots on leaves; severe infection may cause premature leaf drop.

Impact: Weakens the tree, especially young plants.

Fruit Rot / Post-Harvest Rot

Causal Agents: *Colletotrichum spp., Alternaria spp.,* and *Botryodiplodia spp.*

Symptoms: Soft, sunken spots on fruits; rotting during storage; sometimes covered with fungal growth.

Impact: Significant post-harvest losses.

Harvesting and Threshing

Harvesting: Mangoes are ready for harvest when they reach the appropriate size, color, and maturity, which varies by variety. Mature fruits usually have a change in color from green to a slight yellowish or reddish tinge, and the stem may start to turn brown. Harvesting is done carefully by hand or using poles with baskets to avoid bruising the fruit.

Threshing (if needed): Unlike grains, mangoes are generally not threshed in the traditional sense. However, after harvesting, the fruits are sorted and separated from stems, leaves, or damaged fruits. Sometimes mechanical graders are used to separate fruits by size or quality for packing and marketing.

Yield

1. Rainfed conditions: 8–12 t/ha

2. Irrigated conditions: 15–20 t/ha

Using improved varieties and better orchard management practices can significantly increase mango yield.

Post-Harvest Management

After harvesting, mango fruits should be cleaned and sorted according to size and quality. They should be stored at proper temperature (10–13 °C) and relative humidity (85–90%) to extend shelf life. Packaging in ventilated crates or boxes, timely grading, and careful handling can prevent bruising and spoilage. Controlled atmosphere storage, cold storage, and post-harvest treatments like hot water dipping or fungicide application can help reduce post-harvest losses and protect the fruits from pests and diseases.

Conclusion

Mango farming is both profitable and environmentally sustainable due to its perennial nature and relatively low maintenance once established. Using improved varieties, proper orchard management, balanced fertilization, efficient irrigation, and integrated pest and disease management can greatly enhance productivity and profitability. Therefore, mango cultivation is important for boosting farmers' incomes, ensuring nutritional security through fruit consumption, and supporting livelihoods, especially in regions suitable for fruit orchards.

References

1. Tharanathan, R. N., Yashoda, H. M., & Prabha, T. N. (2006). Mango (Mangifera indica L.),"The king of fruits"—An overview. *Food reviews international*, *22*(2), 95-123.
2. Das, S. C., Datta, M., Ray, P., Singh, S. K., Jena, R. K., Das, B., & Ray, S. K. (2019). Mango (Mangifera indica) Cultivation in north-eastern region of india. *Adv Agric Res Technol J*, *3*, 54-66.
3. Bally, I. S. (2006). Mangifera indica (mango). *Species profiles for pacific island agroforestry*, *4*(7), 1-25.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Resource-Use Efficient Agronomy for Climate-Resilient Agriculture

Article ID: 72829

Saurabh Suman[1], Yash Nandan[1], Satyam Raj[2]
[1]Doon (PG) College of Agriculture Science & Technology, Dehradun, Uttarakhand.
[2]Indira Gandhi National Open University, Bettiah, Bihar.

Abstract
Resource-Use Efficient agronomy is a set of agronomic practices which aims to stabilize the use of resources in agriculture like water, land, nutrient and energy while maintaining stable yields and income. It involves practices like conservation tillage, efficient irrigation methods, integrated nutrient management and use of improved crop varieties which helps to improve yields under conditions of stress and changing climatic conditions. Robust extension services helps farmers adopt such practices thereby helping in sustainable food production in the long run.

Introduction
Climate change is rapidly putting pressure on the natural resource reservoir on which the agriculture depends. The constantly changing climate causing extreme high temperatures, erratic rainfall has put a heavy toll on the agricultural lands. The changing rainfall patterns either causes drought in one place or flooding in the other both causing sufficient damage to agricultural soils and crops. Higher temperatures increase the rate of evapotranspiration thereby reducing soil moisture and causes groundwater depletion, which ultimately result in lower water resources needed for agriculture. Climate change is also causing significant damage to land resources in the form of soil erosion, salinization, desertification, etc. thereby reducing land available for cropping. A nutrient loss through runoff, leaching and volatilization has also been increasing with changes in climatic patterns. The heat and moisture stress occurring due to changing climates has also reduced the response of crops to moisture and fertilizers resulting in reduction in production and productivity. Rising energy demands has also resulted in increase of the production costs. In light of this, resource use efficient agronomy has become undeniably a very essential tool for ensuring sustainable agricultural production under these changing climatic conditions.

Concept of Resource Use Efficiency
Resource use efficiency is a measure of how effectively resources such as land, water, energy, and labour are used in agricultural production (Agricorn, 2023). It is an important concept in sustainable agriculture as it can help to reduce the negative environmental impacts of agriculture while maximizing productivity and profitability.

The main resources involved in agriculture include water, land, nutrients and energy. Using these resources efficiently is of utmost importance in today's world. Water use efficiency is very essential for sustainable agriculture as water is very critical for any life to grow. Water use efficiency can be increased through practices such as rainwater harvesting, through use of micro-irrigation practices such as drip irrigation instead on using traditional methods of irrigation like flooding as well through use of drought resistant crops. Land, the base on which the crops grow needs to be efficiently used for agricultural production to be sustained. Land use efficiency can be achieved by using practices such as intercropping, crop rotation, multi-storied cropping and using agroforestry techniques. Energy use efficiency can be achieved by use of efficient irrigation practices, improved farm mechanization practices and use of renewable energy sources. Nutrient use efficiency can be increased by using the right nutrient source at the right time, right place, right dose and right rate, by using appropriate methods of fertilizer application and by adopting precision nutrient management practices. Managing these resources efficiently will ultimately aid in sustainable crop production and productivity.

Major Resource Efficient Agronomic Practices
Some of the major resource use efficient agronomic practices include:

1. Conservation Tillage: Conservation Tillage has been defined as any tillage operation that leaves more than 30% of plant residues at the soil surface after seeding (SARE, 2020). The most common forms of conservation tillage include No-tillage, Ridge-tillage, Strip-Tillage, Mulch-tillage and Minimum tillage. In No-till, the soil is undisturbed by tillage during the entire year. Mulch tillage is a form of conservation tillage that involves leaving a minimum of one-third of the soil surface covered with stubble mulch. This method is designed to reduce the amount of tillage while maintaining a layer of organic material on the soil surface. Strip tillage means tilling in narrow strips while ridge tilling involves tilling leaving the ridges. Minimum tillage implies a tillage reduction, but 30% of the soil surface covered by residues. Conservation tillage practices help reduce soil erosion, conserve soil moisture, improve soil structure, reduce runoff and hence help in climate-resilient agronomy.

2. Efficient irrigation practices: Efficient irrigation practices for conserving water resources include use of irrigation practices like drip and sprinkler irrigation. Drip irrigation involves applying water directly into the root zone, thus minimizing evaporation and runoff losses. Sprinkler irrigation aids in even application of water resulting in less water wastage compared to traditional flooding systems. Irrigation scheduling is also very important. Irrigation scheduling ensures that water is applied to the crops according to the critical stages of water requirements, which prevents over irrigation or under irrigation. Rainwater harvesting is also a very critical conservation practice as it helps in saving rainwater for using later as per requirements.

3. Integrated nutrient management: Integrated Nutrient Management refers to the maintenance of soil fertility and of plant nutrient supply at an optimum level for sustaining the desired productivity through optimization of the benefits from all possible sources of organic, inorganic and biological components in an integrated manner (TNAU Agritech portal, n.d.). Integrated nutrient management plays an important role in conservation agronomy as it helps in nutrient use efficiency, helps in improving soil health, improves activities of soil microorganisms, minimizes nutrient losses, and reduces dependence on chemical fertilizers thus helping in long term productivity.

4. Improved crop varieties: Use of improved crop varieties can help with improving the production and yield with the use of lower amount of resources thereby conserving resources. Some improved varieties can produce yield with the use of same or lower amount of nutrients and water thereby improving nutrient use efficiency and water use efficiency respectively. Some improved varieties may be developed to tolerate stress like drought, flood, and frost reducing the need for excess inputs. This is how improved crop varieties can be developed to help in resource use efficient agronomy.

Role of Resource Efficiency in Climate Resilience

Resource use efficiency plays a key role in building climate resilience in crops. Efficient conservation of water through practices such as rainwater harvesting, use of improved irrigation practices, use of drought tolerant crop varieties can help in maintaining production and productivity during periods of water stress as well as flooding caused due to erratic rainfall patterns. Resource use efficient systems also optimize yield by improving nutrient and water use helping the plant metabolism during periods of high temperatures as well as during declining soil fertility situations caused due to changing climatic conditions. Overall by maximizing the efficiency of inputs-land, water, energy and nutrients resource use efficiency plays a pivotal role in developing climate resilience for maintaining a sustainable production system.

Benefits to Farmers

1. Efficient use of resources helps in lowering cost of cultivation of farmers.
2. Higher production and productivity of crops, leading to higher income for farmers.
3. Environmental benefits achieved from resource use efficiency include enhanced soil health and reduction in wastage of the natural resources.
4. Increased resilience to climatic stresses.

Extension and Policy Support Needed

Extension and policy support play a pivotal role in the promotion of resource use efficient agronomy among farmers. A robust extension service is essential for knowledge dissemination through field demonstrations, trainings for farmers, and digital advisory tools, which in turn enable farmers to comprehend and implement efficient water, nutrient, and energy management practices. Capacity building and training programs must be designed to enhance skills in conservation agriculture, precision farming, and the use of climate-smart technologies. It is particularly important to focus on smallholders, youth, and women farmers, as they represent the most vulnerable segments of the farming community. Supportive policies should commit to the integration of resource efficient agronomy as the core of agricultural development programs. Besides, steps need to be taken to provide easy access to credit and insurance facilities thereby, lowering the risks associated with the adoption of new practices. Agricultural subsidies, such as those for efficient irrigation systems, precision equipment, and soil health practices, together with market and performance-based incentives, can be very effective in motivating farmers to not only adopt resource use efficient agronomic practices but also to keep them going over time.

Conclusion

Thus, it can be concluded that, resource use efficient agronomy is not just an option but a viable survival strategy in the face of climate change, scarcity of resources and inputs and rising production costs. It helps in ensuring sustainable productivity, economic benefits to farmers and protection of natural resources by optimizing the use of water, energy, nutrients and inputs. It also helps in enhancing climate resilience and stabilizing yields. Hence, it has proved to be very efficient technique for ensuring food security and farmer livelihoods.

References

1. Agricorn (2023).Resource Use Efficiency. https://www.agricorn.in/2023/03/resource-use-effciency-and-optimization-techniques.html
2. SARE (2020). Conservation Tillage Systems in the Southeast. https://www.sare.org/publications/conservation-tillage-systems-in-the-southeast/chapter-1-introduction-to-conservation-tillage-systems/what-is-conservation-tillage/
3. TNAU Agritech portal (n.d.). Nutrient Management:: Integrated Nutrient Management. https://agritech.tnau.ac.in/agriculture/agri_nutrientmgt_integrntrientmgt.html

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Precision Nutrient Management as a Tool for Sustainable Crop Productivity

Article ID: 72830

Saurabh Suman[1], Yash Nandan[1], Roop Kishore Sharma[1]
[1]Department of Agriculture, Doon (PG) College of Agriculture Science & Technology, Selaqui, Dehradun [Affiliated to HNBGU, Srinagar].

Abstract
Increasing fertilizer prices and deteriorating soil health have rendered the continued use of traditional uniform fertilizer practices untenable. Precision nutrient management (PNM) provides a crop and site-specific solution whereby the necessary nutrients are applied in the correct amount, at the right time, and in the appropriate place. By employing measures such as soil testing, remote sensing, variable rate technology, and Nano/slow release fertilizers PNM can achieve higher nutrient use efficiencies, greater crop yields, and improved environmental sustainability. However, the involvement of farmers and the extension services providing them with training and demonstrations are the main factors determining the successful uptake of PNM, which thus becomes an indispensable instrument for the success of PNM.

Introduction
Rising fertilizer costs has become a serious concern all over the world leading to decline in profits for farmers, especially the smallholder farmers. At the same time with the rise in indiscriminate use of fertilizers and using them more than required without proper soil testing, the soil health has been declining rapidly along with rapid nutrient depletion. According to the 2023 FAO India Report, nearly 60% of Indian agricultural soils are suffering from degradation, partly due to post-Green Revolution practices. Adding to the problems is the traditional "one size fits all" approach which has been proving to be harmful for the soil and crop health as it leads to overuse of fertilizers and its wastage. As such, the need of precision nutrient management has been growing day by day. Precision nutrient management offers a sustainable solution as it helps to provide right nutrient at the right time, right rate and right place according to crop requirements thereby cutting down costs as well as saving soil and crop health from excessive use of fertilizers.

Meaning of Precision Nutrient Management
Precision nutrient management is a precise method of application of nutrients, based on the variability in soil and micro-climatic conditions that occur within the field. The scale of nutrient management recommendation domains change from large regions to farms, single fields or even single parcel within a large field. (Patil, 2009).

While traditional nutrient use largely involves uniform application over the entire field irrespective of crop and soil, precision nutrient management involves site specific nutrient use based on soil and crop demands. Traditional approaches often rely on general nutrient recommendations which may either lead to over-application or under-application of the nutrients, which reduces the nutrient use efficiency. However nutrient use efficiency in terms of precision nutrient management is high due to application as per specific needs of crops and soil. In traditional nutrient use approach fertilizer wastage is high coupled with degradation of soil fertility posing higher risk of nutrient leaching and runoff which is not the case in site specific nutrient management. As such, precision nutrient management gives more stable yields in the long run as compared to traditional approaches.

Key principles of Precision Nutrient Management
This strategy adheres to the principles of 4Rs which are as follows (Nasiro and Mohammednur, 2024):

1. **Right Source**: Ensuring a balanced supply of essential nutrients, considering both naturally available sources and the characteristics of specific products, in plant-available forms.
2. **Right Rate**: Assessing and applying the proper amounts of nutrients to meet crop needs and minimize losses.
3. **Right Time**: Making nutrients available when crops need them most, reducing losses.
4. **Right Place**: Placing nutrients where crops can easily access them, reducing losses.

Tools and Techniques
1. Soil Testing: It forms the basis of precision nutrient management. The testing of the soil in laboratory or by using rapid kits is done for applying nutrients as per crop and soil demands. A digital soil testing kit named "Pusa Soil Test and Fertilizer Recommendation Meter" was developed by IARI which quantitively determines ten soil parameters namely pH, EC, organic C, available P, K, S, Zn, lime requirement and gypsum requirement.

2. Remote Sensing: It involves the use of drones and satellites to get information on nutrient status of crops and soils in different inaccessible areas. Through indices such as Normalized Difference Vegetation Index (NDVI), different nutrient deficient zones can be identified and accordingly management can be done.

3. Variable rate technology (VRT): It enables farmers to apply varying amounts of fertilizers or nutrients across a field based on soil testing, yield maps, or other data sources. VRT uses GPS data to vary the rate of nutrient application across a field based on soil test results and crop requirements (Sahoo *et al.*,2023).

4. Leaf Color Chart: Leaf Color Chart is a tool which is used for nitrogen status assessment in rice crops and as such nutrient management can be done according to its needs.

5. Site Specific Nutrient Management: Site specific nutrient management attempts to account for regional and seasonal yield potential and crop nutrient demand, spatial variability in indigenous nutrient supply, field specific in-season variability in crop nutrient demand and location specific cropping systems and crop management practices.

6. Mobile apps: Various mobile apps such as RiceXpert, Fertilizer Calculator Goa has been recently developed which prescribes soil test-based fertilizer recommendations to major crops like rice in case of RiceXpert.

7. Nano and slow release fertilizers: Nano and slow release fertilizers helps in controlling the rate of nutrient release from the fertilizers thereby improving the nutrient use efficiency. Examples of nano fertilizers include Nano Urea, Nano Zinc etc. and that of slow release fertilizers like Sulphur coated urea, Polymer coated urea etc.

Benefits of Precision Nutrient Management

Precision nutrient management has several benefits to offer which are as follows:

1. Higher nutrient use efficiency.
2. Reduction in costs incurred in fertilizer use
3. Helps in reducing soil degradation hence improving soil fertility and further better crop yields.
4. Crops receive nutrients according to their actual needs, resulting in better growth, uniformity, and higher-quality produce.
5. Ultimately increases the income of the farmers.
6. Overall helps in environmental protection from indiscriminate use of fertilizers.

Role of Farmers and Extension System

Farmers are the backbone to the successful implementation of the practices of precision nutrient management as they are the ones who need to adopt the practices in order to make it successful. The extension system also has a great role to play in it. Extension personnels can help by creating awareness among farmers about the various new practices and all the benefits associated with them. The training and on-field demonstrations conducted by them would help them become confident in the various new techniques like soil testing, use of leaf color chart which would make them adopt these practices more effectively. Together farmers and extension system can together contribute to sustainable nutrient management practices.

Constraints and Field Level Challenges

There are many constraints to the adoption of precision nutrient management which are as follows:

1. High cost of tools and equipments.
2. Lack of awareness among farmers
3. Poor access to soil testing facilities by the farmers
4. Lack of technical skills of the farmers
5. Farmers generally hesitate to go for new practices leaving behind the traditional approaches.
6. The farmers might not be well educated to use some of the latest technologies.

Conclusion

Precision nutrient management is a very important tool for sustainable agronomy which allows farmers to apply nutrients in the right amount, place rate and time. It makes farming not only productive but environmentally safe by reducing excessive fertilizer use thus lowering costs and increasing nutrient use efficiency. Precision nutrient management, combined with farmer involvement, extension services, and use of modern technologies, can be a decisive factor in making agriculture sustainable and profitable in the long run.

References

1. Nasiro, K., & Mohammednur, T. (2024). Precision nutrient management amid climate change challenges: a review. *Science Frontiers*, *5*(3), 110-122.
2. Patil, V. C. (2009). Precision nutrient management: A review. *Indian Journal of Agronomy*, *54*(2), 113-119.

3. Sahoo, R. N., Ranjan, R., Mahajan, G. R., Das, B., Tripathi, R., & Sinha, N. (2023). Modern Tools and Techniques of Precision Nutrient Management in Major Crops. *Indian Journal of Fertilisers*, *19*(11), 1178-1183.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

From Daily Wage Labourer to Lac Farmer: The Inspiring Journey of Shri Chandan Beena

Article ID: 72831

Udaykumar, M. S[1], S. K. Pandey[1]
[1]Scientist, ICAR-National Institute of Secondary Agriculture, Namkum, Ranchi-834010 (Jharkhand).

Introduction

In the tribal heartland of Jharkhand, where agriculture is often constrained by limited resources and market access, stories of transformation through knowledge and innovation stand out as powerful sources of inspiration. One such remarkable story is that of Shri Chandan Beena, a progressive farmer from Sogod village of Rajaulatu Panchayat, Namkum block, Ranchi district, whose life changed dramatically through scientific lac cultivation and institutional support from ICAR-National Institute of Secondary Agriculture (ICAR-NISA), Ranchi.

Born into a family of nine members, Shri Chandan Beena completed his education up to the Intermediate level. He owns about 8 acres of land, which today supports a diversified and integrated farming system comprising paddy, vegetables, cereals, poultry, duckery, goatery, and lac cultivation. However, this success was not achieved overnight—it is the result of years of struggle, learning, and determination.



Struggles Before 2016: Livelihood Under Stress

Before 2016, the socio-economic condition of Shri Chandan Beena was far from stable. Despite owning valuable natural resources, his livelihood depended on multiple low-paying and uncertain activities. He worked as a daily wage labourer, assisted in a seed and fertilizer shop, drove an auto-rickshaw, and sold vegetables in weekly local markets. These activities provided subsistence income but offered no long-term security.

Ironically, while he owned more than 100 Kusum trees and 50-60 Ber trees—highly suitable host plants for lac cultivation—he lacked scientific knowledge, technical guidance, and market awareness regarding lac. Like many farmers in the region, he handed over his host trees to traders on a sharing basis. This arrangement turned exploitative when, after harvesting, he was cheated badly. Against an actual production of 5 quintals and 17 kg of lac, he received only 1 quintal and 17 kg.

This incident became a turning point in his life. It opened his eyes to the true economic potential of his resources and the risks of remaining dependent on middlemen without scientific and institutional support.

Turning Point: Contact with ICAR-NISA

In 2016, Shri Chandan Beena came in contact with Shri Shaktidhar Koiri, an experienced lac farmer, who introduced him to Dr. Ghoshal, Scientist, ICAR-NISA, Ranchi. Through this interaction, he received scientific training and technical guidance on lac cultivation, including brood lac selection, inoculation methods, host management, pest control, and post-harvest practices.

Encouraged by the guidance, he decided to take up independent lac cultivation. He began cautiously by inoculating just 2.5 kg of brood lac on 1–2 host trees. The results were encouraging, both in terms of production and confidence. Gradually, he expanded lac cultivation to 15 Kusum trees, earning a profit of around ₹ 60,000 in the initial stage itself.

Expansion and Diversification: Building a Sustainable Farming System

With growing experience and confidence, Shri Chandan Beena steadily expanded and strengthened his farming system. Today, he maintains more than 100 Kusum trees, 55–60 Ber trees, and around 800 Semialata plants, making lac cultivation the backbone of his farm enterprise.

He began Semialata plantation in 2021 with 400 plants, which has now increased to around 800 plants. To maximize land and water use efficiency, he practices intercropping of vegetables such as French bean, tomato, peas, and other seasonal crops under Semialata plantations. The adoption of drip irrigation further improved productivity while reducing water use.

This integrated approach not only enhanced farm income but also generated local employment, as he pays around ₹25,000–30,000 annually as labour wages, contributing to rural livelihood generation.

Lac Cultivation: The Most Profitable Enterprise

Among all his farm activities, lac cultivation has emerged as the most profitable enterprise. From lac alone, Shri Chandan Beena now earns an annual income of ₹3–5 lakh, surpassing returns from other agricultural and allied activities. In addition, income from paddy, vegetables, poultry, duckery, and goatery contributes about ₹1.5 lakh per annum.

During the agricultural year 2024–25, he harvested around 10 quintals of lac. Out of this, about 3 quintals were sold in the Bengal market, 2 quintals in Sisai market, and 2 quintals in the local market, while nearly 3 quintals were retained as brood lac for the next season. This planned marketing and retention strategy reflects his improved understanding of both production and sustainability.



Fig: Lac based integrated farming

Economic Impact: Before and After ICAR-NISA Intervention

Before coming in contact with ICAR-NISA, Shri Chandan Beena's annual income ranged between ₹ 1.2-1.5 lakh, derived mainly from irregular wage labour and small farm activities, leaving little scope for savings or investment. After adopting scientific lac cultivation under the guidance of ICAR-NISA, his total annual income has increased substantially to ₹5-6 lakh. Lac cultivation alone now contributes more than half of his total income. This sharp rise in income highlights the transformative economic impact of scientific interventions, capacity building, and proper utilization of existing natural resources.

Social Transformation and Leadership

The economic gains from lac cultivation have translated into visible social and lifestyle improvements. Shri Chandan Beena is now constructing a pucca house using income generated from lac. He ensures quality education for his children, with five of them studying in good schools, breaking the cycle of poverty and insecurity that once defined his family.

Beyond his own success, he has emerged as a motivator and role model for fellow farmers in the region. He actively shares his experiences, encourages others to adopt lac cultivation, and demonstrates that with scientific guidance, institutional support, and confidence, rural youth and farmers can achieve sustainable livelihoods.

Conclusion: A Model for Rural Jharkhand

The journey of Shri Chandan Beena—from a daily wage labourer to a successful lac entrepreneur—clearly demonstrates the power of secondary agriculture, particularly lac cultivation, in enhancing farm income and rural resilience. His story underscores the crucial role played by ICAR-NISA, Ranchi, in providing scientific knowledge, technical backstopping, and confidence to farmers.

Today, Shri Chandan Beena stands as a symbol of hope and transformation, proving that scientific agriculture, when combined with determination and local resources, can bring lasting socio-economic change in rural Jharkhand. His journey is not just a personal success story but a replicable model for thousands of farmers across lac-growing regions of India.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Digital Labour in Indian Agriculture: The Growing Gig Economy

Article ID: 72832

K.Pravallika[1], R. Shiva Shankar[2]
[1]Ph.D. Scholar, College of Agriculture, Professor Jayashankar Telangana Agricultural University Hyderabad-500030.

Summary of Article
Indian agriculture is undergoing a quiet but significant transformation driven by digital platforms, mobile applications and app-based service models. The emergence of digital labour or the gig economy in agriculture is reshaping how farmers access services, information, machinery and markets. From app-based tractor hiring and drone spraying to digital advisory and on-demand farm labour, Agri-gigs are creating new livelihood opportunities while improving farm efficiency. This article explores the nature, drivers, opportunities and challenges of the growing gig economy in Indian agriculture, with a focus on its implications for farmers, rural youth and women.

Introduction
Indian agriculture has long relied on family labour, informal wage workers and community-based exchange systems. Recent advances in digitisation, widespread smartphone use and supportive Agri-tech policies have given rise to digital labour, commonly known as the gig economy. This model involves short-term, task-based work delivered through online platforms and mobile applications. Across India, Agri-gig platforms now link farmers with service providers for land preparation, sowing, spraying, harvesting, transportation, soil testing and advisory services. Custom hiring centres, app-based machinery rentals and drone-as-a-service models are especially beneficial for small and marginal farmers who lack the resources to own costly equipment. While the agricultural gig economy resembles urban platform-based work, it has distinct rural features. Agri-gigs are seasonal, location-specific and aligned with crop cycles, yet they offer flexibility, income diversification and new employment opportunities for rural youth, Agri-entrepreneurs and women. NITI Aayog has observed that gig employment, particularly location-based gig work, remains predominantly concentrated in urban areas. The rapid expansion of smartphone-enabled digital platforms has significantly lowered transaction costs in recent years, creating new opportunities for the gig economy to expand beyond local boundaries. However, this expansion continues to be constrained by the requirement for agglomeration effects, as economies of scale and scope are more easily achieved in densely clustered markets.

Digital Platforms and Agri-Gig Services
Digital labour in agriculture operates through a range of platforms and service models. These include:

1. Custom Hiring and Machinery Platforms: Farmers can rent tractors, harvesters, seed drills and other machinery on an hourly or per-acre basis through mobile applications. This reduces capital investment and enhances mechanisation among smallholders (Singh et. al., 2015).

2. Drone and Precision Farming Services: Trained gig workers operate drones for pesticide spraying, crop monitoring and mapping. This model has gained momentum with government support for drone technology in agriculture.

3. Digital Advisory and Extension Services: Agri-advisors, soil testing professionals and crop consultants provide on-demand advice through apps, call centres and chat-based platforms.

4. Market and Logistics Gigs: Digital platforms connect farmers with transporters, graders and market intermediaries, improving supply chain efficiency and price discovery.

These services collectively contribute to the formalisation of previously informal agricultural labour markets while introducing performance-based payment systems.

Opportunities for Farmers and Rural Workforce
The growing gig economy presents multiple benefits for Indian agriculture. Farmers gain timely access to specialised services, reduce dependency on local labour shortages and improve productivity. For small and marginal farmers, shared access to machinery lowers production costs and enhances profitability.

For rural youth, agri-gigs provide employment opportunities beyond traditional farm labour. Skilled youth trained in operating machinery, drones or digital tools can earn higher incomes and gain entrepreneurial experience. Women's participation in digital agriculture is also increasing, particularly in advisory services, data collection and platform coordination roles (Singh and Mishra, 2015).

Moreover, digital labour aligns with national initiatives such as Digital India, Skill India and the promotion of Farmer Producer Organisations (FPOs), strengthening institutional support systems in rural areas.

Challenges and Concerns

Despite its potential, the agri-gig economy faces several challenges. Digital literacy gaps, limited internet connectivity and regional disparities restrict platform adoption among resource-poor farmers. Gig workers often lack job security, social protection and access to formal benefits such as insurance and pensions.

Regulatory frameworks for digital labour in agriculture are still evolving. Issues related to fair wages, data ownership, platform accountability and worker rights require policy attention. Singh et. al., (2015) found that without institutional safeguards, gig workers remain vulnerable to exploitation and income instability.

Personal Opinion Column

The gig economy should not replace traditional extension systems but complement them. A hybrid model that integrates public extension, private platforms and community institutions can ensure inclusivity and sustainability. Capacity building, digital skill training and gender-sensitive platform design are essential to ensure equitable participation in digital agriculture.

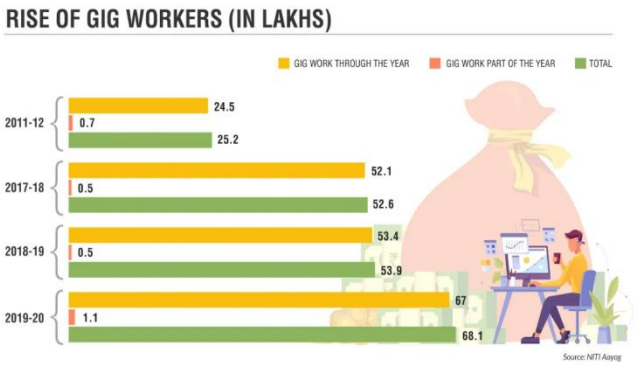
Summary / Conclusion

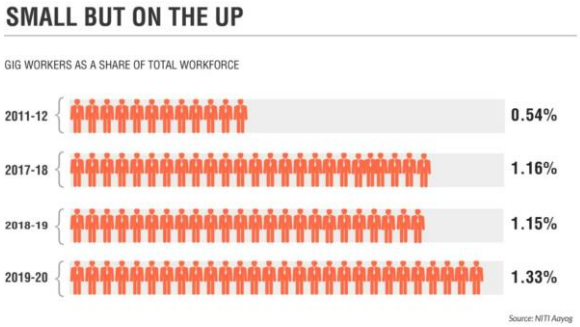
Digital labour and the gig economy are redefining agricultural work in India by introducing flexibility, efficiency and innovation. While agri-gigs offer promising opportunities for farmers and rural workers, inclusive policies and robust governance mechanisms are crucial to address emerging challenges. With the right balance between technology, regulation and social protection, the gig economy can contribute significantly to the future of Indian agriculture.

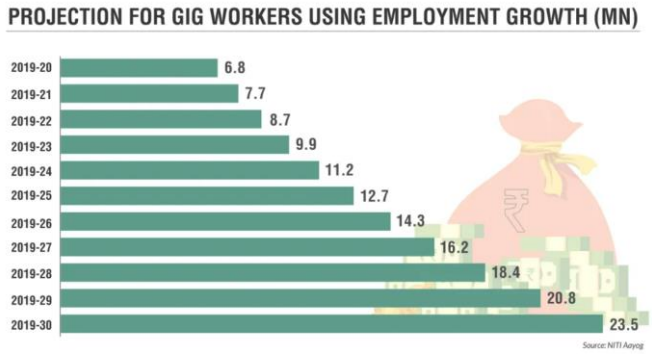
References

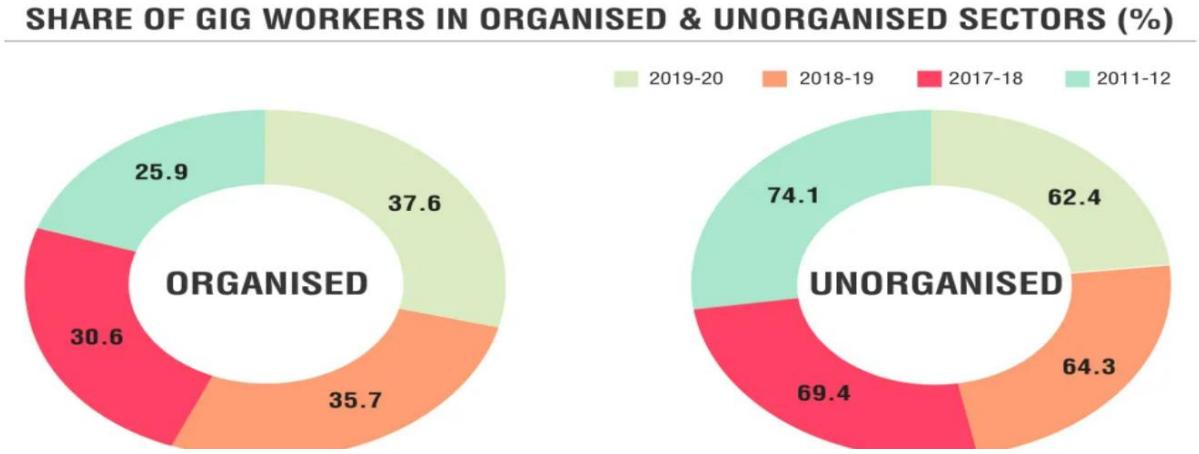
1. Dutta R.N., (1984). Comparative ecological study of makhana in Darbangha region. Ph.D. thesis. Ranchi University, Ranchi, Bihar.
2. Ho H., Cheu Y. and Luo I., (1953). The detection of vitamin B, and C in Chinese drugs. Journal of Taiwan Pharmacy Association. 5(1):5-20.
3. Singh R., Kumar S. and Verma P., (2015). Digital interventions in Indian agriculture: Emerging trends and challenges. Indian Journal of Agricultural Economics. 70(3):345-356.
4. Singh A. and Mishra R., (2015). Technology-enabled extension services and farmer participation. Journal of Extension Education. 27(2):5412-5418.










SHARE OF GIG WORKERS IN ORGANISED & UNORGANISED SECTORS (%)
2019-20
2018-19
2017-18
2011-12
25.9
37.6
ORGANISED
30.6
35.7
74.1
62.4
UNORGANISED
64.3
69.4

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Seeds of Change: Unraveling the Story of Genetically Modified Organisms

Article ID: 72833

Dr. Gadi Sri Harsha Vardhan[1], Dr. Basanta Kumar Borah[2]
[1]Ph.D Agricultural Biotechnology.
[2]Associate Professor, Assam Agricultural University.

A Seed is Planted

In the quiet corridors of a village in Maharashtra, an old farmer, Mr. Rao, holds a peculiar seed in his hand. It's a cotton seed like any other at first glance. But this one, called *Bt* cotton, contains a gene borrowed from a bacterium. It helps the plant resist bollworms, a notorious cotton pest, once the scourge of its fields. Rao doesn't know the science behind it, but he does know this: it saved his crop last year.

Meanwhile, in urban kitchens, millions unknowingly pour a spoonful of oil made from soybeans or canola, much of which may have originated from genetically modified (GM) crops grown halfway across the globe.

The story of genetically modified organisms - GM foods - isn't just about science. It's a tale of myths and facts, of promises and concerns, of international trade, local ecology, and global governance. Let's journey through this complex terrain.

What Exactly are GMOs?

Genetically Modified Organisms (GMOs) are living beings - plants, animals, or microorganisms - whose genetic material has been altered in ways that do not occur naturally through reproduction or natural recombination. In the context of food, GM crops have been engineered to exhibit certain traits: pest resistance, herbicide tolerance, or improved nutritional content.

The first commercially grown GM food crop was the Flavr Savr tomato in the U.S. in 1994, designed to resist spoilage by enhancing the shelf life. Since then, GM varieties of corn, soybean, cotton, canola, sugar beet, and more have proliferated across agricultural landscapes, particularly in the western part of the world.

Myths that Refuse to Die

GM foods have, over the years, accumulated a folklore of their own. Here are some of the most persistent myths - and what science says about them:

1. Myth: All GM foods are unsafe.

Reality: Extensive reviews by institutions like the World Health Organization (WHO), FAO, and regulatory bodies in over 70 countries, including the U.S. FDA and the European Food Safety Authority (EFSA), have concluded that GM foods approved for market are as safe as their conventional counterparts.

2. Myth: GMOs cause cancer or allergies.

Reality: No credible scientific study has established a link between approved GM foods and cancer or allergies. However, new GMOs are rigorously tested for allergenicity before approval.

3. Myth: GMOs are unnatural and therefore harmful.

Reality: While the technology is indeed synthetic, humans have been altering plant genetics for centuries through selective breeding. Genetic engineering is more precise but doesn't necessarily make the food "unnatural" in a dangerous sense.

4. Myth: All GM crops are sterile (the 'Terminator seed' myth).

Reality: Commercial GM seeds are not sterile. However, farmers often repurchase seeds annually due to licensing agreements with seed companies or because hybrid crops may not retain their traits reliably in the next generation.

The Benefits that Cannot Be Ignored

Despite controversies, GM crops offer tangible benefits:

1. Higher Yields and Resilience: GM crops like *Bt* cotton in India have reduced losses from pest attacks and increased yields.

2. Reduced Pesticide Use: *Bt* crops produce their own pest deterrents, leading to fewer pesticide applications and, in turn, reduced chemical exposure for farmers and the environment.

3. Drought Tolerance and Nutritional Enhancement: New generations of GM crops are being developed to withstand extreme weather and enhance nutrition (e.g., Golden Rice enriched with Vitamin A).

The Unseen Bite - Are We Already Eating GM Foods?

Though India officially allows only GM cotton for cultivation, we are not isolated from GMOs. India imports large quantities of edible oils - especially soy and canola - from countries like the U.S., Brazil, and Argentina, where over 99% of these crops are genetically modified. Countries like Argentina, which is a net exporter of commodities derived from GMOs to numerous markets in the world, including India. Though the export documentation for grains declares the GM content, the country does not treat non-DNA-containing products derived from GM plants as being genetically engineered (Source: USDA Report Number: AR2022-0023).

Every country has its own way of classifying GM and Non-GM crop which creates ambiguity. Moreover, in the current context countries like India has limited market options for importing edible oil for its domestic consumption.

Cross-Border Concerns - Transgenes Without Borders

The possibility of **transgene migration** - the movement of genetically engineered traits to local or wild relatives - is a genuine concern. Bangladesh has commercially cultivated *Bt* Brinjal since 2014 after the approval from its National Committee on Biosafety (NCB). Given the porous borders and the fact that pollinators don't respect national lines, there's a possible risk of gene flow into India's native brinjal varieties.

However, experts stress that gene flow depends on compatibility between varieties and environmental conditions. Vigilance, cross-border monitoring, and proper biosafety protocols are critical.

The Dilemma - Between Progress and Preservation

India has been cautious with GM food crops, and for good reason.

The Challenges:

1. Biodiversity at Stake: India is one of the world's richest centers of agricultural biodiversity. The concern is that widespread adoption of GM crops may reduce genetic diversity as farmers abandon traditional varieties.

2. Farmer Vulnerability: Many worry that dependence on corporate seed companies could create a monopoly, with farmers having to buy new seeds every season at high costs.

3. The *Bt* Cotton Experience: India's only approved GM crop - *Bt* cotton - offers lessons. It initially improved yields and cut pesticide use, but over time, pests adapted, and secondary pests emerged. In some parts of the country, farmers started using more chemical sprays again. In some areas, indiscriminate use led to ecological imbalances and farmer distress.

The Way Forward - Managing the Gene Genie

If India decides to expand GM crop cultivation, several safeguards must be in place:

1. Strengthened Regulation: A transparent and independent biosafety authority, with input from farmers, scientists, and civil society.

2. Coexistence Strategies: Allowing GM and non-GM crops to coexist through buffer zones, labeling, and farmer education.

3. Seed Sovereignty: Encouraging public-sector GM research to counterbalance corporate monopolies and make seeds affordable and reusable where possible.

4. Ecological Monitoring: Long-term environmental assessments to track impacts on wild species and pollinators.

Epilogue: A Story Still Being Written

The story of GM foods is not one of villains and heroes. It's a complex narrative shaped by evolving science, economics, ethics, and environmental stewardship. For the Indian public, farmers, and policymakers, the challenge is not to reject or embrace GMOs blindly, but to ask the right questions:

1. What do we want our food system to look like?
2. How to ensure food safety while address food security?
3. How do we balance innovation with caution?
4. Can we engineer crops without engineering inequality?

As Mr. Rao plants his next cotton crop, and as you pour that spoon of oil into your pan, the story continues - written by seeds, scientists, and societies alike.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Plasma-Activated Water: Physico-chemical Characteristics, Production Techniques and Utilization

Article ID: 72834

Suraj N Gund[1], Rutuja S. Pisal[2], Dr. Amol S. Solanke[3]

[1]Ph. D. Scholar, Department of Agril. Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar.
[2]Ph. D. Scholar, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar.
[3]Asst. Prof. Affiliated to Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Introduction

Plasma-Activated Water (PAW) is a novel product generated when cold atmospheric plasma interacts with water, resulting in the formation of reactive oxygen and nitrogen species (RONS) such as hydrogen peroxide, nitrites, nitrates, ozone and hydroxyl radicals. These reactive species impart unique physicochemical properties that enable PAW to act as an effective antimicrobial, oxidative and signaling medium. The growing interest in PAW is driven by its broad applications across agriculture, food safety, environmental management and medicine. In agriculture, it promotes seed germination, crop growth and pathogen suppression without harmful residues. In food industries, PAW serves as an eco-friendly disinfectant, offering a sustainable alternative to chemical sanitizers. Its medical potential has also been highlighted in wound healing, sterilization and even cancer therapy.

Unlike conventional chemical treatments, PAW is residue-free, sustainable and can be generated on demand using relatively simple plasma devices. Its effectiveness, however, is influenced by multiple factors, including plasma source, exposure time, storage conditions and the intrinsic chemistry of the treated water. These factors collectively determine the concentration and stability of reactive oxygen and nitrogen species (RONS), which are primarily responsible for PAW's distinctive properties.

The accumulation of RONS not only imparts antimicrobial and oxidative activity but also alters the fundamental physicochemical characteristics of PAW. For instance, the presence of reactive species increases the electrical conductivity of the solution while reducing surface tension, which in turn enhances evaporation rates. Such changes can be beneficial for processes involving phase-change heat transfer, leading to improved heat removal efficiency (Low *et al.*, 2023). Thus, the dual impact of PAW—both as a chemically active solution and as a medium with modified physical behavior broadens its potential applications across diverse fields. In this work, we first examine the physicochemical properties of PAW followed by a discussion of common generation techniques. We then highlight the wide range of applications of PAW in agriculture, food safety, environmental remediation, and medicine. Finally, we review recent advances in miniaturized plasma generators designed to produce plasma-activated aerosols, offering new possibilities for direct and localized decontamination of surfaces (Low *et al.*, 2023).

Physicochemical Properties of Plasma-Activated Water

When plasma comes into contact with water, it generates a variety of reactive oxygen and nitrogen species (RONS) at the air–liquid interface. These primary species quickly interact with water molecules and with one another, giving rise to secondary species that are central to the unique properties and applications of plasma-activated water (PAW) (Chandana *et al.*, 2018). Broadly, these reactive species fall into two groups: long-lived species such as hydrogen peroxide (H_2O_2), ozone (O_3), nitrite (NO_2^-), and nitrate (NO_3^-), which can remain stable for minutes to days (Lukes et al., 2014 and Glaze et al., 1987). and short-lived species such as hydroxyl radicals (•OH), nitric oxide (NO), and peroxynitrite ($ONOO^-$), which exist only for nanoseconds to a few seconds before rapidly transforming into more stable compounds (Tarabova *et al.*, 2019 and Pryor *et al.*, 1986). because short-lived species act almost immediately, scientists are developing in situ applications of PAW and plasma-activated aerosols to harness their effects more effectively. The following sections outline the physical properties of PAW, the role of reactive oxygen species and reactive nitrogen species and the methods used to analyze these reactive species.

Table 1: Physiochemical properties of PAW:

Sr. No.	Property	Key Factors / Explanation	Behavior/Trend	References
1.	Density	Free-moving charged species and ions diffuse into water, increasing ionic concentration and density	Increases with plasma treatment	Low *et al.*, 2023.
2.	pH	Low pH (acidic) but safe and non-toxic; affects stability of reactive species (stable at neutral pH, unstable at <3.5)	Decreases with treatment duration, then stabilizes at steady state	Shen *et al.*, 2016.

3.	Oxidation-reduction potential (ORP)	Contribution from H_2O_2, OH, O_3, NO_3^-, NO_2^-, and $ONOO^-$, which act as strong oxidants/reductants	High ORP values observed	Kaushik *et al.*, 2018.
4.	Surface tension	Presence of NO_3^- ions disrupt hydrogen bonding at the air-liquid interface	Decreases with increase in electrical conductivity	Petersen and Saykally 2005.
5.	Electrical conductivity	Due to diffusion of reactive ions and species into water during plasma exposure	Increases significantly (100-500 mS/cm reported)	Zhang *et al.*, 2016

Production of Plasma-Activated Water via Dielectric Barrier Discharge

Unlike plasma jets, dielectric barrier discharge (DBD) generates atmospheric-pressure plasma directly in ambient air, making it scalable for PAW production (Yan *et al.*, 2017). The concentration of reactive species is influenced by both setup and operating parameters.

1. Setup parameters include:

a. Electrode material: Silver electrodes promote stronger oxidation, yielding higher NO_3^- but lower O_3 concentrations compared to stainless steel and brass (Ragni et al., 2017).

b. Dielectric material: Alumina enhances filament formation and heat dissipation, while quartz sustains higher potentials, increasing ionization and reactive species (Ozkan et al., 2019).

c. Electrode gap: Narrower distances enhance electron accumulation and reactive species generation, improving microbial inactivation (Iqbal *et. al.*, 2014).

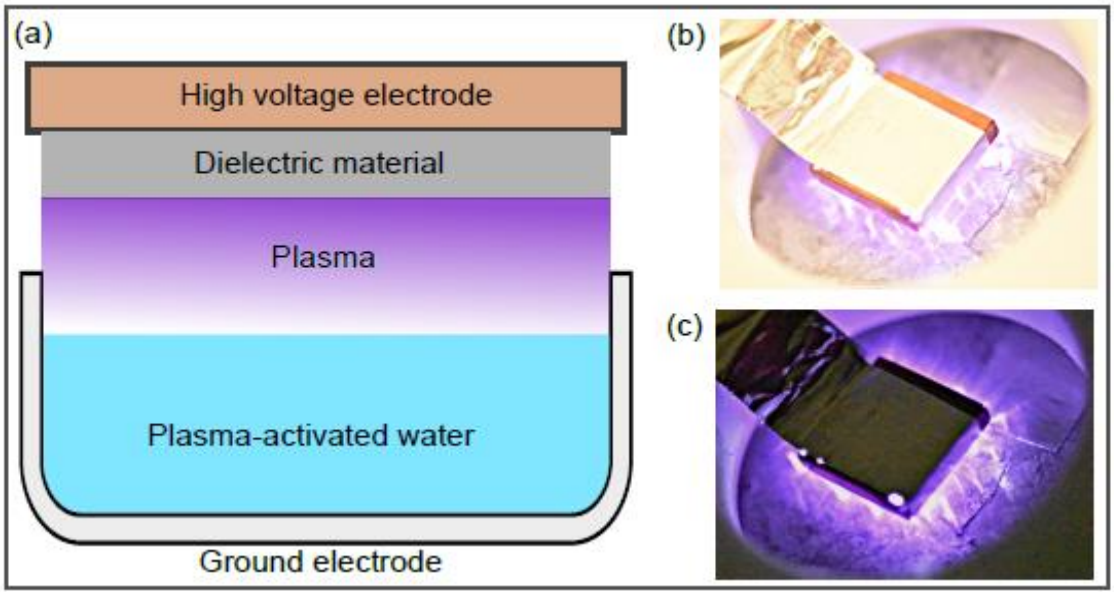
d. Dielectric thickness: Thicker substrates sustain higher potentials and enable uniform micro-discharges (Ozkan et al., 2019).

2. Operating parameters include:

a. **Electrical power:** Increasing power elevates OH, H_2O_2, NO_3^-, and NH_4^+ concentrations due to higher energy density. Frequency and duty cycle also affect plasma efficiency, e.g., SMZ degradation improved from 77.3% to 89.2% when frequency increased from 150 to 200 Hz at a 75% duty cycle.

b. Treatment duration: Longer exposure increases NO_2^-, NO_3^-, O_3, and H_2O_2 concentrations.

c. Surrounding gas: Helium modifies breakdown voltage, discharge characteristics, and electron density compared to ambient air.



Applications of Plasma-Activated Water

Plasma-activated water (PAW), enriched with reactive oxygen and nitrogen species (RONS), has attracted growing attention due to its antimicrobial, oxidative, and signaling properties. Its applications extend across agriculture, food safety, medicine, and environmental engineering.

1. Agriculture: PAW has shown potential as a sustainable alternative to chemical fertilizers and pesticides. It enhances seed germination, root development, and plant growth, likely through RONS-mediated modulation of signaling pathways [Ref]. PAW also induces systemic resistance in plants, improving tolerance to abiotic stresses such as drought and salinity

[Ref]. Moreover, its antimicrobial properties help suppress plant pathogens, reducing reliance on synthetic agrochemicals.

2. Food Safety and Preservation: PAW is widely studied as a residue-free decontamination technology. It effectively inactivates bacteria, fungi, and viruses on fresh produce, meat, seafood, and minimally processed foods [Ref]. Compared to chemical sanitizers, PAW leaves no toxic residues and maintains product quality, making it suitable for postharvest treatment. It also reduces pesticide residues and mycotoxins, thereby improving food safety and shelf life.

3. Medicine and Healthcare: In biomedical applications, PAW demonstrates strong antimicrobial activity against multidrug-resistant pathogens, making it suitable for surface and instrument disinfection. It promotes wound healing by stimulating angiogenesis and reducing infection risk. PAW has also been investigated for applications in dentistry (biofilm removal, root canal disinfection) and dermatology (treatment of chronic wounds and skin infections). Importantly, it is considered biocompatible when applied under controlled conditions.

4. Environmental Applications: PAW plays a significant role in wastewater treatment and pollutant degradation. Its oxidative species degrade pharmaceuticals, dyes, and organic contaminants, offering an eco-friendly alternative to conventional advanced oxidation processes. It has also been explored for surface sterilization in hospitals and food industries, reducing microbial load on packaging materials and processing equipment. The scalability of dielectric barrier discharge systems makes PAW a promising tool for large-scale environmental applications.

References

1. Chandana, L.; Sangeetha, C.; Shashidhar, T.; Subrahmanyam, C. Non-thermal atmospheric pressure plasma jet for the bacterial inactivation in an aqueous medium. Sci. Total Environ. 2018, 640–641, 493–500. [CrossRef]
2. Glaze, W.H.; Kang, J.W.; Chapin, D.H. The Chemistry of Water Treatment Processes Involving Ozone, Hydrogen Peroxide and Ultraviolet Radiation. Ozone Sci. Eng. 1987, 9, 335–352. [CrossRef]
3. Iqbal, M.M.; Turner, M.M. Influence of Gap Spacing between Dielectric Barriers in Atmospheric Pressure Discharges. Contrib. Plasma Phys. 2015, 55, 444–458. [CrossRef]
4. Kaushik, N.K.; Ghimire, B.; Li, Y.; Adhikari, M.; Veerana, M.; Kaushik, N.; Jha, N.; Adhikari, B.; Lee, S.J.; Masur, K.; et al. Biological and medical applications of plasma-activated media, water and solutions. Biol. Chem. 2018, 400, 39–62.
5. Low, M.; Hung, Y.M.; Tan, M.K. Cooling enhancement for light-emitting diode using plasma-activated water. Appl. Therm. Eng. 2023, 230, 120671.
6. Low, M.; Sow, W.S.; Hung, Y.M.; Tan, M.K. Increase in Leidenfrost point via plasma-activated water. Int. J. Therm. Sci. 2023,184, 107908.
7. Lukes, P.; Dolezalova, E.; Sisrova, I.; Clupek, M. Aqueous-phase chemistry and bactericidal effects from an air discharge plasma in contact with water: Evidence for the formation of peroxynitrite through a pseudo-second-order post-discharge reaction ofH2O2and HNO2. Plasma Sources Sci. Technol. 2014, 23, 015019.
8. Ozkan, A.; Dufour, T.; Bogaerts, A.; Reniers, F. How do the barrier thickness and dielectric material influence the filamentary mode and CO2 conversion in a flowing DBD? Plasma Sources Sci. Technol. 2016, 25, 045016. [CrossRef]
9. Petersen, P.B.; Saykally, R.J. Adsorption of ions to the surface of dilute electrolyte solutions: e Jones-Ray effect revisited. J. Am. Chem. Soc. 2005, 127, 15446–15452.
10. Pryor, W.A. Oxy-Radicals and Related Species: Their Formation, Lifetimes, and Reactions. Annu. Rev. Physiol. 1986, 48, 657–667.
11. Ragni, L.; Berardinelli, A.; Iaccheri, E.; Gozzi, G.; Cevoli, C.; Vannini, L. Influence of the electrode material on the decontamination efficacy of dielectric barrier discharge gas plasma treatments towards Listeria monocytogenes and Escherichia coli. Innov. Food Sci.Emerg. Technol. 2016, 37, 170–176. [CrossRef]
12. Shen, J.; Tian, Y.; Li, Y.; Ma, R.; Zhang, Q.; Zhang, J.; Fang, J. Bactericidal Effects against S. aureus and Physicochemical Properties of Plasma Activated Water stored at different temperatures. Sci. Rep. 2016, 6, 28505.
13. Tarabova, B.; Lukeš, P.; Hammer, M.U.; Jablonowski, H.; von Woedtke, T.; Reuter, S.; Machala, Z. Fluorescence measurements of peroxynitrite/peroxynitrous acid in cold air plasma treated aqueous solutions. Phys. Chem. Chem. Phys. 2019, 21, 8883–8896.
14. Yan, D.; Sherman, J.H.; Keidar, M. Cold atmospheric plasma, a novel promising anti-cancer treatment modality. Oncotarget 2017,8, 15977–15995. [CrossRef]
15. Zhang, Q.; Ma, R.; Tian, Y.; Su, B.; Wang, K.; Yu, S.; Zhang, J.; Fang, J. Sterilization Efficiency of a Novel Electrochemical Disinfectant against Staphylococcus aureus. Environ. Sci. Technol. 2016, 50, 3184–3192.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Emerging Precision Farming Strategies for Resource-Efficient Agricultural Systems

Article ID: 72835

T. Ragul[1], Dr. D. Leninraja[2], Dr. P. Radha[3], Dr. K. Manobharathi[4], R. Abirami[5]

[1]M. Sc., Research Scholar, Dept of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-3.

[2]Assistant Professor, Dept of Soil Science and Agricultural Chemistry, HC&RI, Periyakulam, Theni, TNAU, Tamil Nadu.

[3]Assistant Professor, Dept of Biochemistry, FC&RI, Mettupalayam, TNAU, Tamil Nadu.

[4]Assistant Professor, Dept of Agricultural Extension, Mother Terasa College of Agriculture, Illuppur, Pudukkottai, TNAU, Tamil Nadu.

[5]Ph. D., Research Scholar, Dept of Soil Science and Agricultural Chemistry, HC&RI, Periyakulam, Theni, TNAU, Tamil Nadu.

Summary of the Article

Precision agriculture uses modern technology to help farmers work smarter. By using tools like GPS, artificial intelligence and a real-time data management system, farmers can better understand their fields and crops. This allows them to use water, fertilizers, and chemicals more efficiently by reducing waste and lowering costs during cultivation. As a result, farming becomes more productive, sustainable and environmentally friendly. In this article, we examine how precision farming is revolutionizing agriculture, enhancing productivity and making it environmentally friendly.

Introduction

Modern agriculture faces a serious challenge in producing more food for a growing population while using fewer natural resources. Land, water, fertilizers and energy are becoming increasingly scarce and expensive. At the same time, climate change is making farming more unpredictable. Precision agriculture is revolutionising the farming sector by using technology to enhance crop yields, decrease waste and promote sustainability. As the global population increases and resources become more limited, farmers are embracing different innovative techniques to produce more food by reducing environmental impacts. This strategy ensures that all resources such as water, fertilizers and pesticides are utilised effectively.

Precision farming has emerged as a powerful solution. By using digital tools, sensors and data-driven technologies, farmers can now apply inputs such as water, fertilizers and pesticides more accurately. This approach not only improves productivity but also reduces waste and environmental damage. Precision farming is transforming traditional agriculture into a smarter, more efficient system.

Smart Tools Powering Modern Precision Farming

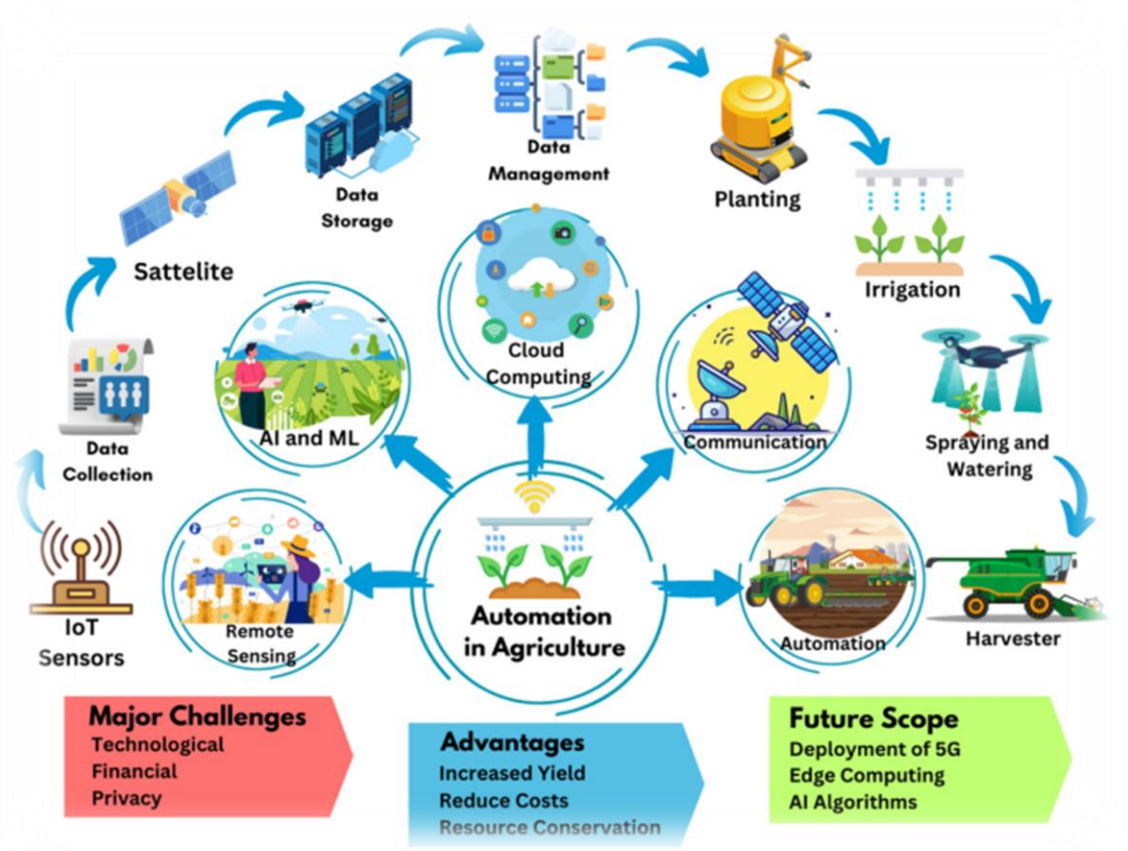
Modern precision agriculture is driven by a range of smart technologies that help farmers manage their fields more efficiently.

1, GPS and Geographic Information Systems (GIS): Farmers can create detailed maps that show differences in soil fertility, moisture and crop growth across their land.

2. IoT Sensors and Drones: Sensors placed in the field will continuously monitor soil conditions, temperature and plant health, while drones capture real-time images to identify problems such as pest attacks or nutrient deficiencies at an early stage.

3. Automated Machinery: Machinery such as tractors, seeders and harvesters equipped with artificial intelligence reduces labour requirements and ensures the accurate application of seeds, fertilizers and chemicals.

4. Variable Rate Technology (VRT): Improves efficiency by adjusting the amount of water, fertilizers and pesticides according to the specific needs of different field zones. In addition, big data and artificial intelligence analyze large volumes of farm information to provide practical recommendations on crop management, irrigation scheduling and pest control, helping farmers make smarter and more timely decisions.



Benefits of Precision Agriculture

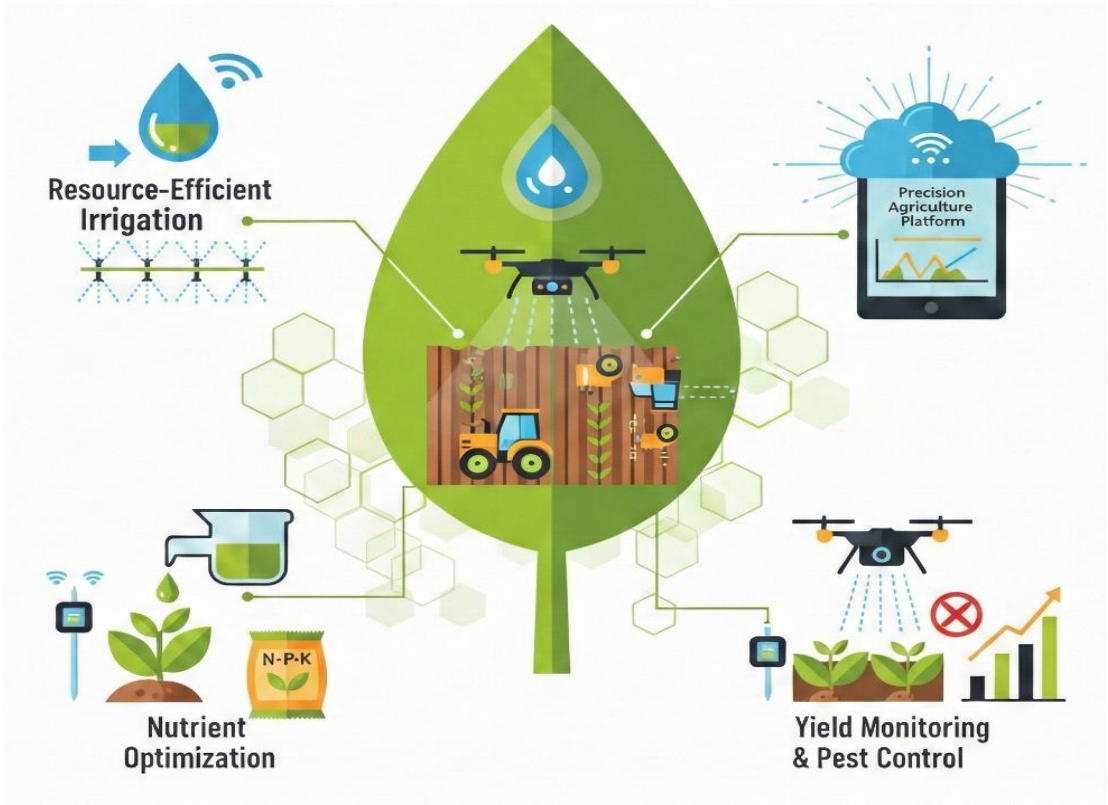
1. Higher Crop Yields: Precision agriculture helps farmers to understand exactly what each part of the farm needs and crops receive the right care at the right time. This leads to healthier plants, stronger growth and higher yields without expanding farmland.

2. Efficient Use of Resources: Instead of applying water, fertilizers and pesticides uniformly, precision tools deliver them only where they are truly needed. This smart targeting minimises waste, conserves natural resources and ensures that every input serves a clear purpose.

3. Reduced Production Costs: By avoiding unnecessary applications of inputs, farmers significantly lower their operational expenses. Using fewer chemicals, less water and optimised fuel not only saves money but also improves overall farm profitability.

4. Environmental Sustainability: Precision farming supports environmentally responsible agriculture. Reduced chemical runoff protects soil health, preserves water quality and safeguards beneficial organisms, thereby maintaining long-term ecosystem balance.

5. Better and Faster Decision-Making: With access to real-time data from sensors, satellites and drones, farmers gain deeper insight into crop conditions. This information empowers them to make timely, evidence-based decisions on planting, irrigation, harvesting and disease management, reducing risks and improving outcomes.



Challenges in Precision Agriculture

1. High Initial Investment: Technologies such as GPS-guided machinery, drones and sensor networks require substantial upfront investment. For small and marginal farmers, these expenses can be difficult to afford, limiting widespread adoption.

2. Limited Technical Skills and Training: Precision farming relies heavily on digital tools and data analysis. Many farmers may lack the necessary technical knowledge to operate these systems effectively or to interpret the information they generate.

3. Poor Digital Connectivity in Rural Areas: Reliable internet access is essential for real-time data collection, cloud-based analysis and remote monitoring. However, many rural and remote farming regions still suffer from weak network coverage and unstable connectivity.

Conclusion

Precision agriculture offers a smart and practical way to meet the growing demand for food while protecting limited natural resources and the environment. Using modern technologies and data-based farming practices, it helps farmers improve crop yields, reduce waste and manage their fields more efficiently. Although challenges such as high costs, lack of technical skills and poor internet access still limit its adoption, proper training, supportive policies and affordable technologies can help overcome these barriers. With continued innovation and strong institutional support, precision farming has the potential to create a more sustainable, resilient and productive agricultural system for future generations.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Climate Change Vulnerability and Adaptation in Kiwifruit Production Systems

Article ID: 72836

Duyu Monya[1], Oying Jamoh[2]
[1]College of Horticulture and Forestry, CAU, Pasighat, Arunachal Pradesh-791102.
[2]Krishi Vigyan Kendra, Dibang Valley, Arunachal Pradesh, 792101.

Introduction

Climate change represents one of the most significant long-term threats to the sustainability of perennial horticultural systems, including kiwifruit (*Actinidia* spp.) production. Unlike annual crops, kiwifruit orchards involve long-term investments and are highly sensitive to climatic stability, particularly with respect to winter chilling, spring frost risk, water availability, and pollination dynamics (Rajan et al., 2024). Rising temperatures, increasing rainfall variability, more frequent extreme weather events, and shifting pest & disease regimes are already affecting major kiwifruit-producing regions such as China, Italy, New Zealand, Chile, and emerging areas, including India's Himalayan belt (Pergola et al., 2022; Zhang et al., 2023). Their narrow climatic envelope compounds the vulnerability of kiwifruit systems. Kiwifruit requires sufficient winter chilling for uniform budbreak, moderate summer temperatures for fruit growth and quality, and adequate soil moisture throughout the growing season (Rajan et al., 2024). Deviations from these climatic thresholds can result in substantial yield losses, fruit quality degradation, and increased production costs. Consequently, climate change adaptation is becoming a central pillar of sustainable kiwifruit production.

Temperature Extremes and Phenological Shifts

1. Rising Winter Temperatures and Chilling Deficits: Kiwifruit vines have specific chilling requirements during winter dormancy to ensure synchronized budbreak and flowering. Most commercial cultivars of *Actinidia deliciosa* require 600-900 chilling hours, while *A. chinensis* cultivars generally require 300-600 chilling hours (Rajan et al., 2024). Rising winter temperatures in temperate regions are increasingly leading to insufficient chilling accumulation, resulting in delayed, uneven budbreak, weak flowering, and reduced fruit set (Zhang et al., 2023). In China and parts of southern Europe, winter warming has already caused chilling deficits in several production zones, leading to irregular phenology and yield instability. Similar trends are emerging in the Himalayan regions of India, including Arunachal Pradesh, where warming winters are shortening dormancy periods and advancing flowering by 7-15 days compared with historical baselines (Rajan et al., 2024).

2. Increased Risk of Late Spring Frosts: While winters are becoming warmer on average, early spring warming has increased the frequency of phenological advancement, thereby exposing developing buds and flowers to late frost events. Frost damage during flowering can cause near-total crop failure in exposed orchards. In New Zealand and Italy, spring frosts have resulted in substantial economic losses during anomalous cold spells following early budbreak (Pergola et al., 2022). In Himalayan regions, frost vulnerability is increasing as flowering advances earlier into frost-prone windows.

Adaptive management approaches include the deployment of low-chill and frost-tolerant cultivars, application of dormancy-breaking agents, frost protection technologies (wind machines and overhead sprinklers), strategic site selection, and canopy management to delay budbreak (Rajan et al., 2024).

Water Stress and Rainfall Variability

1. Increased Drought Frequency: Climate projections indicate declining summer rainfall and increasing evapotranspiration in Mediterranean Europe, China, and parts of Chile, exacerbating irrigation demand in kiwifruit orchards (Pergola et al., 2022). Prolonged drought stress reduces fruit size, accelerates softening, and impairs sugar accumulation (Zhang et al., 2023). In the Northeastern region of India, although annual rainfall remains high, the erratic onset of the monsoon and uneven intra-seasonal distribution are emerging as significant risks. Rainfed kiwifruit orchards in Arunachal Pradesh increasingly experience moisture stress during flowering and early fruit development.

2. Flooding and Excess Rainfall: Extreme rainfall events can lead to waterlogging, root hypoxia, soil erosion, and nutrient leaching (Lago et al., 2019). Heavy monsoonal downpours in the Himalayan regions have intensified soil erosion on sloping orchards, reducing long-term soil fertility.

Adaptation strategies include precision drip irrigation, soil moisture monitoring, rainwater harvesting, mulching, terracing, contour bunding, subsurface drainage, and the use of drought-tolerant rootstocks (Pergola et al., 2022).

Heat Stress and Fruit Quality Degradation

High temperatures (>35 °C) during fruit development negatively affect fruit size, texture, and sugar-acid balance (Zhang et al., 2023; Rajan et al., 2024). Heat stress also increases water demand and predisposes fruit to sunburn damage,

particularly in exposed canopies (Pergola et al., 2022). In southern China and Mediterranean Europe, heat waves have become more frequent, leading to increased sunburn incidence and a decline in overall fruit quality (Zhang et al., 2023; Nikkhah et al., 2017). In Himalayan regions, rising summer temperatures are extending the growing season but also increasing evapotranspiration stress.

Adaptation strategies include shade nets, reflective mulches, optimized canopy architecture, adjusted planting density, trellis redesign, heat-tolerant cultivars, and enhanced irrigation scheduling during heat waves (Zhang et al., 2023; Rajan et al., 2024).

Pest and Disease Dynamics under Climate Change

Climate warming alters pest and pathogen lifecycles, expanding their geographic range and seasonal activity (Wu, 2020). Warmer winters enable higher overwintering survival of insect pests, while humid conditions favor fungal and bacterial pathogens.

In kiwifruit systems, climate change has been linked to increased incidence of bacterial canker (*Pseudomonas syringae* pv. *actinidiae*), expanded populations of scale insects and thrips, and greater fungal disease pressure (Wu, 2020; Rajan et al., 2024). These trends are likely to increase pesticide reliance unless integrated pest management (IPM) strategies are strengthened.

Adaptation strategies encompass the development and adoption of climate-resilient integrated pest management (IPM) frameworks, the use of stress- and disease-resistant cultivars, and the promotion of biological control agents as sustainable alternatives to chemical inputs. These approaches are further strengthened by the integration of disease forecasting models and early-warning systems, which enable timely interventions, reduce crop losses, and enhance the overall resilience of production systems under changing climatic conditions (Wu, 2020).

Soil Degradation and Carbon Losses

Climate change accelerates soil degradation through increased erosion, organic matter decomposition, and nutrient leaching. In sloping orchards of the Himalayas and Mediterranean regions, intense rainfall events are a major driver of soil erosion (Pergola et al., 2022). Loss of soil organic carbon reduces fertility and weakens climate resilience by diminishing water-holding capacity and nutrient cycling efficiency.

Climate-resilient approaches involve the adoption of cover cropping to improve soil cover and nutrient cycling, reduced tillage practices to conserve soil structure and moisture, and the application of compost to enhance soil organic matter and microbial activity. These measures are complemented by the integration of agroforestry systems, which provide microclimate regulation and biodiversity benefits, and the incorporation of biochar to improve soil carbon sequestration, water-holding capacity, and long-term soil health (Lago et al., 2019).

Pollination Risks and Ecosystem Services

Successful kiwifruit production depends heavily on pollination, primarily by bees. Climate-induced shifts in flowering phenology can lead to mismatches between flowering periods and pollinator activity. In regions experiencing erratic spring temperatures, asynchronous flowering and reduced pollinator abundance have been observed, resulting in poor fruit set (Rajan et al., 2024; Lago et al., 2019).

Adaptation interventions include pollinator habitat enhancement, floral strips, diversification of pollination agents, cultivar flowering synchronization, and reduced pesticide exposure to pollinators (Lago et al., 2019; Rajan et al., 2024).

Regional Perspective: Climate Vulnerability in Arunachal Pradesh

Kiwifruit orchards in Arunachal Pradesh represent a low-input, agroforestry-based production system embedded within forest–agriculture mosaics. While these systems exhibit inherent ecological resilience, they face emerging climate risks:

1. Warming winters reducing chilling accumulation (Rajan et al., 2024)
2. Erratic monsoon patterns affecting moisture availability
3. Increased soil erosion on terraced slopes
4. Emerging pest and disease pressures (Rajan et al., 2024).

However, the region also offers significant adaptive advantages, including high baseline biodiversity, high organic matter soils, and strong agroforestry potential. Targeted interventions such as low-chill cultivars, solar-powered drip irrigation, community-based IPM, and structured agroforestry orchard designs can significantly enhance climate resilience while maintaining low environmental footprints (ICAR, 2021).

Institutional and Policy Dimensions of Climate Adaptation

Effective climate adaptation in kiwifruit systems requires institutional support, policy incentives, and knowledge dissemination. In India, relevant policy instruments include:

1. Mission for Integrated Development of Horticulture (MIDH)

2. National Agroforestry Policy
3. Pradhan Mantri Krishi Sinchai Yojana (PMKSY)
4. Organic farming initiatives (PKVY, MOVCDNER)
5. Renewable energy schemes (PM-KUSUM)
6. Integrating climate adaptation goals into these frameworks can accelerate the adoption of sustainable orchard practices.

Synthesis and Implications for Sustainable Kiwifruit Production

Climate change is reshaping the biophysical and economic landscape of kiwifruit production. Key vulnerabilities include chilling deficits, frost risk, drought stress, heat waves, pest expansion, and soil degradation. However, a suite of agronomic, technological, and ecosystem-based adaptation strategies offers pathways to resilience.

The most effective adaptation measures are those that simultaneously enhance environmental sustainability, productivity stability, and socio-economic viability. These include precision irrigation, agroforestry-based orchard diversification, integrated pest management, soil carbon restoration, and pollinator conservation (Rajan et al., 2024).

For emerging kiwifruit-growing regions such as Arunachal Pradesh, a sustainability-first development pathway centred on organic farming systems, agroforestry integration, and the adoption of climate-resilient cultivars presents a strategic opportunity to establish a low-input, environmentally responsible, and high-value kiwifruit sector. Leveraging the state's rich biodiversity, relatively low chemical footprint, and favourable agro-climatic conditions, such an approach can enhance ecosystem services, conserve soil and water resources, and strengthen climate resilience while meeting the rising demand for premium and organic produce. Moreover, aligning kiwifruit development with national climate action and horticultural development frameworks can support inclusive livelihood generation, hill-specific sustainable agriculture, and long-term economic viability, positioning Arunachal Pradesh as a model region for climate-smart and sustainable kiwifruit production in India.

References

1. Lago, M. D. C. F., Gallego, P. P., & Briones, M. J. (2019). Intensive cultivation of kiwifruit alters the detrital foodweb and accelerates soil C and N losses. *Frontiers in microbiology*, *10*, 686.
2. Nikkhah, A., Emadi, B., Soltanali, H., Firouzi, S., Rosentrater, K. A., & Allahyari, M. S. (2016). Integration of life cycle assessment and Cobb-Douglas modeling for the environmental assessment of kiwifruit in Iran. *Journal of Cleaner Production*, *137*, 843-849.
3. Pergola, M., Persiani, A., D'Ammaro, D., Pastore, V., D'Adamo, C., Palese, A. M., & Celano, G. (2022). Environmental and energy analysis of two orchard systems: a case study in mediterranean environment. *Agronomy*, *12*(10), 2556.
4. Rajan, P., Natraj, P., Kim, M., Lee, M., Jang, Y. J., Lee, Y. J., & Kim, S. C. (2024). Climate change impacts on and response strategies for kiwifruit production: A comprehensive review. *Plants*, *13*(17), 2354.
5. Wu, J. H. (2020). Cultivar, environment and integration of cultural practices will determine the future of the kiwifruit industry. *Scr. Hortic*, *20*, 171-178.
6. Zhang, Y., Sun, H., Ge, M., Zhao, H., Hu, Y., Cui, C., & Wu, Z. (2023). Difference in energy input and output in agricultural production under surface irrigation and water-saving irrigation: a case study of Kiwi Fruit in Shaanxi. *Sustainability*, *15*(4), 3114.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Agriculture at the Crossroads: Can India Turn its Oilseed Paradox into an Opportunity?

Article ID: 72837

Boniga Mohan Uday Raj[1], D.A. Rajini Devi[1], K. Divya[1], M. Medha[1]
[1]Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India.

Introduction

India's oilseed sector occupies a paradoxical position in the agricultural economy. Despite being one of the largest producers of oilseeds globally, the country continues to rely heavily on imports to meet its growing edible oil demand. Oilseeds such as soybean, mustard, groundnut, and rapeseed are central to India's cropping systems, farmer livelihoods, and agri-trade performance, yet structural constraints have limited their contribution to domestic self-sufficiency and export competitiveness (Tiyndel et al., 2025; Sharma & Deshmukh, 2024).

The importance of oilseeds extends beyond production volumes. They play a critical role in nutritional security, industrial raw material supply, and foreign exchange earnings, while also offering scope for crop diversification in predominantly rain-fed regions (Srinivasan, 2004). However, low productivity, high yield variability, and increasing exposure to global price fluctuations have constrained the sector's growth potential (Bhati & Kumar, 2020). Trade liberalization has further intensified price volatility by transmitting international shocks into domestic markets, thereby increasing income uncertainty for oilseed farmers (Joarder, 2018).

India's oilseed trade performance also reveals sharp contrasts. While mustard seed exports have shown resilience and market stability, soybean exports have weakened under intense global competition, resulting in an uneven export landscape (Tiyndel et al., 2025). This divergence highlights that India's oilseed challenge is not merely one of production shortfall, but of competitiveness, price stability, and policy coherence. Understanding the interaction between production dynamics, trade patterns, and price behaviour is therefore essential for designing effective policy interventions aimed at reducing import dependence and stabilizing farmer incomes.

Export Performance: A Mixed Outcome

India's oilseed export performance varies considerably across crops. Mustard seed exports have shown strong growth and maintained a positive trade balance during the last decade. Countries such as Malaysia, Nepal, and the UAE have emerged as stable and high-retention markets, indicating sustained international demand for Indian mustard seed (Tiyndel et al., 2025).

In contrast, soybean exports have declined, resulting in a negative trade balance despite India's large production base. Intense competition from major global exporters such as the United States and Brazil has eroded India's market share in international soybean trade (Sharma & Deshmukh, 2024). These contrasting trends highlight the need for **crop-specific export strategies** rather than uniform trade policies.

Price Volatility and Market Uncertainty

Price volatility remains one of the most critical challenges confronting the oilseed sector. Trade liberalization and increased integration with global markets have transmitted international price fluctuations into domestic markets, particularly for rapeseed and mustard (Bhati & Kumar, 2020). High and unpredictable price movements discourage investment by small and marginal farmers, who dominate oilseed cultivation in India.

Evidence from commodity market studies shows that futures markets, while essential for price discovery, can sometimes amplify spot price volatility when speculative activity is poorly regulated (Malhotra & Sharma, 2016). Macroeconomic variables such as inflation, GDP growth, and industrial demand further influence oilseed price dynamics, complicating farmers' production decisions (Joarder, 2018).

Import Dependence and Policy Constraints

India's dependence on edible oil imports has increased due to rapid growth in consumption, changing dietary patterns, and relatively cheaper international prices. While domestic oilseed demand has grown at around 6 per cent annually, production growth has remained close to 2 per cent, widening the demand-supply gap (Bhati & Kumar, 2020).

Policy simulations indicate that fixed high tariffs are ineffective in stabilizing domestic prices. Instead, flexible policy instruments such as variable tariffs and adaptive trade measures are more effective in protecting farmers and consumers from extreme international price volatility without imposing excessive fiscal costs (Srinivasan, 2004).

Pathways for Strengthening the Oilseed Sector

The literature consistently emphasizes that resolving India's oilseed paradox requires a multi-pronged approach:

1. Productivity enhancement through improved seed technology, irrigation support, and extension services (Sharma & Deshmukh, 2024).

2. Price stabilization mechanisms combining MSP, calibrated trade policy, and regulated futures markets (Malhotra & Sharma, 2016).

3. Export diversification, focusing on crops and destinations with high retention capacity, such as mustard seed exports to Southeast Asia (Tiyndel et al., 2025).

4. Balanced trade policies that reduce excessive import dependence while maintaining consumer welfare (Srinivasan, 2004).

Conclusion

India's oilseed sector stands at a critical juncture. The country possesses substantial production capacity, yet structural weaknesses in productivity, price stability, and trade competitiveness continue to limit its potential. Addressing these challenges holistically can transform oilseeds into a driver of farmer income growth, nutritional security, and sustainable agricultural exports. With informed policy design and targeted investments, India can turn its oilseed paradox into a long-term opportunity for agricultural transformation.

References

1. Bhati, M., & Kumar, R. (2020). Price volatility of oilseeds under trade liberalization in India: Analysis of rapeseed and mustard. *International Economic Studies*, 50(1), 29–40.
2. Joarder, S. (2018). The commodity futures volatility and macroeconomic fundamentals: The case of oil and oilseed commodities in India. *International Econometric Review*.
3. Malhotra, M., & Sharma, D. K. (2016). Volatility dynamics in oil and oilseeds spot and futures markets in India. *Vikalpa*, 41(2), 132–148.
4. Sharma, H. J., & Deshmukh, M. S. (2024). Trade dynamics and global competitiveness of India's oilseeds sector. *European Economic Letters*, 14(3).
5. Srinivasan, P. V. (2004). Managing price volatility in an open economy environment: The case of edible oils and oilseeds in India. IFPRI Discussion Paper No. 69.
6. Tiyndel, G. J., Bhatia, J. K., Bishnoi, D. K., Malik, D. P., Bhardwaj, N., Godara, A. K., & Kumar, A. (2025). Export ecosystem of oilseeds in India: Performance, competitiveness, and future projections of oilseed demand. *Indian Journal of Economic Development*, 21(4), 675–684.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Comparative Performance of Area, Production and Productivity of Major Crops in India and Telangana (2024-25)

Article ID: 72838

D.A. Rajini Devi[1], B. Mohan Uday Raj[2], K. Divya[3]
[1]Professor Jayashankar Telangana Agricultural University (PJTAU), Hyderabad, Telangana.

Introduction

Area, production and productivity (APY) indicators are fundamental for understanding the performance and structural changes in Indian agriculture. While expansion of cultivated area contributed significantly to growth in the early decades, recent agricultural development has increasingly depended on productivity enhancement. In this context, state-level analysis is crucial, as regional heterogeneity largely determines national outcomes. Telangana has emerged as an important contributor to India's agricultural output after its formation, particularly in cereals, pulses, oilseeds and cotton.

Area Under Major Crops: India vs Telangana (in Thousand Hectares)

Table 1 presents the distribution of cropped area across major crops in India and Telangana. Rice occupies a prominent position, with Telangana accounting for 9.38 per cent of India's rice area and ranking third nationally. Cotton is another notable crop, where Telangana contributes 15.78 per cent of the national area, again ranking third, highlighting the state's specialization in fibre crops.

In contrast, Telangana's share in pulses such as gram, moong and urad remains relatively small, reflecting agro-climatic constraints and historical cropping patterns. Earlier studies have documented a gradual decline or stagnation in area under food grains at the national level, alongside diversification towards commercial and high-value crops (Chand & Parappurathu, 2019; Reddy, 2021). Telangana's area pattern broadly aligns with these national trends, with stronger emphasis on rice, cotton and selected oilseeds.

Table 1. Area under Major Crops in India and Telangana (2024-25) (in Thousand hectares):

Crop	India	Telangana	% share of area of Telangana in India	Rank of Telangana
Rice	51266.63	4809.45	9.38	3
Maize	12091.45	578.84	4.79	7
Jowar	3995.43	167.28	4.19	6
Tur	4335.7	215.38	4.97	5
Gram	9122.11	69.76	0.76	11
Urad	3157.1	29.58	0.94	14
Moong	5898.7	33.52	0.57	13
Groundnut	5761.76	104.52	1.81	9
Sesamum	1575.77	12.99	0.82	12
Soybean	12951.96	154.29	1.19	6
Sunflower	194.45	8.62	4.43	5
Safflower	64.36	2.44	3.79	3
Sugarcane	5449.93	20.59	0.38	14
Cotton	11483.62	1812.31	15.78	3

Source: Authors calculation from information at DA & FW, 2024-25.

Production Performance: Contribution of Telangana Production in Thousand Tonnes(in Thousand Tonnes)

Production trends reveal Telangana's increasing importance in India's agricultural output (Table 2). The state contributes 11.62 per cent of India's rice production and ranks second, indicating that productivity gains supplement area expansion. In cotton, Telangana accounts for nearly 19.5 per cent of national production, underscoring its role as a major cotton-producing state.

For maize and jowar, Telangana's production share exceeds its area share, implying superior yield performance. Similar patterns have been reported by Birthal et al. (2020), who emphasized that yield improvements, rather than area expansion, have driven output growth in several states. Telangana's experience supports this argument.

Table 2. Production under Major Crops in India and Telangana (2024-25) (in Thousand Tonnes):

Crop	India	Telangana	% share of Telangana in India	Rank of Telangana
Rice	150184.26	17445.68	11.62	2

Maize	43408.98	3392.11	7.81	5
Jowar	4954.65	384.86	7.77	6
Tur	3623.87	201.16	5.55	4
Gram	11114.49	122.92	1.11	10
Urad	2242.28	43.26	1.93	13
Moong	4243.98	23.62	0.56	15
Groundnut	11941.73	220.07	1.84	10
Sesamum	893.35	8.26	0.92	11
Soybean	15268.33	290.68	1.9	6
Sunflower	236.11	14.07	5.96	4
Safflower	43.27	3.21	7.42	3
Sugarcane	454610.97	1916.19	0.42	12
Cotton	29724.18	5788.73	19.47	3

Source: Authors calculation from information at DA & FW, 2024-25.

Productivity Advantage of Telangana (in Kg/Ha)

Productivity is the most striking dimension of Telangana's agricultural performance (Table 3). The table presents a comparative analysis of crop productivity (kg/ha) for major crops in India and Telangana, along with absolute and percentage differences and national ranking of Telangana. The results reveal significant inter-state productivity heterogeneity, reflecting differences in agro-climatic conditions, irrigation access, technology adoption, and institutional support.

Cereals: Strong Productivity Advantage for Telangana

Rice productivity in Telangana (3627 kg/ha) is 19% higher than the national average (2929 kg/ha), placing the state 4th nationally. This superior performance can be attributed to:

1. Expansion of assured irrigation through major projects,
2. Higher adoption of HYVs and mechanization,
3. Improved input availability.

Earlier studies have shown that irrigated rice systems in southern India exhibit significantly higher yields compared to rainfed regions (Birthal et al., 2020; Reddy, 2021).

Maize and Jowar show even stronger gains. Telangana's maize productivity is 39% higher, while jowar productivity is 46% higher than the national average, ranking Telangana 4th and 2nd, respectively. These gains align with findings that maize and sorghum respond strongly to improved hybrids and better crop management under semi-arid conditions (Joshi et al., 2021).

Pulses: Selective Yield Gains with Crop-specific Variability

Productivity gains in pulses are crop-specific:

1. Urad productivity in Telangana is 51% higher than the national average, placing the state 1st in India.
2. Gram productivity is 31% higher, ranking Telangana 2nd nationally.
3. Tur shows only a modest 10% advantage, while moong productivity is marginally lower (-2%) than the national average.

This pattern reflects differential varietal response and sensitivity of pulses to rainfall variability.

Oilseeds: Telangana as a High-Productivity State

Telangana exhibits a clear productivity edge in several oilseeds:

1. Soybean productivity is 37% higher than the national average, with Telangana ranked 1st.
2. Safflower productivity is 49% higher, also ranking 1st.
3. Sunflower productivity is 26% higher.

These results corroborate earlier evidence that oilseeds in semi-arid regions respond well to improved agronomy and varietal development when supported by irrigation and extension services (Chand & Parappurathu, 2019).

Commercial Crops: Yield Gains but Inter-State Competition

Sugarcane productivity in Telangana (93,064 kg/ha) exceeds the national average by 10%, ranking 3rd, though it remains below top-performing states like Tamil Nadu and Maharashtra. This reflects the capital- and water-intensive nature of sugarcane cultivation.

Cotton productivity is 19% higher than the national average, ranking 5th. Telangana's performance reflects widespread adoption of Bt cotton and better pest management, consistent with findings by Birthal et al. (2020).

Across crops, Telangana demonstrates a systematic productivity advantage over the national average, particularly in:
1. Cereals (maize, jowar),
2. Pulses (urad, gram),
3. Oilseeds (soybean, safflower).

The few exceptions (moong, marginal gains in groundnut) highlight the continuing influence of climatic variability and crop-specific constraints.

The results strongly support the argument that productivity-led agricultural growth, rather than area expansion, is the dominant pathway for Telangana's agricultural development.

Table 3. Productivity of Major Crops in India and Telangana (2024-25) (in Kg/Ha):

Crop	India	Telangana	Absolute change	% change	Rank of Telangana
Rice	2929	3627	698	19	4
Maize	3590	5860	2270	39	4
Jowar	1240	2301	1061	46	2
Tur	836	934	98	10	12
Gram	1218	1762	544	31	2
Urad	710	1462	752	51	1
Moong	719	705	-14	-2	12
Groundnut	2073	2106	33	2	5
Sesamum	567	636	69	11	7
Soybean	1179	1884	705	37	1
Sunflower	1214	1632	418	26	5
Safflower	672	1316	644	49	1
Sugarcane	83416	93064	9648	10	3
Cotton	440	543	103	19	5

Source: Authors calculation from information at DA & FW, 2024-25.

Policy Implications

The comparative APY analysis highlights that:
1. Productivity enhancement is the primary source of agricultural growth in Telangana.
2. Continued support in seed systems, extension services and price mechanism is essential.

Conclusion

The 2024-25 APY data clearly demonstrate that Telangana has emerged as a high-performing agricultural state in productivity terms, contributing to national production of key crops such as rice and cotton. While area expansion remains limited, yield improvements have driven output growth. These findings reinforce the need for productivity-focused, state-specific agricultural strategies to ensure sustainable growth and farmer income stability.

References

1. Birthal, P. S., Khan, T., Negi, D. S., & Agarwal, S. (2020). Impact of climate change on yields of major food crops in India. *Agricultural Economics Research Review*, 33(2), 151–160.
2. Chand, R., & Parappurathu, S. (2019). Historical and spatial trends in agricultural growth in India. *Indian Journal of Agricultural Economics*, 74(1), 1–17.
3. Joshi, P. K., Gulati, A., Birthal, P. S., & Tewari, L. (2004). *Agriculture diversification in South Asia: Patterns, determinants and policy implications. Economic and Political Weekly*, 39(24), 2457–2467.
4. Reddy, A. A. (2021). State-specific pathways for agricultural growth in India. *Indian Journal of Agricultural Economics*, 76(4), 495–509.
5. Chand, R., & Parappurathu, S. (2019). Historical and spatial trends in agricultural growth in India. *Indian Journal of Agricultural Economics*, 74(1), 1–17.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Role of Robotics in Dairy and Food Industry

Article ID: 72839

Dhruvin Patel[1], PS Minz[2]
[1]M. Tech (Dairy Engineering), ICAR-NDRI, Karnal, India.
[2]Principal Scientist, Dairy Engineering Division, ICAR-NDRI, Karnal, India.

Introduction

The agriculture, dairy and food processing sectors are undergoing rapid transformation due to the adoption of robotics and automation technologies. Increasing demand for safe and high-quality food, rising labor costs and shortage of skilled manpower have accelerated the use of robotic systems in food industries (Bechar and Vigneault, 2016). Robotics ensures precision, hygiene and operational efficiency, making it a vital component of modern food processing.

Applications of Robotics in Dairy and Food Industry

Robotics has found wide-ranging applications across different stages of dairy and food processing, from raw material handling to final product packaging. One of the most common uses of robots in food industries is in picking and placing operations. Vision-guided robotic arms equipped with grippers or suction cups are used to pick delicate food items such as fruits, vegetables, bakery products and confectionery items without causing physical damage. These robots ensure uniform handling speed and accuracy, which is difficult to achieve through manual labor (Kamble et al., 2020).

In dairy processing plants, robots are increasingly employed for handling milk crates, cheese blocks, butter cartons and pouch milk. Robotic arms transfer filled containers from production lines to secondary packaging units, minimizing human contact and reducing the risk of microbial contamination. In cheese and paneer plants, cutting and portioning robots ensure uniform size and weight, thereby improving product consistency and reducing material losses (Bogue, 2016).

Palletizing and depalletizing robots are widely adopted in large-scale food and dairy industries. These robots automatically stack cartons, sacks and crates on pallets in a systematic manner, improving warehouse efficiency and logistics management. Automated palletizing not only increases throughput but also reduces physical strain and occupational injuries among workers. In dairy plants handling high volumes of packaged milk, milk powder and ghee tins, palletizing robots enable continuous operation with minimal downtime (Bechar and Vigneault, 2016).

Robotics also plays a vital role in quality inspection and sorting operations. Vision-based robotic systems integrated with sensors and cameras are used to detect defects such as cracks, improper sealing, color variation and contamination in packaged food products. In fruit and vegetable processing units, robots sort produce based on size, color and shape, ensuring standardized quality for consumers. Such automated inspection systems help reduce wastage and improve compliance with food safety regulations (Mahalik and Nambiar, 2010).

In the primary dairy sector, robotic milking systems have revolutionized modern dairy farming. Automated milking robots allow cows to be milked voluntarily, reducing animal stress and improving milk yield. These systems continuously monitor milk quality parameters such as fat content, somatic cell count and temperature, while also tracking animal health indicators. The data generated supports precision dairy farming and improves farm-level decision-making (Jacobs and Siegford, 2012).

Additionally, robotics is being applied in cleaning and sanitation processes within food industries. Robotic cleaning systems integrated with Cleaning-in-Place (CIP) technology ensure effective and consistent cleaning of processing equipment, pipelines and storage tanks. Automated sanitation improves hygiene standards, reduces water and chemical consumption and enhances overall plant efficiency.

Overall, the integration of robotics across multiple stages of dairy and food processing improves productivity, ensures product safety and supports sustainable industrial practices.

Role of Robotics in Food Quality and Safety

Robotics plays a vital role in ensuring consistent food quality and safety in dairy and food industries. Vision-guided robotic systems equipped with cameras and sensors are widely used to inspect products for defects such as improper sealing, leakage, color variation, labeling errors and foreign matter. These automated inspections help prevent substandard products from reaching consumers and reduce product wastage, while ensuring compliance with food safety standards (Mahalik and Nambiar, 2010; Bogue, 2016).

In dairy processing plants, robotic systems minimize direct human contact during processing and packaging, thereby reducing the risk of microbial contamination. Automated robots are used to check filling accuracy and packaging integrity of milk pouches, bottles and cartons. Robotics is also applied in sanitation through automated cleaning and Cleaning-in-

Place (CIP) systems, which ensure effective, repeatable cleaning of pipelines and processing equipment, improving hygiene and optimizing the use of water and chemicals (Brennan et al., 2018; Madsen et al., 2019).

Robotics further strengthens food safety management through improved traceability and digital monitoring. Integration of robotic systems with data acquisition and monitoring tools enables continuous recording of processing, inspection and sanitation parameters. Such data-driven approaches support HACCP implementation, regulatory compliance and rapid decision-making, ultimately enhancing consumer confidence and ensuring safe, high-quality food products across the supply chain (Van der Vorst et al., 2009).

Challenges and Future Prospects

Despite its advantages, the adoption of robotics in food industries faces challenges such as high initial investment, requirement of technical expertise and difficulties in integrating robots with existing infrastructure (Kamble et al., 2020). Future developments in artificial intelligence and Industry 4.0 are expected to improve affordability, flexibility and adoption of robotics in agriculture and food processing (Bechar and Vigneault, 2016).

Conclusion

Robotics has become a key driver of modernization in the dairy and food industry by enhancing operational efficiency, ensuring product safety and reducing dependency on manual labor. The use of robotic systems in material handling, picking, palletizing, quality inspection and dairy farming has significantly improved productivity while maintaining high hygiene standards. These technologies help address major challenges such as labor shortages, workplace safety and consistency in product quality.

Although high initial investment and technical requirements remain barriers, continuous advancements in artificial intelligence, sensor technologies and Industry 4.0 frameworks are making robotic solutions more accessible and adaptable. The integration of robotics with digital monitoring and data-driven decision-making supports sustainable and traceable food production systems. Overall, the adoption of robotics in agriculture and food processing industries holds strong potential to improve efficiency, competitiveness and food security, while contributing to long-term sustainability of the sector.

References

1. Bechar, A. and Vigneault, C., 2016. Agricultural robots for field operations: Concepts and components. *Biosystems Engineering*, 149, pp.94–111.
2. Bogue, R., 2016. Robots in the food industry: A review. *Industrial Robot: An International Journal*, 43(1), pp.6–14.
3. Brennan, L., Ferdowsi, B. and Yusoff, R., 2018. Automation and robotics in food manufacturing: Trends, challenges and opportunities. *Trends in Food Science & Technology*, 81, pp.1–13.
4. Daberkow, S.G. and McBride, W.D., 2003. Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies. *American Journal of Agricultural Economics*, 85(3), pp.657–668.
5. Jacobs, J.A. and Siegford, J.M., 2012. Invited review: The impact of automatic milking systems on dairy cow management, behavior, health and welfare. *Journal of Dairy Science*, 95(5), pp.2227–2247.
6. Kamble, S.S., Gunasekaran, A. and Gawankar, S.A., 2020. Sustainable Industry 4.0 framework: A systematic literature review. *Journal of Cleaner Production*, 258, 120776.
7. Kutzbach, H.D., 2000. Trends in power and machinery for agriculture. *Agricultural Engineering International: CIGR Journal*, 2, pp.1–17.
8. Madsen, S.M., Mathiassen, S.E. and Hansen, A., 2019. Automation in food processing and its impact on work environment and productivity. *Food Control*, 98, pp.162–170.
9. Mahalik, N.P. and Nambiar, A.N., 2010. Trends in food packaging and manufacturing systems and technology. *Trends in Food Science & Technology*, 21(3), pp.117–128.
10. Pedersen, S.M., Fountas, S. and Sørensen, C.G., 2006. Economic and environmental analysis of precision farming technologies. *Computers and Electronics in Agriculture*, 52(1–2), pp.1–16.
11. Shah, D. and Patel, K., 2021. Applications of robotics and automation in dairy processing industries. *Indian Journal of Dairy Science*, 74(4), pp.321–328.
12. Van der Vorst, J.G.A.J., Tromp, S.O. and van der Zee, D.J., 2009. Simulation modelling for food supply chain redesign; integrated decision making on product quality, sustainability and logistics. *International Journal of Production Economics*, 121(1), pp.161–174.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

RNA Based Biopesticides in Plant Disease Management: An Emerging Approach

Article ID: 72840

Kavita Kushwaha[1], Saransh Kumar Gautam[2]

[1]Department of Plant Pathology, Rani Lakshmi Bai Central Agricultural University, Jhansi- 280003, Uttar Pradesh.

[2]Department of Silviculture and Agroforestry, Rani Lakshmi Bai Central Agricultural University, Jhansi-280003, Uttar Pradesh.

Abstract

Sustainable agriculture places a strong emphasis on ecologically friendly and efficient strategies. RNA interference (RNAi), a natural mechanism in eukaryotes that reduces transcript production in a sequence-specific way, can be used to control plant diseases and pests. Topical application of dsRNA molecules triggering RNAi has been demonstrated to provide protection without necessitating transgene integration of dsRNA-expressing constructs. Although the expression of transgenes causing pathogen-specific RNA interference (RNAi) has been shown to be effective against several significant pathogens and insect pests, genetic modification (GM) of crops is still controversial in many countries. The development of RNAi-nanoparticle carrier spray compositions, the precise targeting of critical pathogen genes, and potential structural alterations to the RNA molecules themselves are all vital to the success of this novel approach. RNA-based biopesticides are thereby becoming a more accurate and focused substitute for conventional pesticides, providing species-specific control with less harm to the ecosystem.

Keywords: RNAi, SIGS, biopesticide, dsRNA.

Introduction

In recent decades, RNA interference (RNAi), a potent gene-silencing process conserved in eukaryotes, has received extensive attention due to its potential role as a tool for plant research, especially in terms of understanding the effects of gene regulation in response to abiotic and biotic stress. Scientists have exploited the intrinsic ability of the plant RNAi involving the sequence-specific silencing machinery to target desired pathogenic genes.

RNAi-based transgenic approaches have enabled plants to produce specific dsRNAs that induce RNAi-mediated gene silencing in target organisms upon ingestion of plant material, a technique known as Host-Induced Gene Silencing (HIGS). One notable example is the transgenic corn *Zea mays* variety SmartStax Pro, developed to target the corn rootworm (*Diabrotica virgifera*). This variety has been approved for commercial use by the U.S. Environmental Protection Agency, the U.S. Food and Drug Administration, and the U.S. Department of Agriculture.

However, the stable expression of fungal-specific dsRNAs in plants through transgenic approaches presents technical and time constraints. Moreover, limited public acceptance of genetically modified (GM) crops has hindered the large-scale adoption of HIGS.

To address these challenges, a transgene-free strategy known as Spray-Induced Gene Silencing (SIGS) was developed. This method involves the topical application of dsRNA or siRNA directly to plant tissues as a biopesticide. Since specific regulatory guidelines for dsRNA-based products are not yet established, they currently fall under the same regulatory framework as traditional synthetic pesticides and plant protection products. (PPPs).

RNAi: Functional Basis of RNA Biopesticides

Eukaryotes have two primary RNAi pathways: the microRNA (miRNA) pathway and the short interfering RNA (siRNA) pathway. In the miRNA pathway, endogenous MIR genes are transcribed into imperfectly duplexed stem-loop hairpin RNAs, which are processed by Dicer endonucleases into 21-nt miRNAs. These miRNAs target mRNAs for cleavage or translational repression through sequence complementarity [3]. In the siRNA pathway, perfectly duplexed dsRNA is cleaved by Dicer endonucleases into 21-24-nt siRNAs. These siRNAs mediate mRNA cleavage, induce translational inhibition, and can also trigger epigenetic modifications, such as DNA methylation and histone methylation.

The cellular mechanism of dsRNA-induced RNAi in plants involves several key steps:

1. Upon cellular uptake of dsRNAs, DICER-LIKE (DCL) endonucleases quickly cleave them into 20 to 25-nucleotide siRNAs with 2-nt 3' overhangs at both ends.

2. One strand of the siRNAs is incorporated into an ARGONAUTE (AGO) protein, forming an RNA-induced silencing complex (RISC).

3. The siRNA molecules guide the RISC to the cytoplasm, where it scans for and recognizes complementary transcripts, leading to their cleavage or degradation and resulting in post-transcriptional gene silencing (PTGS).

Formulation of RNA Biopesticides

1. Selection of target gene: Instead of identifying an essential gene the approach should rather be to identify which gene's knockdown would result in rapid lethality even at low doses of dsRNA. Commonly targeted regions may involve the genes for beta-tubulin protein and sterol biosynthesis inhibitors which can be an alternative to chemical fungicides such as benzimidazoles and azoles respectively.

2. Production of dsRNA: dsRNA for its corresponding target gene can be produced either by *in vitro* or *in vivo* transcription methods. Under *in vitro* transcription, oppositely oriented promoters are (e.g., T7) flanked by the target gene, producing sense and antisense transcripts that form highly pure dsRNA, though the process is expensive (e.g., €200/g). In *in vivo* transcription, the target gene is cloned into a plasmid (e.g., L4440) with similar promoters and transformed into microorganisms (e.g., *Escherichia coli* HT115 DE3). Induction generates dsRNA at a lower cost but with lower purity.

3. Application:

a. Mode: One of the simplest techniques is the low-pressure (1–2 bar) foliar pressure spraying. Even though, the dsRNA primarily stays on the leaf surface and is accessible to chewing insects, it is quickly degraded or washed off. Other mode involves biolistic guns, mechanical inoculation by cotton swabbing or hand rubbing, agroinfiltration, trunk injection for hard wood plants, petiole absorption, soil and root drenching, root and seed soaking (Figure 1). Additionally, microbes such as bacteria, virus, mycorrhiza and even endophytes can be transformed to produce endogenous dsRNA. These transformed microbes are further used for dsRNA delivery inside plants.

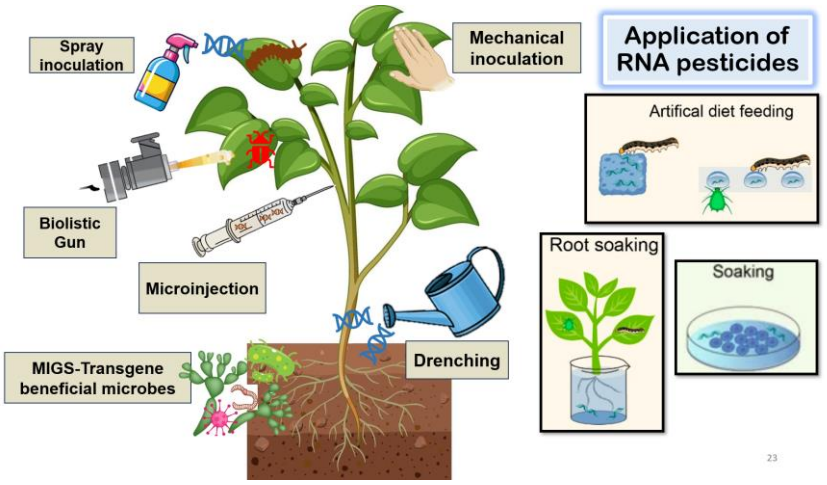


Figure1: Modes of application of dsRNA biopesticides (Source: Biorender)

b. Dose: It is estimated that about 2 to 10 grams of dsRNAs are needed per hectare of arable land. This amount can vary depending on factors such as the sensitivity of the target species to RNAi, the capacity for systemic silencing, the application method, and the delivery techniques used.

c. RNA Carriers: The limited cellular absorption and rapid rate of disintegration of dsRNA insecticides provide a significant obstacle to their efficacy. Different formulations can be employed to address deterioration brought on by internal causes including the action of nucleases in the insect's salivary glands, midgut, and haemolymph, as well as external effects like UV radiation, wash-off, and microbial activity. Nano carriers are particularly effective in overcoming these issues, improving the half-life of dsRNA and its uptake by plants. Common nano carriers include carbon and gold nanoparticles, minicells, quantum dots, star-polycations, and layered double hydroxides (LDH). Carrier formulations need to be non-toxic, biodegradable, and reasonably priced. These requirements are satisfied by LDH nanosheets, which have been demonstrated increased biocontrol potential of exogenously applied dsRNAs against plant viruses, insect pests, and fungal pathogens. LDH when complexed with dsRNA in a formulation is known as BioClay™

Factors Affecting the Efficiency of Biopesticides

The efficiency of the RNA biopesticide is correlated to the efficient uptake of dsRNA by the plant and successful assimilation into the target pathogen to direct the silencing of essential genes.

1. Target gene selected: The effectiveness of RNAi varies considerably between species, genotypes, and tissues of the same species, as well as across different regions for the same transcript. This variability is likely due to the fact that gene silencing efficiency does not always directly correlate with the degree of pathogen growth inhibition.

2. Length and concentration of dsRNA: Recent research has shown that small to medium-sized dsRNAs (21-60 bp) administered topically to plant cells require 2 bp 3' overhangs for strong silencing activity. Too long or too short transcript may lead to improper identification and cleavage by DICER enzyme.

3. Mode of application: The absorption capacities of dsRNA in different plant organs, such as leaves, petioles, buds, roots, stems, and seeds, can influence the effectiveness of exogenous dsRNA treatments. A study comparing various dsRNA delivery methods—such as high-pressure spraying on leaves, petiole absorption, and postharvest spraying—found that the reduction in *Botrytis cinerea* disease symptoms in grapevine varied depending on the application method [5].

4. Delivery strategy used: The effectiveness of RNAi depends on the accessibility of dsRNA/siRNA at the site of the target pathogen, which is influenced by the delivery method. Comparisons between SIGS and HIGS delivery modes have shown that SIGS is more effective in silencing target gene expression than HIGS owing to the immediate exposure of the target against dsRNA. The persistence and stability of the applied RNA on plant surfaces are crucial and may be influenced by factors such as the tissue's 'wettability.' Higher wettability has been shown to improve RNA uptake. Additionally, the structure and composition of the cuticle and wax layers, along with the density and aperture of stomata, also affect RNA absorption.

Fate of dsRNA Inside Plant

Studies on plant-pathogen interactions have revealed complex bidirectional communication mediated by RNA molecules. Host plant-derived dsRNA can be transferred to pathogens, triggering RNAi and reducing their virulence, while pathogen-derived dsRNA can enter host cells, hijack the RNAi process, and suppress host immunity. This interaction is largely mediated by extracellular vesicles. The fate of dsRNAs in plants may also involve mechanisms such as symplastic and apoplastic movement, local and systemic silencing, as well as DNA methylation and histone modifications.

Commercialized dsRNA Product

The registration of Ledprona (trade name CalanthatM) as a plant protection product against Colorado potato beetles, targeting the beetle proteasome beta type-5 subunit (PsMB5), in the USA on December 22, 2023, is indeed a landmark event for RNAi-based pest management research. Ledprona's success is the product of more than 20 years of intense international research. This accomplishment highlights the substantial scientific effort needed to commercialize RNAi-based pest control products.

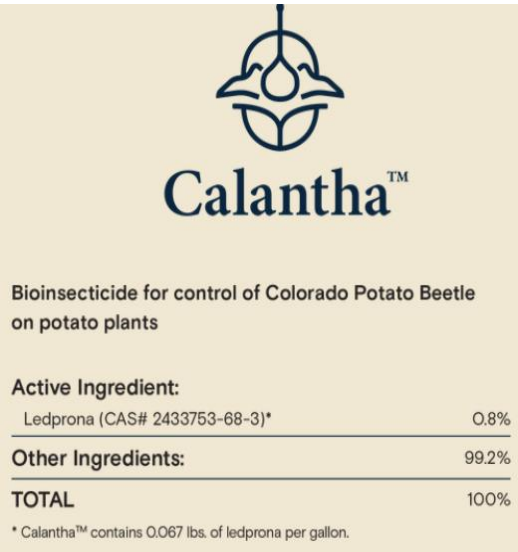


Figure 2: First sprayable dsRNA product to be commercialized- Calantha targeting Colorado potato beetle (*Leptinotarsa decemlineata*)

Conclusion

RNAi-based crop protection methods, such as HIGS and SIGS, offer eco-friendly alternatives to chemical fungicides, providing high specificity and non-toxicity due to the widespread presence of RNAi in eukaryotes and the regular consumption of RNA by humans in fresh fruits and vegetables. However, the widespread adoption of dsRNA as a crop protection strategy has been hindered by high production costs. In 2008, the cost of dsRNA synthesis was around USD 10,000 per gram. Thankfully, advances in technology have significantly reduced these costs. In vitro dsRNA synthesis now costs approximately USD 100 per gram, while microbial and cell-free production have reduced costs to about USD 2 and under USD 1 per gram, respectively. With an estimated 10 g/ha required for field applications, the cost of dsRNA sprays is now comparable to traditional fungicide use.

References

1. Darlington, M., Reinders, J.D., Sethi, A., Lu, A.L., Ramaseshadri, P., Fischer, J.R., et al. 2022. RNAi for western corn rootworm management: Lessons learned, challenges, and future directions. *Insects*, 13: p.57.

2. EC.2009. Regulation (EC) No. 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. Off. J. Eur. Union L 309, 1–50.
3. Dalakouras, A., Koidou, V. and Papadopoulou, K. 2024. DsRNA-based pesticides: Considerations for efficiency and risk assessment. *Chemosphere*, p.141530.
4. Das, P.R. and Sherif, S.M. 2020. Application of exogenous dsRNAs-induced RNAi in agriculture: challenges and triumphs. Front. Plant Sci. 11: p.946.
5. Nerva, L., Sandrini, M., Gambino, G. and Chitarra, W. 2020. Double-stranded RNAs (dsRNAs) as a sustainable tool against gray mold (Botrytis cinerea) in grapevine: Effectiveness of different application methods in an open-air environment. *Biomolecule* 10: p.200.
6. Rodrigues, T.B., Mishra, S.K., Sridharan, K., Barnes, E.R., Alyokhin, A., Tuttle, R. et al. 2021. First sprayable double-stranded RNA-based biopesticide product targets proteasome subunit beta type-5 in Colorado potato beetle (*Leptinotarsa decemlineata*). Front. Plant Sci. , 12: p.728652.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Bacillus-Based Biocontrol: A Pathway to Sustainable Crop Protection

Article ID: 72841

Prabhu Narayan Meena[1]

[1]Present address; ICAR- National Research Institute for Integrated Pest Management, Rajpur Khurd, New Delhi-110068, India.

Introduction

The utilization of chemicals to control diseases in economically essential crops has been practised for a long time and is preferred by the farmers due to its low cost and immediate effect. But their associated adverse effects on human life and other living microorganisms and ability to enter the food chain through the accumulation of toxic residues had encouraged the hunt for more sustainable alternatives. In this context, integrated diseases management with antagonistic microorganism play potent role to mitigate these problems. Moreover, research is also focused towards eco-friendly management of plant pathogens by employing of antagonists for improving of crop production within an integrated crop management system. Among the antagonistic, *Bacillus* species have potential to suppress the plant pathogen by antagonism and competition (Mnif *et al*., 2015). *Bacillus* spp. inhibits the growth of different pathogens by involving various mechanism such as production of antibiotics, production of siderophores, releasing of hydrolytic enzyme, inducing of systemic resistance and competition for nutrient and space (Beneduzi *et al*., 2012). Apart from, *Bacillus* spp. also acts as biofertilizers or biostimulators, either by facilitating the uptake of certain nutrients from the environment (nitrogen fixation, phosphate solubilisation), or by providing the plant with a compound (biosynthesis of plant hormones) (Borriss *et al*., 2011). Hence, with the present facts, it is presumed that *Bacillus* spp. represents an alternative to synthetic pesticides, agrochemicals and other chemical fertilizers. The beneficial effect of *Bacillus* spp. on plant growth and yield have been demonstrated in several agricultural crops including wheat, maize, common bean, potato, soybean, sunflower, tomato, pepper, cucumber, and many others (Aloo *et al*., 2019).

Present Scenario of Bio-Pesticides

In India, bio-pesticide consumption accounts for about 12.4% of overall pesticide consumption. Bio pesticides are very less used in previous years but their use has suddenly surged from last few years. Consumption of neem, has increased from 83 MT to 686 MT, while *Bacillus thuringiensis* (Bt) climbed from 40 to 71MT. According to DPPQS data, the overall consumption of biopesticides in India increased by 40% from 2014-2015 to 2018-2019 GOI (2020). Similarly, according to Union Ministry of Agriculture, between 2010-2011 and 2016-2017, the all-India consumption of bio-pesticides increased from 5151 to 7816.40 MT, while chemical pesticides decreased from 55,540 to 55235.8 MT. There are currently 970 bio-pesticide products registered with the Central Insecticides Board and Registration Committee (CIBRC) Tripathi et al. (2020). Bacterial, fungal, viral, and other (plant-based, pheromones) biopesticides account for 29, 66, 4, and 1 percent of total bio-pesticide production, respectively Mishra et al. (2020). The main bio-pesticides manufactured and used in India are neem-based insecticides, *Bacillus thuringensis*, NPV, and Trichoderma. Trichoderma, Pseudomonas, and NPV-H are the most often used bio-pesticides in 2019-20. Among the bio-pesticides *Trichoderma viride* account 26%, *Pseudomonas fluorescence* 18% and *Bacillus* spp. used only 4%. *Trichoderma asperellum* is utilised against 87 different crops, 70 soil-borne diseases, and 18 foliar diseases, respectively. Although, Bacillus is very less use compared to other antagonist but now days, it might be used in various cereal, pulses, oilseed and horticulture crops as endophytes. Due to indiscriminate use and ill health effect of chemical pesticides, farmers divert towards to bio-pesticides. Moreover, bio-pesticide is the only technology that can be used to control the widespread resistance of chemical pesticides to pest insects in a safe, cost-effective, and environmentally beneficial manner.

Use of Bacillus Against Different Pathogens and Crops

Bacillus has been used against different pathogens in different crops due to their antibiotic, lytic enzyme, siderophores and systemic acquired resistance (SAR) mechanism. Bacillus also enhanced plant growth through PGPR activities and help in N_2 fixation, P-solubilisation and in synthesis of different hormones.

Targeted pathogens by Bacillus bacteria			
Name of bacteria	**Target of pathogen**	**Plant disease**	**Reference**
Bacillus subtilis	***Fusarium* spp.**	**Clove rot of garlic**	**Bjeli´c *et al*., 2018**
Bacillus subtilis	***Fusarium graminearum***	**Head blight of wheat**	**Zalila-Kolsi *et al*., 2016**
Bacillus subtilis	***Pythium ultimum***	**Damping off of bean**	**Ongena *et al*., 2005**
Bacillus subtilis	***Gaeumannomyces graminis var.tritici***	**Take-all of wheat**	**Yang *et al*., 2018**

Bacillus subtilis	*Rhizoctonia solani*	Stem canker and black scurf of potato	Saber *et al.*, 2015
Bacillus amyloliquefaciens	*Fusarium oxysporum* f. sp. *lycopersici*	Wilt of tomato	Guleria, *et al.*, 2016
Bacillus amyloliquefaciens	*Clavibacter michiganensis*	Bacterial canker of tomato	Gautam *et al.*, 2019
Bacillus sp.	*Fusarium verticillioides*	Stalk and ear rot of maize	Douriet-Gámez *et al.*, 2018
Bacillus subtilis	*Bipolaris sorokiniana*	Spot blotch of wheat	Villa-Rodríguez *et al.*, 2019
Bacillus licheniformis	*Magnaporthe grisea*	Blast disease of rice	Rais, *et al.*, 2017
Bacillus subtilis	*Fusarium oxysporum* f.sp. *capsici*	Wilt of pepper	Yu *et al.*, 2011
Bacillus subtilis	*Rhizoctonia solani*	Sheath blight of rice	Spaepen *et al.*, 2007
Bacillus amyloliquefaciens	*Tomato spotted wilt virus*, *Potato virus Y*	Wilt disease of tomato	Beris *et al.*, 2018
Bacillus subtilis	*Alternaria solani*, *Phytophthora infestans*	Early and late blight of tomato	Chowdappa *et al.*, 2013
Bacillus sp.	*Colletotrichum capsica*	Anthracnose of chili	Jayapala *et al.*, 2019
Bacillus subtilis	*Fusarium oxysporum* f. sp. *cucumerinum*	Root rot of cucumber	Chen *et al.*, 2010
Bacillus sp.	*Plasmopara halstedii*	Downy mildew of sunflower	Nandeeshkumar *et al.*, 2008
Bacillus subtilis BHHU100	*Sclerotina sclerotiorum*	Soft rot of pea	Jain *et al.*, 2012
Bacillus sp.	*P. digitatum*	Diseases in mandarin	Tian *et al.*, 2020
Bacillus subtilis 1.50% L.F (T Stanes Bs-1 Strain MTCC 25072)	*Mycosphaerella musicola*	Sigatoka of banana	DPPQS
Bacillus subtilis 2.0% AS (Strain No. IPL/BS-09, Accession No. MTCC 5728)	*Xanthomonas oryzae pv. oryzae*	Paddy BLB	DPPQS
Bacillus subtilis 1.15% AS (MTCC Accession no. 5786)	*Erysiphe necator*	Grapes powdery mildew	DPPQS
Bacillus *thuringiensis* var. *krustaki*	Bollworm	cotton	DPPQS
Bacillus thuringiensis var. *4rustaki*, serotype H-39, 3B, Strain Z-52	Stem borer & Leaf folder, *Heliothis* sp. *Spodoptera*,	Rice, cotton, Tobacoo	DPPQS
Bacillus thuringiensis serovar 4rustaki (3a, 3b, 3c) 5.0% WP Potency 55000 SU	American Bollworm	cotton	DPPQS
Bacillus thuringiensis var. *5rustaki* 0.5% WP serotype 3a, 3b, 3c, Strain DOR Bt-1 NAIMCC-B-01118, Potency 13329 IU/mg min. U/s 9(3b)	*Helicoverpa armigera*	Pigeon pea	DPPQS
Bacillus thuringiensis var. *5rustaki* 0.5% WP serotype 3a, 3b, 3c, Strain DOR Bt-1, Potency 16000 IU/mg min.	*Helicoverpa armigera*	Chickpea	DPPQS

Bio-Formulation of Bacillus in India and World

Bacillus bacteria formulations are available in India and world against various pathogens because bacillus bacteria have potential to persist in adverse environment, stable, viable and not develop resistance under field conditions. Moreover,

this bacterium grows very fast in different media, produce endospore and release various antagonistic metabolites. In this context, most of the private companies commercialized the bacillus-based bio formulation in different crops.

Bacillus species	Bio-formulation	Plants	Company
Bacillus subtilis	Biosubtilin®	Cereals, vegetables, legumes, oilseeds, cotton, and others	Biotech International Ltd.,India
Bacillus megaterium	Symbion-P®	Cereals, legumes, oilseeds, vegetables	T. Stanes & Co. Ltd., India
Bacillus subtilis	Serenade®	Vegetables, fruits	AgraQuest Inc. USA
Bacillus subtilis	Subtilex®	Vegetables, legumes, cotton, and others	Becker Underwood, Inc.,USA
Bacillus subtilis	Bio Safe®	Vegetables, Legumes, cotton	Lab. Biocontrole Farroupilha, Brazil
Bacillus subtilis	Ecoshot®	Vegetables, legumes, fruits, and others	Kumiai Chemical Industry, Japan
Bacillus pumilus	Yield Shield®	Legumes, cereals, vegetables, sugar beet, cotton	Bayer Crop Science, USA
Bacillus spp.	Sublic®	Several crops	ELEP Biotechnologies, Italy
Bacillus pumilus	Sonata®	Vegetables, fruits	AgraQuest Inc., USA

Future Used or Conclusion of Bacillus Bacteria

Presently, Bacillus demand is rising steadily in India due to adverse effect of chemical pesticides on environment, animal and human health. When bacillus-based formulation used in Integrated Pest Management (IPM) system, its efficacy can be equal or better than traditional pesticides especially in vegetable and fruits crops. Now days, bacillus can be smart inputs and major components in IPM program. Bacillus bacteria can be used as bio-agent, bio-fertilizer, bio-stimulant for sustainable crop production improvement. It can be safe, have high potential in minimum application and used for break of resistance. Presently their contribution is 4% among the bio-pesticides due to lack of awareness and unavailability in the market. Developments of resistance strain of pathogen against fungicides were reported in various crops. In such situation, it can be potent alternative of chemical pesticides in fruit, oilseed and vegetables crops. In future their role will be more significant in plant protection and have potential role in development of future Integrated Pest Management (IPM) strategies especially in fruit and vegetable crops.

References

1. Mnif, I., Grau-Crespo, R.., and Ghribi, D., (2015). Antifungal and antibacterial activities of lipopeptides produced by Bacillus subtilis. *International Journal of Peptide Research and Therapeutics*, 21, 303-315. https://doi.org/10.1007/s10989-015-9469-7.
2. Beneduzi, A., Ambrosini, A., and Passaglia, L. M. P., (2012). Plant growth-promoting rhizobacteria (PGPR): Their potential as antagonists and biocontrol agents. *Genetics and Molecular Biology*, 35(4), 1044-1051. https://doi.org/10.1590/S1415-47572012000600020.
3. Borriss, R., Chen, X. H., Rueckert, C., Blom, J., Becker, A., Baumgarth, B., and Pühler, A., (2011). Relationship of Bacillus amyloliquefaciens clades associated with strains DSM7 and FZB42. *Journal of Bacteriology*, 193(13), 3502-3513. https://doi.org/10.1128/JB.00350-11.
4. Aloo, B. N., Makumba, B. A., and Mbega, E. R., (2019). The potential of Bacilli rhizobacteria for sustainable crop production and environmental sustainability. Applied *Microbiology and Biotechnology*,103, 2829-2848. https://doi.org/10.1007/s00253-019-09617-5.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Water Use Efficiency in Hydroponics vs Conventional Agriculture in Tamil Nadu

Article ID: 72842

Miruthula Krishnaveni A[1], Ramachandran J[2]

[1]Undergraduate Student in Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

[2]Teaching Assistant in Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

Abstract

Tamil Nadu's agriculture faces chronic water scarcity, making efficient irrigation crucial. Hydroponic systems (Soilless cultivation in controlled environments) promote extremely high water-use efficiency (WUE) compared to field farming. A comprehensive literature review (≥20 sources) shows hydroponics can cut water use by 80–95% per unit yield. For example, hydroponic lettuce requires only ~20 L of water per kg of produce versus ~250 L/kg in open fields, and recirculating hydroponic systems typically save 80–90% of irrigation water. In Tamil Nadu trials (e.g. TANUVAS, Chennai), hydroponic maize fodder achieved ~1.5 L/kg (fresh). Controlled-environment cultivation also yields far more per area (e.g., ~11× for lettuce). Tables below summarize these findings (water per yield and system comparisons). Overall, hydroponics offers dramatically higher WUE and yields for Tamil Nadu's vegetable/fodder production, though at the expense of higher capital and energy needs.

Keywords: Energy footprint; Resource-use efficiency; Soilless agriculture; Sustainable crop production; Water use efficiency (WUE)

Introduction

Tamil Nadu is semiarid to tropical, with monsoon-dependent irrigation and frequent droughts. Agriculture consumes most freshwater, leaving little margin for error under climate stress [Kumar, P.,et. al. (2020)] [Graamans, L., et. al. (2023)]. Hydroponics—growing plants in nutrient solutions instead of soil—is increasingly studied as a water-saving alternative. By recirculating water and nutrients, hydroponics can slash water use while boosting yield [Graamans, L., et. al. (2023)] [Mehra, S., Patel, R., & Joshi, M. (2025)]. For example, a lifecycle study reported hydroponic lettuce used only ~20 L/kg versus ~250 L/kg for field-grown lettuce (over 90% reduction) [Barbosa, G. L. et. al. (2015)] [Graamans, L., et. al. (2023)]. This review synthesizes results from global studies and Tamil Nadu–specific trials, focusing on WUE, crop types, climate adaptation, and system efficiencies.

Findings

1. Dramatic water savings: Hydroponic systems consistently use far less water. In controlled lettuce production, hydroponic cultivation required only ~20 L of water per kg of lettuce, versus ~250 L/kg in drip-irrigated field conditions [Barbosa, G. L. et. al. (2015)]. Similarly, high-tech closed greenhouse tomato systems can use as little as ~4 L/kg, compared to ~60 L/kg in open-field tomato farming [Van Woerden, S. C., & De Groot, J. (2010)] [Van Woerden, S. C., & De Groot, J. (2010)]. These savings (≈90–95%) arise from minimal evaporation/runoff and reuse of nutrient solution [Mehra, S., Patel, R., & Joshi, M. (2025)] [Graamans, L., et. al. (2023)]. A recent review quantified that recirculating hydroponic systems reduce water use by up to 90% compared to conventional irrigation [Chandran, R., & Kumar, S. (2021)].

2. Crop yields and efficiency: The efficiency gains in hydroponics extend to yield. Hydroponic lettuce achieves roughly 11× the annual yield of field lettuce (e.g. ~43 vs 3.9 kg/m²/yr) [Barbosa, G. L. et. al. (2015)] [Mehra, S., Patel, R., & Joshi, M. (2025)]. In Tamil Nadu trials, a low-cost hydroponic chamber produced ~240 ton/ha of fresh maize fodder in 8 days [Kumar, P., et. al. (2020)]. These intensification gains mean that hydroponics can multiply productivity on limited land. Controlled environments (greenhouses with regulated light, temperature, CO_2) enable year-round cultivation, effectively decoupling production from Tamil Nadu's erratic monsoon [Kumar, R., Singh, P., & Sharma, D. (2024)] [Mehra, S., Patel, R., & Joshi, M. (2025)].

3. Case data from Tamil Nadu: Local experiments confirm the WUE advantage. TANUVAS (Chennai) reported ~1.5 L of water per kg of fresh maize fodder grown hydroponically (8-day sprout) [Kumar, P., et. al. (2020)], implying water use <5% of field fodder production. A case study (Coimbatore) found hydroponic fodder maize and cowpea highly nutritious and efficient (though exact WUE not given) [Patel, M., Desai, K., & Shah, V. (2020)]. A recent LCA-based study of Tamil Nadu greenhouse lettuce found hydroponic greenhouse production had a lower water footprint per unit than indoor vertical or conventional models [Sinha, R., Verma, P., & Rao, P. (2024)].

Table 1. Water use per kg of crop yield in hydroponic vs conventional systems. Hydroponics uses roughly one-tenth the water for lettuce and tomato [Barbosa, G. L. et. al. (2015)] [Van Woerden, S. C., & De Groot, J. (2010)].

Crop	Conventional (L/kg)	Hydroponic (L/kg)	~Water Saved
Lettuce	~250 L/kg (open field)	~20 L/kg (greenhouse)[Barbosa, G. L. et. al. (2015)]	~92%
Tomato (open-field)	~60 L/kg (drip field)	~4 L/kg (closed GH) [Van Woerden, S. C., & De Groot, J. (2010)]	~93%
Maize (fodder)	≈50 L/kg (field estimate)	~1.5 L/kg (8-day sprouts) [Kumar, P.,et. al. (2020)]	~97%

Table 2. Comparison of conventional vs hydroponic systems in Tamil Nadu context (illustrative). Hydroponics runs at ~10% of the water use of conventional farming [Graamans, L., et. al. (2023)] [Barbosa, G. L. et. al. (2015)], with much higher yields per area [Barbosa, G. L. et. al. (2015)].

Aspect	Conventional Agriculture	Hydroponic Systems
Typical crops	Rice, millets, pulses, maize	Leafy greens (lettuce, spinach), tomatoes, cucumber, fodder
Water use (L/kg)	High (e.g. ~250 L for 1 kg lettuce)	Low (e.g. ~20 L for 1 kg lettuce) [Barbosa, G. L. et. al. (2015)]
Yield (kg/m²/yr)	Lower (lettuce ~3.9)	Higher (lettuce ~43) [Barbosa, G. L. et. al. (2015)]
Land use	Extensive fields, open-air	Intensive (stacked beds, greenhouse)
Seasonality	Rain-dependent, drought-vulnerable	Year-round (controlled environment)
Inputs & control	In-situ soil nutrients, higher pesticide/herbicide use	Precise nutrient solution, minimal pesticide
Energy demand	Moderate (mostly for irrigation)	Higher (lighting, HVAC, pumps)

Discussion

1. The data show hydroponic systems vastly outperform traditional methods in WUE. In Tamil Nadu's water-limited setting, saving 80–90% of irrigation water is transformative. Controlled-environment culture also mitigates climate extremes: it buffers heat and monsoon variability, ensuring stable yields [Kumar, R., Singh, P., & Sharma, D. (2024)] [Mehra, S., Patel, R., & Joshi, M. (2025)]. However, hydroponics incurs higher capital and operational costs (greenhouses, pumps, energy for lighting/heating) [Mehra, S., Patel, R., & Joshi, M. (2025)]. Energy use can raise the carbon footprint unless renewable power is used [Mehra, S., Patel, R., & Joshi, M. (2025)]. Nevertheless, integrated approaches (e.g. using solar power or waste heat) are being explored to reduce hydroponic energy demands.

2. For Tamil Nadu's agriculture, hydroponics is most suitable for high-value vegetables and fodder crops. Conventional staples like paddy cannot easily be grown hydroponically; instead, hydroponics can complement field farming by producing vegetables/fodder with minimal water. Our review indicates that certain crops (lettuce, tomato, cucumber, maize/cowpea fodder) thrive under TN-like conditions in hydroponics. For example, coir- and pine-aggregate hydroponic media in Tamil Nadu achieved high tomato yields [Ravindran, V., & Balakrishnan, P. (2015)], and indoor aeroponic lettuce systems are under development locally [Karthik, S., Prakash, R., & Anand, S. (2024)].

3. In practice, upscaling hydroponics in Tamil Nadu will require overcoming barriers: technical expertise, initial investment, and ensuring affordable energy. Government and private initiatives (e.g., agritech incubators, subsidies) are starting to address these. The benefits to water conservation and food security are clear: by reducing irrigation needs by 4–10× [Graamans, L., et. al. (2023)] [Barbosa, G. L. et. al. (2015)], hydroponics could significantly cushion Tamil Nadu agriculture against drought and water stress.

Conclusion

Hydroponic cultivation offers **exceptionally high water-use efficiency** compared to conventional agriculture in Tamil Nadu's context. Review of over 20 sources shows hydroponics can achieve comparable or higher yields using roughly 10–20% of the irrigation water (Table 1). Leafy greens and fodder crops grown hydroponically require only 1–20 L water per kg of produce [Barbosa, G. L. et. al. (2015)] [Kumar, P., et. al. (2020)], versus hundreds of litres in the field. These gains align with Tamil Nadu's urgent need for water-saving agriculture. Future adoption will hinge on economic factors, but the environmental and productivity benefits are substantial. Emphasizing hydroponics for suitable crops could allow Tamil Nadu farmers to drastically stretch scarce water resources while increasing yields [Graamans, L., et. al. (2023)] [Mehra, S., Patel, R., & Joshi, M. (2025)].

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Improved Varieties of Rice in Gujarat

Article ID: 72843

S. R. Patel[1], N. R. Makwana[2]
[1]Assistant Professor, Polytechnic in Agriculture, NAU, Vyara.
[2]Agricultural officer, Main Rice Research Station, AAU, Navagam.

Abstract
Rice is a major food crop in Gujarat, cultivated under diverse agro-climatic conditions ranging from irrigated transplanted systems to aerobic and direct-seeded environments. To enhance productivity, grain quality, and resilience against biotic and abiotic stresses, several improved rice varieties have been developed and released by agricultural universities and research institutions in the state. Varieties such as Gujarat Anand Rice 22 (Swagat), Gujarat Rice 21 (Vatrak), Gujarat Aerobic Rice 201 (Anand Akshat), and Gujarat Rice 25 (GR-25) exhibit higher yield potential, better milling and cooking quality, and improved resistance or tolerance to major pests and diseases like blast, stem borer, and plant hoppers. Some varieties also possess enhanced nutritional traits, including higher iron and zinc content, and are suitable for water-saving cultivation methods. Adoption of these improved rice varieties, along with recommended agronomic practices, has significantly contributed to increased rice productivity, profitability, and sustainability in Gujarat.

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple food crops of India and plays a vital role in food and nutritional security. In Gujarat, rice is mainly cultivated during the Kharif season in districts receiving medium to high rainfall, particularly in South Gujarat, Middle Gujarat, and parts of North Gujarat. Despite having suitable agro-climatic conditions in several regions, the average productivity of rice in the state has traditionally remained lower than the national average due to factors such as use of traditional varieties, biotic and abiotic stresses, inefficient water management, and changing climate conditions.

To overcome these constraints and to meet the increasing demand for rice from a growing population, the development and adoption of improved rice varieties have become essential. Agricultural universities such as Anand Agricultural University (AAU), Navsari Agricultural University (NAU), and Junagadh Agricultural University (JAU), along with ICAR institutes, have played a significant role in developing high-yielding, stress-tolerant, and location-specific rice varieties suitable for Gujarat. These improved varieties are designed to perform well under transplanted as well as direct-seeded and aerobic conditions, while offering better resistance to major pests and diseases and improved grain quality.

Improved rice varieties not only contribute to higher yields but also support sustainable rice cultivation by reducing water use, input costs, and crop losses. Some recently released varieties also address nutritional security through enhanced micronutrient content and better market acceptability. Therefore, the introduction and widespread adoption of improved rice varieties are crucial for increasing rice productivity, ensuring farmers' income, and promoting sustainable agriculture in Gujarat.

Improved Rice Varieties Recommended in Gujarat

Variety	Average Yield	Maturity Duration	Special Features
Gujarat Rice 25 (GR-25 – Mahatma)	~6301 kg/ha	Medium duration (approx. ~130-140 days)	High yield, bold grain, moderate pest resistance.
Gujarat Anand Rice 22 (Swagat)	~5613 kg/ha	Medium maturity	Long slender grain, good milling quality, resistant to major pests & blast.
Gujarat Rice 21 (Vatrak)	~5345 kg/ha	Early to medium maturity	Medium slender grain, good tillering, higher micronutrients (Fe & Zn)
GR-18 (DevliKolam)	~5462 kg/ha	Medium duration	Medium slender grain, good quality, moderate pest tolerance
GR-19 (Auranga)	~5305 kg/ha	Medium duration	Short bold grain, salt-tolerant, suitable for saline soils
GNR-8 (Aarti)	~4700 kg/ha	Early maturing	Long bold grain, suited for aerobic/low water conditions
GR-17 (Sardar)	~5566 kg/ha	Early maturity	Long bold grain and good grain quality.

Impact of Improved Rice Varieties

The adoption of improved rice varieties has had a significant positive impact on rice cultivation in Gujarat. These varieties have contributed to increased productivity, improved crop resilience, and enhanced socio-economic benefits for farmers. One of the most notable impacts is the substantial increase in yield. Improved varieties such as Gujarat Anand Rice 22, Gujarat Rice 21, and Gujarat Aerobic Rice 201 have demonstrated higher yield potential compared to traditional and older varieties, thereby helping to narrow the yield gap and improve overall rice production in the state.

Improved rice varieties have also enhanced resistance and tolerance to major pests and diseases, including blast, stem borer, leaf folder, and plant hoppers. This resistance reduces crop losses and lowers dependence on chemical pesticides, resulting in reduced production costs and a safer agro-ecosystem. Additionally, varieties suited for aerobic and direct-seeded conditions have helped conserve water and labor, addressing critical issues of water scarcity and rising labor costs in Gujarat.

Another important impact is the improvement in grain quality and market value. Many improved varieties possess better milling recovery, desirable grain size and shape, and superior cooking qualities, which increase consumer acceptance and fetch better prices for farmers. Some varieties are also enriched with micronutrients such as iron and zinc, contributing to nutritional security.

Overall, the impact of improved rice varieties extends beyond yield enhancement to include economic stability for farmers, sustainable use of natural resources, and strengthened food and nutritional security. Their continued adoption, supported by extension services and availability of quality seed, plays a crucial role in the sustainable development of rice-based farming systems in Gujarat.

Summary

Improved rice varieties released and recommended for Gujarat's rice ecosystems combine higher yield potential with appropriate maturity durations to fit the Kharif rain pattern and local conditions. They also offer better grain quality and pest/disease resistance compared with traditional cultivars, supporting farmers' productivity and income.

References

1. Anand Agricultural University (AAU). (2021). Gujarat Anand Rice 22 (Swagat): Variety release proposal and production recommendations. Anand, Gujarat.
2. Anand Agricultural University (AAU). (2021). Gujarat Rice 21 (Vatrak): Improved high-yielding rice variety for Gujarat. Anand, Gujarat.
3. Anand Agricultural University (AAU). (2023). Gujarat Aerobic Rice 201 (Anand Akshat). Department of Genetics and Plant Breeding, Anand, Gujarat.
4. Navsari Agricultural University (NAU). (2023). Research accomplishments and crop production recommendations. Navsari, Gujarat.
5. Directorate of Rice Research (ICAR-IIRR). (2018). Rice improvement and production technologies. Indian Council of Agricultural Research, Hyderabad, India.
6. Government of Gujarat. (2022). Agricultural statistics at a glance. Department of Agriculture, Farmers Welfare and Co-operation, Gandhinagar, Gujarat.
7. Hegde, D. M., & Kumar, P. (2019). Impact of improved rice varieties on productivity and income of farmers. Indian Journal of Agricultural Economics, 74(3), 412–420.
8. Singh, R. K., & Singh, U. S. (2020). Advances in rice varietal development and their role in sustainable agriculture. Oryza, 57(2), 89–97.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Integrating Trees into Farming Systems: Agroforestry as a Nature-Based Solution for Climate and Livelihood Resilience

Article ID: 72844

Thounaojam Bidya Chanu[1]
[1]ICAR-Indian Institute of Soil and Water Conservation, Dehradun, Uttarakhand.

Abstract
Agroforestry, the deliberate integration of trees with crops and livestock, is increasingly recognized as an effective Nature-based solution for addressing climate change, livelihood vulnerability and ecosystem degradation. By enhancing carbon sequestration, soil fertility, water regulation, biodiversity and farm diversification, agroforestry supports both climate mitigation and adaptation. In India, where smallholder agriculture is highly exposed to climatic risks, agroforestry strengthens resilience by moderating microclimates, improving soil and water conservation and reducing dependence on external inputs. Diversified tree-based systems enhance food security and income stability while lowering pressure on natural forests. Supported by enabling policies such as the National Agroforestry Policy, agroforestry offers significant potential for sustainable land use, climate-resilient agriculture and socio-ecological resilience across diverse agro-ecological regions.

Keywords: Agroforestry, Nature-based solutions (NbS), Climate change mitigation, Livelihood resilience, Food security.

Introduction
Agroforestry—the intentional integration of trees with crops, livestock and sometimes fisheries on the same land unit—is increasingly recognized as a powerful Nature-Based Solution (NbS) that delivers simultaneous benefits for climate mitigation, climate adaptation, livelihood resilience and ecosystem conservation. Practiced for millennia across diverse agro-ecological regions, agroforestry systems provide critical ecosystem services including carbon sequestration, soil fertility enhancement, water regulation, biodiversity conservation and diversified farm production.

Smallholder agroforestry systems remain widespread in developing countries where traditional ecological knowledge complements scientific innovations. These systems represent proven, locally adapted models that support both adaptation to climate variability and mitigation of greenhouse gas emissions, making them ideal candidates for scaling up as NbS.

What Makes Agroforestry a Nature-Based Solution?
Nature-based solutions work with nature rather than against it. The International Union for Conservation of Nature (IUCN) defines NbS as actions that protect, sustainably manage, and restore ecosystems while addressing societal challenges and enhancing human well-being and biodiversity. Agroforestry aligns closely with this definition by integrating trees into agricultural landscapes to enhance ecological functions while meeting farmers' economic needs.

Trees in agricultural landscapes act as natural shields. Their roots bind the soil, reduce erosion and improve water infiltration. Their leaves add organic matter, enriching soil fertility. Above ground, trees create cooler microclimates that protect crops from heat stress and strong winds. Collectively, these benefits make farms more resilient to climate extremes.

Climate Change, Agriculture and Vulnerability in India
India faces intensifying climate risks including erratic monsoons, rising temperatures, floods, droughts and widespread land degradation. With nearly half of the population dependent on agriculture and allied sectors, rural livelihoods—particularly those of small and marginal farmers—are highly vulnerable to climate variability. In this context, agroforestry emerges as a climate-smart, nature-based strategy capable of addressing multiple vulnerabilities simultaneously.

Agroforestry Traditions and Contemporary Relevance in India
Agroforestry is deeply rooted in Indian farming traditions. Practices such as growing neem, mango, tamarind, mahua or fodder trees on field bunds and integrating trees with crops or pastures reflect long-standing farmer knowledge. These systems are now gaining renewed relevance as climate resilience mechanisms, offering ecological buffering, productivity stability and reduced pressure on natural forests.

Climate Change Mitigation through Agroforestry
Agroforestry contributes significantly to climate mitigation by sequestering carbon in above-ground biomass, roots and soils. Trees store nearly 50% of their dry biomass as carbon and enhance soil organic carbon through litter fall and root

turnover. Agroforestry systems also reduce emissions of methane (CH_4) and nitrous oxide (N_2O) by improving soil structure and nutrient cycling.

The inclusion of nitrogen-fixing species such as *Dalbergia sissoo*, *Albizia lebbeck* and *Leucaena leucocephala* enhances soil fertility and reduces reliance on synthetic fertilizers. By supplying timber, fuelwood and fodder from agricultural lands, agroforestry reduces pressure on natural forests and associated deforestation emissions, aligning with national climate commitments and mechanisms such as REDD+.

Agroforestry for Climate Adaptation and Livelihood Resilience

As a multifunctional land-use system, agroforestry enhances adaptive capacity across India's diverse landscapes. In arid and semi-arid regions, species such as khejri, neem and acacia provide fodder, shade and income during droughts. In flood-prone areas, trees stabilize soils and reduce erosion while in Himalayan regions, integrating horticultural trees with annual crops buffers farmers against temperature fluctuations and erratic snowfall.

By moderating microclimates, conserving soil moisture and diversifying outputs, agroforestry functions as a risk-spreading safety net for climate-exposed households.

Water Regulation, Soil Health and Biodiversity Benefits

Agroforestry enhances water regulation by improving infiltration, reducing runoff and increasing soil water-holding capacity. Root systems and organic matter improve soil structure, strengthening resilience in rain-fed systems. Additionally, agroforestry landscapes mimic natural ecosystems, providing habitats for pollinators, birds and beneficial insects. This biodiversity supports key ecological functions such as pest regulation, pollination and nutrient cycling.

Food Security and Economic Resilience through Agroforestry

By diversifying production to include crops, fruits, fodder, fuelwood, and non-timber forest products, agroforestry strengthens food and nutritional security. Trees stabilize yields by protecting crops from climatic stress while diversified income sources reduce exposure to market volatility and crop failure. Systems based on poplar and eucalyptus in northern India or mahua, tamarind, and aonla in tribal regions demonstrate strong livelihood and nutritional benefits.

Policy Support and Scaling Potential

India's National Agroforestry Policy (2014)—the first of its kind globally—recognizes agroforestry as a strategic land-use system for expanding tree cover outside forests, improving market access, and supporting climate goals. Agroforestry is also integrated into initiatives such as the National Mission for Sustainable Agriculture and the Green India Mission. Given India's vast rain-fed and degraded lands, scaling up agroforestry holds immense potential for carbon sequestration, land restoration, and sustainable food systems.

Advantages and Limitations of Agroforestry as a Nature-Based Solution (NbS)

Advantages:

a. Enhances soil fertility, nutrient cycling, and soil organic carbon
b. Reduces erosion, improves microclimate, and conserves biodiversity
c. Sequesters carbon in biomass and soils
d. Increases resilience to climate extremes
e. Diversifies livelihoods and strengthens food and nutritional security
f. Reduces long-term input costs through ecosystem services.

Disadvantages:

a. Requires careful species selection and skilled management
b. Potential competition for light, water and nutrients if poorly designed
c. Delayed economic returns from tree components
d. Market, technical and extension constraints
e. Policy and tenure barriers including tree-felling regulations.

Conclusion

Agroforestry represents a holistic nature-based solution that addresses climate change mitigation, climate adaptation, food security and livelihood resilience in an integrated manner. By enhancing carbon storage, conserving water and soil, supporting biodiversity and diversifying incomes, agroforestry strengthens the socio-ecological resilience of rural landscapes. As climate risks intensify, scaling up agroforestry across India's diverse agro-ecological zones is not merely an option but an imperative for building a sustainable, inclusive and climate-resilient future.

References

1. Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (Eds.). (2016). *Nature-based solutions to address global societal challenges*. IUCN.
2. FAO. (2020). *Forests: Nature-based solutions for climate change*. Committee on Forestry. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/nd487en/nd487en.pdf
3. Gupta, H., Janju, S., Mahajan, A., Singh, C., Sharma, S., & Prajapati, A. (2024). Forests and agroforestry: Nature-based solutions for climate change mitigation. In H. Singh (Ed.), *Forests and climate change*. Springer. https://doi.org/10.1007/978-981-97-3905-9_21
4. Islam, M. A. (2026). Agroforestry: A nature-based solution to mitigate climate change impacts and improve crop production systems for food security in arid regions. In M. K. Suleiman & S. A. Shahid (Eds.), *Fostering arid lands agriculture in the face of climate change* (Advances in Global Change Research, Vol. 81). Springer. https://doi.org/10.1007/978-3-031-98490-7_11
5. IUCN. (2020). *Guidance for using the IUCN Global Standard for Nature-based Solutions* (1st ed.). IUCN.
6. Kumar, B. M. (2025). Agroforestry: A nature-based solution for mitigation and adaptation to climate change and agrobiodiversity conservation. In H. Pathak, W. S. Lakra, A. Gopalakrishnan, & K. C. Bansal (Eds.), *Advances in agri-food systems*. Springer. https://doi.org/10.1007/978-981-96-0759-4_3
7. Wangmo, K., Kumar, A., Narula, S. A., & Magry, M. A. (2025). Agroforestry systems as nature-based solutions for climate risk and livelihood sustainability: A case study from Bhutan. *Agroforestry Systems, 99*, 178. https://doi.org/10.1007/s10457-025-01262-0

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Development of Sweet-Heat Multi-Texture Snack Bites- A New Product Concept

Article ID: 72845

Dharmendrasinh Zala[1]
[1]M. Tech, Dairy Technology Department, SMC Collge of Dairy Science, Anand.

Introduction

The global snack industry is rapidly evolving toward experiential eating, where consumers seek bold flavors, interactive textures, and visually exciting products. Sweet-heat ("Swicy") flavor profiles combined with multi-texture formats are gaining strong traction among Gen Z and millennials due to their sensory appeal, social-media friendliness, and indulgent experience.

The Sweet-Heat Multi-Texture Snack Bites are designed to deliver a three-stage sensory experience—crunchy exterior, creamy middle, and a delayed spicy finish—positioning the product as a premium, viral-ready snack.

Advantages of Sensory-Driven Snack Design

1. Enhances eating experience through flavor layering
2. Encourages repeat consumption due to novelty
3. Strong social-media and impulse-purchase appeal
4. Differentiates from conventional chips and extruded snacks
5. Allows premium pricing due to experiential value.

Target Audience

1. Gen Z and millennials
2. Urban snack consumers
3. Social-media-active users
4. College students and young professionals
5. Premium snack buyers
6. Café and QSR customers.

SWOT Analysis

Strengths:

a. Unique sweet-heat flavor combination
b. Multi-texture sensory experience
c. High visual and viral appeal

Weaknesses:

a. Slightly higher production complexity
b. Requires precise process control

Opportunities:

a. Growing demand for experiential snacks
b. Export potential to global snack markets
c. Limited competition in multi-texture snacks.

Threats:

a. Flavor imitation by competitors
b. Shelf-life management for filled snacks.

Market Research

Gap in Market: Most snacks offer either bold flavor or texture—not both in a layered sensory format.

Consumer Insights: Consumers prefer snacks that are:

a. Sweet first, spicy later
b. Crunchy with a surprise inside
c. "Instagrammable" and shareable

Trend Analysis:

a. Rise of "Swicy" flavors
b. Growth of filled and layered snacks
c. Snackification replacing meals

Product Overview

Product Description:

a. Bite-sized crunchy snack balls
b. Sweet mango-chili outer coating
c. Creamy cheese / plant-based center
d. Delayed chili heat finish
e. Ready-to-eat premium snack

Key Features:

a. No artificial colors
b. No trans-fat
c. Shelf-stable product
d. Suitable for vegetarian consumers.

Ingredient Sourcing

1. Corn/rice flour
2. Mango powder
3. Chili seasoning blend
4. Sugar / jaggery powder
5. Cheese powder or plant-based cream
6. Modified starch
7. Edible vegetable oil
8. Natural flavor enhancers.

Product Formulation (Per 1 Kg)

Ingredient	Quantity (g)	% w/w
Corn/Rice flour	420	42
Vegetable oil	180	18
Cheese / plant-cream	120	12
Mango powder	80	8
Sugar/Jaggery powder	70	7
Chili seasoning	40	4
Modified starch	50	5
Salt & spices	40	4

Nutritional Information (Approx.)

Nutrient (per 100 g)	Value
Energy	480-520 kcal
Protein	7-9 g
Carbohydrates	55-58 g
Total Fat	25-28 g
Dietary Fiber	3-4 g
Sodium	450-550 mg

Process Flow Diagram

Raw material receiving
1. Cleaning & sieving
2. Dough preparation
3. Forming & filling
4. Frying / baking
5. Seasoning & coating
6. Cooling
7. Metal detection
8. Packaging
9. Finished goods storage.

Process Step	Hazard	Control Measure	CCP
Raw material receiving	Chemical/Microbial	Approved suppliers	No
Filling operation	Microbial	Temperature control	Yes

Frying/Baking	Biological	Time-temperature	Yes
Metal detection	Physical	Metal detector	Yes
Packaging	Moisture ingress	Controlled environment	No

Costing Calculation (Indicative)

Component	Cost (INR/kg)
Raw materials	170-190
Processing	35-45
Packaging	20-25
Overheads & QC	15-20
Total Cost	240-280
Suggested MRP	450-600

Fssai Requirements

1. Product category: Ready-to-eat extruded/fried snack
2. FSSAI State/Central License mandatory
3. Labeling as per FSS (Labelling & Display) Regulations, 2020
4. Nutritional declaration mandatory
5. Shelf-life validation required.

Testing

1. Sensory evaluation (heat balance & texture)
2. Nutritional analysis
3. Oil stability testing
4. Microbiological testing
5. Shelf-life testing

Packaging & Storage

1. Metallized PET/PE pouches
2. Nitrogen flushing recommended
3. Store below 25°C in dry conditions.

Commercialization

1. Modern retail stores
2. E-commerce platforms
3. Cafés & QSR chains
4. Export snack markets.

Marketing Strategy

Positioned as a premium experiential snack delivering crunch, creaminess and heat in one bite.
Marketing focus on:

1. Social-media challenges
2. Influencer tasting videos
3. Limited-edition flavor drops.

Conclusion

The Sweet-Heat Multi-Texture Snack Bites represent a next-generation snack concept that aligns with evolving consumer demand for bold flavors, interactive textures and visual excitement. The product offers strong differentiation, premium positioning and excellent scalability for domestic and international markets.

AGRICULTURE & FOOD: E-NEWSLETTER
WWW.AGRIFOODMAGAZINE.CO.IN
ISSN: 2581 - 8317

Development of Probiotic Puffed Millet Snack with Flavor-Bursting Technology – A New Product Concept

Article ID: 72846

Dharmendrasinh Zala[1]
[1]M. Tech, Dairy Technology Department, SMC College of Dairy Science, Anand.

Introduction

The snack food industry is shifting toward functional and health-oriented products. Probiotics are widely recognized for their role in improving gut health, immunity and digestion. Millets, known for their high fiber, mineral content, and sustainability, serve as an excellent base for nutritious snacks. This product integrates probiotic fortification with puffed millet snacks using flavor-bursting technology to enhance both health benefits and sensory appeal.

Advantages of Probiotic Fortification

1. Improves gut health and digestion
2. Enhances immunity
3. Supports nutrient absorption
4. Adds functional value to snacks
5. Aligns with clean-label and wellness trends.

Target Audience

1. Health-conscious consumers
2. Urban population
3. Children and teenagers
4. Fitness enthusiasts
5. Elderly population.

Market Research

Gap in Market: Limited probiotic-based millet snacks in ready-to-eat category.
Consumer Insights: Preference for healthy snacks without compromising taste.
Trend Analysis: Rising demand for functional foods, probiotics, and millet-based products.

Product Overview

1. Ready-to-eat puffed millet snack
2. Probiotic-loaded seasoning coating
3. Crunchy texture with instant flavor release
4. Vegetarian and clean-label product.

SWOT Analysis

Strengths • Probiotic benefits • Nutritious millets • Innovative concept	**Weaknesses** • Probiotic stability issues • Higher cost
Opportunities • Growing gut-health market • Export potential	**Threats** • Regulatory claims • Market competition

Ingredient Sourcing

Ingredient	Quantity (g)	% w/w
Millet grains (Jowar/Bajra/Ragi)	600	60
Flavor seasoning	180	18
Maltodextrin	120	12
Probiotic culture	20	2
Salt & spices	80	8

Nutritional Information (Approx. Per 100 g)

Nutrient	Value
Energy	380-400 kcal
Protein	9-11 g
Carbohydrates	68-72 g
Fat	4-6 g
Dietary Fiber	8-10 g

HACCP Plan (Summary)

Process Step	Hazard	Control Measure	CCP
Raw material receiving	Chemical/Microbial	Approved suppliers	No
Puffing	Biological	Temperature control	Yes
Probiotic coating	Microbial	Hygienic handling	Yes
Metal detection	Physical	Metal detector	Yes
Packaging	Moisture	Controlled environment	No

Costing Calculation (Indicative)

Component	Cost (INR/kg)
Raw materials	140-160
Processing	30-40
Packaging	20-25
Overheads & QC	15-20
Total Cost	205-245
Suggested MRP	400-550

FSSAI Requirements

1. Product category: Ready-to-eat snack foods
2. Valid FSSAI license mandatory
3. Labeling as per FSS (Labelling & Display) Regulations, 2020
4. Probiotic claims as per FSSAI guidelines
5. Shelf-life validation required.

Packaging & Storage

1. Metallized PET/PE pouches
2. Nitrogen flushing recommended
3. Store below 25°C in cool and dry place.

Conclusion

The Probiotic Puffed Millet Snack with Flavor-Bursting Technology is a novel functional snack combining nutrition, innovation, and consumer appeal. The product aligns strongly with current health trends and has excellent potential for commercialization.