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Growing seed

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CLIMATE-SMART HORTICULTURE FOR A NET-ZERO FUTURE

[1]Shakila Sadasivam*, [2]Akino Asokan, [3]Vinothini. N and [4]Akshaya S. B.

Email
shakilas@srmist.edu.in

[1]Department of Floriculture and Landscape Architecture, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District – 603 201, Tamil Nadu, India

[2]Department of Fruit Science, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District – 603 201, Tamil Nadu, India

[3]Depatment of Seed Science and Technology, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District – 603 201, Tamil Nadu, India

[4]Department of Plant Pathology, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District – 603 201, Tamil Nadu, India

Climate-smart horticulture (CSH) refers to the integration of sustainable practices, smart technologies, and resilient crop systems that adapt to a changing climate while reducing greenhouse gas (GHG) emissions. It aligns with the broader goal of achieving net-zero emissions, where carbon released is balanced by carbon captured or avoided. As climate change continues to pose serious challenges to global agriculture, the horticulture sector must evolve towards sustainable, resilient, and low-carbon practices. Climate-smart horticulture (CSH) emerges as a forward-thinking approach that aligns productivity with environmental responsibility. This article explores the concept of CSH and its relevance toward a net-zero future.

Climate-Smart Horticulture integrates environmentally responsible practices and modern innovations to ensure:

- Adaptation to climate variability,
- Mitigation of greenhouse gas (GHG) emissions, and
- Enhanced productivity for food, nutrition, and income security.

Unlike conventional methods, CSH is guided by a long-term vision of reducing the carbon footprint while increasing resilience against weather extremes, pests, and declining soil health.

Importance of Climate-Smart Horticulture

Horticultural crops such as fruits, vegetables, flowers, and spices are susceptible to environmental stress. Rising temperatures, erratic rainfall, and increased pest incidence have made traditional practices unreliable and resource-intensive. Therefore, adopting climate-smart practices is no longer optional, and it is essential for aiming at economic stability, sustainability and to meet carbon neutrality targets.

The Three Pillars of Climate-Smart Horticulture are,

1. Mitigation
    - Adoption of low-emission technologies: solar-powered irrigation, energy-efficient greenhouses.
    - Use of organic amendments and biofertilizers to reduce reliance on synthetic fertilizers.
    - Carbon sequestration through agroforestry and perennial horticultural systems.
2. Adaptation
    - Climate-resilient cultivars (e.g., drought-tolerant vegetables, heat-resilient fruits).
    - Mulching, drip irrigation, and protected cultivation are used to manage erratic weather patterns.
    - Pest and disease management aligned with shifting ecological conditions.
3. Productivity Enhancement
    - Precision horticulture using sensors, AI, and GIS for better resource use.
    - Integrated nutrient and water management systems to increase efficiency.
    - Diversification of crops and value-added processing to enhance farmer income.

Pathway to Net-Zero Horticulture

1. Renewable Energy Integration: Replacing diesel pumps and fossil-based heating systems with solar, wind, and biogas options reduces carbon intensity drastically.

2. Sustainable Input Management: Switching to slow-release, organic, or bio-based fertilizers and pesticides can cut N_2O emissions while improving soil health.

3. Circular Economy Approaches: Utilizing crop residues for compost, vermiculture, or biochar production closes nutrient loops and adds carbon to soil.

4. Low-Carbon Postharvest Techniques: Cold chains powered by clean energy, packaging from biodegradable materials, and efficient logistics reduce postharvest losses and emissions.

Achieving net zero in horticulture involves balancing emissions with carbon capture and avoidance:

Intervention	Benefit
Solar energy	Cuts GHG emissions from fuel-based systems
Organic inputs	Reduce soil-based emissions and improve carbon stock
Crop residue management	Minimizes methane emissions; produces bio-compost
Tree-based systems	Act as long-term carbon sinks

Urban horticulture, vertical gardens, and rooftop farming also contribute to reducing urban heat islands and improving air quality, especially relevant for youth-led initiatives in cities.

Horticulture – a Solution to Climate Change

Horticulture offers unique advantages: perennial fruit trees act as carbon sinks, vertical gardens in urban areas cool microclimates, and ornamental plants purify air. When managed with a climate-smart lens, the sector becomes not just climate-resilient but climate-positive. The strategies to mitigate climate change are as follows,

- Protected cultivation can reduce water usage by **up to 50%** and pesticide use by **70%**.
- Solar pumps reduce CO_2 emissions by **1.5–2 tons/year per pump**.
- Transitioning to organic inputs can cut nitrous oxide emissions by **30–40%**.

Conclusion

In the face of climate change, agriculture and allied sectors must evolve rapidly, and horticulture is no exception. While horticultural crops enrich diets, generate livelihoods, and add aesthetic value to our surroundings, the environmental cost of intensive practices, energy use, synthetic inputs, and high-water demand has become increasingly apparent. Therefore, transitioning to climate-smart horticulture is not merely an option, it is an urgent necessity.By blending traditional wisdom with technological innovation, it enables a contribution to a net-zero future, where food security and environmental integrity are addressed. Let the nation achieve “More Crop per Drop, More Growth with Less Carbon.”

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MARINE PROTECTED AREAS (MPAS) IN AUGMENTING FISH BIODIVERSITY

[1]Kashish Bhardwaz and [1]Ujjwala Upreti*

Email
upretiujjwala452@gmail.com

[1]Department of Fisheries Science, Doon P.G. College of Agriculture and Allied Sciences, Dehradun, Uttarakhand, India

MPAs can be defined as a clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

MPAs are clearly defined geographic spaces managed through legal or other effective means to achieve long-term conservation of nature and ecosystem services. They may range from no-take zones (full protection) to multiple-use zones (regulated extraction), IUCN.

India has a network of MPAs established under various legal frameworks, most notably the Wildlife (Protection) Act of 1972. This includes:

- **Marine National Parks**: Provide the highest level of protection, with strict regulations on human activities. Examples include the Gulf of Kachchh Marine National Park in Gujarat, the Gulf of Mannar National Park in Tamil Nadu, and the Sundarbans National Park in West Bengal.
- **Marine Wildlife Sanctuaries**: Allow regulated activities, such as traditional fishing, in designated zones. Examples include the Malvan Marine Wildlife Sanctuary in Maharashtra and the Gahirmatha Marine Sanctuary in Odisha, both of which are well-known for Olive Ridley Sea turtle nesting.
- **Conservation Reserves and Community Reserves:** These categories, introduced by the Wildlife Protection Act Amendment of 2002, promote community involvement and sustainable use, though they are less commonly used for purely marine areas.
- **Other relevant categories:** While not legally classified as MPAs, areas such as Ramsar Sites with marine influence (e.g., Chilika Lake), Ecologically Sensitive Areas (ESAs)

under the Environment (Protection) Act, 1986 (e.g., Lakshadweep coral reefs), and Coastal Regulation Zones (CRZs) all play important roles in marine conservation (Al-Abdulrazzak, D., & Trombulak, S. C., 2012).

Needs to establish MPAs

1. Designing a Marine Protected Area (MPA) on a tropical coral reef can improve reef quality and increase fish biomass, which is crucial for commercial fish stocks.
2. During the rebuilding phase of a fishery, it is important to protect depleted stocks and habitats by halting fishing on collapsed or near-collapsed stocks. This allows the resource to recover.
3. Protecting genetic structure by preventing population bottlenecks, preserving diverse age groups and subpopulations, and utilising an MPA network to safeguard fish genetic traits.
4. Limiting bycatch by temporarily or permanently closing areas with high discard rates.
5. Allocating use rights in specific locations to reduce competition or enhance opportunities for specific user groups (e.g., artisanal or recreational fishermen) (Laxmilatha *et al*., 2015).

MPAs Enhancing Fish Biodiversity

1. MPAs provide a safe habitat for fish to breed, grow, and recover, resulting in population growth.
2. Spillover Effect: Increased fish biomass in MPAs can benefit biodiversity beyond the protected areas.
3. Habitat Restoration: Preventing destructive practices like bottom trawling promotes reef recovery, mangrove regrowth, and seagrass bed expansion, which are important fish habitats (Lester, S. E., *et al*., 2009).
4. MPAs can serve as climate refuges, allowing temperature-sensitive species to survive warming waters (e.g., coral reef MPAs in the Pacific).
5. MPAs protect genetic diversity by increasing population sizes and reproductive outputs.
6. MPA networks promote ecosystem connectivity by providing corridors for larval dispersal, improving genetic flow and resilience across regions (Roberts *et al*., 2017).

Fig 1: Major Marine Protected Areas in India

Global Examples

1. The Great Barrier Reef MPA (Australia) has over 1,500 fish species and saw a 2x-4x increase in fish biomass in no-take zones.
2. Apo Island MPA in the Philippines has pioneered community-based conservation, increased fish diversity, and generated local income through ecotourism.
3. The Chagos Archipelago (Indian Ocean) is one of the largest MPAs with significant biomass recovery of predatory fish (Edgar, G. J. *et al*., 2014).

Challenges include ineffective enforcement, paper parks (MPAs only on paper), stakeholder conflict (e.g., with fishers), and climate change compromising long-term effectiveness.

Innovations include AI-based monitoring (e.g., Global Fishing Watch) for real-time detection of illegal fishing and community-led MPAs that promote compliance and local benefits. Blue Carbon credits from MPA-restored ecosystems aid financing (Sala, E. *et al*., 2021).

Conclusion

Marine Protected Areas are an effective strategy for increasing fish biodiversity, rebuilding overfished stocks, and strengthening ecosystem resilience. Their success is dependent not only on designation, but also on effective enforcement, community engagement, environmental planning, and adaptive governance.

MPAs are not simply no-fishing zones. When well-designed, enforced, and community-supported, they serve as biodiversity banks, rebuilding fish populations, improving ecosystem resilience, and promoting sustainable livelihoods. Dynamic MPAs, blue carbon mapping, and AI-powered surveillance can transform MPAs' role as biodiversity hotspots in the Anthropocene.

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BREEDING TECHNIQUES IN FRUIT PLANTS FOR VARIETY DEVELOPMENT: INNOVATIONS FOR SUSTAINABLE HORTICULTURE

[1]Sahanob Nath*, [1]Subhradip Bhattacharjee and [1]Jagathjhuti Datta

Email

nathsahanob@gmail.com

[1]Growing Seed, Dharmanagar, North Tripura, 799251, India

Fruits are among the most essential components of the human diet. They provide vitamins, minerals, antioxidants, and dietary fiber, contributing to nutrition security and good health. Beyond their dietary significance, fruit crops are central to the horticultural economy, generating substantial income for farmers, creating rural employment, and strengthening agro-based industries.

With the rapid rise in population, urbanization, and global trade, the demand for high-quality fruits is increasing. Consumers are seeking fruits that are nutritious, attractive, seedless, and have long shelf life, while growers require varieties that are high yielding, resistant to diseases and pests, tolerant to climate change, and suitable for intensive production systems.

Fruit breeding is therefore the key scientific approach to achieve these goals. Breeding techniques—ranging from traditional hybridization to modern molecular and genome editing tools—are reshaping horticulture and opening new possibilities for sustainable fruit production.

Objectives of Fruit Plant Breeding

The primary goals of fruit breeding can be summarized as follows:

- **Yield Improvement**: Developing varieties that can produce more fruits per unit area.
- **Quality Enhancement**: Improving fruit taste, aroma, size, color, texture, nutritional value, and storage capacity.
- **Stress Resistance**: Developing tolerance against diseases, pests, drought, salinity, and temperature extremes.
- **Maturity & Harvest Time**: Creating early or late-maturing varieties to ensure year-round supply.

- **Seed lessness & Convenience Traits**: Popular among consumers (e.g., seedless grapes, citrus).
- **Processing Suitability**: Varieties with uniform size, high juice recovery, or specific traits for canning, drying, and export.

Challenges in Fruit Crop Breeding

Breeding fruit crops is more complex compared to cereals or vegetables due to the following reasons:

1. **Long Juvenile Phase**: Fruit trees like mango or apple may take 5–10 years to bear fruits, delaying breeding cycles.
2. **High Heterozygosity**: Most fruit plants are cross-pollinated, leading to genetic variability that complicates trait fixation.
3. **Polyploidy**: Many fruits (banana, citrus, strawberry) are polyploid, making inheritance patterns complex.
4. **Clonal Propagation**: Vegetative propagation maintains variability but limits conventional breeding approaches.
5. **Climate Change**: Emerging biotic and abiotic stresses demand rapid development of resilient varieties.
6. **Limited Genetic Resources**: Some crops have narrow genetic bases, restricting breeding potential.

Despite these challenges, innovative breeding tools are steadily overcoming such limitations.

Sources of Genetic Variability

Breeding relies on **variability**, the raw material for selection. Sources include:

- **Germplasm Collections**: National and international gene banks preserve fruit diversity for breeding programs.
- **Wild Relatives**: Valuable for transferring traits like disease resistance (e.g., wild grapes resistant to downy mildew).
- **Mutation**: Spontaneous or induced mutations create novel traits such as dwarfism or seedlessness.
- **Soma clonal Variation**: Variations arising in tissue culture, sometimes useful in developing new cultivars.

- **Biotechnology**: Tools like molecular markers and tissue culture expand genetic resources and improve selection efficiency.

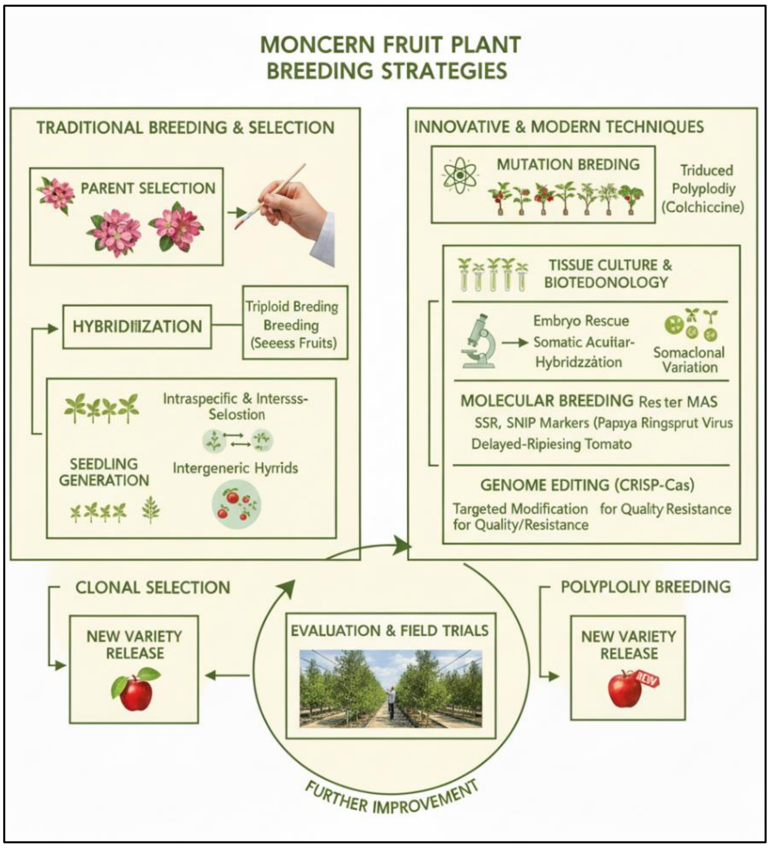
Traditional Breeding Techniques in Fruit Crops

Selection

- **Clonal Selection**: Used in vegetatively propagated fruits like banana and mango. Superior clones are identified and multiplied.
- **Mass Selection**: Applied in seed-propagated fruits like guava to improve populations for uniformity and yield.

Hybridization

- Crossing two or more parents to combine desirable traits.
- **Intraspecific Hybridization**: Between varieties of the same species (e.g., mango hybrids).
- **Interspecific Hybridization**: Between species of the same genus, such as citrus hybrids (tangelo, tangor).
- **Intergeneric Hybridization**: Rare, but used in rootstock development (e.g., citrange from Citrus × Poncirus).



Polyploidy Breeding

- Inducing polyploidy with chemicals like colchicine or oryzalin.
- Production of triploid (seedless) varieties in citrus and banana.

Mutation Breeding

- Use of radiation (gamma rays, X-rays) or chemicals (EMS) to induce variability.
- Examples: 'Thompson Seedless' grape mutants, seedless guava, dwarf papaya lines.

Modern Breeding Approaches in Fruit Plants

Marker-Assisted Selection (MAS)

Molecular markers such as SSR, RAPD, and SNP allow early selection for traits like disease resistance and fruit quality.

Genomic Selection & GWAS

Advanced genomics enables trait mapping and prediction of breeding values, useful in long-generation crops like mango and apple.

Genetic Engineering

- **Transgenic Fruits**: Papaya resistant to *papaya ringspot virus* in Hawaii.
- **Delayed Ripening Tomato**: Example of genetic engineering for shelf-life extension.

Genome Editing (CRISPR-Cas)

- Precise modifications in fruit genomes.
- Potential for developing seedless varieties, improving stress tolerance, and enhancing nutritional quality.

Tissue Culture & Soma clonal Variation

- **Micropropagation**: Mass multiplication of elite varieties.
- **Embryo Rescue**: Overcoming seed abortion in wide crosses.
- **Somatic Hybridization**: Fusion of protoplasts for novel hybrids.

Breeding Strategies for Major Fruit Crops

Mango

- Objectives: dwarfness, regular bearing, fruit quality.
- Example hybrids: 'Mallika' (Neelum × Dashehari), 'Amrapali' (Dashehari × Neelum).

Banana

- Triploid breeding for seedless edible bananas.
- Tissue culture for mass propagation of disease-free plants.

Citrus

- Seedless hybrids (Kinnow seedless).
- Rootstock breeding for nematode and drought tolerance.

Grapes

- Focus on seedlessness, disease resistance, and export quality.
- Popular variety: 'Thompson Seedless' and its mutants.

Apple

- Breeding for scab resistance (e.g., 'PRI' series).
- Dwarfing rootstocks for high-density planting.

Other Fruits (short notes)

- **Papaya**: 'Pusa Nanha' (dwarf), PRSV-resistant transgenics.
- **Guava**: Seedless selections, 'Arka Mridula'.
- **Pomegranate**: 'Bhagwa' for export markets.
- **Litchi & Jackfruit**: Breeding at early stages but with potential.

Role of Biotechnology in Fruit Breeding

- **DNA Fingerprinting**: Variety identification and protection.
- **Genomic Resources**: Whole genome sequencing (mango, banana, citrus) aids in trait discovery.
- **Cryopreservation**: Long-term germplasm storage.
- **Bioinformatics**: Data-driven breeding decisions and trait mapping.

Conclusion

Fruit breeding has traveled a long journey—from simple clonal selections in ancient times to modern genome editing and digital breeding tools. Despite challenges like long juvenile phases and complex inheritance, remarkable progress has been made in developing high-yielding, seedless, disease-resistant, and export-quality fruit varieties.

The future lies in integrating traditional knowledge with modern tools, ensuring sustainability, and aligning breeding objectives with farmers' needs and consumers' preferences. In this way, fruit breeding will not only improve productivity but also contribute to nutritional security, rural development, and a sustainable horticultural future.

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FISH OIL TO PHARMA: THE JOURNEY OF MARINE BIOACTIVES

Email

[1]Praveenkumar Pandiyan* and [2]Ajeet Soni

praveenkumar@tnfu.ac.in

[1]Department of Fish Processing Technology, Dr. MGR Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam, Tamil Nadu, India

[2]Department of Fish Processing Technology, College of Fisheries Science & Research Centre, Etawah, Uttar Pradesh, India

The marine environment, covering more than 70% of the Earth's surface, is an immense and largely untapped source of bioactive compounds. These compounds — derived from fish, algae, seaweeds, crustaceans, and marine microbes — hold great promise in addressing many of today's health challenges. For centuries, humans have consumed seafood for its flavor and nourishment. But recent research highlights the ocean's hidden potential: the production of natural molecules with antimicrobial, anticancer, anti-inflammatory, and antioxidant effects. As we navigate the 21st century, the intersection of marine biology, nutrition, and pharmaceutical sciences is revealing a new frontier — one where marine bioactives evolve from dietary supplements into targeted therapeutic agents.

From the Ocean to Our Plate: Nutritional and Functional Foundations

A. Richness of Marine Lipids

Marine lipids, particularly from oily fish like salmon, tuna, and sardines, are packed with omega-3 polyunsaturated fatty acids (PUFAs) like EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid). These fats are essential to human health and cannot be synthesized endogenously.

B. High-Quality Proteins and Micronutrients

Fish offer a complete profile of amino acids and are rich in micronutrients including iodine, calcium, selenium, vitamin D, and B-complex vitamins. Even small indigenous species like *Amblypharyngodon mola* contain retinol and dihydro-retinol, essential for vision and immunity.

C. Cardiovascular and Cognitive Health

Numerous clinical trials and WHO recommendations support the regular intake of fish to prevent cardiovascular diseases, reduce triglycerides, and improve brain function and mood stability.

Marine Bioactive Compounds: Nature's Hidden Pharmaceuticals

A. Fatty Acids and Beyond

While omega-3 PUFAs have gained attention for heart and brain health, marine organisms also produce unique lipid classes such as methoxylated, halogenated, and branched fatty acids, especially in invertebrates like sponges and gorgonians. Some of these have antimicrobial, immunomodulatory, and even antitumoral properties.

B. Antioxidants from the Sea

Compounds such as astaxanthin (from crustaceans), fucoxanthin (from brown seaweed), and phenolic compounds (from algae and cyanobacteria) help neutralize oxidative stress, which contributes to aging, cancer, and neurodegenerative disorders.

C. Marine Polysaccharides

Algal polysaccharides like alginates, fucoidans, and carrageenans exhibit anti-viral, anticoagulant, and immune-boosting properties. These are increasingly used in dietary supplements, wound healing materials, and anti-obesity formulations.

Marine Bioactive Peptides (MBPs): Tiny Molecules, Massive Impact

A. Peptides with Potency

Enzymatic hydrolysis of fish muscle, skin, and viscera produces peptides that serve as natural inhibitors for ACE (angiotensin-converting enzyme), demonstrating antihypertensive effects. Others have antioxidant, antimicrobial, and opioid-like actions.

B. Sources and Extraction

Marine bacteria, microalgae, and fungi also synthesize bioactive peptides. These are extracted using green biotechnological approaches including enzyme-assisted extraction, membrane filtration, and chromatography.

C. Market and Regulation

While MBPs are not yet widely used in mainstream pharmaceuticals, the nutraceutical industry is actively commercializing marine peptides for use in protein drinks, functional snacks, and elderly nutrition formulations.

From Fish Oil to Clinical Pills: Functional Foods Meet Pharmaceuticals

A. Nutraceuticals and Functional Foods

Marine-derived supplements like fish oil capsules, krill oil, and algae-based omega-3s are widely available. These are not only used for cardiovascular wellness but also increasingly for sports nutrition and eye health.

Fig 1. Fish Oil Capsules

B. Marine Drugs and Clinical Trials

FDA-approved marine-derived drugs such as Lovaza and Vascepa (both purified omega-3 formulations) are prescribed to treat high triglyceride levels. Additionally, several marine compounds — including those from cone snails and sea sponges — are in clinical or pre-clinical stages for cancer and neuropathic pain.

C. Emerging Trends

Nanoencapsulation, emulsion technology, and bio-delivery systems are being developed to enhance the absorption and effectiveness of marine bioactives.

Sustainability, Circular Economy, and the Blue Biotech Revolution

A. From Waste to Wealth

Fish processing byproducts (heads, skin, bones, viscera) are being upcycled into hydrolyzed protein powders, oils, collagen, gelatin, and bioactive peptides, reducing environmental load and creating value-added products.

B. Role in Sustainable Development Goals (SDGs)

Marine bioactives directly support SDG 2 (Zero Hunger), SDG 3 (Good Health), and SDG 12 (Responsible Consumption and Production). Integrating marine bioproducts into local diets can address malnutrition and food insecurity, particularly in coastal and island communities.

C. Eco-Friendly Technologies

Modern extraction processes such as subcritical water extraction, enzyme-assisted extraction, and membrane technologies align with green chemistry principles, making the production of bioactives more sustainable.

Future Prospects and Research Frontiers

A. Marine Bioprospecting

Deep-sea organisms, extremophiles, and marine symbionts offer immense untapped potential for discovering new antibiotics, anticancer agents, and metabolic modulators.

B. Interdisciplinary Collaboration

The journey from fish to pharma requires a collaborative ecosystem — involving fisheries scientists, marine ecologists, biotechnologists, nutritionists, and pharmaceutical developers.

C. Challenges Ahead

Issues such as standardization, clinical validation, regulatory approval, and consumer acceptance remain barriers that must be addressed with science-based policies and public education.

Conclusion: A Sea of Possibilities

The story of marine bioactives is not just about fish oil or seaweed capsules. It's about how the ocean's bounty — once seen as mere food — is transforming into a robust platform for health, wellness, and therapeutics. With continued research, innovation, and sustainable harvesting, the marine realm could hold the keys to solving some of the greatest health challenges of our time.

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UNDERSTANDING HOST PHYSIOLOGY FOR EARLY DETECTION OF FOLIAR DISEASES IN FLORICULTURE CROPS

Email

akshayaagri14@gmail.com

[1]Akshaya S.B*, [2]Shakila Sadasivam, [3]Jeyajothi R and [4]Vinothini N

[1]Department of Plant Pathology, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District - 603 201, Tamil Nadu, India

[2]Department of Floriculture and Landscape Architecture, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District - 603 201, Tamil Nadu, India

[3]Department of Agronomy, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District - 603 201, Tamil Nadu, India

[4]Department of Seed Science and Technology, SRM College of Agricultural Sciences, SRM Institute of Science and Technology, Baburayanpettai, Chengalpattu District - 603 201, Tamil Nadu, India

Floriculture involves the cultivation of flowering and ornamental plants for commercial and aesthetic purposes. With growing global demand for flowers, maintaining plant health has become increasingly important. Among the major challenges in this field are foliar diseases that affect leaves, the primary photosynthetic organs, leading to reduced growth, flower production, and visual appeal. Traditional disease detection often relies on visible symptoms, which appear only after significant physiological damage has occurred. Hence, there is a pressing need for early detection methods rooted in the understanding of plant physiological responses to disease onset.

Major Foliar Diseases in Flower Crops

Common foliar pathogens affecting floricultural crops include

Disease Name	Causal Organism (Scientific Name)	Commonly Affected Flower Crops
Powdery Mildew	*Erysiphe cichoracearum, Podosphaera spp.*	Rose, Marigold, Chrysanthemum
Leaf Spot	*Alternaria alternata, Cercospora spp.*	Gerbera, Dahlia, Zinnia

Anthracnose	*Colletotrichum gloeosporioides, C. capsici*	Hibiscus, Gladiolus, Chrysanthemum
Rust	*Puccinia spp., Uromyces spp.*	Marigold, Snapdragon, Carnation
Downy Mildew	*Peronospora spp., Plasmopara spp.*	Petunia, Impatiens, Aster
Botrytis Blight (Grey Mould)	*Botrytis cinerea*	Rose, Geranium, Begonia
Bacterial Leaf Spot	*Xanthomonas campestris, Pseudomonas spp.*	Carnation, Gerbera, Chrysanthemum
Septoria Leaf Spot	*Septoria spp.*	Carnation, Aster
Stemphylium Leaf Spot	*Stemphylium solani*	Cotton (ornamental cultivars), Marigold
Cercospora Leaf Spot	*Cercospora carotae, C. gossypina*	Gerbera, Dahlia, Carnation

Physiological Responses to Pathogen Infection

Plants exhibit various physiological changes upon pathogen invasion, even before symptoms become visible. These include:

- ✓ Reduction in chlorophyll content: Decreases photosynthesis and causes chlorosis.
- ✓ Altered stomatal behaviour: Affects transpiration and gas exchange.
- ✓ Elevated reactive oxygen species (ROS): Trigger plant defence mechanisms.
- ✓ Hormonal imbalances: Particularly involving salicylic acid, Jasmonic acid, and ethylene.

Monitoring these physiological parameters can provide an early indication of stress, aiding in the pre-symptomatic detection of foliar diseases.

Physiological Indicators for Disease Monitoring

Parameter	Physiological Change	Detection Method
Photosynthetic Rate	Decline due to chloroplast damage or stomatal closure	Chlorophyll fluorescence, gas exchange tools
Stomatal Conductance	Irregular transpiration patterns	Pyrometry, thermal imaging
ROS Accumulation	Elevated oxidative stress markers (e.g., H_2O_2, MDA)	Biochemical assays, biosensors
Leaf Pigment Shifts	Altered chlorophyll, carotenoid, and anthocyanin levels	Hyperspectral imaging, pigment quantification
VOC Emissions	Pathogen-induced changes in volatile profiles	GC-MS, electronic nose
Leaf Water Potential	Disruption due to vascular blockage or necrosis	Pressure chamber, remote sensing

Integrating Technology with Plant Physiology

- ✓ Hyperspectral imaging: Detects delicate spectral changes linked to stress.
- ✓ Drones with multispectral cameras: Survey large fields to identify affected zones.
- ✓ IoT-based sensors: Measure microclimate, chlorophyll index, and other physiological traits.
- ✓ Machine learning models: Predict disease onset using physiological data patterns.

Application of Integrating Technology in Floriculture Crops

Floricultural crops are particularly sensitive to foliar diseases due to their aesthetic value and market timing.

- **Roses**: Early detection of powdery mildew via stomatal conductance and VOC profiling.
- **Gerbera & Carnation**: Leaf spot and blight monitored through pigment degradation and ROS markers.
- **Orchids**: Viral infections detected via hyperspectral shifts and water potential changes.
- **Chrysanthemums**: Rust and bacterial blight diagnosed using fluorescence and VOC sensors.

Conclusion

Understanding host physiology provides a valuable framework for the timely detection of foliar diseases in floriculture. By monitoring key physiological changes and integrating them with smart sensing technologies, growers can achieve better disease control, reduce losses, and ensure sustainable flower production. As precision floriculture continues to evolve, physiology-driven disease surveillance will be central to modern crop protection strategies.

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