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Net-Zero Horticulture: Reducing the Environmental Footprint through Carbon Sequestration and Agro-Waste Repurposing

Paresh Bhagat[1] and Radheshyam Dhole[2]

Abstract: -

Horticulture is a major contributor to agricultural productivity and nutrition security, but it also contributes significantly to greenhouse gas (GHG) emissions through conventional cultivation practices, energy-intensive inputs, and post-harvest waste. The concept of net-zero horticulture emphasizes minimizing emissions while enhancing carbon sequestration and repurposing agro-waste into value-added products. Techniques such as biochar production, composting, cover cropping, and renewable energy integration offer opportunities to reduce the environmental footprint. This article examines the challenges, emerging technologies, and future strategies for implementing net-zero horticulture in India.

Keywords: Net-zero horticulture, carbon sequestration, agro-waste management, sustainable agriculture, climate-smart horticulture, India etc.

Introduction:

Horticulture, including fruits, vegetables, ornamental plants, and spices, plays a crucial role in India's agricultural economy. However, conventional horticultural practices contribute to greenhouse gas emissions via chemical fertilizers, fossil fuel use in irrigation and machinery, and post-harvest losses. With climate change posing an increasing threat, there is an urgent need to transition toward sustainable practices that reduce environmental impact.

Net-zero horticulture aims to balance emissions with carbon sequestration and waste repurposing strategies, effectively minimizing the sector's carbon footprint. This includes using soil carbon enhancement techniques, recycling agro-waste into organic fertilizers or energy, and adopting climate-smart practices.

Paresh Bhagat[1] and Radheshyam Dhole[2]

[1] Research Scholar,

[2]Assistant Professor,

Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University, Jamuhar Sasaram, Bihar- 821305

Net-zero horticulture is aligned with India's broader climate commitments under the Paris Agreement and supports sustainable food systems.

Current Challenges in Achieving Net-Zero Horticulture

1. High GHG Emissions The extensive use of synthetic fertilizers and pesticides contributes to nitrous oxide and carbon dioxide emissions. Energy-intensive irrigation and mechanization further increase the carbon footprint.
2. Agro-Waste Management Horticulture generates significant organic waste, including fruit and vegetable peels, crop residues, and pruning residues. Improper disposal leads to methane emissions and environmental pollution.
3. Lack of Awareness and Knowledge Farmers often lack knowledge about carbon sequestration techniques, biochar application, or circular waste management approaches. Without training, adoption rates remain low.
4. Economic Constraints Implementing net-zero practices may require upfront investments in renewable energy systems, composting units, or soil amendment technologies, which can be a barrier for smallholder farmers.
5. Limited Policy and Market Incentives Although government schemes promote sustainable agriculture, incentives specifically targeting carbon sequestration and net-zero horticulture are limited. Carbon credit schemes for horticulture remain underdeveloped.

Technological Innovations for Net-Zero Horticulture

1. Carbon Sequestration in Soil Techniques such as cover cropping, mulching, and organic amendments enhance soil organic carbon. Biochar application not only sequesters carbon but also improves soil fertility and water retention. Agroforestry integration in orchards further stores carbon in woody biomass.
2. Agro-Waste Repurposing Crop residues and pruning waste can be converted into compost, organic fertilizers, and bioenergy. Anaerobic digestion of organic waste produces biogas, reducing reliance on fossil fuels. Value-added products such as vermicompost, organic liquid fertilizers, and biochar support sustainable production while generating income.
3. Precision Agriculture and Smart Irrigation Sensor-based irrigation, soil moisture monitoring, and nutrient management reduce energy consumption and optimize fertilizer

use. Digital tools allow precise application of inputs, minimizing environmental impact.

4. Renewable Energy Integration Solar-powered pumps, biomass-based energy systems, and small-scale wind energy reduce dependency on fossil fuels in horticulture operations. Solar drying of fruits and vegetables minimizes post-harvest losses while using clean energy.
5. Climate-Smart Crop Varieties Adopting drought-tolerant, pest-resistant, and high biomass crops enhances carbon sequestration while maintaining productivity. Research on high-yield organic inputs also supports emission reduction strategies.

Conclusion and Future Perspectives

Net-zero horticulture represents a paradigm shift toward sustainable, low-carbon food production. Its adoption offers multiple benefits: reduced greenhouse gas emissions, improved soil health, minimized environmental pollution, and enhanced resilience to climate change.

To scale net-zero horticulture in India, the following strategies are crucial:

1. **Capacity Building and Training:** Educating farmers on carbon sequestration, agro-waste management, and renewable energy adoption.
2. **Policy Support and Incentives:** Developing carbon credit schemes, subsidies for renewable energy, and incentives for sustainable horticulture practices.
3. **Research and Development:** Innovating cost-effective technologies for biochar production, organic nutrient management, and precision farming.
4. **Market Development:** Promoting value-added organic products derived from agro-waste and linking them with premium markets.

Conclusion

Achieving net-zero horticulture requires coordinated efforts from farmers, policymakers, researchers, and industry stakeholders. By integrating carbon sequestration practices, repurposing agro-waste, and embracing climate-smart technologies, India can transition toward a sustainable horticultural sector that balances productivity with environmental stewardship.

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