Promoting Protected Cultivation in India

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BACKGROUND

Mitigation of climate change and safeguarding future food production centred on health and sustainability require the agriculture sector to step up its transition to more resource-efficient and climate-friendly technologies. Reasons for seeking better agriculture include (1) rapidly increasing world population, (2) urbanization, (3) aging population, (4) economic growth, (5) agricultural investments, (6) economic inequality, (7) greater competition for natural resources, (8) climate change, (9) trans-boundary pests and diseases, and (10) plateauing of agricultural productivity for many crops. A more fundamental approach to food production in tune with contemporary innovations occurring in other domains of science and technology is required. One such innovation is Protected Cultivation that has the potential to overcome the majority of shortcomings of traditional agriculture.

https://doi.org/10.52151/aet2026502.1924

PROTECTED CULTIVATION

Crops in open fields are subjected to a large number of biotic and abiotic stresses leading to their partial or complete failure. Protected cultivation came into existence with a view to provide economically justifiable protection against the important stresses. Protective cultivation technologies generally include Anti-Hail / Anti-Bird Nets, Cloche, Mulching, Row cover/ low tunnel, Floating row cover, Shade/ Net house, Micro-irrigation, Hydroponics, Aeroponics, Aquaponics, Aeroponics, Zeoponics, Greenhouse, Plant factory, and Agri-cube. Protected cultivation is an intensive technology in terms of capital, energy, and technology.

Protected cultivation allows the raising of plants anytime, anywhere on or under land/ water, and in space. Crop productivity is possible to be maximized per unit area, per unit time, per unit input, and per unit volume. The crop output has high-quality and is free from all kinds of contaminants.

The most advanced type of protected cultivation, plant factory (indoor plant production) systems, backed up by the concerted efforts of industry, government and academia, is now gaining momentum in the forms of urban agriculture and vertical farms.

ENGINEERING CONCERNS

Protected cultivation today relates to sustainability, resource efficiency, and automation through the incorporation of optimized design of structures, energy conservation, use of renewable energy sources, smart micro-climate control, and machines for crop operations including robots and autonomous ground and arial vehicles.

Simple structures are adequate under mild climates. However, greenhouses for harsher climates need to be designed not only for strength

but also for energy conservation. Preceding three decades have witnessed significant advancements in the management of climate control, production technologies, and strategies to improve resource use efficiency in greenhouses.

Greenhouse climate control is practised for extension of growing season, increasing the yield, and enhancing the produce quality with maximized resource use efficiency. Recent engineering developments in greenhouse technology relate to structural design; covering materials; climate control strategies, hybrid lighting, robotics, AI, rainwater retention pond, energy conservation, renewable energy applications, combined heat and power systems, suspended hydroponics, hyperspectral imaging.

For colder regions, hybrid lighting in greenhouses combines high-pressure sodium (HPS) lamps and light-emitting diodes (LEDs) to balance energy efficiency with beneficial heat generation. LEDs provide better light spectrums and lower operational costs.

Non-electric greenhouse cooling relies on passive techniques to manage temperatures, primarily focusing on ventilation, shading, evaporative cooling, and earth-tube heat exchangers. Key methods may include installing automatic solar-powered roof vents, applying 50-70% external shade cloth, painting roofs with reflective whitewash, using water barrels for thermal mass, and maximizing natural airflow through lower side vents.

A digital twin is a virtual construct, representing the structure, context, and behaviour of a physical system.

A digital twin is born out of using advanced sensor technology, IoT, and AI. The digital twin keeps on getting updated with data from its physical twin and, thus, it is dynamic and changing. The digital twin helps to monitor the physical system in real time, make predictions, and take management decisions.

Greenhouses with no carbon footprint achieve net-zero emissions by generating 100% of their energy on-site via renewable sources like solar, geothermal, or waste heat, coupled with high-efficiency design. Key features include passive solar design, superior insulation, thermal mass (water barrels, sand batteries, rock-beds), and energy-efficient lighting (LED/optical films).

PROTECTED CULTIVATION IN INDIAN CONTEXT

Protected cultivation is a futuristic form of agriculture capable of offsetting the threats of climate change and shortages of land and natural resources. India began to develop and harness the benefits of protected cultivation in late 1980s. This technology could be used to engage Gen Z youth in the development of next-generation agriculture. Protected cultivation systems fit very well in modern value chains that aim at increasing number of quality-conscious urban consumers.

Estimated global protected cultivation area today is 5.6 M ha with about 83% area in China. Protected vegetable cultivation in China has expanded to a total area of 4.0 M ha. Total area under all forms of protective cultivation in India today is only about 0.125 M ha. Our country needs to target at least one million ha under protected cultivation in the next decade to create millionaire farmers and 10 million jobs, besides ensuring the availability of high-quality horticultural produce for domestic and export markets.

Adoption of protected cultivation technologies throughout the country would require R&D efforts to provide solutions to emerging field problems. There is so far no dedicated institution in the country to lead the protected cultivation programme. Therefore, establishment of an institute on protected cultivation technology (say, National Institute on Protected Cultivation Technologies) is essential to support the protected cultivation programme in India.