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Adoption of Protected Cultivation - in Context to Indian Farming Scenario

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ABSTRACT

The increase in environmental stress greatly affects crop production in this era of climate change. Excessive exploitation of natural resources is also contributing towards degradation of crop environment that ultimately gets reflected through low production and productivity of crops. Some areas of our country having arid and semi-arid climate is also not suitable for growing certain crops of high-demand in open-field where installation of protected structures can effectively grow crops that could generate revenue and provide employment to un-educated youths. Protected cultivation requires various sensors, automation devices which can efficiently work as per the requirement of the crop and improve the productivity. It overcomes many biotic and abiotic factors such as photo-stress, water stress, heat stress, weed growth, soil nutrient deficiencies, high wind velocities and atmospheric carbon dioxide, pest and diseases. Protected cultivation is a scientifically sound technique for growing vegetables, flowers and other high value as well as consumable crops. Various centrally funded schemes are also present that can enable farmers to adopt protected cultivation to boost their economy. This writeup encompasses the present scenario of protected cultivation in India along with certain benefits, constraints and achievements.

Keywords: *Automation devices, Heat stress, Pest and Disease, Photo-stress, Protected cultivation*

INTRODUCTION

Protected cultivation basically refers to growing of vegetables, fruits, flowers and other high-value crops under certain structures having specific controlled microclimate to enable off-season production and minimize use of inputs required in production on the other hand, maintaining quality of the produce. It protects the crops from pest, disease and other biotic and abiotic stress (Jewett and Jarvis, 2001). Indian farmers basically adopt structures like green house, shade net, polyhouses and low tunnels where the main growth regulating factors like light, temperature, humidity and others are maintained as per the cultivated crops (Manjunatha *et al.,* 2023). Protected cultivation increases the cropping intensity and improves total production. Productivity and quality of crops are seriously affected by biotic and abiotic stress factors in the current changing climate. Major problems arise due to extreme temperatures, sunshine, water availability, relative humidity, weeds, nutrient deficiencies, wind velocity, carbon dioxide concentration, illnesses, and insect pest occurrences in horticultural crop production (Rasheed *et al.,* 2020; Trivedi, 2019). Protected cultivation guarantees higher returns due to higher yield with superior quality. Moreover, it ensures efficient utilization of fertilizers, pesticides, and water incomparision to the open field conditions (Sanwal *et al*., 2004; Martínez-Blanco *et al*., 2011; Van Lenteren, 2000; Yang *et al*., 2014). Vegetables like tomatoes, cucumbers cultivated in green-houses are bigger in sizes with superior quality while on the other hand, flowers or orchids cultivated like gerbera, roses have excellent bloom quality and higher market values. Using technologies such as automated climate-control systems, fertigation, and drip irrigation can cut production costs and lessen environmental impact by reducing water and fertilizer use. The enclosed environment also acts as a physical barrier to many pests and diseases, decreasing reliance on chemical pesticides and promoting more environmentally friendly farming practices (Jain *et al.,* 2025). Protected cultivation first began in India in the 1990s and presently being adopted in states of Maharashtra, Andhra Pradesh, Chhattisgarh, Madhya Pradesh etc. The Government of India has launched several programs to promote protected cultivation, including the National Horticulture Mission (NHM), National Horticulture Board (NHB), Rashtriya Krishi Vikas Yojana (RKVY), and the Horticulture Mission for North East and Himalayan States (HMNEH). The flagship NHM provides substantial support, offering a 50% subsidy for constructing protected cultivation structures and an additional 50% subsidy for purchasing planting material and for vegetable and flower cultivation within polyhouses or shade-net houses (Prakash *et al.,* 2020). Although protected cultivation offers clear advantages, several barriers that limit its adoption among certain farmer groups: high upfront investment, the need for specialized technical knowledge, and limited awareness among small and marginal farmers. Additionally, maintenance costs, uneven access to credit, and gaps in local supply chains for quality materials and spare parts discourage many growers. Moreover, training and extension services are often insufficient, due to which farmers hesitant to shift from traditional practices towards modern protected cultivation methods. Despite the existence of certain challenges, the outlook for protected horticulture is promising in terms of producing superior produce all the year round and fetching high price. Strengthening of market linkages, farmer cooperatives, SHGs and public–private partnerships can further reduce risk and improve returns, making protected cultivation increasingly feasible for smallholders. As more farmers learn about protected farming and receive hands-on training, many will start using adopting these advance systems, that will help them grow crops all year, earn better incomes, and cope better with changing climate.

OBJECTIVES OF PROTECTED CULTIVATION

The main objectives for protected cultivation are simple. It acts as a shield against both biotic and abiotic stress with the motto of resource conservation while increasing the quality of the produce and high price of the cultivated crops.

- Lower and precise utilization of water.
- No to well manageable weed growth.
- Application of fungicides or pesticides are reduced.
- More output per unit of space.
- Production of high-quality crops.
- Year-round production of crops with increased self-life.
- Growing of high-value crops and propagation methods become feasible.
- Genetically modified crops are easily cultivated.

(Krishna et al., 2023)

STRUCTURES INVOLVED IN PROTECTED CULTIVATION

Various types of protected structures are innovated for cultivation of crops in controlled or modified environment. They are as follows:

- **Low tunnels:** These simple structures consist of nets or plastic sheets draped over low wire hoops to cover plant rows. They protect crops from wind, frost, pests, and insects. They maintain the crop temperature by keeping them warm and protect from frost during early growth stages.
- **Walk-in tunnels:** Walk-in tunnels that are larger and robust facilitate further protection and are used in off-season for cultivating vegetables (Kaur and Singh, 2021)
- **Insect-proof Net houses:** These are framed constructions clad with fine mesh (40-50 mesh size) designed to exclude insect pests. Crops susceptible to various viruses for e.g., tomatoes, chillies and cucurbits can be grown safely (Sharma et al., 2019).
- **Shade Net Houses:** The coverings used are UV-stabilized in such houses. These structures reduce heat stress along with wind protection in tropical and subtropical places. They are particularly well suited for the production of ornamental foliage and leafy vegetables (Rana *et al.,* 2018).
- **Greenhouses/Polyhouses:** These semi-permanent structures provide a partially controlled environment for light, temperature, humidity, carbon dioxide concentration, and air circulation. Such structures are enclosed by transparent or translucent coverings, (made of polyethylene, poly carbonate and glass materials). Greenhouses enable year-round or off-season cultivation of high-value crops such as flowers, fruits, and vegetables (tomatoes, strawberries, capsicum, and flowers like carnations and gerberas) (Kumar *et al.,* 2020). with climate-controlled and naturally ventilated greenhouses are present, having fan-pad cooling, heating, and fogging systems. Polyhouses are typically more cost-effective for small and medium size farming households.
- **Mist chambers:** These enclosed propagation units maintain elevated humidity through periodic misting to support the rooting and establishment of cuttings, seedlings, and tissue-cultured plantlets. They enhance plant survival and root development.
- **Plastic tunnels:** Constructed as arched or semi-circular frames that are covered with plastic film, these structures create a warm, humid microclimate that facilitates early or extended-

season crop production. Although these are larger in both span and height, plastic tunnels are conceptually similar to low tunnels.

- **Mulching:** Mulching involves covering the soil surface around plants with synthetic fabrics, organic residues, or plastic films to regulate soil temperature and moisture, improve soil structure, reduce erosion, and suppress weed growth.
- **Trench cultivation:** This technique entails digging trenches and covering them with plastic film to grow vegetables under severe winter conditions. The trenches conserve moisture and capture heat from the sun and surrounding soil, creating a warmer microenvironment for crops.
- **Floating plastic covers:** This method uses transparent plastic sheeting laid over large open areas to protect crops from snow, frost, and low temperatures. As it creates a greenhouse effect, thus extends the growing season.
  (Shukla *et al.,* 2024)

CURRENT SCENARIO IN INDIA

Presently, approx. 58,000 ha area are covered with protected farming facilities and common crops grown are tomato, capsicum, cucumber, broccoli, red cabbage, leafy vegetables, radish among vegetables and roses, gerbera, carnations Chrysanthemum among flowers, strawberry, papaya, exotic fruits etc (Keshwania *et al.,* 2021). The agro-climatic condition of India varies regionally. From north to south and east to west, there are various agro-climatic zones having different cropping patterns according to the respective zone. Protected cultivation is in its early growing stage with 0.2% area under it compared to Turkey, Israel and Netherlands (Thakur *et al.,* 2023). The Centre for Protected Cultivation Technology was set up in 1998–99 as a demonstration farm and, in January 2000, was launched as an Indo-Israel project. The initiative was implemented jointly by the Government of India (through DARE & ICAR) and the Government of Israel (through MASHAV & CINADCO). The project farm was intended to showcase technologies for intensive, commercially focused peri-urban horticulture to enhance crop quality and productivity. The centre was also designated to serve as a nodal hub for R&D and training (ToT) in these areas. (Nair and Barche, 2014 and Saravaiya *et al.,* 2014). The leading states of India covered under protected cultivation are Maharashtra, Andhra Pradesh, Karnataka, Chhattisgarh, Gujarat, Himachal Pradesh, Uttarakhand, Telangana, Rajasthan, Punjab, Haryana, Uttar Pradesh and NE- States. As Per the Ministry of Agriculture and Farmers' Welfare (2021), Andhra Pradesh leads in protected cultivation area with 5,142 hectares, followed by Karnataka (4,152 ha), Chhattisgarh (3,666 ha) and Gujarat (3,075 ha), among other states. There are some well-suited hybrids from private sectors that are cultivated under protected cultivation are- Tomato: Naveen 2000 Plus, Avtar, Pusa Tomato (Protected-1), Pusa Rakshit, Arka Meghali, Arka Saurav, Pant Poly House Tomato-1, Pant Poly House Tomato Hybrid-1; Cherry tomato: Punjab Red Cherry, Punjab Sona Cherry, Punjab Kesar Cherry, Pusa Cherry Tomato-1; capsicum: Indra, Bharat, Mahabharat, California Wonder, Orobelle, Tanvi Plus; Parthenocarpic cucumber: Kian, Nun-9729 and Nun 3019, Pant Parthenocarpic Cucumber-2; Besides these private sector hybrids, hybrids developed by research organizations under public sector that are released: Pusa Seedless Cucumber-6, Him Palam Khira-1 in cucumber; Arka Basant and Arka Gaurav in capsicum; and Pusa Rakshit, Arka Meghali, Arka Saurav in tomato suitable for cultivation under protected structures. Swarna and Shonima have been developed by crossing a stable tetraploid line of watermelon KAU-CL-TETRA-1(4×) with diploid males (2×) namely, CL-4 (red fleshed) and CL-5 (Yellow fleshed), respectively This scientific method can boost higher production both in commercially grown high value vegetable crops but also in certain vegetables such king chilli, bird eye chilli, dale chilli that are endemic to north eastern region even under adverse agro-climatic conditions (Krishna *et al.,* 2023 and Devi *et al.,* 2025).

CORE ELEMENTS USED IN PROTECTED CULTIVATION

i) Structural Components

- Polyhouse/greenhouse frames of galvanized iron or steel structures that withstand wind and load.
- UV-stabilized LDPE film of 200-800 microns providing durability with better light transmission.
- Polycarbonate sheets of 16 mm twin wall that are highly insulated and resistance to impact.
- Shade-nets with 35%-90% shading capacity in hot climates.

(Kale *et al.,* 2019; NCERT, 2024)

ii) Climate Control Systems

Temperature and Humidity Management

- DHT22, STC-3028 sensors that are effective for real-time monitoring of air, temperature and relative humidity.
- Natural (side and roof vents) or forced ventilation (exhaust fans and pad-fog cooling system).
- Night-time insulation through use of thermal screens and foggers or misters enabling evaporative cooling.

(Jaber, 2024; Zbotic, 2026)

iii) Light Management

- Light Dependent Resistor (LDR) that sense or monitor light intensity.
- Supplemental LED grow lights (250W) and automated shade-nets.

(Jaber, 2024)

iv) CO2 Enrichment

- CO_2 sensors and dosing systems monitor and maintain concentration of carbon dioxide at 700-1200 ppm to regulate photosynthesis at closed periods.

(Li *et al.,* 2018; Villagran *et al.,* 2025)

v) Irrigation and fertilizer application

- **Drip irrigation and fertigation:** Drip irrigation enables in water to reach the root zones efficiently minimizing evaporation and disease spread. Through delivery of water, nutrients are also supplied in combination for which EC and pH probes supervise quality of nutrient solution and dosing pumps enable in supplying fertilizers to the crops according to the crop growth stage (Gorantiwar *et al.,* 2022).

vi) IoT and Automation

- Microcontrollers such as ESP32, Arduino or PLC-based systems enable recording real-time data.

- IoT systems like Wi-Fi or LoRa gateways transmit data to cloud storage for future monitoring/analysis in real-time.
- Human-Machine Interface panels enables on-site control and visualization.
- Sensors, weather stations, and control systems to track and adjust conditions such as temperature, humidity, light, and CO_2 EC and pH. Sensors are also fitted near crops canopy/root zones and also beside roof vent, misters etc. to record conditions existing inside a protected structure.
  (Gorantiwar *et al.,* 2022; Nguyen, 2025)

vii) Energy efficient facilities through installation of photo-voltaic panels to run coolers, fans, pumps and sensors and rainwater harvesting structures with collection, filtration and re-directing for irrigation purpose (Gorantiwar *et al.,* 2022).

CULTIVATION MEDIUM UNDER PROTECTED FARMING

- **Soil cultivation** is the conventional way of cultivating crops directly in soil. However, crops are often affected by soil-borne pests and diseases due to avoidance of soil sterilization methods.
- **Cultivation in growing media/substrate** such as **hydroponics and aeroponics** which is a soilless method that is becoming increasingly popular among farmers and agri-entrepreneurs. In this system, vegetables are grown under protected conditions using media like cocopeat, rock wool, vermicompost, perlite, and vermiculite, which helps reduce infestation from soil-borne disease or pest.
  (Krishna *et al.,* 2023)

BENEFITS OF PROTECTED CULTIVATION

Key benefits of protected cultivation are summarized below:

- Complete avoidance of adverse climatic condition.
- Off-season production and supply of crops.
- Effective management of pest and disease.
- High quality and healthy seedlings are obtained.
- Production and productivity per unit of land area is increased.
- Enables cultivation of crops in areas where open field cultivation is a major constraint.
- Effective water management due to involvement of drip irrigation, floggers or misters.
- Efficient nutrient management through fertigation.
- Introduction of sensors and automation provide real-time data on crop health and other cultivation practices.
- Multiple cropping is possible.
- Use of hydroponics, aeroponics is feasible.
- Controlled environment reduces the use of agro-chemicals for pest and disease management providing healthy and nutritious crops to the consumers.
- Small and the marginal land holders get chance to boost their income by cultivating vegetable crops suited for the international markets.
- Employment generation for youths.

(Panwar *et al.,* 2009; Ummiyah *et al.,* 2017; Selvakumar *et al.,* 2019; Maitra *et al.,* 2020; Sheeba *et al.,* 2025).

CONSTRAINTS OF PROTECTED CULTIVATION

There are few constraints that if resolved could improve the scenario of protected cultivation in India. They are as follows:

- Lack of proper irrigation infrastructure lead to non-adoption of protected cultivation practices in arid areas.
- Non-availability of quality growing media and low fertile soil is a major concern.
- Low-cost structures face issues due to uneven or erratic climatic condition.
- Requirement of high installation cost due to hi-tech automation systems require to be fitted inside greenhouse for monitoring and managing of crops grown.
- Sudden peak in material prices, logistics and taxation in setting up protected structures along with applying for loans at affordable interest rates for small or marginal farmers are major barriers.
- Reduction of financial assistance cutoff from 50% to 35% in general areas can lead to farmers with lower financial strength in avoiding adoption of protected cultivation and re-routing towards conventional farming.
- Skill-development training and awareness generation is limited to certain areas only as protected cultivation required high skill in operating the highly automated devices and real-time data collection.
- In tropical and sub-tropical areas, the hot and humid condition prevailing can affect the crops grown inside protected structure for which high quality exhaust, cooling pad, fan, foggers, pumps and sensors are required to be operational throughout day and night leading to increase in operational cost.
- For heat control in Indian condition, proper and frequent venting is required that leads to loss of CO_2 that limits enrichment for crops.
- The automated sensors, UV films require to be working perfectly for obtaining excellent yield and failure of such materials can cause yield loss in crop. So, maintenance is required.
- Lack of field demonstration, access to technical training, and advisory support.
- Late disbursement of funds and approval of project due to unstable coordination between banks, subsidy agencies and technical support agencies.
- Sudden cost celling, subsidy conditions are also responsible for project delay.
- Poor market linkage with small holders.
- Lack of awareness about the benefits of protected cultivation among farmers.
- Shortage of labours as high labour demand during planting, pruning and harvesting period is required.
- Poor or no cold-chain facility lead to post-harvest loss in addition to lack of access to transportation facilities cause deterioration of quality.
- Lower market price often leads to not receiving optimum price for the produce (Keerthika *et al.,* 2026; Mbambalala *et al.,* 2026 and Sarath Chandran *et al.,* 2026).

STRATEGIES FOR ADOPTION AMONG FARMERS

To increase adoption of protected cultivation, farmers need practical support that matches local conditions and real market demand. The most effective steps include better training, stronger extension services, timely access to quality inputs, affordable financing, and climate-specific technologies that are easier to use and maintain.

Adoption will improve further if these technologies are designed with energy efficiency, mechanization, and site-specific planning in mind. At the same time, market-linked measures such as flexible pricing, direct marketing channels, and special insurance support are important so farmers are protected when prices fall or demand becomes unstable. In simple terms, protected cultivation will spread more successfully when it is not treated only as a production technology, but as a complete system that connects farmers to training, finance, inputs, risk protection, and assured markets (Sheeba *et al.,* 2025).

GOVERNMENT SUPPORT SCHEMES

The Government of India extend support for protected cultivation through MIDH and the National Horticulture Board (NHB), with additional support provided under RKVY and NMSA.

KEY SCHEMES

- Mission for Integrated Development of Horticulture (MIDH): This is the centrally sponsored scheme for horticulture, and it aids for protected cultivation structures such as polyhouses, shade net houses, plastic tunnels, and walk-in tunnels.
- National Horticulture Board (NHB): NHB supports commercial horticulture projects under protected cover on a project mode that includes planting material, irrigation, fertigation, and mechanization.
- Rashtriya Krishi Vikas Yojana (RKVY): Protected cultivation is also supported under RKVY.
- National Mission for Sustainable Agriculture (NMSA): This also supports protected cultivation especially for climate-resilient farming.

ASSISTANCE PATTERN

- Under MIDH, assistance is basically provided at 50% of the maximum permissible cost for protected structures such as greenhouses/polyhouses, shade net houses, and tunnels, with area limits varying by structure and beneficiary category.
- NHB provides a credit-linked back-ended subsidy of 50% of the total cost for project of protected cultivation above the eligible minimum area, with a ceiling of Rs. 56 lakh per project.
- For the North Eastern Region, NHB guidelines highlight a lower project area threshold, making easier access for beneficiaries in that region.
  (MA&FW, 2018; MIDH Operational Guidelines, 2024; MA&FW, 2026)

LIMITATIONS

- Cladding materials are expensive, short-durability and sometimes unavailable
- Non-availability of equipment.
- Hand-pollination in cross-pollinated varieties and Parthenocarpic hybrid development.

- The setup is expensive for small and marginal farmers and without proper economical backup farmers are not interested.
- Poor market access for high value crops and lack of logistics infrastructure (Nair and Barche, 2014).

CONCLUSION

In order to improve the productivity of agricultural crops and other ornamental plants for strengthening the economical backbone of the farmers, such technology holds huge potential. Protected cultivation can easily boost the production potential of a country's agriculture share and also contribute towards sustainable agricultural development through production of certain crops of high export value and off-season crops all the year round. It addresses various climatic risks and conserves resources in crop production and brings diversification in income generation. Though there remain some constraints but better progress can be attained with cluster-based models, stronger value chain linkages, capacity building programmes, reducing the extension gaps and better linkage between financial institutions and technical support providers with the farmers through suitable schemes or supportive programmes. If implementation of protected cultivation throughout the country is carried with keeping in mind about the economic condition of the farmers then in coming future it can enhance productivity stability, resource conservation, and farm incomes, thus, placing it as an important component of agrarian transformation.

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