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Protected cultivation of vegetable crops present status and prospects

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Abstract

Protected cultivation is a modern agricultural technology that provides favourable growing conditions for vegetable crops through structures such as greenhouses, polyhouses, shade-net houses, tunnels, and rain shelters. It improves crop productivity, quality, water and nutrient-use efficiency, and enables year-round and off-season production. Major vegetables grown under protected conditions include tomato, capsicum, cucumber, brinjal, lettuce, and leafy vegetables. In India, government programmes such as MIDH and NHB support the adoption of protected cultivation. However, high initial investment, technical requirements, and maintenance costs remain major constraints. Future developments in IoT, automation, hydroponics, aeroponics, artificial intelligence, and precision fertigation are expected to further improve the efficiency and sustainability of protected vegetable production.

Keywords: Protected cultivation, greenhouse, polyhouse, vegetable crops, fertigation, hydroponics.

1. Introduction

Protected cultivation refers to the production of crops within structures that provide a degree of control over environmental factors such as temperature, relative humidity, radiation, ventilation, irrigation and, in advanced systems, carbon dioxide concentration. The primary objective is to create a favourable microclimate that supports crop growth while reducing the effects of adverse environmental conditions.Protected cultivation has become an important component of modern horticulture because conventional open-field production is increasingly

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affected by climatic variability, extreme temperatures, irregular rainfall, pests and diseases.

By modifying the crop environment, protected structures can facilitate higher productivity, better produce quality and more reliable production schedules. Protected cultivation also provides opportunities for off-season vegetable production, when market prices may be favourable (Singh & Sirohi, 2006).The technology ranges from relatively simple low tunnels and shade-net structures to sophisticated climate-controlled greenhouses equipped with automated ventilation, cooling, fertigation and sensor systems. The selection of a structure depends on crop requirements, climatic conditions, investment capacity and the intended production system.

2. Types of Protected Cultivation Structures

2.1 Greenhouse/Polyhouse

A greenhouse or polyhouse is a framed structure covered with transparent or translucent material such as polyethylene, glass or polycarbonate. The covering permits solar radiation to enter while reducing the effects of adverse weather conditions.Temperature, humidity, ventilation, irrigation and nutrient supply can be managed according to crop requirements. Polyhouses are particularly suitable for high-value vegetables such as tomato, capsicum, cucumber, brinjal and lettuce.Protected structures can significantly modify the crop microclimate. In a study conducted in the hot-arid region of Rajasthan, cucumber grown under a naturally ventilated polyhouse exhibited better growth and yield than crops grown under insect-proof and shade-net houses (Khapte *et al*., 2021).

Suitable crops

- Tomato
- Capsicum
- Cucumber
- Brinjal
- Lettuce
- Leafy vegetables

2.2 Insect-Proof Net House

An insect-proof net house is covered with fine mesh that restricts the entry of insect pests while allowing air movement and light penetration. Such structures are useful for reducing insect-mediated disease transmission and can contribute to reduced pesticide use.

Suitable crops

- Tomato
- Chilli
- Capsicum
- Brinjal
- Cucumber
- Leafy vegetables

2.3 Shade-Net House

A shade-net house is covered with shade material that reduces solar radiation and crop temperature. Shade levels can be selected according to crop requirements.

It is particularly useful in regions with high solar radiation and for crops or nursery plants that are sensitive to excessive heat and light.

Suitable crops

- Leafy vegetables
- Coriander
- Nursery plants
- Shade-tolerant horticultural crops

2.4 Low Tunnel

Low tunnels are small structures constructed over crop rows using hoops covered with polyethylene or other protective materials. They are relatively inexpensive and are useful for protecting young plants from low temperatures, frost, wind and adverse weather.

Suitable crops

- Cucumber
- Melon
- Watermelon
- Pumpkin
- Other cucurbits

Low tunnels are particularly useful for off-season vegetable production and can provide an economical form of protected cultivation (Singh & Sirohi, 2006).

2.5. Walk-In Tunnel or High Tunnel

Walk-in tunnels are taller structures that allow workers to enter the structure for irrigation, training, harvesting and other crop-management activities. They generally have a lower investment requirement than sophisticated climate-controlled greenhouses. They are suitable for vegetables such as tomato, cucumber, capsicum, leafy vegetables and nursery crops.

2.6 Row Covers

Row covers consist of lightweight plastic or fabric materials placed directly over crop rows. They provide protection from low temperature, wind and certain insect pests.

Suitable crops

- Cabbage
- Cauliflower
- Radish
- Carrot
- Other short-duration vegetables

2.7 Rain Shelter

Rain shelters consist primarily of a protective roof that prevents direct contact of rainfall with the crop while maintaining natural ventilation. They can be useful in regions receiving heavy or prolonged rainfall.

Suitable crops

- Tomato
- Capsicum
- Chilli
- Other vegetables sensitive to excessive rainfall

3. Greenhouse Construction Materials

The structural components of a greenhouse generally include galvanized iron (GI) pipes, polyethylene covering, insect-proof nets, shade nets, ventilation systems, drip irrigation and fertigation equipment.

Component	Typical specification	Purpose
GI column	60 mm OD × 2 mm thickness	Main structural support

Component	Typical specification	Purpose
GI arch/rafter	48 mm OD × 2 mm	Roof support
GI purlin	32 mm OD × 2 mm	Roof structural support
GI bracing	25 mm OD × 2 mm	Structural stability
Polyethylene film	UV-stabilized, approximately 200 µm	Covering material
Insect-proof net	40–50 mesh	Pest exclusion
Shade net	35–75% shade	Reduction of solar radiation
Cooling pad	Approximately 100–150 mm	Evaporative cooling
Exhaust fan	Approximately 36–50 inch	Ventilation
Drip lateral	Approximately 16 mm	Irrigation/fertigation
Main pipe	50–63 mm	Water distribution
Sub-main	32–40 mm	Water distribution
Spring wire	Approximately 2 mm	Fixing covering material
Lock channel	Approximately 1.5–2 mm	Securing polyethylene film

The precise dimensions should be selected according to the structural design, local climate, wind load, crop, covering material and applicable engineering standards rather than treating the above values as universal specifications.

4. Classification of Greenhouses

Greenhouses can be classified according to their structural design, shape, purpose and climatic suitability.

4.1 Lean-to greenhouse

A lean-to greenhouse is attached to an existing building or supporting structure. It is generally suitable for small-scale production, nurseries and home gardens.

4.2 Even-span greenhouse

The roof slopes are approximately equal on both sides. This design is commonly used for commercial vegetable production.

4.3 Uneven-span greenhouse

The two roof slopes have different dimensions. This type can be adapted to specific climatic and topographic conditions.

4.4 Ridge-and-furrow greenhouse

Several greenhouse spans are joined together. This design is useful for large commercial production units.

4.5 Quonset or hoop greenhouse

The structure has a curved roof supported by hoops. It is comparatively simple and can be economical for low- to medium-cost protected cultivation.

4.6 Saw-tooth greenhouse

Saw-tooth structures contain roof openings that facilitate natural ventilation. They can be useful in warm climates where removal of hot air is important.

5. Standard Dimensions of Selected Greenhouse Types

Greenhouse type	Typical width	Typical length	Approximate height
Even-span	5–9 m	20–30 m	2.5–4.3 m
Uneven-span	5–9 m	20–30 m	2.5–4.0 m
Ridge-and-furrow	6–9 m/span	30–100 m	4–6 m
Quonset/hoop	4–8 m	20–30 m	2.5–3.5 m
Lean-to	3–6 m	10–20 m	2.5–4.0 m
Saw-tooth	6–9 m	30–100 m	4–6 m

These dimensions are indicative rather than mandatory. Actual dimensions should be determined according to engineering requirements, site conditions and the specific crop-production system.

6. Role of Protected Cultivation in Vegetable Production

Protected cultivation provides several important advantages over conventional open-field cultivation.

6.1 Higher productivity

Protected structures allow growers to maintain a more favourable microclimate. Temperature, humidity, radiation and water supply can be managed to improve photosynthesis, flowering, fruit set and crop growth. Research on cucumber under hot-arid conditions demonstrated that naturally ventilated polyhouse cultivation produced substantially higher yield than insect-proof and shade-net structures (Khapte *et al*., 2021).

6.2 Off-season production

Protected cultivation allows vegetables to be produced outside their normal growing season. This can provide access to premium markets and potentially improve farm profitability.

6.3 Improved quality

Controlled environmental conditions can improve fruit size, colour, shape, firmness and marketable yield.

6.4 Efficient water and nutrient use

Drip irrigation and fertigation deliver water and nutrients directly to the root zone. This reduces unnecessary water application and allows more precise nutrient management.

6.5 Reduced pest pressure

Insect-proof structures can physically restrict pest entry, while controlled environments may reduce disease pressure. Consequently, pesticide applications may be reduced when integrated pest-management practices are properly implemented.

6.6 Climate resilience

Protected structures provide partial protection against heavy rain, wind, frost, excessive solar radiation and temperature extremes. This makes them useful tools for adapting vegetable production to climatic variability.

7. Protected Cultivation and Microclimate Management

The principal advantage of a protected structure is its ability to modify the crop microclimate. Important environmental factors include:

- Temperature
- Relative humidity
- Solar radiation
- Air movement
- Root-zone temperature
- Soil/substrate moisture
- Nutrient concentration
- Carbon dioxide concentration

For example, Khapte *et al*., (2021) reported that naturally ventilated polyhouse conditions modified temperature, relative humidity and radiation in cucumber, resulting in improved crop performance compared with insect-proof and shade-net structures.

Advanced greenhouses use fans, evaporative cooling pads, ventilation openings, heating systems, shade screens and sensors to maintain environmental conditions within an appropriate range.

8. Irrigation and Fertigation

Efficient irrigation is essential in protected vegetable production. Drip irrigation is commonly used because it provides water directly to the root zone and minimizes evaporation and runoff. Fertigation combines irrigation with fertilizer application. It permits frequent and precise delivery of nutrients according to crop growth stage. Protected cultivation can therefore improve water and fertilizer-use efficiency when irrigation scheduling, substrate moisture and nutrient concentration are appropriately monitored.

9. Hydroponics and Aeroponics

Modern protected cultivation increasingly incorporates soilless production systems.

Hydroponics

Hydroponics involves growing plants without conventional soil, using a nutrient solution supplied to the root zone. It can be particularly useful where land or soil quality is limiting.

Aeroponics

Aeroponics involves suspending plant roots in an enclosed environment and delivering nutrients through a fine mist. It offers efficient use of water and nutrients but requires greater technical control and reliable equipment.The current MIDH guidelines explicitly promote newer components including hydroponics, aeroponics, soil replacement and sensor-based automation for fertigation.

10. Government Support for Protected Cultivation in India

Government programmes have played an important role in promoting protected horticulture in India. The Mission for Integrated Development of Horticulture (MIDH) supports protected cultivation activities including greenhouses, shade-net houses, rain shelters, plastic tunnels and anti-bird/anti-hail nets. The programme also includes modern components such as hydroponics, aeroponics and sensor-based fertigation automation. The National Horticulture Board (NHB) also provides financial assistance under its relevant horticultural development schemes, subject to prevailing guidelines, eligibility requirements, project size and approved cost norms. Current NHB guidance should be consulted because assistance provisions and technical requirements can be revised. Therefore, subsidy percentages should not be presented as universally fixed figures without specifying the particular scheme, component, beneficiary category and year of the guideline.

11. Present Status of Protected Cultivation in India

Protected cultivation has developed considerably in India, particularly in regions where high-value vegetable production, peri-urban horticulture and off-season production are economically attractive. Tomato, capsicum, cucumber, chilli, brinjal, lettuce and leafy vegetables are among the important crops cultivated under protected conditions.States with substantial adoption include parts of Maharashtra, Karnataka, Gujarat, Tamil Nadu, Punjab, Haryana, Himachal Pradesh and Rajasthan. Adoption is influenced by climate, availability of markets, access to infrastructure, technical knowledge and government assistance.Protected cultivation is particularly relevant to regions where high temperatures, excessive rainfall, frost or pest pressure restrict open-field production.

12. Protected Cultivation in Chhattisgarh

Chhattisgarh has considerable potential for protected vegetable production because of its expanding horticultural sector, increasing urban demand and opportunities for producing high-value vegetables.Protected cultivation can help Chhattisgarh farmers produce high-value vegetables during favourable market windows while protecting crops from excessive rainfall, temperature fluctuations and pest pressure.However, successful expansion requires appropriate structure selection, farmer training, quality planting material, irrigation infrastructure, reliable electricity, technical support and strong market linkages.

13. Present Status of Protected Cultivation Worldwide

Protected cultivation is widely practiced in countries including China, Spain, Japan, South Korea, Turkey, Italy, the Netherlands and the United States. China has developed an especially large protected horticulture sector, while European countries such as the Netherlands have developed highly sophisticated greenhouse systems incorporating automation, climate control, hydroponics and precision production.

Modern international greenhouse production increasingly integrates:

- Automated climate control
- Hydroponics

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- Sensor-based irrigation
- Artificial intelligence
- Robotics
- LED lighting
- Automated fertigation
- Computer-based crop monitoring
- Renewable energy

The comparison of protected cultivation area among countries should be made cautiously because definitions and reporting methods differ between sources and years.

14. Production of Major Vegetable Crops under Protected Cultivation

The following values may be used as indicative production parameters, but actual plant density and yield vary with cultivar, greenhouse design, climate, training system, fertigation programme and management.

Crop	Example cultivar/hybrid	Spacing	Indicative yield under protected cultivation
Tomato	Arka Rakshak	45 × 45 cm	120–180 t/ha
Capsicum	Indra	45 × 45 cm	80–120 t/ha
Brinjal	Arka Navneet	60 × 45 cm	100–120 t/ha
Cauliflower	Pusa Snowball K-1	45 × 45 cm	25–35 t/ha
Cabbage	Pusa Mukta	45 × 45 cm	40–60 t/ha
Chilli	Indam-5	45 × 45 cm	80–100 t/ha
Lettuce	Grand Rapids	25 × 25 cm	25–35 t/ha
Spinach	All Green	Close spacing	~30 t/ha
Coriander	Gujarat Coriander-2	Close spacing	8–12 t/ha
Cucumber	Terminator/other hybrids	40 × 40 cm	150–200 t/ha

Crop	Example cultivar/hybrid	Spacing	Indicative yield under protected cultivation
Bottle gourd	Pusa Navin	200 × 60 cm	40–60 t/ha
Watermelon	Sugar Baby	100 × 60 cm	50–70 t/ha
Bitter gourd	Priya	100 × 60 cm	25–35 t/ha

These figures should be treated as indicative package-of-practice values rather than guaranteed yields.

15. Economics and Major Constraints

Although protected cultivation can increase productivity and enable premium production, it also requires greater capital and technical management than conventional farming.

Major advantages

1. Higher productivity per unit area.
2. Off-season production.
3. Improved quality and uniformity.
4. Better water and fertilizer-use efficiency.
5. Partial protection against adverse weather.
6. Potential reduction in pesticide use.
7. Better opportunities for high-value vegetable production.
8. Possibility of year-round production.

Major constraints

1. High initial investment.
2. High cost of repair and maintenance.
3. Requirement for skilled labour.
4. Dependence on reliable irrigation and electricity.
5. Technical complexity in advanced structures.
6. Requirement for quality planting material.
7. Pest and disease outbreaks can spread rapidly in enclosed environments.
8. Market-price fluctuations.

9. Limited cold-chain and post-harvest infrastructure.
10. Difficulty in accessing technical assistance in some rural areas.

16. Future Prospects

The future of protected vegetable cultivation lies in combining conventional greenhouse technology with digital agriculture and resource-efficient production systems.

16.1 Smart greenhouses

Sensors can continuously monitor temperature, humidity, light, substrate moisture and nutrient conditions. Automated systems can then adjust ventilation, irrigation and fertigation.

16.2 IoT-based monitoring

Internet-connected sensors can allow farmers to monitor greenhouse conditions remotely and receive alerts when temperature, humidity or irrigation conditions become unsuitable.

16.3 Artificial intelligence

Artificial intelligence can support disease detection, yield prediction, irrigation scheduling and optimization of greenhouse climate.

16.4 Automation and robotics

Automation can reduce labour requirements for irrigation, fertigation, harvesting, crop monitoring and climate management.

16.5 Hydroponics and aeroponics

Soilless systems are likely to expand in areas with limited land or poor soil conditions. The inclusion of hydroponics and aeroponics in current MIDH guidelines demonstrates the policy interest in these technologies.

16.6 Renewable energy

Solar-powered pumps, sensors, cooling systems and greenhouse equipment could reduce dependence on conventional electricity and improve sustainability.

17. Conclusion

Protected cultivation is an important technology for increasing the productivity, quality and reliability of vegetable production. Greenhouses, polyhouses, shade-net houses, insect-proof net houses, tunnels and rain shelters create favourable microclimates that allow farmers to reduce the impact of adverse environmental conditions and produce high-value vegetables more efficiently.Scientific evidence indicates that the choice of protected structure has a substantial influence on crop microclimate and productivity. For example, naturally ventilated polyhouse conditions produced markedly better cucumber performance than insect-proof and shade-net structures under hot-arid conditions (Khapte *et al*., 2021). In India, government programmes such as MIDH provide support for protected structures and are increasingly incorporating hydroponics, aeroponics and sensor-based automation. Nevertheless, high capital requirements, technical complexity, energy costs, skilled-labour requirements and market constraints continue to limit adoption.The future of protected vegetable cultivation will depend on integrating greenhouse technology, precision irrigation, fertigation, IoT sensors, automation, artificial intelligence, hydroponics, renewable energy and improved market linkages**.** With appropriate technical training, affordable structures and effective government support, protected cultivation can contribute substantially to higher farmer income, efficient resource use, climate resilience and food and nutritional security.

References

Banjare, C., Mahanta, D., Sahu, P., & Choudhary, R. (2024). A comprehensive review on protected cultivation: Importance, scope and status. *International Journal of Environment and Climate Change, 14*(7), 46–55.

Indian Council of Agricultural Research. (2022). *Handbook of horticulture* (2nd ed.). ICAR, New Delhi.

Jain, S., Kore, D. S., Kishorkumar, G. K., Mohapatra, A., Baksh, H., Kumar, V., Mohanty, S., & Haokip, S. W. (2023). A comprehensive review on protected cultivation of horticultural crops: Present status and future prospects. *International Journal of Environment and Climate Change, 13*(11), 3521–3531.

Khapte, P. S., Meena, H. M., Kumar, P., Burman, U., Saxena, A., & Kumar, P. (2021). Influence of different protected cultivation structures on performance of cucumber (*Cucumis sativus* L.) in Indian hot arid region. *Journal of Agrometeorology, 23*(3), 265–271. https://doi.org/10.54386/jam.v23i3.25

Khapte, P. S., Kumar, P., Panwar, N. R., Burman, U., Rouphael, Y., & Kumar, P. (2021). Combined influence of grafting and type of protected environment structure on agronomic and physiological traits of single- and cluster-fruit-bearing cucumber hybrids. *Agronomy, 11*(8), 1604. https://doi.org/10.3390/agronomy11081604

Ministry of Agriculture and Farmers Welfare. (2025). *Mission for Integrated Development of Horticulture (MIDH): Operational guidelines 2025*. Government of India.

National Horticulture Board. (2025). *Final operational guidelines and cost norms under National Horticulture Board schemes*. Ministry of Agriculture and Farmers Welfare, Government of India.

National Horticulture Board. (2025). *Operational guidelines*. Ministry of Agriculture and Farmers Welfare, Government of India.

Nguyen, G. N., & Singh, Z. (2024). Editorial: Recent advances in research and development for vegetable crops under protected cultivation. *Frontiers in Plant Science, 15*, 1459919.

Patel, N. B., Saravaiya, S. N., & Kumar, S. (2018). Analysis of bell pepper (*Capsicum annuum*) cultivation in response to fertigation and training systems under protected environment. *The Indian Journal of Agricultural Sciences, 88*(7).

Samanta, S., Kumar, S., & Khoisnam, N. (2023). Current status, future prospects, and obstacles for protected cultivation in India. *Agri Journal World, 3*(2).

Sharma, R., Singh, N., & Kayastha, R. (2020). Comparative economic analysis of capsicum cultivation under protected and open field conditions in Himachal Pradesh. *International Journal of Current Microbiology and Applied Sciences, 9*(8), 1002–1012.

Singh, B., & Sirohi, N. P. S. (2006). Protected cultivation of vegetables in India: Problems and future prospects. *Acta Horticulturae, 710*, 355–358. https://doi.org/10.17660/ActaHortic.2006.710.38

Singh, J., Nagar, D. D., Meena, V. S., Bhushan, B., Bhatnagar, P. R., & Naved, S. (2015). Growth, quality and pest infestation in tomato under protected cultivation in the semi-arid region of Punjab. *Indian Journal of Horticulture, 72*(4), 518–522.

Singh, R. P., Sahu, R., Bagora, R., & Moharana, R. L. (2022). Protected cultivation of horticultural crops: A comprehensive review. *International Journal of Environment and Climate Change*.

Somasundaram, J., Sinha, N. K., Dalal, R. C., Lal, R., Mohanty, M., Naorem, A. K., Hati, K. M., Chaudhary, R. S., Biswas, A. K., Patra, A. K., & Chaudhari, S. K. (2020). No-till farming and conservation agriculture in South Asia—Issues, challenges, prospects and benefits. *Critical Reviews in Plant Sciences, 39*(3), 236–279.

Tyagi, S., Nanner, A. H., Nishad, S. K., Nandan, B., Kumar, V., Bhamini, K., & Shamim, S. A. (2015). Protected cultivation for peri-urban areas: An investment for the 21st century. *Rashtriya Krishi, 10*(1), 75–76.

Verma, R., Sahu, P., & Mishra, A. (2025). Economic analysis of protected horticulture in Chhattisgarh. *International Journal of Agricultural Economics, 12*(1), 25–33.