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A Comprehensive Review on Protected Cultivation: Importance, Scope and Status

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The practice of protected cultivation of horticultural crops has become increasingly important in contemporary agriculture, providing a host of advantages including higher yields, improved quality, and defence against pests and unfavourable weather. This thorough analysis seeks to illustrate protected cultivation practices as they stand today and investigate their potential in horticulture going forward. The examination starts out by going over the many kinds of protected production buildings and their benefits and drawbacks, such as greenhouses, high tunnels, and shade houses.

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The importance of protected farming in addressing issues related to global food security is then emphasised by maintaining crop output all year round and minimising reliance on seasonal changes. The impact of protected cultivation techniques which include enhanced crop morphogenesis, precipitation control, and the optimisation of environmental parameters like temperature, humidity, and carbon dioxide levels on the growth and development of horticultural crops is further examined in this review. In addition, the application of cutting-edge technologies such as aeroponics, hydroponics, and vertical farming in protected growing systems is discussed and its potential to maximise crop output while consuming the least amount of resources is highlighted. The study also explores the difficulties and limitations associated with adopting protected cultivation, such as the need for synthetic inputs, energy requirements, and financial issues. It talks about environmentally friendly and sustainable ways to reduce these problems and support ecological balance, like using renewable energy sources and switching to organic farming methods. The investigation concludes that discussing some potential developments and trends in protected cultivation going forward, including as the application of artificial intelligence, the integration of precision agriculture methods, and the uptake of smart farming technologies. These developments could lead to increased yield and quality improvements in the production of horticulture crops by further optimising resource utilisation, enhancing automation, and improving crop monitoring and management.

Keywords: Greenhouses; environmentally friendly; hydroponics; food security; vertical farming; protected cultivation.

1. INTRODUCTION

The process of cultivating crops in a partially or fully enclosed space, such as a greenhouse, shade house, or high tunnel, is known as protected cultivation [1]. The main goal of protected farming is to maximise environmental elements while creating a regulated microclimate that protects the crops from harmful weather, pests, and illnesses [2]. It entails the application of structures, materials, and technologies that offer environmental control over temperature, humidity, light, and other variables while also serving as a protective barrier [3,4,5]. This technique lengthens the growing season, improves crop quality and output, permits year-round or out-of-season farming, and lessens dependency on outside variables. Vegetables, fruits, flowers, and herbs are just a few of the horticultural crops that are produced using protected agriculture [6]. Crop productivity and quality are highly impacted by biotic and abiotic stressors in the current changing environment [7]. Extreme temperatures, sunshine, water availability, relative humidity, weeds, nutrient deficiencies, wind velocity, carbon dioxide concentration, illnesses, and insect pest occurrences are some of the difficulties faced by horticultural crop production in North India [8]. Techniques for protected cultivation have shown to be an effective means of addressing these limitations, particularly in regions with harsh climates [9]. Using buildings like greenhouses, protected farming entails producing higher-quality crops outside of their typical growing seasons [10]. Fresh produce is delivered, especially in periurban areas, thanks to this method, which boosts farmer profitability and shortens transportation times [11]. Transparent materials, like polythene or glass, that serve as selective radiation filters are used to cover greenhouse buildings. They trap long-wavelength solar radiation inside while allowing short-wavelength solar light to pass through [12]. As a result, the building experiences a greenhouse effect, which traps solar energy and raises interior temperatures [13]. The increased temperature has an impact on plant photosynthetic rate, transpiration, stomatal aperture, and leaf temperature [14]. Plant physiological conditions can be manipulated by managing the greenhouse environment [15]. For example, plant respiration causes CO_2 levels to rise when the greenhouse is closed at night. The next day's early morning hours are spent using this increased CO_2 for photosynthesis.

Fast development and higher output are encouraged by the greenhouse's higher temperature, relative humidity, CO_2 levels, and better nutrition [16]. Cooling devices including fan pad systems, ventilation, and fogging can be used to control the temperature inside a greenhouse [17]. These methods maximise vegetable crop output potential and allow for year-round production of desired crops. Further enhancing yields under protected farming include closer planting and higher plant density [18]. Open-field and sheltered agriculture need different management techniques. Multistory crop growing in greenhouses has become essential in peri-urban areas to supply the need for fresh produce, strawberries, flowers, and fruit tree nurseries [19]. Protection farming systems incorporate a variety of strategies, including mulching, drip irrigation, fertigation, naturally ventilated polyhouses, and more [20]. Furthermore, in the Northern Plains of India, walk-in polytunnels have lately become lucrative technologies, demonstrating their usefulness for growing crops such as tomatoes, cucumbers, and cucurbits, as well as for building nurseries during the off-season [21].

2. OBJECTIVES OF PROTECTIVE CULTIVATION

Protection of stores against biotic factors like pests and the frequency of complaints they get, as well as abiotic stress (physical or caused by non-living organisms) such as temperature, excess or lack of water, hot or cold swelling, etc.

- Reduced usage of water and manageable weed growth.
- Increasing output per unit of space.
- Reducing the amount of fungicides used in agricultural products.
- Encouragement of premium, high-quality horticultural produce.
- High-value adaptation, propagation, and addition of crops that are known to thrive in particular areas.
- Products derived from floral, vegetable, or fruit crops that are available all year round.
- Generated from superior genetic transplantation without any complaints.

3. NOVEL APPROACHES TO PROTECTED CROP GROWING FOR ORNAMENTAL PLANTS

Modification of agricultural techniques for indoor greenhouse flower growing vegetables in greenhouses is a relatively new practice in India, where it's being used more frequently to make high-end products for export in the off-season. The only way for a floriculture unit to succeed is through efficient manufacturing of ornaments with an export-focused is excellent, and the quality is great. In order to maintain acceptable costs while ensuring consistency in production quantity and quality, greenhouse manufacturers must implement the newest technologies available. Studies on the standardisation of agricultural technologies, for instance effective use of low-cost greenhouses. Cultivation of carnations, tuberoses, gerberas, and roses always superior to the flowers and more fruitful [13].

4. NEW DEVELOPMENTS IN PROTECTED VEGETABLE CROP CULTIVATION

Vegetables have been consumed for decades and are a rich source of nourishment. Many growers in peri-urban areas of the nation can successfully diversify their traditional husbandry by endorsing or utilising colourful situations of defended civilization technologies for the production of horticultural crops with an eye towards their coffers. This will satisfy the arising demand for unusual and unusual off-season horticultural yield as well as the year-round demand for high-value vegetables like slicing tomatoes, coloured peppers, and parthenocarpic cucumbers, among other things. The other sector that requires total diversification from the current nursery caregiving system is high-quality vegetable nurseries. Due to a lack of capital, low-cost or medium-sized growers have straightforward organisational structures. Vegetable polyhouse civilization is emerging as a technical product technology to break the seasonal hedge and overcome biotic and abiotic constraints, resulting in crop duration that is enhanced over an open field situation. In comparison with open field settings, the highest number of fruit weights and yield were obtained in poly homes. On the poly house, several protected technologies showed lower net return and BC, but on an open field, it was lowest.

5. EMERGING PATTERNS IN SEED PRODUCTION THROUGH PROTECTED CULTIVATION

Currently, seed cultivation is essential for efficient growth, and seeds grown in polyhouse structures are free of diseases and pests that are often found in open agriculture. In order to generate seeds, a number of structures are employed: Among the main constructions are walk-in tunnels, affordable poly-houses, insect-proof net dwellings, climate-controlled greenhouses, semi-controlled greenhouses, naturally ventilated greenhouses, and plastic low tunnels.

1. Glasshouses with climate and partially regulated climate

Poly houses, or glasshouses with semi-climate control or temperature regulation, are used to cultivate high-value exotic crops for long growing seasons and higher yields. Otherwise, the growing season is shorter on an open field. These structures are appropriate for growing high-value vegetables including parthenocarpic cucumbers, sweet peppers, cherries, and sliced tomato products, among others. The primary barrier to employing this kind of structure is the initial or starting point of construction and ongoing cost of comparable glasshouses, which significantly raises the price of seed when compared to seeds grown in open fields or under other structures. However, under comparable structures, seed quality and yield are always much higher [22].

2. Naturally ventilated greenhouses

Due to their inherent aeration, greenhouses can be used to cultivate a variety of vegetables and fruits, including parthenocarpic cucumbers, summer squash, muskmelon, and tomatoes, for seed. However, the time required for cultivation and seed production is less than in greenhouses with climate control or semi-climate control [23].

3. Commercial Production

Sweet pepper, tomato, brinjal, and other vegetable seeds, such cucurbits, can be produced using insect-proof net buildings. During the rainy and post-rainy seasons, these structures can shield crops from viruses and other insects like fruit borer pests [24]. Not only is the seed yield consistently lower than in other greenhouse types, but the production costs are also significantly cheaper [25].

4. Seed Production

Cucurbit seed production, including bottle gourd, bitter gourd, summer squash, muskmelon, and watermelon, can be done in walk-in tunnels [26]. In temperate parts of the world, high tunnels are used to warm the soil for agricultural development, extending the growing season [27].

6. THE CURRENT STATE OF PROTECTED AGRICULTURAL CROP CULTIVATION AND ITS PROSPECTS FOR THE FUTURE

The Position of Protected Cultivation Worldwide

Global Adoption: Protected farming practices, such high tunnels and greenhouses, are becoming more and more commonplace, especially in areas with harsh weather or little arable land [28].

Variety of Crops: A large range of horticultural crops, including as decorative plants, fruits, vegetables, and flowers, are grown there [29].

Technological Advancements: Developed nations have made significant investments in cutting-edge controlled environment agriculture technology, such as hydroponics, automated climate control, and vertical farming [30].

Sustainable Practices: To lessen agriculture's environmental impact, an increasing emphasis is being placed on sustainable and organic production methods within protected areas [31].

Market Expansion: Businesses now have potential because to the growing market for protected cultivation technology, equipment, and services [32].

Indian Protected farming Status

Rapid Growth: The necessity to supply the country's rising demand for fresh and off-season goods has led to a steady increase in the use of protected farming techniques in India in recent years [33].

Good Climate: India's varied climate, which includes strong monsoons and extremely high temperatures, making it an excellent place for protected agriculture, which prolongs growing seasons and shields crops from bad weather [34].

Horticulture Diversity: India uses protected cultivation methods to develop a wide range of horticulture crops, such as exotic fruits, flowers, and vegetables [35].

Government Initiatives: To encourage protected cultivation and encourage farmers to embrace greenhouse and polyhouse technology, the Indian government has launched a number of programmes and incentives [36]. Notwithstanding the expansion, there are still difficulties, such as the high cost of the initial investment, the lack of technical expertise among small-scale farmers, and sustainability issues [37].

Research and Innovation: Developing region-specific technologies for protected farming and increasing crop production is a major focus of

Indian agricultural institutions and research organisations [38].

Export Opportunities: India's horticultural exports have benefited from protected farming, as some commodities are now sold in foreign markets [39].

Future Prospects: It appears that protected cultivation has a bright future. Protected cultivation provides a sustainable way to address the rising demand for horticulture products as the population grows and the amount of arable land available decreases [40]. It lowers the need for water and pesticides, improves crop quality, and permits year-round cultivation.

7. NEW DEVELOPMENTS IN PROTECTED AGRICULTURE TECHNOLOGY

Drones for crop monitoring, robotics for harvesting, precision agriculture methods, and the incorporation of Internet of Things (IoT) solutions for data collecting and analysis are a few new technologies in protected cultivation [41,42]. Growing contribution of protected agriculture to addressing world food demand: The production of food that satisfies the world's demand requires protected farming [43]. It makes it possible to produce premium crops in areas with unfavourable climates.

It also improves agricultural yield, lowers post-harvest losses, and guarantees a steady supply of fresh vegetables all year long. Possibilities and obstacles in protected agriculture Although protected horticulture presents a multitude of potential, it is not without its drawbacks. These consist of the original setup expenses, energy usage, appropriate upkeep, and guaranteeing the best possible environmental circumstances for crop growth [44]. But there are chances to overcome these obstacles and increase the use of protected agriculture thanks to technological improvements and growing public knowledge of sustainable agricultural methods.

8. IMPORTANT PESTS

Due to the favourable conditions within, greenhouse vegetable crops, which are farmed worldwide, are susceptible to a wide range of illnesses and pest infestations. Pests in greenhouses can result in enormous losses. Arthropod pests such as nematodes, fungi, bacteria, thrips, and aphids, as well as diseases brought on by viruses, fungi, and bacteria, are the leading causes of crop losses. Depending on a number of variables, including the viral strain, crop variety, age of the plant at infection time, and temperature during disease development, the percentage of losses caused by a virus can range from 5% to 90% [45,46]. In vulnerable pepper varieties, severe losses from the tomato mosaic virus (ToMV) have been documented [47]. The virus known as tomato infectious chlorosis virus (TICV) affects a variety of plant hosts. In 1993, Orange County estimated a $2 million loss to the global tomato industry). The tomato yellow leaf curl virus, which is spread by whiteflies, increased crop loss to 100% in Mediterranean regions, whereas western flower thrips in UK glasshouses caused 90% of the crop loss [48]. According to reports, the Pythium species is responsible for some notable crop losses in greenhouse vegetable crops. When plant products are stored or transported, Botrytis species can result in significant post-harvest losses [49,50].

9. IPM AND PROTECTED CULTIVATION

Recently, as a result of consumers' demands for residue-free food and resistance to chemical pesticides used to control greenhouse pests, biological management has become more popular. This has made it possible to develop integrated pest management (IPM) strategies for long-term crop protection [51,52,53]. IPM prevents pest damage while having the fewest negative effects possible on the environment, non-target creatures, and human health. In order to keep pests below economically significant levels while maintaining the sustainability of the environment, consumer health, and farmer profitability, it entails integrating all appropriate plant protection techniques. Since diseases and insects pose a serious threat to greenhouse production, controlling them is essential to growing plants that are healthy, pest-free, and undamaged. Therefore, a bio-intensive approach incorporating sanitation, mechanical barriers, scouting, GAP protocols, biocontrol, and specific pesticides when required should be a part of a greenhouse IPM plan. Nowadays, practically all greenhouse vegetable crops, including tomatoes, cucumbers, sweet peppers, brinjal, lettuce, etc., are grown under integrated pest management (IPM) in many parts of the world [54,55,56].

10. ROBOTICS IN PROTECTED CULTIVATION

Automation is a useful technology that helps to sustain some robotic tasks. Different kinds of machinery are covered under the technology protection policy. Protected development is a high-risk, high-return creative strategy that only permits the production of valuable crops like tomatoes, sweet peppers, and cucumbers, as well as flowers like roses, gerberas, chrysanthemums, and a variety of trimmed plants. This type of creation has faced challenges in Western social orders, such as growing creation office sizes, rising labour costs, growing problems finding sufficiently skilled workers, representatives' health problems from heavy and boring work, and growing competition in the domestic and international business sectors. Accurate cultivation techniques, which treat plants as a single unit, are also becoming the standard since they enable better control over the quantity and kind of crop produced while utilising resources as efficiently as anticipated. This has led to a much more realistic push for computerization and sophisticated mechanics given the continuous demands on human labour. Regarding various operations, such as harvesting, mechanisation has emerged as a recent criterion and has been developed [57,58,59].

11. PROBLEMS OR DIFFICULTIES WITH PROTECTED FARMING IN INDIA

In India, protected vegetable growing is relatively new, despite its long history. Very little thought has been given to fully realising the huge potential of protected vegetable cultivation.

The following are some restrictions and problems that make cultivation more difficult:

1. In spite of the significance of vegetables such as cucumber, tomato, cherry tomato, and sweet pepper, no particular breeding work has been conducted to produce types or hybrids suitable for cultivation in greenhouses or other protected environments. The high cost of exotic seeds prevents Indian farmers from purchasing them.
2. Although some of these vegetable varieties are sold domestically, they don't meet the standards for higher-end or export markets.
3. Indian growers should not employ climate-controlled greenhouses due to their high initial cost and continuous operational expenses.
4. To maintain the heating and cooling systems in the greenhouses, many parts of the nation require a more consistent power supply.
5. Some plants, like sweet pepper in Delhi's winter circumstances, may have lower yields when exposed to excessive amounts of sun radiation during particularly important times.
6. Despite the country's diverse agro-climatic zones, not much has been done to standardise greenhouse and other protected structure designs.
7. Under various forms of protected structures, potential vegetable crop production technologies have not been explored for the nation's diverse agroclimatic zones.
8. It is difficult to obtain the materials required to clad the required qualifications. Furthermore, greenhouses are not equipped with the right tools to regulate the atmosphere.
9. No specific research projects are being conducted on growing vegetables with protection.
10. Packaging and on-farm value-added materials are few, making it difficult to provide markets with high-quality products.

12. CONCLUSION

Growing crops in a controlled environment with the ability to adjust temperature, humidity, and light levels according to the crop's individual needs is known as protected farming. The overall production is raised and healthier plants are encouraged in this regulated environment. Protected farming methods come in many forms, such as plastic tunnels, insect-proof net homes, naturally ventilated poly houses, raised beds, trellising, and drip watering, in addition to greenhouses that are forced to ventilate. These techniques can be applied singly or in concert to develop a good growth environment that protects plants from extreme weather, lengthens the growing season, or permits the production of off-season crops. By lowering evaporation losses, drip irrigation, when combined with mulch films and raised beds, provides advantages like better soil moisture retention and weed control.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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