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Impact of Protected Cultivation on Growth, Yield and Quality of Fruits, Vegetables and Flowers

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Abstract
The potential for protected cultivation to transform horticulture production is enormous since it can increase productivity, guarantee product quality, and support environmental sustainability. To realize its full potential and transform it into a climate-resilient and inclusive agricultural practice, carefully considered investments in policy, research, and farmer education are necessary. A key development in contemporary horticulture, protected cultivation presents a viable answer to issues including climate variability, diminishing land productivity, and rising demand for premium goods. Protected agriculture improves the development, productivity, and quality of fruits, vegetables, and flowers by providing exact control over environmental factors including temperature, humidity, light intensity, and nutrient delivery. The function and effects of protected cultivation systems are critically examined in this review, with particular attention paid to how they affect crop performance, resource efficiency, economic feasibility and sustainability. The study examines several protected cultivation methods, including greenhouses, low tunnels, polyhouses, and net houses, and describes their structural elements, working principles, and applicability to various agro climatic zones. Research indicates that crops cultivated in protected environments exhibit enhanced physiological characteristics, such as increased root development, chlorophyll content, and leaf area index. When compared to open-field systems, these enhancements directly result in noticeably higher yields and higher-quality produce.

1. INTRODUCTION

In contemporary horticulture, protected cultivation has become an essential tactic to get around the drawbacks of open-field farming. Farmers are using controlled environment agriculture to ensure sustainable production in response to the mounting issues of soil degradation, water shortages, and climate variability, as well as the rising demand for high-quality produce. A variety of methods, including polyhouses, greenhouses, shade nets, and plastic tunnels, are included in protected culture. These methods allow for the control of temperature, humidity, light, and other environmental elements to produce the best possible growing conditions for plants. The use of covered farming has increased significantly in recent years, especially in areas with unpredictable weather or a shortage of arable land. These buildings offer a steady microclimate that encourages consistent growth, improves physiological processes, and reduces the dangers of pests, illnesses, and unfavorable weather conditions. Because of this, farmers are able to grow crops all year round, which raises cropping intensity and boosts total production. Because they are so susceptible to changes in the environment, horticultural crops including fruits, vegetables, and flowers are especially affected by protected farming. According to studies, crops cultivated in sheltered environments frequently have greater quality, larger yields, and superior growth parameters than those grown in open fields. For example, greenhouse-grown tomatoes and cucumbers have shown increased fruit size, consistent ripening, and longer shelf life. Likewise, flower crops cultivated in polyhouses, such as roses and gerberas, exhibit improved bloom quality and increased market value. In addition to its agronomic advantages, shielded cropping promotes resource efficiency. By integrating technology like automated climate control systems, fertigation, and drip irrigation, production costs and environmental effect can be reduced by using less water and fertilizer. Additionally, the enclosed space serves as a barrier against a variety of common pests and diseases, lowering the need for chemical pesticides and encouraging environmentally responsible agricultural methods. Despite its benefits, a number of obstacles prevent protected farming from being widely adopted, including as the high initial cost, the requirement for technical know-how, and the low awareness among small and marginal farmers. However, the future of protected cultivation in horticulture seems bright thanks to growing government support, scientific advancements, and the creation of low-cost technologies. The goal of this review is to present a thorough evaluation of how protected cultivation affects fruit, vegetable, and flower development, yield, and quality.

2. PROTECTED CULTIVATION TECHNOLOGIES

Using semi-controlled or fully controlled conditions to grow crops with improved protection from external climatic challenges is known as protected farming. The main objective is to establish the ideal microclimate to facilitate increased output, improved quality, and resource efficiency. Various technologies are employed based on crop variety, investment capability, and area climate. With their own set of benefits, they include polyhouses, greenhouses, shade nets, insect-proof net houses, low tunnels, and walk-in tunnels. By permitting year-round production, increasing the efficiency of resource utilization, and producing higher returns, protected cultivation technologies have completely transformed the horticultural industry. For best results, the technology selection should take into account local agroclimatic conditions, financial viability, and technological know-how.

2.1. Poly houses and Greenhouses

The most popular protected structures in horticulture are greenhouses and polyhouses. These are made of transparent covering materials that trap sunlight and regulate internal temperature, including glass, polyethylene, or polycarbonate. Both climate-controlled and naturally ventilated greenhouses are available, with features like fan-pad cooling, heating, and fogging systems. For small to medium-sized farming, polyhouses are typically more cost-effective. According to (Kumar *et al.*, 2020), these systems work especially well with high-value crops including tomatoes, strawberries, capsicum, and flowers like carnations and gerberas.

2.2. Shade Net Houses

Framed buildings covered in UV-stabilized netting, shade net houses provide some protection from strong winds and sunlight. To lessen heat stress and enhance plant establishment, they are typically utilized in tropical and subtropical areas. Shade percentages range from 25% to 90%, depending on the crop (e.g., nursery plants, orchids, and green vegetables) (Rana *et al.*, 2018).

2.3. Insect-Proof Net Houses

Fine mesh nets (40–50 mesh size) are used in these buildings to keep out pests, particularly sucking insects like aphids, thrips, and whiteflies. These structures greatly lessen the need for chemical pesticides when producing crops that are susceptible to viruses, like tomatoes, chilies, and cucurbits (Sharma *et al.*, 2019).

2.4. _Low Tunnels and Walk-In Tunnels

Low tunnels, sometimes referred to as row covers, are made of flexible hoops that are covered in clear film. They are primarily used to keep crops warm and prevent frost during the early stages of growth. Larger and more robust, walk-in tunnels provide comparable protection and are utilized for growing vegetables throughout the off-season (Kaur and Singh, 2021).

2.5. Climate Control and Automation

Automated systems for irrigation, fertigation, humidity management, and temperature adjustment are all part of contemporary protected farming. Real-time monitoring and decision-making are made possible by sensors and Internet of Things-based technologies, which boost output and resource efficiency (Mehta *et al.*, 2022). Additionally, greenhouses are incorporating hydroponic and aeroponic technologies, which advances soilless, controlled-environment farming.

2.6. Government and Institutional Support

Through training initiatives and subsidies, organizations such as ICAR and NHB support protected agriculture in India. Under the MIDH and RKVY programs, states including Himachal Pradesh, Maharashtra, and Karnataka have extensively embraced these technologies (NHB, 2020).

3. IMPACT OF PROTECTED CULTIVATION ON GROWTH PARAMETERS

By creating a regulated microclimate, protected culture has a major impact on the morphological and physiological growth parameters of horticultural crops. When compared to open-field farming, sheltered environments significantly improve key growth characteristics such plant height, leaf area index, stem girth, root development, and overall biomass accumulation.

3.1. Plant Height and Biomass Accumulation

Increased humidity, controlled temperature, and better light diffusion all contribute to the increased vegetative growth of crops cultivated in greenhouses or polyhouses. For example, research on bell peppers and tomatoes has revealed that when placed in protected buildings as opposed to open ones, plant height increases by 20–35% (Singh *et al.*, 2020). Reduced abiotic stress and improved nutrient absorption made possible by ideal soil and aerial conditions are the main causes of this.

3.2. Leaf Area and Chlorophyll Content

An essential metric for evaluating photosynthetic capacity is the leaf area index (LAI). Vegetables like lettuce and cucumber have demonstrated noticeably increased LAI under protected settings, which leads to better biomass production and light interception (Kumar and Dhaliwal, 2019). Furthermore, it has been discovered that shielded cultivation improves chlorophyll production, resulting in more effective photosynthesis and deeper green foliage.

3.3. Root Development and Shoot-Root Balance

An essential metric for evaluating photosynthetic capacity is the leaf area index (LAI). Vegetables like lettuce and cucumber have demonstrated noticeably increased LAI under protected settings, which leads to better biomass production and light interception (Kumar and Dhaliwal, 2019). Furthermore, it has been discovered that shielded cultivation improves chlorophyll production, resulting in more effective photosynthesis and deeper green foliage.

3.4. Physiological Efficiency

In protected settings, stomatal conductance, transpiration rates, and net photosynthetic activity are more consistent. For instance, shading nets improve water-use efficiency and decrease excessive evapotranspiration. Semi-controlled systems are better at maintaining a balance between the vegetative and reproductive phases in crops like roses and gerberas (Verma *et al.*, 2021).

3.5. Microclimate Influence

Inside shielded shelters, the microclimate protects the plants from wind, extreme cold, and heat. Early crop establishment and faster growth are the results of a combination of stable soil moisture, elevated CO_2 content, and tempered temperature.

Table 1: Comparative Growth Parameters under Protected and Open Field Conditions

Parameter	Open Field	Protected Cultivation
Average Plant Height (cm)	60	85
Leaf Area Index	2.5	4.0
Chlorophyll Content (SPAD units)	35	47
Root Biomass (g/ Plant)	12	19
Days to 50% Flowering	42	36

Source: (Singh *et al.*, 2020), (Kumar and Dhaliwal, 2019), (Bisht *et al.*, 2018)

The data above makes it abundantly evident that crops perform better in protected environments in terms of physiological efficiency and vegetative development. Because these advancements are directly linked to higher yields and higher-quality products, shielded cultivation is a viable strategy for intensive horticultural systems.

4. IMPACT OF PROTECTED CULTIVATION ON YIELD

Protected farming consistently and significantly increases crop output, which is one of its biggest benefits. Protected structures enable year-round production, lessen crop stress, and enhance plant health by establishing a pleasant microclimate, all of which boost yield. Fruits, vegetables, and flowers are examples of high-value horticultural crops where the production boost is very noticeable.

4.1. Yield Enhancement in Vegetables

Significant increases in vegetable output under protected settings have been reported in a number of studies. For instance, compared to open fields, tomatoes grown in polyhouses have demonstrated production gains of 80–120%. This is mainly because of higher fruit set, greater nutrient availability, and a lower incidence of disease (Singh *et al.*, 2020). Similarly, yields of 40–60 t/ha of capsicum grown in net houses have been reported, which is almost twice as much as in conventional systems (Kumar *et al.*, 2019). Because of improved pollination control and climatic stability, bitter gourd and cucumber have also shown notable production gains (Rana *et al.*, 2021). Agronomic techniques, crop variety, structure type, and degree of automation all affect the yield benefits of sheltered farming. However, protected cultivation has continuously outperformed conventional methods across a wide range of horticulture crops and locations, providing a viable path to improve farmers' income and food security.

4.2. Yield Improvement in Fruits

Higher cumulative yields are achieved in fruits through off-season and extended-season production made possible by protected cultivation. Because of improved root development, moisture retention, and early flowering, strawberries grown in low polyhouses or walk-in tunnels exhibit a 40–70% increase in output (Bisht *et al.*, 2018). Likewise, melons grown in polyhouses with vertical trellising have shown improved fruit set and weight uniformity (Kaur and Dhaliwal, 2020). There have also been notable increases in productivity from high-density papaya and pomegranate plantings beneath shade nets (Patel *et al.*, 2021).

4.3. Flower Yield and Quality

In floriculture, protected cultivation not only results in higher-quality flowers but also longer stems, more blooms, and more frequent flowering. Comparing polyhouse farming to open cultivation, gerbera, rose, and carnation have shown output improvements of 1.5 to 2 times (Verma *et al.*, 2021). This performance is greatly influenced by elements like regulated humidity and less exposure to pests (Nath and Yadav, 2020).

4.4. Multi-Season and Off-Season Production

One important element in raising the overall yearly production under protected structures is the capacity to grow crops outside of their normal growing seasons. In North India, for example, low tunnels can be used to grow vegetables like fenugreek, spinach, and coriander all winter long, improving cropping intensity and cumulative output (Meena *et al.*, 2022).

4.5. Case Studies and Yield Comparisons

These conclusions are supported by empirical data from several locations. In Himachal Pradesh, protected tomato growing produced yields of 105 t/ha as opposed to 55 t/ha in open fields (ICAR, 2020). While open-field counterparts only produced about 30 t/ha of capsicum in Karnataka, polyhouse-grown capsicum produced 60 t/ha (NHB, 2021). The productivity benefit of protected systems is highlighted by these consistent outcomes.

5. IMPACT OF PROTECTED CULTIVATION ON QUALITY ATTRIBUTES

Protected culture greatly improves the horticultural produce's physical, nutritional, and aesthetic qualities in addition to increasing growth and production. It contributes to the production of consistent, aesthetically pleasing, nutritionally enhanced, and shelf-stable fruits, vegetables, and flowers by offering a stable microenvironment. Particularly in high-end and export markets, quality features are essential for market value and consumer approval.

5.1. Physical Quality Parameters

Fruit size, weight, color consistency, hardness, and shape are all improved by protected cultivation. For example, compared to those grown in open fields, tomatoes and bell peppers grown in polyhouses are typically stiffer, more symmetrical, and have better skin texture (Kaur and Dhaliwal, 2020). According to Bisht et al. (2018), strawberries cultivated in walk-in tunnels have superior fruit gloss, color, and consistency. Because of better water management and less environmental stress, the frequency of cracking and deformed fruits in cucurbits and other solanaceous vegetables is greatly decreased in controlled conditions (Singh *et al.*, 2021). These quality enhancements lower postharvest losses and increase consumer preference.

5.2. Nutritional Quality

In general, crops grown under protection have better nutritional characteristics. According to reports, greenhouse-grown tomatoes and capsicums have increased amounts of beta-carotene, lycopene, and vitamin C because of improved nutrient absorption and less oxidative stress (Kumar *et al.*, 2020). Under net homes and polyhouses, leafy vegetables such as spinach and lettuce also exhibit higher levels of minerals and chlorophyll (Meena *et al.*, 2019). Furthermore, exact nutrient delivery is ensured by regulated fertigation techniques, which improves the accumulation of vital macro- and micronutrients. Cucurbits and melons have been found to have higher levels of soluble solids (°Brix) and total sugars, which improves their sweetness and flavor (Patel *et al.*, 2020).

5.3. Sensory and Aesthetic Qualities

Additionally, protected structures enhance flavor, texture, and aroma—all of which are critical for customer satisfaction. Protected settings aid in the production of longer stems, larger flower heads, and improved coloration in cut flowers like roses, carnations, and gerberas—features that have a direct impact on market price (Verma *et al.*, 2021). Additionally, fewer flaws and mechanical problems result from reduced exposure to wind and pests.

5.4. Reduced Residue Load and Shelf Life

Due to the semi-enclosed environment and reduced pest pressure, the need for pesticide application is lower in protected cultivation. As a result, the final produce often has lower pesticide residue levels, making it safer for consumption and export (Sharma *et al.*, 2018). Furthermore, improved firmness, skin integrity, and moisture retention under protected cultivation contribute to a longer shelf life. For instance, greenhouse-grown cucumbers and tomatoes have shown 3–5 days longer storage ability compared to open-field produce (Rana *et al.*, 2019).

5.5. Postharvest and Market Benefits

Particularly in urban and export markets, high-quality produce from covered structures commands premium market pricing. Supply chains benefit greatly from the combination of consistent appearance, enhanced flavor, and extended shelf life (NHB, 2021). Numerous horticultural crop quality parameters are improved by protected farming, which also conforms to export regulations and consumer preferences. The economic viability of protected farming systems is directly impacted by these quality enhancements, which are just as important as yield increases.

6. CROP-WISE ANALYSIS

Numerous horticultural crops have demonstrated considerable promise for protected cultivation. Its effects, however, differ depending on the crop type, location, structure, and management techniques. A more focused knowledge of how protected settings benefit particular horticultural categories—fruits, vegetables, and flowers—is made possible by a crop-wise analysis. Vegetables and flowers exhibit the highest responsiveness to protected agriculture in terms of both output and quality, according to the crop-wise analysis. Fruits have encouraging results with technological optimization, while being less common under protection. The success of protected agriculture systems can be greatly increased by carefully choosing crops and designing structures according to market and geographical specifics.

6.1. Vegetables

Because of their short cycles and sensitivity to climate changes, vegetables are among the most responsive crops grown under protection. Leafy greens, tomatoes, capsicums, and cucumbers have all demonstrated exceptional adaptability to low tunnels, net houses, and polyhouses.

Tomato: Tomatoes have better quality, longer harvest times, and higher fruit set when grown under protection (Kumar *et al.*, 2020). Depending on season and structure, yields can rise to 100–120 t/ha. Because of improved pollination and reduced disease burden, capsicum (bell pepper), a highly responsive crop, yields considerably more in net homes (Patel *et al.*, 2021).

Cucumber: Trellising techniques and increased humidity in polyhouses help cucumbers reach maturity faster and have longer fruiting times (Bisht *et al.*, 2019).

Leafy greens: With reduced evapotranspiration and increased chlorophyll content, lettuce, spinach, and fenugreek thrive under shade nets (Meena *et al.*, 2020).

6.2. Fruits

Fruit crops are increasingly being grown under protection, particularly high-value or climate-sensitive types.

Strawberry: Grown extensively in walk-in tunnels, strawberries have better sugar content, larger fruit, and better roots. The harvesting season is also prolonged by protected cultivation (Bisht *et al.*, 2018).

Papaya: Plants grown under shade nets exhibit improved fruit set, greater plant vigor, and decreased viral infestation (Singh and Srivastava, 2021).

Melons: Early flowering, increased sweetness, and enhanced uniformity are advantages of growing watermelon and muskmelon in polyhouses (Rana *et al.*, 2020).

6.3. Flowers

Floriculture under protection is very profitable since high-quality blooms fetch premium rates.

Gerbera: Under polyhouses, it displays better coloration, longer stem length, and more blooms per plant (Verma *et al.*, 2021).

Rose: Roses benefit from long flowering times and consistent bud size when grown widely in greenhouses (Nath and Yadav, 2020).

Carnation: In semi-controlled polyhouse circumstances, carnations flourish, producing more flowers and having a longer shelf life despite being sensitive to temperature changes (Kaur *et al.*, 2022).

Table 2: Comparative Benefits of Protected Cultivation across Crops

Crop Type	Crop Name	Yield Increase (%)	Key Quality Gains
Vegetable	Tomato	80–100%	Fruit firmness, size, TSS
Vegetable	Capsicum	80–100%	Uniform size, color, shelf life
Vegetable	Cucumber	70–90%	Length, smoothness, storage
Fruit	Strawberry	50–80%	Sweetness, gloss, uniformity
Fruit	Papaya	40–60%	Fruit set, virus resistance
Fruit	Melon	60–90%	Sugar content, early maturity
Flower	Gerbera	100–150%	Stem length, color intensity
Flower	Rose	80–120%	Bud uniformity, flower count
Flower	Carnation	70–110%	Bloom life, stem quality

Source: Compiled from (Kumar *et al.*, 2020), (Verma *et al.*, 2021), (Meena *et al.*, 2020), (Patel *et al.*, 2021), (Kaur *et al.*, 2022)

7. CHALLENGES AND LIMITATIONS

Protected agriculture has several agronomic and economic benefits, but adoption and long-term success are fraught with difficulties, particularly in developing nations like India. These problems vary from governmental limitations and environmental concerns to high capital expenditures and gaps in technical know-how.

7.1. High Initial Investment and Cost Barriers

The biggest obstacle is the substantial upfront financial outlay needed to establish net homes, polyhouses, or greenhouses. A climate-controlled greenhouse can cost more than ₹2,500 per m^2, while a naturally ventilated polyhouse can cost between ₹800 and ₹1,000 per m^2 (NHB, 2021). Even with subsidies, this is a major obstacle for small and marginal farmers. The financial burden is increased by operational expenses such as energy use for climate control, fertigation devices, irrigation systems, and building maintenance (Rao *et al.*, 2018).

7.2. Limited Technical Expertise

In order to operate protected cultivation, one needs unique expertise in crop-specific agronomy, climate regulation, pest control, and irrigation scheduling. Farmer undertraining frequently results in less-than-ideal yields and low financial returns (Kumar and Meena, 2020). In rural or hilly areas, scalability is further constrained by a lack of extension support and skilled labor (Singh and Sidhu, 2020).

7.3. Pest and Disease Build-up in Closed Environments

Although covered culture lessens exposure to outside pests, the high humidity and restricted air circulation in the enclosed space might serve as a breeding ground for several bacterial, viral, and fungal illnesses (Sharma *et al.*, 2019). If left unchecked, crops like tomatoes and cucumbers are especially vulnerable to infestations like thrips, leaf spot, and powdery mildew. Outbreaks result from the frequent disregard for hygiene guidelines and integrated pest management (IPM) techniques.

7.4. Lack of Region-Specific Designs and Crop Recommendations

The standardized designs used by the majority of covered structures might not work for all crops or climate zones. For example, coastal or high-humidity areas might not be suitable for a design that is perfect for North India (Verma *et al.*, 2021). Guidelines for crop selection, planting dates, and nutrient management in protected areas are also lacking in terms of location (ICAR, 2020).

7.5. Marketing and Value Chain Constraints

Accessing premium markets is frequently a challenge for farmers that cultivate goods under protected agriculture. The pricing advantage is gone if postharvest handling, grading, and branding are done incorrectly. Because of shifting market demand, protected cultivation is frequently regarded as high-risk (Rana and Choudhary, 2019).

7.6. Environmental Concerns

There are long-term environmental problems when plastics are used for drip systems, roofing, and mulching. Plastic contamination is a result of inadequate infrastructure for recycling or disposal (Nayak *et al.*, 2019). Furthermore, energy-intensive climate-controlled systems raise high-tech greenhouses' carbon footprint (Kaur and Sidhu, 2021).

8. FUTURE PROSPECTS AND RESEARCH NEEDS

In horticulture, protected cultivation has become a game-changing technique that offers improved quality, increased yield, and climate change resilience. However, because of technical, socioeconomic, and environmental obstacles, its full potential is still underused. Innovation, localization, and integration with cutting-edge technologies are critical to the future of protected horticulture. Research must simultaneously fill in the gaps in crop diversification, sustainability, resource optimization, and design.

8.1. Climate-Resilient Structure Design

A significant opportunity for the future is the creation of protected structures tailored to a particular area. The demand for affordable, lightweight, modular greenhouses and net houses that work in a variety of agroclimatic zones is rising. In coastal and desert regions in particular, current designs frequently fall short in the face of harsh temperatures, strong winds, or high humidity (Kaur and Sidhu, 2021). Research needs to concentrate on adaptive design that uses local materials, improves ventilation, and lowers heat load, such as moveable or foldable structures (Verma *et al.*, 2022).

8.2. Integration of Smart and Digital Technologies

The future of artificial intelligence (AI), automation, and sensors is directly related to safe farming. Utilizing remote sensing and the Internet of Things (IoT), precision-controlled irrigation, fertigation, and climate regulation can optimize output while reducing resource use (Meena *et al.*, 2020). Decision support systems (DSS) can benefit from real-time data on temperature, humidity, soil moisture, and pest occurrence to improve farm management. Research on affordable smart sensors designed for smallholder greenhouses is still crucial (Kumar *et al.*, 2021).

8.3. Crop Diversification and Genetic Improvement

The majority of crops grown under protection now are gerbera, tomatoes, and capsicums. In order to expand the economic basis, research has to find new crop varieties that are ideal for controlled settings, like high-value herbs, exotic fruits, and medicinal plants (Rawat and Yadav, 2020). Furthermore, breeding initiatives ought to create cultivars that are especially suited to environments with low light levels, high humidity, and high densities. The development of such crop kinds can be accelerated through the application of CRISPR-based genome editing and genomic selection (Singh *et al.*, 2021).

8.4. Sustainable Resource Management

Sustainability of the environment must be considered in future systems. The development of closed-loop water recycling systems, organic substrates, and biodegradable plastics is urgently needed to lessen the environmental impact (Nayak *et al.*, 2019). For remote or resource-constrained locations, solar-powered greenhouses and passive cooling systems provide energy-efficient substitutes (ICAR, 2020).

8.5. Policy Support and Financial Models

Policies that are inclusive are essential for future growth. In order to make protected cultivation inexpensive and scalable, research should concentrate on establishing business models including cooperative-based systems, farmer producer organizations (FPOs), and public-private partnerships (PPPs) (Rao *et al.*, 2018).

8.6. Training, Extension, and Farmer Empowerment

Training programs in protected agriculture need to be tailored to smallholders, women, and young people. To boost awareness and acceptance, research institutions should focus on developing visual information, simulation tools, and mobile-based advising platforms (Patel *et al.*, 2021).

9. CONCLUSION

In contrast to conventional open-field agriculture, protected cultivation offers a robust, effective, and highly profitable alternative, marking a revolutionary change in the production of horticulture crops. In the face of growing problems from climate change, unpredictable weather, degraded soil, and rising food demand, protected farming offers a flexible and scalable way to maintain horticultural yield and raise smallholder farmers' standard of living.

The growth parameters, yield potential, and quality qualities of a variety of horticultural crops are all markedly improved by sheltered cultivation, as this review makes clear. The productivity and quality of vegetables such as tomatoes, capsicums, and cucumbers have improved significantly because to fertigation, controlled irrigation, and ideal microclimatic conditions. Melons and strawberries, for example, have shown greater flavor, uniformity, and beauty under tunnel and polyhouse systems. Bloom quality, stem strength, and marketability have been significantly improved in floriculture, especially for crops like carnations, roses, and gerberas. In terms of economics, protected cultivation guarantees year-round crop availability, improved resource efficiency, and larger profit margins. Even while infrastructure still has a high upfront cost, there is a positive long-term return on investment, particularly when backed by suitable market access, training, and government regulations. Protected farming is positioned as a potent instrument for equitable development since it creates jobs, especially for women and young people in rural areas. Despite its potential, a number of obstacles stand in the way of the broad use of protected agriculture, including expensive startup costs, a lack of technical expertise, a lack of designs tailored to a particular region, and inadequate market connections. A multifaceted strategy is needed to overcome these constraints, including the creation of localized structures, the use of smart technology (such as automation and the Internet of Things), the investigation of crop types that are conducive to protected farming, and inclusive legislative frameworks that provide institutional and financial support. Protected horticulture's future depends on incorporating sustainable materials, technology, and climate-smart techniques into system design. To guarantee long-term ecological and economic sustainability, research must also examine eco-efficient techniques, crop diversity, and organic production methods. In conclusion, by increasing yield, guaranteeing quality, and encouraging sustainable behaviors, protected cultivation has the potential to completely transform horticulture. In the 21st century, it can be a key component in attaining climate resilience, rural prosperity, and nutritional security with the correct mix of research, innovation, policy, and community involvement.

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