Review Article

An Insightful Exploration of Protected Cultivation in Horticultural Crops: A Comprehensive Review

ABSTRACT:

The survey starts by examining various sorts of protected cultivation, encompassing a variety of techniques such as greenhouses, polytunnels, modern nurseries, high passages, and shade houses, as well as their benefits and constraint has emerged as a pivotal component in horticultural practices. It then, at that point, features the significance of protected cultivation in tending to worldwide food security challenges by guaranteeing all year crop creation and decreasing dependence on occasional varieties. This comprehensive review delves into the multifaceted aspects of protected cultivation in horticultural crops, aiming to provide a nuanced understanding of its impact on crop yield, quality, and resource efficiency. The audit further investigates the effect of protected cultivation strategies on the development and advancement of plant crops, including further developed crop morphogenesis, precipitation the board, and the streamlining of natural factors like temperature, moistness, and carbon dioxide levels. Besides, the usage of cutting-edge innovations like aquaculture, aeroponics, and vertical cultivating inside protected cultivation frameworks is inspected, with an accentuation on their true capacity for amplifying crop efficiency while limiting asset utilization. The article synthesizes recent advancements, challenges, and future prospects in this field, shedding light on the dynamic interplay between environmental factors, crop physiology, and technological interventions. By critically evaluating the existing literature, we present a synthesis of knowledge that can inform both researchers and farmers in optimizing protected cultivation for sustainable and resilient horticultural production systems.

Keywords: Protected Cultivation, Yield, Quality, Environmental Factors etc.

➢ Introduction:

The global demand for high-quality horticultural crops has witnessed unprecedented growth, fueled by urbanization, changing dietary preferences, and the pursuit of healthier lifestyles. In this context, protected cultivation has evolved into a strategic approach to enhance crop productivity, mitigate environmental risks, and ensure year-round supply. Growing crops in enclosed or partially enclosed environments, such as high tunnels, shade houses, or greenhouses, is known as protected cultivation (Lamichhane *et al.* 2023). Unlike open-field cultivation, protected cultivation provides a controlled environment, allowing

growers to manipulate factors such as temperature, moistness, humidity, light,nutrient availability and other natural factors (Gruda *et al.* 2014). This level of precision enables the cultivation of a diverse range of crops, including fruits, vegetables, and ornamental plants, under optimal conditions.This review aims to offer a comprehensive exploration of protected cultivation in horticultural crops, unraveling its underlying principles, technological innovations, and the ecological implications of its adoption. As we navigate through the intricacies of protected cultivation, we will examine key factors influencing crop performance within these controlled environments, ranging from physiological responses to agronomic practices (Jewett *et al.*2001). Furthermore, we will discuss the challenges associated with protected cultivation, such as energy consumption, environmental sustainability, and economic viability, while proposing potential solutions and avenues for future research.Through this exploration, we aspire to contribute valuable insights to the scientific community, policymakers, and growers alike, fostering a deeper understanding of the role protected cultivation plays in shaping the future of horticultural production (Rasheed *et al.* 2020). By embracing a holistic perspective, this review sets the stage for informed decision-making and innovative approaches to address the growing demand for sustainable and resilient horticultural systems in a rapidly changing global landscape. The structure's temperature rises as a result of this trapping solar energy and creating a greenhouse effect (Gorjian *et al.* 2021). Plants' photosynthetic rate, transpiration, stomatal aperture, and leaf temperature are all affected by the elevated temperature (Pallas *et al.* 1967). Controlling the nursery climate permits control of the physiological states of the plants (Paradiso *et al.* 2022). For example, shutting the nursery around evening time prompts an expansion in CO_2 levels coming about because of plant breath. This raised CO_2 is then used for photosynthesis during the early morning hours of the next day. The expanded temperature, relative moistness, CO_2 levels, and further developed sustenance inside the nursery advance quick development and expanded creation (Gelder *et al.* 2012). The temperature inside a nursery can be directed by integrating cooling frameworks like ventilation, misting, or fan cushion frameworks (Sethi *et al.* 2007). These advancements empower all year creation of wanted vegetable harvests and amplify their yield potential. Closer planting and higher plant thickness under Protected 10-15 kg/m^2. The worldwide creation of agricultural harvests under protected cultivation is assessed to be around 150 million tons. The significant yields delivered under protected cultivation incorporate vegetables (tomatoes, cucumbers, peppers, lettuce, and so on.), organic products (strawberries, raspberries, blueberries, and so on) (Fernandez *et al.* 2018), and blossoms (roses, gerberas, carnations, and so on). In India, the major agricultural harvests

delivered under protected cultivation incorporate tomatoes, cucumbers, capsicums, roses, and gerberas (Pachiyappan *et al.* 2022). As per the Food and Agriculture Organization of the United Nations (FAO), the worldwide region under protected cultivation was assessed to be 2.76 million hectares in 2022. China is the world forerunner in protected cultivation, with north of 4 million hectares under creation development further improve yields (Nordey *et al.* 2017). Open-field production and protected cultivation have different management practices. In peri-metropolitan regions, multistorey harvest development in nurseries has become basic to fulfil the need for new vegetables, strawberries, blossoms, and organic product tree farms (Pancharatnam, 2012). Protected cultivation systems employ a variety of methods, including naturally ventilated polyhouses, drip irrigation, fertigation, and mulching (Aditya *et al.* 2023). Moreover, stroll in polytunnels have as of late arisen as beneficial advances in the Northern fields of India, demonstrating their reasonableness for developing yields like tomatoes, capsicum, cucurbits, and laying out nurseries during the slow time of year (Singh *et al.* 2022).

- **Global and Indigenous Scenarios of Protected Crop Cultivation of Horticultural Crops:**

The worldwide region under ProtectedCultivation of plant crops was assessed to be around 623,302 hectares in 2023 with China representing the biggest offer (45%), as per the most recent information from the Food and Agriculture Organization of the United Nations (FAO)(FAOSTAT, 2023). Other significant makers incorporate Turkey, Spain, Italy, and Japan (Tuzel *et al.* 2009). In India, the region under ProtectedCultivation of agricultural yields is around 11 thousand hectares. The main states are Maharashtra, Gujarat, Himachal Pradesh, Karnataka, and Punjab (Singh *et al.* 2022). ProtectedCultivation of green harvests brings about more significant returns and better-quality produce contrasted with open field Cultivation(Ameta *et al.* 2019). The average yield of tomatoes grown in protected areas is between 30-40 kilograms per square meter, while the average yield of tomatoes grown in open fields is between 10-15 kilograms per square meter. The worldwide creation of agricultural yields under ProtectedCultivation is estimated to be around 150 million tons. Vegetables, such as tomatoes, cucumbers, peppers, and lettuce, are the primary crops grown under protected cultivation,fruits (strawberries, blueberries, raspberries, and so on) (Fernandez *et al.* 2018), and flowers (roses, gerberas, carnations, and so on) (Pachiyappan*et al.*, 2022). In India, the major green harvests created under ProtectedCultivation incorporate tomatoes, cucumbers, capsicums, roses, and gerberas (Pachiyappan*et al.*, 2022). According to

the Food and AgricultureOrganization of the United Nations (FAO), The Worldwide region under ProtectedCultivation was assessed to be 2.76 million hectares in 2022. With over 4 million hectares under cultivation, China is the world leader in protected cultivation.

- **Present Status and Future Possibilities of Protected Cultivation of Horticultural Crops:**

1) Global Status of Protected Cultivation

- **Widespread Adoption:** In areas with extreme climates or limited arable land, protected cultivation methods like greenhouses and high tunnels have gained widespread acceptance (Fernandez *et al*,. 2018).
- **Variety of Crops:**It is utilized to grow a large number of green yields, including vegetables, natural products, blossoms, and elaborate plants (Gary *et al*., 1998)
- **Technological Advancements:** Created nations have put vigorously in present day advancements for controlled climate horticulture, including robotized environment control, aquaculture, and vertical cultivating (Benke and Tomkins, 2017).
- **Sustainable Practices:** There's a growing emphasis on sustainable and organic practices within protected cultivation to reduce the environmental footprint of agriculture (Gomiero and Pimentel, 2008).
- **Market Expansion:** The Protected cultivation equipment, innovation, and administrations has developed, offering open doors for business field (Ottman, 2017).

2) Indian Status of Protected Cultivation

- **Rapid Growth:** In India, the reception of protected cultivation strategies has been consistently expanding as of late, determined by the need to satisfy the developing need for new and offseason produce (Kumar and Singh, 2020).
- **Favourable Environment:** India's diverse climate, with its extreme temperatures and monsoon patterns, is ideal for protected cultivation to extend growing seasons and shield crops from bad weather (Kumar *et al.*, 2019).
- **Horticultural Diversity:** A wide assortment of plant crops, including vegetables, blossoms, and extraordinary organic products, are developed involving protected cultivation procedures in India (Asti and Yadav, 2004).

- **Government Drives:** The Indian government has acquainted different plans and motivating forces with advance safeguarded development, empowering ranchers to take on nursery and polyhouse innovations (Pachiyappan *et al.,* 2022).
- **Challenges:** Regardless of development, there are still difficulties, including the high introductory venture cost, specialized information holes among small-scale ranchers, and manageability concerns (Abegunde *et al.,* 2029).
- **New Research Ideas:** Indian agrarian foundations and examination associations are effectively engaged with creating locale explicit advancements for protected cultivation and further developing harvest efficiency (Raina*et al.,* 2009).
- **Export Opportunities:** Protected cultivation has likewise opened up open doors for India's agricultural products, with specific yields being traded to worldwide business sectors (Sengar and rani, 2020).

➢ **Future Possibilities**

The eventual fate of protected cultivation looks encouraging. As the populace increments and accessible arable land diminishes, protected cultivation offers an economical answer for fulfil the developing need for green yields (Slathia*et al.,* 2018). It takes into account all year creation, increments crop quality, and diminishes water and pesticide utilization. Arising advancements in safeguarded development: A few arising advances in protected cultivation incorporate the utilization of robots for crop checking, mechanical technology for gathering, accuracy farming methods (Baylis, 2017), and the mix of Information of Things (IOT) answers for information assortment and examination (Alansari *et al.,* 2018). Protected cultivation's growing significance in meeting global food demands: Protected cultivation assumes a urgent part in fulfilling worldwide food needs (Shiferaw *et al.,* 2013). It considers the creation of top-notch crops in locales with ominous climatic circumstances. Moreover, it decreases post-gather misfortunes, upgrades crop efficiency, and guarantees a predictable stock of new produce consistently. Opportunities and challenges in protected cultivation: While protected cultivation offers various open doors, it likewise faces a few difficulties. These incorporate introductory arrangement costs, energy utilization, appropriate upkeep, and guaranteeing ideal natural circumstances for crop development (Subin *et al.,* 2021). Nonetheless, progressions in innovation and expanding mindfulness about manageable 'cultivating rehearses present open doors for defeating these difficulties and growing the utilization of protected cultivation.

➢ **Types of Protected Structures**

From basic net houses to elaborate greenhouses, there are a variety of secure cultivation structures available. The kind of design picked relies upon the harvest being developed, the environment, and the spending plan accessible.

- **Net houses:** Net houses are the easiest and most reasonable kind of protected structure. They are made of a net mesh that keeps birds, insects, and diseases out of the crop (Singh *et al.,* 2009).
- **Polyhouses:** Polyhouses are made of a plastic film that gives preferable insurance from the components over net houses. They can likewise be warmed and cooled to establish a more controlled climate (Kanwar, 2019).
- **Greenhouses:** Nurseries are the most complex sort of protected structure. They are made of glass or polycarbonate and can be outfitted with an assortment of natural control frameworks (Dalai *et al*., 2020).

➢ **Major Horticultural Crops Grown Under Controlled Climate**

Many plant yields can be developed under safeguarded development, including:

- **Vegetables:** Tomato, capsicum, cucumber, eggplant, lettuce, mixed greens, zucchini and melon (Castilla, 2000).
- **Fruits:** Grapes, apple, pear, peach, plum, cherry strawberry, raspberry and other berry crops (Granatstein*et al.,* 2008).
- **Flowers:** Rose, Jasmine, gerbera, carnation, lilium, anthurium, orchids and chrysanthemum (De and Singh, 2016).

➢ **Technological Advancements in Protected Cultivation**

In recent years, protected cultivation has seen a number of technological advancements.

- **Precision Agriculture Technologies:**Precision agriculture advances, like sensors, drones, and man-made consciousness, are being utilized to improve crop creation and decrease inputs.
- **Sources of Renewable Energy:** Sustainable power sources, for example, sunlight based and wind power, are being utilized to control Protected Cultivation offices.
- **Methods of Integrated Pest Management:**Integrated pest management (IPM) rehearses are being utilized to decrease the utilization of pesticides and composts in protected cultivation (Singh, 2014).

➢ **Appropriate Plant Harvest for Protected Cultivation.**

Many plant crops are appropriate for protected cultivation. A portion of the yields ordinarily filled in safeguarded conditions include:

- **Tomatoes:** Tomatoes are one of the most well-known crops for protected cultivation. Nurseries give ideal circumstances to their development, guaranteeing more significant returns and better-quality organic product contrasted with open field creation (Peet and Welles, 2005).
- **Cucumbers:** Cucumbers flourish in protected conditions, particularly in nurseries or high passages. The controlled environment and insurance from bugs and illnesses add to better returns and further developed organic product quality (Maitra, 2020).
- **Peppers:** The cultivation of sweet and hot peppers in a protected environment is ideal. Nurseries offer the ideal circumstances for pepper plants, taking into consideration expanded developing seasons and expanded creation (Boswell, 1964).
- **Leafy Greens and Lettuce:** Mixed greens, including lettuce, spinach, kale, and arugula, can be developed all year in protected conditions. Nurseries give assurance from outrageous temperatures and take into consideration more exact command over dampness levels (Imler, 2020).
- **Fruits:** Grapes, apple, pear, peach, plum, cherry and Strawberries are normally filled in nurseries or high passages, as these designs give security from downpour, bugs, and sicknesses. This considers better organic product quality and broadened reap periods (Martinez *et al.*, 2021).
- **Flowers:** Roses, chrysanthemums, and gerberas are just a few of the flower varieties that are suitable for protected cultivation. Nurseries offer stable circumstances and assurance from wind and downpour, bringing about greater blossoms. Model as rose, carnation, gerbera, anthurium, lilium, orchids, chrysanthemum (Slathia*et al.*, 2018).
- **Herbs:** Spices like basil, cilantro, mint, and parsley are amiable to protected cultivation. Controlled conditions guarantee predictable development, more significant returns, and better-quality spices (Vázquez *et al*., 2019).
- **Melons:** Cantaloupes and muskmelons, two types of melons, can be grown successfully in safe environments. Fruit quality is improved due to better temperature and humidity control in greenhouses (Huang *et al.*, 2017).
- **Beans:** A few kinds of beans, for example, green beans and sprinter beans, can be filled in protected structures. These conditions offer security from unfriendly weather patterns and nuisances, bringing about expanded efficiency. It is essential

to keep in mind that the suitability of particular crops for protected cultivation may vary depending on the climate of the region, the demand in the market, and the resources that are available. Rancher inclinations and neighbourhood conditions ought to be thought about while choosing crops for protected cultivation(Sabir and Singh, 2013).

- **Future Possibilities of Protected Cultivation**

Protected cultivation is supposed to assume an undeniably significant part in satisfying the worldwide need for new, excellent agricultural produce before very long (Kumar and Singh, 2020). This is because of a number of things, such as:

- The growing population and urbanization
- The rising demand for nutritious and healthy food as a result of population growth and urbanization.
- The necessity of sustainable food production.

- **Benefits of Protected Cultivation**
  - **Provides Favourable Microclimate Conditions to the Plants:**Protected cultivation considers the production of an ideal developing climate by controlling temperature, moistness, and light circumstances. This guarantees that plants get the ideal circumstances for development and advancement (Ummyiah*et al.,* 2017).
  - **Development in all Seasons Considerably under Outrageous Circumstances is Conceivable:**With safeguarded development, harvests can be developed all year, no matter what the outside climatic circumstances. This considers steady creation and a more solid food supply (Nordey*et al.,* 2017).
  - **High Return with Better Quality per Unit Region:**Higher yields per unit area are encouraged by protected cultivation's-controlled environment. In addition, the crops typically exhibit improved quality, including dimensions, colour, taste, and nutritional value (Ameta *et al.,* 2019).
  - **Longer Creation Cycle:**Protected Cultivation expands the creation cycle by shielding crops from unfavourable atmospheric conditions. This empowers ranchers to gather crops for a more extended term, expanding generally speaking result (Nordey*et al.,* 2017).
  - **Needs Less Water System because of Dampness Preservation:** Better moisture conservation results from reduced evaporation of water from protected structures. conserves moisture, requiring less irrigation: Better moisture conservation results

from reduced evaporation of water from protected structures. This, thusly, lessens the water necessities of yields and advances water proficiency (Pascale and Maggio, 2004).

- **Better Suited to High-Value, Off-Season Crops:**Protected Cultivation is especially useful for developing slow time of year crops when their creation is restricted in open fields. This considers the development of high-esteem crops when market costs are higher (Hasan, 2016).
- **Clean Creation because of Less Splashes of Harmful Pesticides:**The controlled environment of protected cultivation aids in the reduction of diseases and pests. Subsequently, ranchers can limit the utilization of unsafe pesticides, prompting cleaner and more sterile harvest creation (Sabir and Singh, 2013).
- **Better Infection and Irritation Control:** Protected Cultivation gives an actual obstruction that forestalls bugs, nuisances, and sicknesses from straightforwardly getting to crops.This makes it possible to take more effective measures against pests and lowers the likelihood of infestations (Fernández *et al.,* 2018).
- **Helps in Early Raising of Nursery:** Protected Cultivation works with the early foundation of seedlings and nursery plants. This enables farmers to get a head start on the growing season and speeds up crop development (Kaushal and Singh, 2019).
- **Security From Wind, Downpour, Snow, Birds, Hail, and so on:**Crops are shielded from hail, wind, snow, birds, and other elements by protected structures. This insurance limits crop harm and guarantees a more elevated level of harvestable yield (Baeza *et al.,* 2011).
- **Produces Independent Work for Taught Youth:**Protected cultivation offers self-employment opportunities for educated individuals because it requires specialized knowledge and skills. This may aid in job creation and rural development (Gindling, 2014).

➢ **Elements Influencing the Reception of Protected Cultivation of Crops**

A few elements impact the reception of Protected Cultivation of green yields. These include:

- **Cost:** The underlying speculation and progressing costs related with setting up and keeping up with protected cultivation designs can be critical. Infrastructure, equipment, materials, and specialized technologies are all included in this. The

moderateness of these ventures can direct the ability of ranchers to take on protected cultivation techniques (Prakash *et al.,* 2021).

- **Information and Abilities:** Taking on protected cultivation strategies requires explicit information and abilities that might be not the same as customary open-field cultivating rehearses. Ranchers need to comprehend ideas, for example, environment control, water system frameworks, bug the board, and yield sustenance inside a safeguarded climate absence of adequate information and abilities can frustrate reception (Nordey*et al.,* 2017).
- **Market Interest and Productivity:** The expected benefit and market interest for green harvests developed utilizing Protected Cultivation procedures assume a pivotal part in reception. Ranchers need confirmation that they can sell their produceat positive costs, counterbalancing the extra expenses related with safeguarded development. The viability and demand for these crops must be determined through market research and analysis (Marra *et al*., 2003).
- **Environment and Ecological Circumstances:** The appropriateness of neighbourhood climatic and natural circumstances for Protected Cultivation is another component affecting reception. Safeguarded designs can give protection against outrageous atmospheric conditions;however, they likewise require satisfactory daylight, water accessibility, and appropriate temperature ranges. It is essential to determine whether the local conditions meet the requirements of protected cultivation (Hanan, 2017).
- **Resources at Hand:** The accessibility and availability of assets like land, water, energy, and talented work are pivotal for fruitful reception. Satisfactory land space, a dependable water source, and admittance to power or elective energy sources are fundamental for setting up and working Protected Cultivation frameworks (Rahman *et al.,* 2022). It's also important to have skilled workers on hand or the ability to train employees.
- **Government Backing and Approaches:** Steady government arrangements, endowments, impetuses, or specialized help can essentially support the reception of protected cultivation These drives assist ranchers with dealing with the underlying speculation costs, give preparing and knowledge sharing stages, and establish a helpful climate for changing to Protected Cultivation techniques (Knowler *et al.,* 2007).

- **Risk the Executives:**Due to the perceived risks and uncertainties, farmers may be wary of adopting protected cultivation. Factors like harvest disappointment,sickness flare-ups, bother pervasions, or market vacillations can influence productivity. Risk the executive's systems, including crop protection, specialized help, and admittance to data, can assist with moderating these worries and support reception. By and large, the reception of Protected Cultivation of green harvests relies upon a blend of monetary, specialized, market, and natural elements. Protected cultivation methods may be more widely adopted if these factors are addressed through education, financial support, market development, and risk management measures (Tack and Yu., 2021).

- **Conclusion:**

Protected Cultivation is a technique for developing harvests in a controlled climate, considering the guideline of variables like temperature, dampness,

and light in view of the particular necessities of the yield. The overall yield and the promotion of healthier plants are both aided by this controlled environment. There are different kinds of Protected Cultivation works on, including constrained ventilated nurseries, normally ventilated polyhouses, bug resistant net houses, conceal net houses, plastic passages, and strategies, for example, mulching, raised beds, trellising, and dribble water system. These practices can be used freely or in mix to establish a positive developing climate, safeguarding plants from unforgiving environments and expanding the development time frame or empowering offseason crop creation. The reception of trickle water system in mix with raised beds and mulch films offers advantages like weed control and further developed soil dampness maintenance by decreasing dissipation misfortunes.

Reference

Abegunde, V. O., Sibanda, M., and Obi, A. (2019). The dynamics of climate change adaptation in Sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers. *Climate, 7*(11), 132.

Aditya, P., Rao, V., Mohapatro, S., Chandra, V., Nanda, C., and Suman, S. (2023). Future trends in protected cultivation: A review. *The Pharma Innovation Journal.* 12(8): 2025-2029

Alansari, Z., Anuar, N. B., Kamsin, A., Soomro, S., Belgaum, M. R., Miraz, M. H., & Alshaer, J. (2018). Challenges of internet of things and big data integration. In *Emerging Technologies*

in Computing: First International Conference, iCETiC 2018, London, UK, August 23–24, 2018, Proceedings 1 (pp. 47-55). Springer International Publishing.

Ameta, K. D., Kaushik, R. A., Dubey, R. B., and Rajawat, K. S. (2019). Protected cultivation-An Entrepreneurship for modern agriculture. *Biotech Today: An International Journal of Biological Sciences*, *9*(1), 35-40.

Asati, B. S., and Yadav, D. S. (2004). Diversity of horticultural crops in north eastern region. *ENVIS Bulletin: Himalayan Ecology*, *12*(2), 1-10.

Baeza EJ, Stanghellini C, and Castilla N. (2011). Protected cultivation in Europe. In International Symposium on High Tunnel Horticultural Crop Production., 987:11-27.

Baylis, A. (2017). Advances in precision farming technologies for crop protection. *Outlooks on Pest Management*, *28*(4), 158-161.

Benke, K., and Tomkins, B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science, Practice and Policy*, *13*(1), 13-26.

Boswell, V. R. (1964). *Pepper production* (No. 276). US Department of Agriculture, Agricultural Research Service.

Castilla, N. (2000). Current situation and future prospects of protected crops in the Mediterranean region. In *International Symposium on Mediterranean Horticulture: Issues and Prospects 582* (pp. 135-147).

Dalai, S., Tripathy, B., Mohanta, S., Sahu, B., and Palai, J. B. (2020). Green-houses: Types and Structural Components. *Protected Cultivation and Smart Agriculture. New Delhi Publishers. New Delhi, India*. 09-17.

D'antonio, C. A. R. L. A., and Meyerson, L. A. (2002). Exotic plant species as problems and solutions in ecological restoration: a synthesis. *Restoration ecology*, *10*(4), 703-713.

De Gelder, A., Dieleman, J. A., Bot, G. P. A., and Marcelis, L. F. M. (2012). An overview of climate and crop yield in closed greenhouses. *The Journal of Horticultural Science and Biotechnology*, *87*(3), 193-202.

De, L. C., and Singh, D. R. (2016). Floriculture industries, opportunities and challenges in Indian hills. *International Journal of Horticulture*, *6*.

De Pascale, S., and Maggio, A. (2004). Sustainable protected cultivation at a Mediterranean climate. Perspectives and challenges. In *International Conference on Sustainable Greenhouse Systems-Greensys 691:* 29-42.

Fernández, J. A., Orsini, F., Baeza, E., Oztekin, G. B., Muñoz, P., Contreras, J. and Montero, J. I. (2018). Current trends in protected cultivation in Mediterranean climates. *Eur. J. Hortic. Sci*, *83*(5), 294-305.

Food and Agriculture Organization of the United Nations (FAO). FAOSTAT. Accessed on 07 December, 2023. Available: https://www.fao.org/faostat/

Gary, C., Jones, J. W., and Tchamitchian, M. (1998). Crop modelling in horticulture: state of the art. *Scientia Horticulturae*, *74*(1-2), 3-20.

Gindling, T. H. and Newhouse, D. (2014). Self-employment in the developing world. *World development*, *56*, 313-331.

Gomiero, T., Paoletti, M. G., and Pimentel, D. (2008). Energy and environmental issues in organic and conventional agriculture. *Critical Reviews in Plant Sciences*, *27*(4), 239-254.

Gorjian, S., Calise, F., Kant, K., Ahamed, M. S., Copertaro, B., Najafi, G. and Shamshiri, R. R. (2021). A review on opportunities for implementation of solar energy technologies in agricultural greenhouses. *Journal of Cleaner Production*, *285*, 124807.

Granatstein, D., Kirby, E. and Willer, H. (2008). Current world status of organic temperate fruits. In *Organic Fruit Conference 873* (pp. 19-36).

Gruda, N., and Tanny, J. (2014). Protected crops. *Horticulture: Plants for People and Places, Volume 1: Production Horticulture*, 327-405.

Hanan, J. J. (2017). *Greenhouses: Advanced technology for protected horticulture*. CRC press.

Hasan, M. (2016). Protected Cultivation and Drip fertigation technology for sustainable food production. *International Journal of Economic Plants*, *3*(3), 102-106.

Huang, Y., Li, W., Zhao, L., Shen, T., Sun, J., Chen, H. and Bie, Z. (2017). Melon fruit sugar and amino acid contents are affected by fruit setting method under protected cultivation. *Scientia Horticulturae*, *214*, 288-294.

Imler, C. S. (2020). *Quantifying temperature effects in controlled environment agriculture leafy greens and culinary herbs* (Doctoral dissertation, Iowa State University).

Jewett, T., and Jarvis, W. (2001). Management of the greenhouse microclimate in relation to disease control: a review. *Agronomie*, *21*(4), 351-366.

Kanwar, M. S. (2019). 5 High-Altitude Protected Vegetable Cultivation–A Way for Sustainable Agriculture. *Applied Agricultural Practices for Mitigating Climate Change 2:* 51.

Kaushal S. and Singh V. (2019). Potentials and prospects of protected cultivation under Hilly Conditions. Journal of Pharmacognosy and Phytochemistry. 8(1):1433-1438.

Jain, S., Kore, D. S., GK, K., Mohapatra, A., Baksh, H., Kumar, V. and 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.

Kumar, D., and Singh, B. (2020). Vegetables cultivation under protected conditions. *Progressive agriculture*, *20*(1-2), 148-152.

Kumar, S., Meena, R. S., Jakhar, S. R., Jangir, C. K., Gupta, A., & Meena, B. L. (2019). Adaptation strategies for enhancing agricultural and environmental sustainability under current climate. *Sustainable agriculture. Scientific Publisher, Jodhpur*, 226-274.

Lamichhane, P., Adhikari, J., and Poudel, A. (2023). Protected cultivation of horticultural crops in Nepal: Current practices and future needs. *Archives of Agriculture and Environmental Science*, *8*(2), 268-273.

Maitra, S., Sairam, M., Shankar, T., and Galkwad, D. J. (2020). Protected cultivation and smart agriculture.

Marra M., Pannell D. J. andGhadim A. A. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve. *Agricultural Systems*. 75(2- 3):215-234.

Martinez-Gómez P. Rahimi Devin S. Salazar JA, López-Alcolea J, Rubio M. and Martinez-Garcia P. J. (2021). Principles and prospects of prunus cultivation in greenhouse. *Agronomy*. 11(3):474.

Nordey, T., Basset-Mens, C., De Bon, H., Martin, T., Déletré, E., Simon, S. and Malézieux, E. (2017). Protected cultivation of vegetable crops in sub-Saharan Africa: limits and prospects for smallholders. A review. *Agronomy for sustainable development*, *37*, 1-20.

Ottman, J. (2017). *The new rules of green marketing: Strategies, tools, and inspiration for sustainable branding*. Routledge.

Pachiyappan, P., Kumar, P., Reddy, K. V., Kumar, K. N. R., Konduru, S., Paramesh, V., and Niranjan, S. (2022). Protected cultivation of horticultural crops as a livelihood opportunity in western India: An economic assessment. *Sustainability*, *14*(12), 7430.

Pallas Jr, J. E., Michel, B. E., & Harris, D. G. (1967). Photosynthesis, transpiration, leaf temperature, and stomatal activity of cotton plants under varying water potentials. *Plant Physiology*, *42*(1), 76-88.

Paradiso, R., and Proietti, S. (2022). Light-quality manipulation to control plant growth and photomorphogenesis in greenhouse horticulture: The state of the art and the opportunities of modern LED systems. *Journal of Plant Growth Regulation*, *41*(2), 742-780.

Peet M. M. and Welles G. Greenhouse tomato production. In Tomatoes. Wallingford UK: *CABI Publishing*. 2005:257-304.

Prakash P., Kumar P., Kar, A. Kishore, P., Singh, A. K. and Immanuel S. (2021). Protected cultivation in Maharashtra: Determinants of adoption, constraints, and impact. *Agricultural Economics Research Review*. 34(2).

Rahman, F., Abid, K., Schmidt, C., Pfaff, G., and Koenig, F. (2010). Interference pigment coated solar cells for use in high radiant flux environments. *JJMIE*, *4*(1).

Rahman, M. M., Khan, I., Field, D. L., Techato, K., and Alameh, K. (2022). Powering agriculture: Present status, future potential, and challenges of renewable energy applications. *Renewable Energy*, *188*, 731-749.

Raina, R. S., Joseph, K., Haribabu, E., and Kumar, R. (2009). Agricultural innovation systems and the coevolution of exclusion in India. *Systems of Innovation for Inclusive Development Project*.

Rasheed, R., Ashraf, M. A., Iqbal, M., Hussain, I., Akbar, A., Farooq, U., and Shad, M. I. (2020). Major constraints for global rice production: changing climate, abiotic and biotic stresses. *Rice research for quality improvement: genomics and genetic engineering: Volume 1: breeding techniques and abiotic stress tolerance*, 15-45.

Sabir, N., and Singh, B. (2013). Protected cultivation of vegetables in global arena: A review. *Indian Journal of Agricultural Sciences*, *83*(2), 123-135.

Sengar R. S, and Rani, V. (2020). Opportunities and prospective of integrated development of 48. horticulture: A review. Annals of Horticulture. 13(1):1-8.

Sethi, V. P., and Sharma, S. K. (2007). Survey of cooling technologies for worldwide agricultural greenhouse applications. *Solar Energy*, *81*(12), 1447-1459.

Shiferaw, B., Smale, M., Braun, H. J., Duveiller, E., Reynolds, M., and Muricho, G. (2013). Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Security*, *5*, 291-317.

Shil, S. (2018). Weather parameters and its impact on agricultural production-A review. *Innovative Farming*, *3*(4), 141-149.

Singh, A. K., and Sabir, N. (2022). Role of Protected Cultivation as Green Technology for Sustainable Environment: Future, Prospect, Potential, Production, Protection, and Profit. In *Handbook of Research on Green Technologies for Sustainable Management of Agricultural Resources* (pp. 81-107). IGI Global.

Singh, B. (2014). *Advances in Protected Cultivation*. New India Publishing Agency.

Singh, H. P., Dhankhar, S. S., and Dahiya, K. K. (2009). *Horticultural crops*. Stadium Press (India) Pvt Limited.

Singh, K. K. Chapter-1 Protected Cultivation of Horticultural Crops. *Chief Editor Dr. RK Naresh*, 1.

Slathia, D., Nisa, M. U., Reshi, M., Dolkar, T., and Hussain, S. (2018). Protected cultivation of ornamentals. *Global Journal of Bio-Science and Biotechnology*, *7*(2), 302-311.

Subin, M. C., Chowdhury, S., and Karthikeyan, R. (2021). A review of upgradation of energy-efficient sustainable commercial greenhouses in Middle East climatic conditions. *Open Agriculture*, *6*(1), 308-328.

Tack, J., and Yu, J. (2021). Risk management in agricultural production. In *Handbook of agricultural economics, Elsevier*. 5:4135-4231).

Tazel Y, and Kacira M. (2021). Recent developments in protected cultivation. In VIII South-eastern Europe Symposium on Vegetables and Potatoes.1320:114.

Tuzel Y, and Leonardi C. (2009) Protected cultivation in Mediterranean region: trends and needs. *J EgeUnivFac Agric*. 46(3):215-23.

Ummyiah, H. M., Wani, K. P., Khan, S. H., and Magray, M. M. (2017). Protected cultivation of vegetable crops under temperate conditions. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 1629-1634.

Van Veenhuizen, R., and Danso, G. (2007). *Profitability and sustainability of urban and periurban agriculture* (Vol. 19). Food & Agriculture Org.

Vázquez, P. P., Ferrer, C., Bueno, M. M., and Fernández-Alba, A. R. (2019). Pesticide residues in spices and herbs: Sample preparation methods and determination by chromatographic techniques. *TrAC Trends in Analytical Chemistry*, *115*, 13-22.