Review Article

Influence of protected cultivation structures on vegetable crops

Abstract

Protected farming is a new technology that is being utilized to grow high-value crops like flowers, vegetables, and other perishable commodities. In contemporary agriculture, protected structures offered an enormous chance for greater productivity and production.Protected cultivation, which is the most effective way to deal with climatic variation provide favourable environment for crop growth thereby achieving greater yield and high-quality produce.Protected cultivation structures such as polyhouses, low tunnels, shadow shade net houses, and green houses are frequently used for crop cultivation. Further, the vegetables grown under these structures possess better quality, decreased pesticide residue and higher yields than the ones grown under open-field conditions.As compared to open field cultivation, the reduction in irrigation water requirement was 35.6 % for shadow hall, 35.2 % for polyhouse and 25.5 % shade net house cultivation. The plant height, number of leaves and number of branches in polyhouse increased by 114.93 %, 83.24 % and 355 % respectively over open field condition. Shadow hall is most suited for the cultivation of vegetables as depicted by higher growth and yield parameters, followed by polyhouse, shade net house. Thus, in terms of enhancing agricultural production, soil fertility, profitability, and sustainability, among other aspects, protected structures-based farming is more beneficial than open field agriculture/conditions. The analysis of the evaluation showed that compared to open environments, the gross and net returns under protected structures (protective cultivation) were much greater.

Keywords: Protected cultivation, protected structures, polyhouse, shadow net, vegetables, yield.

1. Introduction

Protected cultivation or controlled environment agriculture (CEA) is a cropping technique where controlled micro-climate influences the growth and development of a plant (Pattnaik and Mohanty., 2021). The essential factors such as temperature, humidity, light, and others, are regulated as per the requirement of the crop. Green house, polyhouse, shade net house and low tunnels are the different types of protected cultivation structures commonly adopted by the

UNDER PEER REVIEW

Indian farmers **(Manjunath et al., 2022).** A poly house is a framed structure made of transparent or translucent low-density polyethylene that has been UV stabilized to a thickness of 200 microns (800 gauges). This polyethylene generates a greenhouse effect that makes the microclimate ideal for plant growth and development (Sabir et al 2018). A shade net house is a framed building composed of bamboo, angle iron, wood, or GI pipes. It is coated in plastic net, which is composed entirely of polyethylene thread and has been specially treated with UV light to provide varying degrees of shade. It provides crops developing within such a largely controlled climate and environment by lowering daytime light intensity and effective heat. Thus, throughout the year seasonal and off-season farming is feasible. In tropical and subtropical regions, shading nets are utilized for the production of vegetables (Castellano et al. 2008; Ilic et al. 2012; Kittas et al. 2012)

The concept of growing vegetables under protected structures has been gaining popularity among Indian growers, especially those with small land holdings (Kumar and Verma., 2009). Opting for protected cultivation, the productivity of vegetable crops can be increased by 3 to 5 times as compared to open environment (Santosh *et al.*, 2017).

1.1 Need for protected cultivation

In regions with severe weather, scarce land and water resources, and dense populations, protected agriculture is crucial to satisfying the growing demand for high-quality horticultural produce. Additionally, it makes it possible to grow crops all year round and in off-seasons, which can boost farmers' revenue and job prospects. India is second largest after China in vegetable production of 113.5 million tons. However annual requirement of vegetables is estimated to be about 135 million tons by the end of 2020. Low production and productivity of vegetable has been attributed to the extremes of temperatures ranging from 0 to 48℃ during the year (Wani *et al.,* 2017). Use of water is optimized and there's reduction in the consumption by 40-50% (Panda *et al.,* 2008). Reduces diseases, pests and viruses due to biotic stress during rainy and post rainy season. Increasing demand of high-quality vegetables Some of the objectives of protected cultivation are:

- Protection of plants from biotic and abiotic stress
- Efficient use of water with minimum weed infestation
- Enhancing productivity per unit area
- Minimising the pesticides use in crop production

UNDER PEER REVIEW

- Improving the quality and shelf life of produce

1.2 Why Do You Recommend Protected Farming?

Numerous issues, such as severe insect infestations, illnesses, storms, temperatures, and humidity levels over the plant nutrition optimum, hinder the traditional technique of growing vegetables (Nguyen et al., 2009). Nature is the most crucial component in horticulture and environmental effect can be controlled by protected agriculture. Protected farming is the practice of continuously growing crops under regulated weather conditions. Furthermore, vegetables cultivated outside of protected agriculture produce vegetables with exceptional morphology, meaning they have excellent form, size, and color. It is possible to modify the microclimate within the polyhouse (Trivedi et al., 2015). Since some insects are able to see in UV light, UV opaque poly coating keeps insects out of the house. The shielded cultivation method initially surfaced in India in the early 1990s. The liberalization of trade and industry policies allowed for the development of cut flowers with an eye toward export. Consequently, there has been a notable increase as a result of the federal and state governments' initiatives and incentives.

2. Materials and methods

2.1. Protected structures types

There are different types of protected structures that can be used for growing crops in a controlled environment (Debnath et al. 2020). Some of the common ones are:

Low tunnels: These are basic constructions that cover plant rows with nets or plastic films placed over low-hanging wire hoops. They shield plants from wind, frost, pests, and insects.

Net houses: These are framed structures with nylon nets or perforated plastic coverings that block UV rays and keep bugs out. They work well with decorative greens and leafy vegetables.

Greenhouses: The semi-permanent buildings are partially controlled in terms of light, temperature, humidity, CO2, and air circulation. They are covered in transparent or translucent materials. They make it feasible to cultivate high-value products including flowers, fruits, and vegetables either throughout the year and during the off-season.

Mist chambers: These are enclosed spaces where cuttings, seedlings, and tissue culture plants can be propagated with high humidity and misting. They improve plant survivability and roots.

UNDER PEER REVIEW

Plastic tunnels: These are plastic-film covered semi-circular or arched structures that produce an early or late crop production microclimate that is warm and humid. Though bigger in both dimensions and height, they resemble low tunnels.

Mulching: This is the process of improving the soil's temperature, moisture content, and structure by covering the soil's surface around the plants with synthetic textiles, organic materials, or plastic films. They also stop soil erosion and the growth of weeds.

Trench cultivation: In order to cultivate vegetables in harsh winter circumstances, this method involves excavating trenches in the ground and covering them with plastic films. It retains moisture and absorbs heat from the sun and soil.

Floating plastic covers: This technique involves using clear plastic sheets to cover sizable open areas in order to shield crops from snow, frost, and low temperatures. It lengthens the growing season and produces a greenhouse effect.

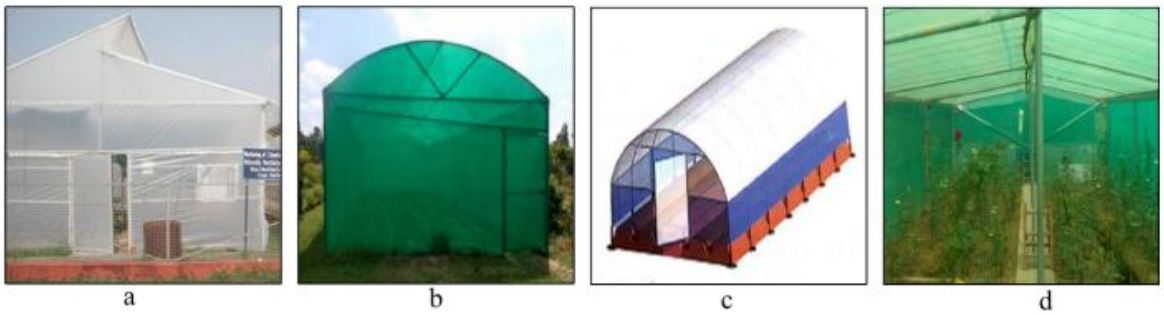

Fig 1. Different protected cultivation structures- (a) Naturally ventilated greenhouse, (b) Shade net greenhouse, (c) Polytunnel and (d) Shadow Hall.

2.2.TECHNOLOGICAL ADVANCEMENTSIN PROTECTED CULTIVATION

Protected farming has seen some technological developments in recent years. Some of them are (Singh 2014):

Precision Agriculture Technologies: Artificial intelligence, drones, sensors, and other precision agriculture technology are being used to maximize crop yield while lowering input costs.

Renewable Energy Sources: Protected agriculture facilities are powered by renewable energy sources including solar and wind power.

Integrated Pest Management Practices: In protected farming, less pesticides and fertilizers are being utilized due to integrated pest management (IPM) techniques.

2.3. Water requirement for vegetable crops

The daily irrigation water requirement for the vegetable crops were estimated by using the following relationship

$$WR = ET_0 \times Kc \times Wp \times A$$

Where,

WR = Crop water requirement (l day^{-1})

ETO = Reference evapotranspiration (mm day^{-1})

Kc = Crop Coefficient

Wp = Wetting fraction (taken as 1 for close growing crops)

A = Plant area, m^2 (i.e. spacing between rows (m) × spacing between Plants (m)

Daily meteorological data recorded during the year 2014-2015 were used to compute reference evapotranspiration (ETO).

3. Results

Table 1. Area achieved under different protected cultivation structures in India (Prakash *et al.*, 2019*)*

Protected cultivation	Total area(ha)	Percent share
Greenhouse structure	298.62	0.14
Naturally ventilated polyhouse	4136.81	1.92
Shade net house	4827.5	2.24

UNDER PEER REVIEW

Plastic tunnel	4868.35	2.26
Walk- in tunnel	3.84	0.00
Plastic mulching	191472.4	88.72
Total	215809.97	100

Table 2 Crops grown under protected cultivation (Pattnaik and Mohanty., 2021)

Flowers	Chrysanthemum, Carnation, Gerbera, Rose, Lilium, Orchid, Gladiolus, etc.
Vegetables	Tomato, Coloured Capsicum (Yellow and Red Bell Peppers), Cucumber, Broccoli, Red Cabbage, Leafy vegetables, Radish, etc.
Fruits	Strawberry
Seedling and Nurseries	Vegetables, Flowers, Tissue Culture, Clonal for Forestry, Fruit Grafting (like Lemon, Citrus, Mango, Guava, Litchi, etc.)

Table 3. Crop coefficients (Kc) and plant area (m^2) of different vegetables

S.No	Crop	Kc initial	Kc middle	Kc end	Plant Area, m^2
1	Tomato	0.6	1.15	0.80	0.5 × 0.5 = 0.25
2	Capsicum	0.6	1.05	0.90	0.45× 0.5 = 0.23
3	Brinjal	0.6	1.05	0.90	0.5 × 0.5 = 0.25
4	Cucumber	0.6	1.00	0.75	0.5 × 0.25 = 0.13
5	Cabbage	0.7	1.05	0.95	0.6 × 0.45 = 0.27
6	Broccoli	0.7	1.05	0.95	0.6 × 0.45 = 0.27
7	Cauliflower	0.7	1.05	1.00	0.6 × 0.45 = 0.27

3.4. Water requirement of winter vegetables under different protected structures (litres day^{-1} $Plant^{-1}$)

UNDER PEER REVIEW

About 60% of greenhouse areas were used for solanaceous crops, which include tomatoes, brinjal, and capsicum. Tomatoes are the most studied crop in the Solanaceae family. According to acreage, tomatoes (Lycopersicon esculentum) are the most widely grown vegetable crop worldwide. They are mostly grown in greenhouses in the winter and spring (Yuan et al. 2001). High water potential is necessary for tomatoes to develop optimally both vegetatively and reproductively. Total water requirement of Tomato crop estimated as 65.12 L plant -1 (257.4 mm) for Sahdenet house which is followed by 56.6 L plant-1(226.6 mm) for polyhouse and 56.3 l plant-1 (225.1mm) for shadow hall (Santosh *et al.*,2017).

Given their economic significance and their ranking as the second most produced crop worldwide, capsicums (*Capsicum annum L.*) are a significant crop in many parts of the world. The ideal temperature range for the growth of capsicum is 20 to 25°C. Temperature variations between 15°C and 32°C typically cause growth to stall and yield to drop (Santos et al. 2009). Seasonal water requirement of Capsicum crop under PCS estimated as 56.92 L plant-1 (252.9 mm) for shade net which is followed by poly house with 49.20 L plant-1(218.7 mm) and shadow hall with 49.11 L plant-1 (218.28 mm). Open field condition estimated higher water requirement with 76.45 Lplant-1 (339.76mm) comparing to other structure.

The cucumber (Cucumis sativus L.) is a warm season crop and grows best at a temperature between 18°C and 24 °C. It is a sub-tropical vegetable crop that grows successfully under conditions of high light, high humidity, high soil moisture, temperature and fertilizers in green-houses (El-Aidy et al. 2007). Cucumber is much lower comparing to other crops due to fact that crop area is much lesser than the other crops i.e 0.13 m2 per plant. Lorenzo et al. (2006). Chilling injury in cucumber is a physiological disorder that occurs in sensitive plants subjected to low temperatures below 12°C.Symptoms of chilling injury include stunted growth, reduced photosynthetic capacity, necrosis and discoloration, abnormal ripening and increased disease susceptibility.

Table 4 :Water requirement of winter vegetables under different protected structures

Tomato				
Month	Poly house	Shade net house	Open	Shadow hall
Nov	0.41	0.45	0.63	0.39
Dec	0.46	0.51	0.66	0.44
Jan	0.52	0.61	0.82	0.53

UNDER PEER REVIEW

Feb	0.45	0.55	0.73	0.47
Total	56.64	65.12	87.45	56.27
Capsicum				
Nov	0.37	0.42	0.58	0.36
Dec	0.34	0.37	0.49	0.32
Jan	0.38	0.45	0.61	0.39
Feb	0.52	0.63	0.84	0.54
Total	49.20	56.64	76.45	49.11
Cucumber				
Nov	0.19	0.21	0.29	0.18
Dec	0.18	0.20	0.26	0.17
Jan	0.21	0.25	0.33	0.22
Feb	0.25	0.30	0.40	0.26
Total	25.16	29.05	38.99	25.08
Cabbage				
Nov	0.46	0.51	0.71	0.44
Dec	0.43	0.47	0.62	0.41
Jan	0.49	0.58	0.79	0.51
Feb	0.60	0.73	0.97	0.62
Total	60.54	69.92	93.89	60.36

UNDER PEER REVIEW

Conclusion:

Vegetable crop protection is a cost-effective approach that benefits farming communities. Because less pesticides are used in the cultivation of vegetables using this method, they are safe to eat. In addition to producing high-quality output, this method offers a friendly atmosphere for off-season cultivation. As a result, this technology can meet the growing demand for veggies from the expanding population.

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UNDER PEER REVIEW

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UNDER PEER REVIEW

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