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Protected Cultivation: Boon for Indian Farmers Income

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Fruits and vegetables are the backbone of horticulture and the best source for overcoming micronutrient deficiencies, providing smallholder farmers with much higher income and job creation per hectare than staple crops. Global vegetable production has doubled over the past quarter century, and the value of global vegetable trade now exceeds that of cereals. India has a wide range of different climatic conditions, but vegetable cultivation practices have generally been limited to regional and seasonal needs. Although the production of vegetables in India increased to the level of 162.18 million tonnes from an area of 9.20 million hectares. However, national food security is becoming an increasing concern and poverty is reflected in the nutritional status of the people. The current per capita availability of vegetables in India is only 210 g against the Recommended Daily Allowance (RDA) requirement of 300 g/capita/day for normal health. Households in large cities in low-income countries spend 50–80 percent of their income on food, and nutritional deficits in macronutrients and essential micronutrients are common. expansion through increased productivity and cropping intensity using modern methods such as sheltered intensive farming/vertical farming using plant environmental control measures, quality seed, fertilisers, irrigation and plant protection. Conservation agriculture is more economically advantageous in the production of high-value, small-volume crops, seeds and planting material, out-of-season fruits and vegetables. With appropriate plant environmental control structures and measures, the environmental constraints prevailing in the region can be overcome, allowing almost year-round cultivation, productivity increases of 25-100% and in some cases more, as well as irrigation water savings of 25-50%. Protected management is offered as an alternative way of management with a much higher carrying capacity. Vertical farming holds the promise of solving these problems by making it possible to produce more food with less resource use.

Introduction

Protected cultivation is the process of growing crops in a controlled environment. This means that temperature, humidity, light and other factors can be regulated according to the requirements of the crop. This helps in healthier and bigger production. There are different types of protected cultivation practices. Some of the commonly used practices are — forced ventilated greenhouse, naturally ventilated poly house, insect proof net house, shade net, plastic tunnel and mulch, raised beds, trellis and drip irrigation. These practices can be used alone or in combination to provide a favourable environment to protect plants from harsh

climates and extend growing time or off-season crop production. The introduction of drip irrigation under raised beds covered with mulch not only kills weeds, but also maintains moisture in the soil for a longer period of time by minimizing evaporation losses. In India, this production is key to the cultivation of horticultural crops under protected cultivation; the area under high-tech horticulture is increasing day by day, productivity and exports have improved tremendously.

Vegetables can be grown out of season using artificial approaches such as greenhouse technology that regulates temperature and humidity for specific vegetable growth. Conservation cultivation refers to cultivation systems in which plants are produced in a controlled environment or the microenvironment surrounding the plant body is partially or completely controlled during growth and development to maximize yield and conserve resources. The concept of growing plants in a controlled environment has been around since the Roman era. Roman gardeners cultivated vegetables for daily consumption in an artificial way (similar to a protected system) (Janick *et al*., 2007).

During the 17th century, the concept of protected buildings emerged in the Netherlands and England. Protected cultivation is very popular all over the world because of its advantages that allow easy cultivation of high-value crops in the off-season. Formally, sheltered cultivation was introduced in greenhouses, and later modifications based on need were introduced using plastic and polymer sheets covered greenhouses, high tunnels, crawl tunnels, low tunnels covered with plastic, insect nets, mulching, shade nets, etc. If extended, one or two additional short-duration crops can be easily obtained, further increasing crop yield per unit area per day compared to open field (Singh et al., 2015). In addition, growing high-value crops/vegetables in protected environments can help improve quality, accelerate maturity and extend fruiting time. Sheltered cultivation is proven to protect crops/vegetables from adverse environmental conditions (heat, hail, strong sun, heavy rains, snow and frost) helping to grow crops even in off-season (Ummyiah *et al*., 2017). Low-cost sheltered structures have recently become profitable technologies under the northern Indian plains, proving their suitability for off-season tomato, pepper, gourd and nurseries.

Scenario of Protected Structures

Worldwide, China stands at the top in terms of total greenhouse area and is having 3.5 million hectares (96 % is under commercial cultivation of fresh vegetables and hybrid seed production) acreage followed by Republic of Korea (Kacira, 2011; Nair and Barche, 2014). It is on record that the area under protected cultivation in the world has exponentially been increasing during last two and half decades. Around 115 countries in the world are growing vegetable in greenhouses. In India, the area under protected cultivation in 2012 13 was around 25 thousand hectares and the greenhouse vegetable cultivation area were about 2000 hectares, respectively (Sabir and Singh, 2013). In the previous two and a half decades, the area under protected cultivation has increased by roughly 75,000 hectares in various kinds (Singh, 2019).

Advantages of Protected Cultivation

- It provides conducive micro climatic conditions for production of high quality vegetables and allows growing multiple crops on the same piece of land in a year. It gives opportunity to fetch a better price of the produce by growing them in off season.
- It supports to raise nurseries of different vegetable crops, hybrid seed production and also protects them.
- Increases the yield, productivity with better quality and attracts enhanced return per unit resource invested.
- Provides alternative venture to cultivate the vegetables in non-growing areas such as high altitudes and deserts.

- It promotes advanced agriculture techniques (hydroponics, aeroponics, vertical cultivation of vegetables).
- Protected cultivation is required less irrigation due to moisture conservation.
- It gives effective control of pests and diseases and becomes easier to produce disease and insects' free seeds of costly vegetables.
- It enables to develop propagation of elite planting material of different horticultural crops.
- Low cost protected structures are ideally suited for progressive farmers having small holdings.
- It is a labour-intensive technology and generates labour-employability.
- It improves better acclimatization of developed plantlets through tissue culture techniques.

Types of Polyhouse

1. **Low-Cost Polyhouse:** The low cost polyhouse /greenhouse is made by polythene sheet of 200 micron (800 gauge), bamboos, ropes (sutli), and nails. The size of the protected structure largely depends upon the purpose and availability of space. This type of polyhouse is generally developed for temperate region and it has 3-5 years of life span. The temperature within polyhouse increases/decreases by 6-10ºC during night and day, than the outside. The day temperature is higher and the night temperature is lower than outside in a pipe framed polyhouse covered with UV stabilised plastic film. The solar radiation that enters the polyhouse is 30-40 % less than that which reaches the soil surface outside. During the summer, the sides of the greenhouse can be opened during the day time to reduce the temperature inside.

2. Medium Cost Polyhouse: The Quonset-shaped greenhouse is a medium-cost greenhouse having a little higher cost that can be made with GI pipe (class B) of 15 mm diameter. The structure is covered with single layer of UV-stabilized polythene of 200-micron thickness. It can be naturally ventilated by providing openable windows along the sides and the roof or else mechanically ventilated by exhaust fans. The fan-pad system can also be used for humidifying the polyhouse, thus temperature could easily be regulated. The life span of frame and covering material is about 10 years and 3 years respectively.

3. High Cost Polyhouse: It is erected with iron/aluminium structure (frame) having dome or cone shaped design. Mechanisms are installed to regulate/control the temperature, humidity, and the light as per the crop demand. Floor and a part of side walls are constructed with concrete. It is highly durable but the cost is about 5-6 times higher than the low cost protected structure. It requires qualified operator, proper maintenance, care, and precautions during operation.

4. Natural Ventilated Polyhouse: It is a manually operated structure, where irrigation, fertigation, and all other operations are being physically controlled. These structures come under mid-range cost structures. Naturally ventilated poly houses are the protected structures, which have no heating or cooling mechanisms for climate control. Cost of these structures is less than hi-tech structure but higher than others. These greenhouses can be utilized for year-round production of parthenocarpic slicing cucumber, off-season muskmelon, tomato, and sweet pepper for 8–9 months at a cost of about Rs.700 800 per sq. m. This structure is made up of stainless steel frame; wall and roof with plastic walls. The polythene sheet (150 micron) used in the structure inhibits UV light entry, conserves CO_2, and improves plant growth and development. The temperature and humidity within the polyhouse are higher than outside, allowing for better photosynthesis and uniform plant development (Palni, 1996 ; Palni and Rawat, 2000). These naturally ventilated polyhouses must be equipped with solar power operated micro sprinklers on the roof top in order to to reduce the temperature during peak summer months. For long-term sustainability, these greenhouses must be combined with

rainwater harvesting and solar power. But now it is the right time for motivating and training the unemployed educated youth in Uttar Pradesh's Bundelkhand region to use naturally ventilated greenhouse technology to cultivate high-value vegetables for better profits. The selection of a suitable design based on the climatic conditions, available market, and type of vegetables is the most important basic pre-requisite for adopting this technology. To make the structure efficient and profitable for cultivating vegetable crops in arid and semi-arid climates, a maximum ventilation of up to 40–50 % is required. Roof tops of greenhouses should be covered with shade nets (preferably black) during excessive heat periods (May–July), with a space between the shade net and the roof surface for air movement. Low-pressure drip irrigation systems can be installed in these greenhouses to make them more energy efficient and eco-friendly (Singh and Hasan, 2011).

5. Shade Net-House: The Bundelkhand region encounters high solar radiation and high temperature that adversely affect crop production. Therefore, the use of shade net houses is essentially required. Shade nets of different shading intensities (40-75 % shading intensity depending on different crops) and a variety of colours, including black, green, and white are used for shade net houses to grow vegetable and ornamental crops easily. Shade net house is considered as one of the real innovations to provide development of healthy seedlings for various horticultural crops irrespective of climatic conditions. These structures are less costly than above structures. It is meant to protect crops from harmful UV and infrared radiation, as well as from severe temperatures and helps to maintain air and soil moisture (Maikhuri *et al*., 2007). Shade nets were also used to shield precious crops from excess sunlight, cold, frost, wind, and insects/birds (Takte *et al.*, 2003). It is recommended to utilize shade net houses on a large scale for the cultivation of various horticultural crops during the hot summer months. Shade nets with black colour are most effective in reducing temperature when compared to other colours such as green, white, or silver because black absorbs maximum heat. Shade nets are best for growing leafy vegetables like beet leaf and green coriander, but they are also good for growing early cauliflower and radish during the months of June to September.

6. Walk-In Tunnels: These are simple, temporary, and low-cost structures made on half-inch GI pipes covered with transparent plastic with a 200-micron thickness, with a tunnel height of 2.0-2.5 m and a width of roughly 4 m that can fit nearly 2 to 3 beds. This structure is covered with UV film, suitable for all types of crops, flowers, and vegetables. These structures are small in size and low in cost therefore, it is generally acceptable to farmers. The fixed investment in plastic can last 5–6 years and the investment on GI frame can last more than 20 years with adequate care. Hence, these structures are considered as temporary and low cost structures. The ideal size for optimum cross ventilation has been standardized, and having single piece coverage of the above sized structure with plastic commonly manufactured by firms of dimension 7 × 30 m or 7 × 36 m, a length of nearly 25–30 m is very suitable for honey bees to fly from one end to the other for pollination. Walk-in tunnels can be used to protect crops from harsh cold weather during the winter months, enabling off season vegetable production. These structures are typically used to grow cucurbitaceous vegetables, although they can be used for other crops with an erect and compact canopy, such as capsicum, lettuce, and bush type beans. They are also good for raising nursery plants.

7.High Tunnels: These are low-cost, temporary structures placed on 3/4 and ½ inch GI pipes and covered with transparent plastic with a thickness of 200-micron. The tunnel's height and width are around 9 ft and 6m, respectively. High tunnels can be used to grow vegetables in the off-season by protecting plants from heavy rains during the rainy season. Cucurbitaceous vegetables are mainly cultivated in these structures, but they can also be utilized for other crops such as coriander seed crops, which can be planted 30-40 days earlier than in open fields.

8. Plastic Low Tunnels: Low temperatures causing serious damage to Rabi and late Rabi crops across the region. A physical barrier in the direction of air flow, as well as the use of plastic sheet, can help to decrease crop loss. These structures are used to cover rows of plants in open fields with transparent plastic sheet stretched over steel hoops that are about 50 cm high and 1 m wide. Low tunnels are supported above the plants by GI wire hoops, which are covered /stretched with a clear or transparent plastic sheet of 20–30 micron, and the sides are fixed by inserting in the soil. These are also called miniature greenhouses. The concept of employing a plastic low tunnel is highly efficient in the early stages of crop development when the crop's strength is low and it is subjected to low temperature stress. It protects plants from harsh climatic conditions such as rain, wind, hailstorm, and snow etc. These are mainly used for raising nursery and also help in early seed germination. Farmers can cultivate a variety of summer squash types (round fruited, long fruited) which is an emerging crop together with netted muskmelon varieties instead of traditional varieties (Singh and Kumar, 2009). Bitter gourd and round melon are two other crops with rising demand that may be cultivated effectively utilising the plastic low tunnel technique and command very high prices during the off-season. This technology is ideal for farmers in India's northern plains, as it is both practical and profitable (Singh *et al*., 2004).

9. Plastic Mulching: Plastic mulching technology, also called surface covered cultivation, largely involves mulching with polythene sheets for addressing three major issues viz., soil and water conservation, leaching of nutrients as well as reduction of weeds and to some extent insect pest damage. Drip irrigation is an integral part of mulching technology. Mulching involves covering the soil around the plant bases with an organic or inorganic material which makes condition more favourable for plant growth and development. Organic mulches, such as leaves, straw, and sawdust, decompose, add nutrients and humus to the soil, enhancing its tilth and moisture retention capacity. Mulches, whether synthetic or plastic, have a variety of favourable benefits on crop yield. Plastic mulch accelerates plant growth by increasing soil temperature, conserving soil moisture, weed control, production of quality produce, and reduction in leaching of nutrients. The plastic mulch is available in different colours and each colour has its own significance. Transparent polyethylene mulch raises the soil temperature by soil solarization used mainly for managing soil-borne diseases and nematodes. The prevention of latent heat loss through evaporation is primarily responsible for this effect. Black polyethylene film also provides effective weed control by blocking more than 90 % of solar radiation, causing etiolated growth and eventual death of weeds under the film. The yellow plastic mulch attracts insects so it can be used to attract and kill insects. The silver-reflective type of plastic mulch associated with higher reflectance causes insect disorientation and repels aphids. The different types of mulches are reflective plastic mulches, infra-red transmitting mulches, and biodegradable plastic mulches. There are different types of laying methods for plastic mulch but large area usage has to involve the help of mechanised and tractor operated mulch layers. Similarly, several low-cost hole cutting devices and transplanting devices are now pouring in the market. Suitable horticultural crops that can take advantage of mulching include plants growing vertically by nature e.g. solanaceous crops and cole crops. Cucurbits like summer squash can also be grown with mulching, but proper staking is required. This technology is again useful for areas with water scarcity or rain fed ecosystems, as it can conserve moisture to the extent of 50 % and 30 % nutrient saving. Thus, we can conserve resources, economise inputs and harvest 25-30 % higher yields, playing a significant role in increasing income and overall upliftment of livelihood of farming families.

Techniques for Production of Healthy Planting Materials

Protected healthy planting material is the backbone of horticultural production systems. Nursery raising requires greenhouses with boom irrigation, glazing material, seeders, trays and cell pack for propagation, container carrying trays, poly tube, bags, cups and labels for proper identification, ground cover and packing of planting material for long distance transportation. As it is highly important to grow disease and pest free healthy planting material, soilless production of nurseries under greenhouses is very important. Plastic nursery trays or pro-trays with various cell sizes are commonly used to raise vegetable seedlings. Flower seedlings are also raised in many types of plastic pro-trays. These trays aid in the correct germination of seeds and cuttings; they give optimum area for each seed and cutting to germinate, reduce mortality, maintain uniform, healthy seedling growth, and are simple to handle, store, and transport. Before filling the media, these plastic trays can be set in thermocol base trays with the same number and size of cavities. Media used are mainly two types, viz., soilless media (3 parts of cocopeat + 1 part each of vermiculite, perlite) which costs about Rs 6000-7000 per 100 kg or indigenous media (2 parts cocopeat +1 part vermi compost/leaf compost and the other combination may include 2 parts vermi compost/leaf compost, one part each of sand and ash. These media may be enriched with Trichoderma). The cost of these media is only Rs 500-1000 per 100 kg. This media is not only cheaper but also has base nutrients available. Overall, hi-tech 198 Horticulture Science for Doubling Farmers' Income nursery is capital, and labour intensive or automation based yet highly remunerative to the extent that it can be adopted in entrepreneurial model by unemployed educated youth.

Vegetable Nursery Raising- A Profitable Business

Off-season vegetable nurseries under a protected structures have shown to be profitable. Because hybrid seeds of many vegetable crops are quite expensive, every seed must be germinated, which necessitates controlled conditions. The primary goal of raisng nursery stocks in a controlled environment is to obtain higher profits and disease-free seedlings during the off-season in order to produce an early crop. Easy management, early nursery, and protection from biotic and abiotic challenges are only a few of the advantages of growing vegetable nursery in protective structures (Sanwal et al., 2004). Cucurbits are warm-season crops that are planted in the last week of March to April, when the night temperature is between 18 and 20˚ C. However, under regulated conditions, their seedlings can be raised in polythene bags between December and January, planted in the field during the last week of February to first week of March, and fruits can be harvested 1.0-1.5 months earlier than the traditional method of direct planting. Soilless growing medium consisting of cocopeat, vermiculite, and perlite in 1:1:1 ratio is used for filling portrays in which seeds are sown for raising seedlings in nursery. Tomato, chilli, capsicum, brinjal, cucumber, cabbage, cauliflower, and broccoli seedlings can also be grown in plastic covered protected structures. The increased temperature inside the polyhouse hastens the germination and early growth of warm season vegetable seedlings for early crop production in the spring and summer. Due to the marketing of vegetables during the off-season, a premium price could be realised. The profit obtained from the production of vegetable seedlings in poly houses is higher, followed by the shade net house than that of open field units of the same area, (Linganagouda, 2016). Nursery growing under poly house showed a significant results. A higher number of plants per unit area and crop growth from the poly house technology resulted in higher early fruit production (Kang and Sidhu, 2005).

Future Prospects and Strategies of Protected Cultivation

The commercial cultivation in protected structures in semi-arid regions needs to address temperature variations, poor soil fertility coupled with low biomass, high wind velocity and

high solar radiation. It is observed that, in spite of several climatic constraints, this region offers an opportunity to grow high value, high quality horticultural crops. Higher sunlight enhances photosynthetic rate and it increases the growth and development. Lower humidity also disfavours the incidence of several disease and pests. Making use of the benefits of challenging climate, the existing protected structures can be modified based on crops requirements and locally available resources. Local availability of any produce is preferred over transported products from afar since they are cheaper, fresher, and, most significantly, more in tune with society's tastes. The construction of transportation infrastructure and socio-economic improvements in urban and peri-urban areas have increased both the market and the quality of produce grown under protected cultivation.

Opportunities

- The escalating population and economy result in a continually increasing demand for vegetables and high valued crops.
- Large-scale self-employment opportunities for unemployed educated youths.
- Increasing the national economy through the selling of high-quality produce on both domestic and international markets.
- Unproductive lands can be converted for good quality production of horticultural crops.
- Protected agriculture has a tremendous potential for increasing the revenue of farmers who choose to grow high-quality, off-season vegetables and cut flowers.
- Increased water efficiency is possible solely with protected cultivation.
- Developing climate-resilient vegetables suitable for protected cultivation.
- Focusing on local values and indigenous knowledge strengthens the link between diversity and sustainable uses, which is crucial when assessing marketability.

Constraints/Limitations in Protected Cultivation

- Higher initial investment cost, short life of poly sheet, and non-availability of cladding materials are the major constraints to the adoption of this technology by the farmers for commercial cultivation.
- Marketing hurdles in the way of protected cultivation included a lack of a minimum support price, excessive price swings, and a lack of market information.
- The components of polyhouse such as fibre glass, cooling pads, fans, etc. have to be imported at a higher cost which includes freight charges and custom duty.
- The design of greenhouses and other structures for various agro-climatic conditions in the region is not standardised.
- The constraints related to lengthy loan procedure, high production cost, and non-availability of quality seedlings.
- Lack of technical guidance, high cost of pesticides and fertilizers create the low production.
- In marketing, the major limitations faced by the farmers are non-payment of prices by commission agents in time and the high cost of transportation.
- Lack of appropriate tools and machinery are also constraints for quality production of horticultural crops.
- Lack of awareness among farmers, relating to prospects of protected vegetable production and also inadequate significant research programme for protected cultivation.
- The initial cost of structure looks unaffordable to the farmers, because he has zero risk affordability, so do not come forward to adopt this technology.
- The protected growers face the major constraints like white fly menace, nematode infestation, frequent occurrence of windstorms, hailstorms, inadequate cold storage facilities in villages, high cost of refrigerated vehicle, etc.

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