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Protected cultivation of vegetables crops for sustainable food production

Due to ever-increasing population, massive urbanization and rapid industrialization, it is becoming challenging to feed the millions in our country. Though, population is increasing at a faster pace; agricultural land capacity can increase by 2% only. As per an estimate, 342 million tonnes of vegetables will be required to cater the demand of consumers by the year 2050. Therefore, to improve the productivity and cropping intensity, protected cultivation of vegetables seems a promising proposition. Protected cultivation is taken up in special structures known as greenhouses. Depending on the covering material, different terminologies have been used in the context of greenhouse structures for instances, glasshouse, polyhouse, shade house, net house, etc.

THIS technology has vast scope, particularly, in peri-urban areas near the major cities, which are rapidly growing markets for fresh vegetables. High value vegetable crops like, tomato, cherry tomato, coloured capsicum, parthenocarpic cucumber, brinjal, etc. and virus free seedlings in agri-entrepreneurial models can be grown profitably with the use of such technologies. The productivity obtained under protected cultivation is three to ten times higher than open methods of cultivation depending on the crops. These technologies offer numerous advantages such as save water, increase crop production, are environment-friendly, give round the year food production, and provide jobs for residents. However, protected cultivation requires thorough planning, utmost consideration and details about timing of production (keeping in view the demand and prevailing market prices), choice of varieties adapted to the off-season environments, consumer preferences, etc. in order to be able to produce high yields of quality produce. It was estimated that about 2.15 lakh hectare of land was brought under the National Horticulture Mission between 2005–06 and 2017–18. The major states adopting the protected cultivation technologies are Chhattisgarh, Odisha, Andhra Pradesh, Gujarat, Madhya Pradesh and Maharashtra. Basically the growth of protected cultivation technology in the country happened mainly due to government policies providing handsome subsidies under various schemes launched by government of India under MIDH (NHM), TM, NHB, RKVY, etc., but merely due to the technical beauty of the technology.

Suitable crops and crop cycle

High value-low volume crops are usually raised in polyhouses. Tomato, cherry tomato, capsicum, parthenocarpic cucumber, gherkins, zucchini, watermelon and muskmelon are the most widely grown vegetable crops under protected cultivation to augment higher return. Initially, most of the varieties suitable for protected cultivation were from private sector; however, at present, many varieties developed by public sector research organizations, such as Tomato: Pusa Tomato (Protected-1), Pusa Rakshit, Arka Meghali, Arka Saurav, Pant Poly House Tomato-1, Pant Poly House Tomato Hybrid-1; Cherry tomato: Punjab Red Cherry, Punjab Sona Cherry, Punjab Kesar Cherry, Pusa Cherry Tomato-1; Cucumber: Pant Parthenocarpic Cucumber-2 and 3, Him Palam Khira-1; Capsicum: Arka Gaurav, Arka Basant, etc. have shown promise for cultivation under protected environment. Recently, Pusa Seedless Cucumber-6 first extra-early variety has been developed which is a parthenocarpic, gynoecious cucumber and is suitable for protected conditions. Likewise, Swarna and Shonima have been developed by crossing a stable tetraploid line of watermelon KAU-CL-TETRA-1(4×)

ADVANTAGES

- Year round production
- Overcoming adverse climate
- Multiple cropping
- Off season production
- High quality and healthy seedlings
- Clean products
- Non-traditional areas: high altitudes deserts
- Efficient management of crop pests
- Self-employment for unemployed educated youths
- Better prices for produce

with diploid males (2×) namely, CL-4 (red fleshed) and CL-5 (Yellow fleshed), respectively. Crop cycle under protected cultivation depends upon market demand and to a fairly good extent upon climatic conditions if crops are being taken under naturally ventilated polyhouses or partially controlled environment. As a result, timing of transplanting can be flexible. For instance, tomato can be transplanted from mid-September to first week of November and accordingly can be harvested till March to May under north Indian conditions. In north-western parts, tomato transplanted in mid-July can continue up to the end of April or mid-May next year depending upon the crop management and climatic conditions. However, the window of flexibility depends upon crops as well. Unlike tomato, Capsicum has relatively smaller window of transplanting period. It is preferable to transplant it from September to October; however, mid-September is the most ideal period of transplant in north India, while in north-west states, it can be transplanted in the first week of August and can continue up to end of April in the next year in the polyhouse. Likewise, capsicum can be grown from October to April without using shade net on the top of the roof of the insect proof net house with 40% shade net intensity; while from October to May, it can be cultivated by using 40-50% shade net over the roof of the insect proof net house. The parthenocarpic cucumber can be grown in insect proof net house from September to mid-December and mid-February to April. Further, off-seasonality should be the main criteria to fetch higher profits. Therefore, planting time should be chosen in such a way that a compromise can be struck between climatic requirement of a crop and market demand.

Parthenocarpic gynoecious cucumber suited for protected cultivation

POINTS TO REMEMBER

- Aerodynamic shape and design along the periphery to withstand stalk and wind effects.
- Fan to pad distance should be limited to 40 m otherwise cooling uniformity will not be attained in fan and pad system.

Dimension and structural design of the greenhouse

The dimension of NV (naturally ventilated) GH should not be more than 50 m × 50 m. Bigger the greenhouse more will be the temperature build up due to poor ventilation. The length of evaporative cooled greenhouse should not be more than 60 m. The height of the greenhouse depends upon its size. However, the ideal height of NV small GH (up to 250 sqm) should be between 3.5 to 4.5 m at gutter. While for large polyhouses, it should be in the range of 5.5 to 6.5 m at gutter. The ideal height at the centre should be between 6.0-6.5 m. The side ventilation can be of 2 m width and roof ventilation 1 m in width. The spacing between two naturally ventilated greenhouses should be 10 to 15 m so that the exhaust from one greenhouse should not enter the adjacent greenhouse. The green structure should be able to take all the loads like dead material, live and wind loads. So, greenhouse should be designed in such a way that it will keep safety, serviceability, general structural integrity and suitability. The foundation, columns and trusses are to be designed accordingly. Design loads prescribed by National Horticulture Board, Gurugram (Technical Standards for Naturally Ventilated, Fan & Pad Green House and Shade Net House; Technical Standard No. NHB-PH-Type 02-2011) may be followed while designing and constructing a greenhouse.

Naturally ventilated polyhouse suitable for hot and humid weather conditions

Bountiful production of tomato under protected cultivation

On the basis of environmental control system, polyhouses can be categorized into two types:

Naturally ventilated polyhouse/greenhouse: These polyhouses/greenhouses do not have any environmental control system except for adequate ventilation and fogger system facility mainly to prevent the crops from adverse weather conditions and other natural pests and diseases. Under such polyhouses, temperature regulation is done through passive means, i.e. without the involvement of energy (electricity). The total minimum ventilated area should be at least 10% of the ground area. The temperature inside greenhouse is moderated by rolling up or rolling down the polythene sheets over side ventilators/ screens. However during summers when temperature inside polyhouse goes beyond 35°C, use of shade net (50%) or reflective aluminet thermal screens is suggested to lower the ambient temperature. Now-a-days, use of aluminet is preferred over traditional shade net due to better cooling. These nets/screens can be spread permanently as a ceiling beneath greenhouse roofs, or to be installed as a moveable thermal screen. Insect proof net of 40-50% perforation is essential for covering the ventilated area. ICAR-IIVR, Varanasi has developed several farmer-friendly technologies for protected cultivation of vegetables under NV polyhouses. These include healthy plug plant production by seed soaking with salicylic acid and azealic acid @ 100 µM for improved germination and vigour. Disease-free nursery raising using non-soil (cocopeat: vermiculite: perlite:: 3:1:1) medium enriched with neem cake (10%), calcium nitrate (20 g/kg) and microbial consortium (3 ml/kg) produce vigorous seedlings. Besides, training and pruning systems have also been developed for high value vegetables crops for improved yield. Two-stem pruning was found to give better quality yield in tomato (11.0 kg/plant), cherry tomato (2.3 kg/plant) and capsicum (2.5 kg/plant), while Umbrella system in Cucumber (3.5 kg/plant), musk melon (4.08 kg/plant), bitter gourd (3.53 kg/plant). Plant growth stage based fertilization schedule has also been worked out for crops like tomato.

Environmental controlled polyhouse/greenhouse: These polyhouses are constructed mainly to extend the growing period of crops or to increase the off-season production of crops by controlling the light, temperature, humidity, carbon-dioxide level and the nature of rooting medium in the polyhouses through external means.

Walk-in tunnels: Walk-in tunnels structure is of 2 or 3 m height and is covered with UV film, which is suitable for all types of vegetable crops like okra, brinjal, tomato, chilli, summer squash, gourds, melons, French bean, etc. This structure is meant for cultivation of vegetables during peak winter months so as to protect the crop against low temperature. Such structures are suitable for off-season cultivation of vegetable crops. For instances, summer squash can be raised from December to February, while bottle gourd, sponge gourd and ridge gourd may be taken up from November to March and muskmelon and watermelon during January to April and October to January.

Plastic low tunnels: These are miniature structures (0.75-1.0 m height) producing greenhouse like effect, which facilitates the entrapment of carbon dioxide; thereby, enhancing the photosynthetic activity. For construction of low tunnels, film of 100 µ is sufficient. It protects plants from harsh climatic conditions such as rain, wind, hail, snow, etc. When the climatic conditions are favourable the cladding material may be removed. These are mainly used for raising nursery or for early cucurbit production, e.g. muskmelon and watermelon. Off-season cultivation of cucurbits under low plastic tunnels is one of the most promising technologies under the northern plains of India.

Net houses: Depending upon the cladding (covering) material used, the net houses may be categorized as either insect-proof net houses or shade net houses. Shade net houses are used for raising vegetables during peak summer months (April to June) to protect the crops against high temperature and radiation. These structures have flat top design and are of 3 m height. It is covered with shading net of suitable shading capacity (35-90% shade) and colour depending on the crop requirement. Leafy vegetables (such as coriander, spinach and mint) can successfully be raised during April to July with 40-60% shading intensity. Likewise, chilli/capsicum can be grown from February to June with 30-40% shading intensity. An insect-proof net house is covered with UV-stabilised insect-proof net of 40–50 mesh for effective restriction on entry of insect-pests in polyhouses. Both nursery raising and quality are

Nursery raising and cucurbits production in plastic low tunnels

Insect-proof net house for low spray production of vegetables

possible under these net houses with proper selection of varieties without application of synthetic pesticides in their production.

Rain shelters: Tomato production is difficult during the hot-wet season in tropical and subtropical climates. Rain shelters protect tomato plants against the impact of heavy rainfall and can reduce disease spread. The shelters are generally used in conjunction with raised plant beds to minimize flooding damage and water logging.

Production system for vegetable crops under protected cultivation

Geoponics or soil system: In this system, crops are grown in natural soil under protected cultivation. It has some demerits such as more disease and pest incidence in soil. However, by far it is predominantly adopted cultivation system.

Soilless cultivation: In recent decades, use of the soilless cultivation method has increased significantly due to the use of methyl bromide as a soil disinfectant between crop cycles. New types of substrates are increasing in the same way with the objective of increasing yield and quality with respect to the plants grown in the soil. Several types of substrates (like coconut fibre, perlite, vermiculite, rock wool, peanut hulls, rice hulls and coco peat, etc.) are used as soilless media and it protects the crops from different soil infections. The solid materials of soilless growing media (hydroponics and aeroponics) alone or in mixtures may provide superior environment for plants in comparison to agricultural soil. However, there isn't enough material on how to grow Indian vegetables using this method, which is why most farmers end up growing 'exotic vegetables' with imported seeds. Many of the components required to build these growth systems have to be imported too, increasing the carbon footprint of what is a low-carbon cultivation method. India is currently importing more than 85% of its exotic vegetables, creating a growth rate of 15-20% per year.

Soilless vegetable production for catering urban demands

Hydroponic cultivation in India is still in infancy stage. Very few research institutions are working on this area of future farming. Researchers at the Bidhan Chandra Krishi Viswavidyalaya, Nadia had initial success in working on vertical farming hydroponically on a small scale. Likewise in C.P.R.I., Shimla, Himachal Pradesh and P.A.U., Ludhiana, scientists have attained success in growing potato tubers in soilless conditions. At C.P.C.T., IARI, New Delhi and C.I.S.H., Lucknow, scientists are working on hydroponic cultivation of crops like cucumber, tomato and capsicum.

In India, hydroponics meets less than 1% of the total food basket. However, the fruits and vegetables hydroponic market is estimated to reach a market value of USD 11,195.74 thousand by 2027 from an initial market value of USD 2544.15 thousand in 2018. The market is estimated to grow at CAGR of 13.53% in the forecasted period 2020-2027. These predictions are favoured by the fact that the sales opportunities abound from Indian producers due to better production costing achievable, markets for such produce in USA, EU, Far and Middle East and India's excellent connectivity to these destinations by land, sea and air. In addition, under post-coronavirus pandemic, the adoption rate of urban hydroponic farming systems around the world are estimated to rise sharply as many individuals have developed a critical point of view towards outdoor food.

Economic feasibility of soilless cultivation

The initial investment into the farm can be quite high; the cost of setting up one acre of land can start from ₹30-35 lakh. When the land is already owned, capital costs per acre every 5 years are ₹30.5 lakhs. Operational costs, with tomatoes as the example crop, in 1 acre per year are ₹9 lakhs and revenue typically averages around ₹33.5 lakhs. If the land is independently owned the profit potential of ₹15 lakhs per year is slightly less than if it were leased, averaging around ₹16.5 lakhs per year. However, it would be important to note that in the first year, when a greenhouse is purchased, 80% depreciation is available under the Indian Income Tax Act to the buyer; 75% bank finance is available through agriculture loans and a 20% subsidy on greenhouses is available from National Horticulture Board (NHB). Besides, insurance is also available for portable greenhouses in India.

Competitive landscape vis-à-vis soilless cultivation

The prominent players in Indian hydroponics market are from private sectors. The key strategies adopted by them is establishment of new commercial plants in tier 1 cities in collaboration between regional producers and global technology providers to meet the growing demand for exotic and organic foods. Further, over the next few years, the market might experience huge competition through major food chains across the globe, establishing their hydroponics farms in India. At commercial level, a project 'Nature Fit', Panchgaon, Manesar commissioned by the Haryana Department of Horticulture is supplying safe, chemical-free fruit and vegetables to residents of Delhi and Gurugram, and encouraging a new generation of urban farmers in India. Indo-Israel Centre of Excellence

for Vegetables, Gharaunda, Haryana and Uttarang, Uttar Pradesh are also imparting training to interested farmers on hydroponic farming. Besides, several start-ups like Delhi-based Khetify, Hyderabad-based Homecrop, Mumbai-based iKheti, Bengaluru-based Greentechlife and Living Greens, Ahemdabad-based myBageecha, Urban Fate Farms (Mumbai, Bengaluru) are providing their services in urban areas for soilless production of crops at home. Likewise, other commercial start-ups such as Living Food Company, Bengaluru (specialized in Microgreen production), U-Farm Technologies, Mumbai (deals in customised modular farm for an individual apartment complex or for a supermarket) and Pindfresh, Chandigarh (manufactures the pipes, lights and all the other equipment for hydroponic plant) are also in fray.

Vegetable grafting for protected cultivation

Grafting is the union of two or more pieces of living plant tissue, which grow as a single unified plant. Grafting vegetable scion plant onto desirable rootstocks is an effective tool to mitigate targeted soil-borne diseases, edaphic stresses (moisture imbalances, salt stress) and enhancing yield and quality of vegetable. In India, researches on vegetable grafting to combat abiotic stresses, particularly moisture imbalance, are underway at ICAR-IIHR, Bengaluru; ICAR-CAZRI, Jodhpur and ICAR-IIVR, Varanasi in Solanaceous and Cucurbitaceous crops. NBPGR regional station, Thrissur, Kerala have done work on *Momordica cochinchinensis*. The female plants were grafted onto the male plants to increase its production. CSKHPKV, Palampur initiated work on grafting and identified more than 22 rootstocks of brinjal, chilli, tomato and cucurbits for importing resistance to bacterial wilt and nematodes. Amongst private sector, VNR Seed Private Limited and Takii Seed India Private Limited are producing grafted vegetable seedlings resistant to bacterial wilt for farmers.

Feats of protected cultivation: IIVR's intervention in empowering rural youths

Quality planting material is the basic requirement for production of high value vegetables. Raising of vegetables seedlings through traditional soil beds is not usually recommended owing to quick soil borne disease dispersal and the vulnerability of roots to damage at the time of uprooting for transplantation. On the other hand, plug tray nursery raising technique is not only efficient in vigorous root development but also suitable to avoid any damage to the roots and shoots of the seedlings at the time of transplanting. Plug tray nursery raising holds tremendous potential in providing job opportunities among rural youths. Training and support imparted by ICAR-IIVR to the tribal girls students of Sonebhadra district has created a success story, never seen before, in the adopted village. Likewise, due to the support provided by the Institutes, a farmer Sh. Awaneesh Patel from Raja Talab, Varanasi earned a net profit of ₹1.31 lakhs from the sale of Capsicum grown under a hitherto deserted 1000 m^2 polyhouse (due to lack of technical know-how). Improved production practices for protected cultivation are uplifting the socio-economic status of the farmers. However, such technologies need to be popularized on large scales, more particularly, among the rural youths.

Plentiful harvest from grafted tomato in polyhouse

Strategies to overcome challenges of protected cultivation

- Most of the greenhouses designed are borrowed from the Western countries. There is a lack of region specific design of protected structures for varied agro-climatic condition. Further, there is a paucity of trained manpower for designing and fabrication of protected structure suited for location-specific environmental conditions. R&D initiatives on the designing of structures suitable for varying agro-climatic condition and development of innovative tools and equipment for protected cultivation need to be promoted in order to achieve efficient mechanization of such protected systems as a whole.
- There are scanty breeding work programs for development of suitable varieties/ hybrids of crops for greenhouse cultivation in India. Exotic seeds are very costly and are out of reach of the Indian growers. Their regular supply is uncertain. Therefore, emphasis should be given to develop indigenous F1 hybrids/ varieties suitable for polyhouses so that seeds are made available to the growers in time and at cheaper rates. Further, work on crop-specific package of practices have been done in titbits, especially, from public sector institutions. There is a great potential for the development of varieties and R&D activities in public-private partnership (PPP) model. Production technologies such as crop architecture, crop-specific fertigation, pollination management, etc. have to be standardized completely for crops like capsicum, cucumber, tomatoes and leafy vegetables.
- There is a looming threat of soil borne pathogens, new emerging pests and nematodes. Therefore, there is a need for mapping of key pest problems in different crops. Similarly, R&D activities on bio-intensive pest management strategies for different crops need to be intensified.
- There is a dearth of proper marketing strategy, which hampers timely disposal of produce from protected cultivation. For mitigation, clustering of protected cultivation may be promoted, especially, in periurban areas. Further, input hubs need to be developed in PPP mode.
- A large section of farmers are still avers to protected cultivation. Despite a significant increase in area under protected cultivation in recent years, the country lags well behind the neighbouring China in its adoption. In addition, there is apprehension that it will be adopted by the large, educated and progressive farmers as protected cultivation technology is capital intensive. To address this issue, massive subsidies, especially on low cost protected structures, may be provided to the economically weaker sections of the farming communities. Regular campaigning to popularise the benefits of such technologies may be undertaken in order to convince farmers to adopt such technologies for realising higher incomes.

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Vertical expansion of nursery under protected conditions using soilless rooting medium

An efficient technology for multiplication of clonal rootstock (M-9, MM-106, MM-111, P-22, B-9, M-27) of apple under greenhouse conditions was standardized. The technique involves wounding/incision on branches with diameter of 5 mm at 30 cm above ground level using sharp knife/blade to remove the bark followed by application of 2,500 ppm IBA as rooting hormone. The treatment starts from the second week of June till the last week of August. Small polybags (filled with rooting medium) are fastened at the points where rooting needs to be initiated. A lightweight substrate (cocopeat) having high moisture holding capacity is used as rooting medium. Staking is accomplished with the help of bamboo poles to hold the bags in a proper position and to keep the plants straight. This technology is very useful in promoting the vertical expansion of the nursery in greenhouse conditions and the multiplication of number of plants per unit area has increased by three to four times with minimum utilization of extra inputs and area. One more additional benefit of this technology is that under the greenhouse conditions, the rootstocks attain sufficient girth (> 6 mm) and all the plants are suitable for budding. The technology not only produced the additional 3-4 rootstocks but also the budded plants which have added advantage to this technology.

Source: ICAR Annual Report 2022-23