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Hybrid and Open Pollinated Seed Production in Vegetable Crops under Protected Cultivation

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ABSTRACT

Seed production in vegetables is the limiting factor in several parts of the country due to biotic stress during rainy and post rainy season do not allow successful vegetable seed production. As a result, most of the vegetables are damaged by the severe incidence of viruses. Climate change greatly affecting crop growth in various agro-climatic zones throughout the world. Vegetable seed production is also not unaffected by the changing climatic scenario, as it affected the seed production of the various temperate vegetables like cabbage, cauliflower, broccoli, knolkhol, brussel's sprouts, carrot, radish, turnip, beetroot, etc. which have specific low-temperature chilling requirements. Various marginal areas are becoming unsuitable for seed production of different vegetables viz., cauliflower, cabbage and other temperate vegetables due to increasing temperature. The vegetables require specific temperature and other climatic conditions for flowering and fruit set. Seed production of capsicum, brinjal, cauliflower and broccoli is very difficult in open conditions in this area which have high rainfall at the maturity stage. To reduce such microclimatic conditions and protection from the incidence of viruses a protected structure provides a big opportunity for virus-free vegetable seed production. Therefore, the seed production of highly remunerative crops namely cucumber, capsicum and tomato is performed under protected environments. The purity maintenance of different varieties/lines can be achieved by growing them under a greenhouse without giving isolation distance particularly in cross-pollinated vegetables namely cabbage, cauliflower and onion. Inadequate availability of quality seed is one of the major causes of low productivity and poor quality of vegetable produce. Thus, to enhance the production and productivity of vegetables, it is necessary to increase the production of quality vegetable seeds. Protected vegetable cultivation has been to increase the production of quality vegetable seeds. Raising seed crops of high-value vegetable crops under protected cultivation can further enhance the production and quality of seeds.

Keywords: Greenhouse, Pollination, Protected cultivation, Seed production, Seed quality, Temperature.

1. INTRODUCTION

The quality seed is the most important input for any crop establishment and contributes a lot for production & productivity. The availability of quality seed at the time of planting is essential for increasing vegetable production (Pimpini *et al.*, 1987). Vegetable growers recognize quality seed as the most strategic resource for higher and better vegetable yields. The good quality seed act as a catalyst for recognizing the potential of other inputs (Singh and Tomar, 2015). The response of all other inputs greatly depends on the quality of seeds. The use of poor quality seeds revokes the utility of all agronomic practices, and every other input applied to the crop no matter how abundantly they are applied. It is estimated that the role of quality seed alone to the total production is about 15 – 20% depending upon the crop to crop, and it can be further raised to 40% with efficient management of other inputs (Koundinya, *et. al.,* 2014). However, the lack of quality seed continues to be one of the greatest barriers to bridge the vast yield gap. Although India ranks second in vegetable production, the quality vegetable seed production in the country has been insufficient (Singh *et al.*, 2007a). Therefore, to approach the potentially realizable yield, the production of quality seed is essential. The plant growth and the quality of seed production are strongly influenced by genetic factors and the environmental factors, in which production is undertaken (Singh and Tomar, 2015). Emphasis should always be given on those factors which contribute to and affect seed quality like the selection of crop and variety, seed source, roguing, harvesting and post-harvest operations, etc.

India is famous for its diverse agro-climatic zones. Its ranges from extreme temperate to extreme tropical between these sub-tropical parts exist in India. So we can grow all types of vegetables with suitable climatic conditions. As far as vegetable seed production is a concern, various problems are faced by the growers for producing quality seed due to extreme hot to extreme cold climate (Pimpini *et al.*, 1987). The majority of seed production occurs in the plain area as the soils are very fertile but extremes of temperatures ranging from 0°C to 49°C during a year do not allow year-round outdoor vegetable seed production. In the upper range of hills, cold desert conditions exist with extreme cold –5° to –30° consequently difficult to grow vegetables from November to March due to heavy snowfall. Hence it is not possible the good quality seed production (Wani *et. al.,* 2011). In several parts of the country due to biotic stress during rainy and post rainy season do not allow successful vegetable seed production. As a result, most of the vegetables are damaged by the severe incidence of viruses. In India 1.2 % of the total cultivated area comes under vegetable cultivation. Most of the vegetables if grown properly have the capacity to give a yield which could be 5 – 10 times higher than any cereal crop. Vegetables provide proteins, carbohydrates, mineral salts, vitamins (Mishra *et al*., 2010) and bulk which along with some cereals and other foods form the essentials of a balanced diet. The daily consumption of vegetables and fruits in advanced countries is 362 g whereas in India it is only 80 g. Regular consumption of vegetables is necessary for the nutritional security of the household. The present production of vegetables in our country is very low. For successful vegetable production better seeds, improved cultural practices and better plant protection methods are essential (Pimpini *et al.*, 1987). Amongst these good quality seeds is the most important component.

The impact of biotic and abiotic stresses under the present changing climate dictates the crop production and quality. The foremost constraints in vegetable crop production in North Indian conditions are the extremes of temperature, wind velocity, sunlight, water, relative humidity, nutrient deficiency, weeds, carbon dioxide concentration and diseases and insect pest incidence. Protected cultivation means to grow with improved quality out of seaso

n under protected structures, thus increasing the profitability for the farmer, especially in hostile climatic conditions (Trivedi and Singh, 2015). This technology has the potential to provide for supply of high-quality vegetables in the peri-urban areas by reducing transportation time and delivering fresh produce (Singh *et al.*, 2007a).

Greenhouses are the structures covered with a transparent material such as glass or polythene. The covering material acts like a selective radiation filter that allows short wavelength solar radiation to pass but traps the long-wavelength radiation. The long wave radiations emitted by the objects and plants in the greenhouse cannot pass through the covering material due to its lesser transparency for it. This results in rising of the temperature inside the greenhouse due to trapped solar energy inside the greenhouse (greenhouse effect). This increased temperature inside the greenhouse affects the leaf temperature, which influences the leaf transpiration, stomatal aperture and also the photosynthetic rate of the plants. The climatic control in the greenhouse can be used for changing the physiological conditions of the plants (Damyanovic *et al*., 1992). By closing the greenhouse during the night, the CO_2 level rises, resulting from respiration by the plants that in turn is used for photosynthesis by the plants during the early morning hours of the next day. The rise in temperature, CO_2 level, relative humidity and enriched nutrition under protected conditions of the greenhouse is responsible for fast growth and increased production (Harisha *et al*., 2019a). The temperature in the greenhouse can be brought down by providing cooling through operating the fan pad system, ventilation and fogging. This facilitates round the year seed production of desired vegetable crops and exploits their maximum seed yield potential (Damyanovic *et al*., 1992). Higher plant density by closer planting and the higher number of fruiting branches per unit area under protected cultivation increases the seed yield tremendously. For protected cultivation the management practices are different than for open field production. Protected cultivation technologies include drip irrigation, naturally-ventilated poly houses, fertigation, mulching, etc. Recently, walk-in polytunnels becoming profitable technologies under Northern plains of India proving its suitability for the cultivation of tomato, capsicum, cucurbits and raising nursery during offseason (Singh *et al*., 2007a). The seed production of highly remunerative crops namely tomato, capsicum and cucumber is performed under protected environments. The maintenance and purity of different varieties/lines can be achieved by growing them under greenhouse without giving isolation distance particularly in cross-pollinated vegetables (Wani *et. al*., 2011).

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The vegetable production was 184394 thousand MT with an area of 10259 thousand hectare during year 2017-18 (DACFW, 2018). India is the second-largest leading country in area and production after china in vegetable production in the world. But the vegetable production is much lower than the present per capita requirement to feed the people of India. The vegetable requirement is 300 g/day/person as recommended by the dietician, we are able to meet about 1/9th of that requirement only. This is due to the lack of availability of quality seed and the use of years back cultivation technology. Vegetable crops face vast challenges in the production of healthy, disease-free and genetically pure seed due to the use of pre-dominantly traditional cultivation practices. Conventional practices of seed production face common problems like lack of sufficient isolation distance, insects, diseases and a virus-free environment (Berke, 2000). Viruses and insects are the most devastating problems for quality seed production in most of the vegetable crops in open field conditions. There are different ways to resuscitate this situation. Bringing additional areas under seed production and the use of improved agro-techniques are some of the important methods to increase vegetable seed production. Another approach is seed production under protected conditions (Harisha *et al*., 2019a). Under which harsh climate like high wind, hot and humid climate, an extreme hot to extreme cool are controlled. The maintenance of genetic purity of different varieties/lines can be achieved by growing them under a greenhouse without giving isolation distance particularly in cross-pollinated vegetables namely cabbage, cauliflower and onion.

Climate change greatly affecting crop growth in various agro-climatic zones throughout the world. Vegetable seed production is also not unaffected by the changing climatic scenario, as it affected the seed production of the various temperate vegetables like cabbage, cauliflower, broccoli, knolkhol, Brussel's sprouts, carrot, radish, turnip, beetroot, etc. which have specific low-temperature chilling requirements. Various marginal areas are becoming unsuitable for seed production of different vegetables viz., cauliflower, cabbage and other temperate vegetables due to increasing temperature. Protected structure, which includes polyhouse, poly-tunnel, shade net, poly mulch, etc. protects the crops from sudden changes in weather and regulates the environment inside these structures (Negi, *et. al.*, 2013). Greenhouse/net house /poly houses are suitable technology under this diverse climate for virus-free good quality vegetable seed production (Pimpini *et al.*, 1987) and as a tool for disease resistance breeding programs. These structures are designed as per the climatic condition of the area. Temperature, humidity, soil conditions, wind velocity, etc. also play a key role in the design of protected structures for vegetable cultivation, but there are several problems and constraints which restrict protected cultivation of vegetable crops (Singh, *et. al.*, 2006). It is therefore necessary to establish the best-suited design of protected structures for different climate along with their techno-economic feasibility. Cultivation under protected conditions delivers higher seed yield with better quality as compared to conventional practices (Pickersgill, 1980). A decade ago, research on seed production of vegetables under protected conditions was initiated in India and great work has been carried out to standardize the technology, i.e. for quality seed production realizing the various biotic and abiotic stress problems encountered in open field seed production. The seed production under protected conditions is highly economical and profitable with limited resources and manpower to provide the best quality seeds of various vegetables cultivated in India and across the world. The seed is the most vital input for vegetable crop production. Most of the vegetable crops have to be started from seed. The production of vegetable seeds requires skill, knowledge and specialization. The efficacy of other inputs like fertilizer, irrigation, weedicide, pesticides, harvesting and processing revolves around the use of the good quality seed. A good quality vegetable seed must confirm the following (Singh and Tomar, 2015):

1. Genetically pure
2. Physiologically pure
3. Physiologically viable
4. Free from weed & other crop seed
5. Free from pest & disease

2. PRINCIPLES OF GREENHOUSE CULTIVATION

Greenhouse cultivation based upon the principle called as greenhouse effects. Generally the greenhouse structure is made with the transparent covering material like polythene and glass that, transmit the sunlight inside the structure. These objects in greenhouse in turn emit long wave thermal radiations for which cladding material has lower transparency. Finally the solar energy gets trapped inside greenhouse and raises the inside temperature. This rise in temperature in greenhouse is responsible for growing of vegetable in cold climate. During summer the raised temperature can be managed by cooling system and ventilation. In commercial greenhouses besides temperature-controlled humidity, photoperiod, carbon dioxide, soil temperature, plant nutrients etc. facilitate round the year production of desired vegetable crops (Trivedi and Singh, 2015). The controlled climatic conditions and soil conditions provide an opportunity to the vegetable crops to express their full yield potentials.

3. WHY PROTECTED CULTIVATION?

The open field for vegetable production encounter with many productions constrains like heavy rain, thunderstorms, temperature, excessive solar radiation and humidity levels above plant growth optima (Max *et al.,* 2009), fungal diseases infestation (Sringarm *et al.,* 2013) and high insect pest infestation pressure (Nguyen *et. al.,* 2009). Environment is the most determinate factor in vegetable crop cultivation (Trivedi and Singh, 2015). Protected cultivation is being used to manage the effect of environment effect. Protected cultivation is the sustainable approach toward the vegetable production under adverse climate. Besides, from protection to adverse climate, the vegetable under protected condition production yield high quality vegetable in terms of size, shape and colors (Sringarm *et al.,* 2013). The micro climate can be changed inside the grenhouse. The UV opaque covering material for poly house helps in restriction of the insect to enter the polyhouse as the certain insect require UV light their vision purpose. Consequently, the use of insecticide is minimal in greenhouse. Due to congenial microclimate inside the grenhouse production of vegetable is higher than the open field condition and that provided better price (Harisha *et al.*, 2019b). The protected cultivation comprises of different devices and technologies namely irrigation soil mulches, windbreaks and the structures which are greenhouse, tunnel, row covers made the production possible throughout the year by modifying the natural environment (Trivedi and Singh, 2015). It will further prolong the harvest period, quality improvement, increase yield and keep the availability of commodities frequently.

4. ADVANTAGES OF PROTECTED CULTIVATION

4.1 Vegetable seed production

Seed production in vegetables is the limiting factor for cultivation of vegetables in hilly region of India as well as in other parts of India. The vegetables require specific temperature and other climatic conditions for flowering and fruit set. Seed production of capsicum, brinjal, cauliflower and broccoli is very difficult in open conditions in this area which have high rainfall at the maturity stage. To reduce such microclimatic conditions and protection from the incidence of viruses a protected structure provides a big opportunity for virus-free vegetable seed production. Therefore, the seed production of highly remunerative crops namely cucumber, capsicum and tomato is performed under protected environments (Berke, 2000). The purity maintenance of different varieties/lines can be achieved by growing them under a greenhouse without giving isolation distance particularly in cross-pollinated vegetables namely cabbage, cauliflower and onion. Hence vegetable production for domestic consumption and export in greenhouse is a technical reality in India. Such protected cultivation system has not only extended the growing season of vegetables and their availability but also strengthen the conservation of different rare vegetables. The major constraint for using protected structure is that the basic or initial cost of manufacture and management cost of such greenhouses is very high which increases the seed cost as compared to seed produced under open field conditions, but seed yield and quality of seed under such structures is always very high (Pickersgill, 1980).

4.2 Hybrid seed production

At present, protected vegetable production is expected to be commercial practice not only because of its potential but also out of sharp necessity. In vegetable production hybrids seeds, transgenic, synthetic seeds, stress resistant varieties are likely to replace conventional varieties. Protected cultivation will be helpful in production of hybrid seeds of cucumber, Winter squash and summer squash by using gynoecious (purely female) lines. Gibberlic acid (GA_3) is used to maintain such lines followed by selfing. The desired pollen is used for production of hybrid seed of cucumber. Similarly, in summer squash Ethaphone is used for inducing female flower at every node, which helps in the hybrid seed production by using desired pollen parent.

4.3 Maintenance and multiplication of self-incompatible line for hybrid seed production

In case of cauliflower, maintaining and multiplication of potential self-incompatible lines for the F1 hybrid seed production is quite difficult. By the use of CO_2 gas the self-incompatibility is temporary eliminated. For this the self-incompatible line is planted in greenhouse and bees are allowed to pollinate the crop when it is full bloom. Then keeping the greenhouse tightly closed within 2-6 hours of pollination, it is treated with CO_2 gas (2-5%) which allows successful fertilization by temporarily eliminating the self-incompatibility.

4.4 Vegetable forcing for domestic consumption and export

During winters in hilly regions, the temperature and solar radiations are sub-optimal for growing off-season vegetables namely binjal, tomato, capsicum, cucumber, chilli and okra. In tomato, low temperature and low radiation leads to puffiness and blotchy ripening. Hence, during extreme of winter season (October-February) these vegetables will be cultivated under polyhouse. In a medium cost greenhouse, the yield of capsicum and tomato can be taken @ 87.2 tonnes/ha and 98.6-110.5 tonnes/ha, respectively. The high priced vegetables- cucumber, asparagus, leek, broccoli, tomato, and capsicum are most important crops for production around metropolitan area and big cities during winter season or off-season. Thus, in the upper hilly region during winter it may be useful to grow capsicum and tomato in plastic tunnels as the plants which are protected from cold and frost will manifest better and faster growth resulting in earlier fruiting than the crops grown in the open conditions.

4.5 Raising off-season nurseries

The cost of hybrid seeds is very high. So, it is necessary that every seed must be viable and vigorous. For 100% germination, it requires the controlled environmental conditions. The cucurbits are warm season crops. Sowing is done in last week of March to end of April when night temperature is around 18-20^{0}C. But in polyhouse their seedlings can be raised during December and January. And by planting these seedlings during end of February and Ist week of March in the open field, their yield could be taken in one and one and a half months in advance than the normal sowing. This technology fetches the extra price due to marketing of produce in the off-season.

Similarly, the seedlings of tomato, capsicum, chilli, brinjal, cucumber, cabbage, cauliflower and broccoli can be grown under plastic tunnel protecting them against severe cold, frost and heavy rains. The environmental conditions particularly rise in temperature inside polyhouse speed up the germination and early growth of warm season vegetable seedlings for raising early crops in spring summer season. Vegetable nursery raising under protected conditions is becoming popular in India especially in hilly regions (Mishra *et al.*, 2010). Management of vegetable nursery in protected structure is easier and early nursery can be raised. Needless to give emphasis, this practice eliminates risk of destruction of nurseries by heavy rains and hail storms because world highest rains occur in this region and the period of rainy season is also wide (April to October). Protection of nursery against biotic and abiotic stresses becomes easier.

4.6 Polyhouse for plant propagation

Sweet potato, pointed gourd, ivy gourd and asparagus are sensitive to low temperature. The healthy propagating materials of these vegetables can be well- maintained under protected structure in winter season before planting their cuttings in early spring summer for higher profit (Singh *et al.*, 2007).

5. TYPES OF PROTECTED STRUCTURES

Greenhouse structure of various types is used for crop production. Although there are advantages in each type of greenhouse for a particular application, in general there is no single type greenhouse, which can be constituted as the best. Different types of greenhouses are designed to meet the specific needs. The different types of greenhouses based on shape, utility, material and construction are briefly given below:

5.1.1 Low-cost or low-tech greenhouse

The low cost greenhouse is a zero-energy chamber made of polythene sheet of 700 gauge supported on bamboos with ropes and nails. It is used for protecting the crop from high rainfall. Its size depends upon the purpose and availability of space. The structure depends on the sunlight for energy. The temperature within polyhouse increases by 5 - 10^0C more than outside. The day temperature is higher and night temperature is lower than the outside in UV stabilized plastic film covered pipe framed polyhouse. The solar radiation enter in the polyhouse 30-40% lower than that reaching the soil surface outside.

Fig. Low Cost Greenhouse for Vegetable Production

5.1.2 Medium-tech greenhouse

Growers prefers to have manually or semiautomatic greenhouse with minimum investment. The medium – tech greenhouse is constructed using galvanized iron (G.I) pipes (class B) of 15 mm bore**.** This greenhouse will have a single layer covering of UV stabilized polythene of 800 gauge. The exhaust fans and thermostat are provided for control the temperature. Evaporative cooling pad is used for maintain the humidity inside the polyhouse. The polyhouse frame and glazing material (polyethylene) have a life span of about 20 years and 2 years, respectively. These types of greenhouses are suitable for dry and composite climatic zones.

Fig. Medium-tech greenhouse

5.1.3 Hi-tech greenhouse

To overcome the difficulties in medium-tech greenhouse, a hi-tech greenhouse where the entire device, controlling the environmental conditions, are supported to function automatically. The hi-tech greenhouse is constructed on the structure (frame) made of iron/aluminum structure, designed cone shaped or domed shaped (as per choice). Temperature, light, and the humidity and are automatically controlled. It is highly durable and about 5-6 times costlier than medium and low tech greenhouse. It requires qualified operator, proper maintenance, care and precautions while operating (Damyanovic *et al*., 1992).

Fig. Hi – tech greenhouse

The low and medium- tech greenhouses have wide scope in production of domestic as well as export-oriented vegetables. Heavy rainfall occurs in NEH region of India during the rainy season (April-October). During this period, growing of vegetables such as tomato, brinjal, cabbage, cauliflower and broccoli in open conditions is very difficult. Severe pest and diseases attack occur due to heavy rains. So growing of vegetable crops in low and medium-tech greenhouse during this period is very profitable. Control of pest and disease in greenhouse is also easy (Damyanovic *et al*., 1992).

5.2 Other protected structures

5.2.1 Plastic low tunnels

These are miniature form of greenhouses to protect the plants from winds, rains, low temperature, frost and other fluctuation of weather. The low tunnels are very simple structures require limited skills to maintain and are easy to constructs and offer multiple advantages. For low tunnel construction, film of 100 micron would be sufficient (Singh *et al.*, 2007a).

5.2.2 Net houses

In high rainfall regions the Net houses are used for vegetable cultivation. The roof of the net houses is covered with suitable cladding material. Sides are made of wire mesh of different gauges. Such structures are useful in upper hilly regions.

5.2.3 Naturally ventilated polyhouse

This type of polyhouse does not have any environmental control system except for the adequate ventilation and fogger system to prevent basically the damage from weather variations.

5.2.4 Environmental controlled polyhouse

The polyhouse helps to extend the growing season and permits off-season production by controlling temperature, light, humidity, carbon-dioxide level.

6. SUITABLE CROPS FOR SEED PRODUCTION UNDER PROTECTED CONDITIONS

Greenhouses, mainly the semi-climate and climate controlled are used for seed production of high value low volume vegetables as the crop get very short crop season under open field conditions. The high value low volume vegetables include cherry tomatoes, slicing tomatoes, sweet peppers, parthenocarpic cucumbers etc. In naturally ventilated greenhouses, seed production of tomato, sweet pepper, cucumber including parthenocarpic cucumber, muskmelon, summer squash etc. but the duration for seed crop and the seed yield are less compared to semi-climate and climate controlled greenhouses.

The insect proof net-houses can be used commercially for seed production of tomato, sweet pepper, brinjal and other vegetables like cucurbits etc. These structures are used to protect the crop against viruses and insects like fruit bores during rainy and post rainy season. But the seed yield is always less as compared to all types of greenhouses including cost of seed production, which is also very less compared to greenhouse. Walk-in-tunnels can be used for seed production of cucurbits like watermelon, muskmelon, summer squash, bottle gourd, bitter gourd etc. even during off-season. But these structures can only be used during peak winter months to protect the crops against low temperature injury and frost (Dec- Feb) in north Indian plains. Walk-in-tunnels, plastic low tunnels are suitable for raising seed crops of leek, onion, French bean, garden pea etc. especially in hilly areas where their seed maturity coincides with the rains. Plastic low tunnels can be commercially used for off-season seed production of cucurbits (Table 1). The basic purpose of low tunnels is to advance the seed crops which is not possible under open field conditions of northern plains of India.

Table 1: Type of protected structures and vegetable crops suitable for seed production and duration of seed production under northern plains of India

S. No.	Protected structure	Suitable vegetable crops for seed production	Duration of seed crop
1	Semi-controlled greenhouses	Tomato, cherry tomato, sweet pepper	9-11 months
2	Climate controlled greenhouses	Tomato, cherry tomato, sweet pepper & cucumber	10-12 months
3	Naturally ventilated greenhouses	cucumber Tomato sweet pepper musk melon summer squash	9-10 months 8-9 months 7-8 months 8-9 months 6-7 months
4	Insect proof net houses	Cucumber Tomato sweet pepper	6-7 months 6-7 months 7-8 months

5	Walk in tunnels	Watermelon, muskmelon, and other cucurbits	4-5 months
6	Plastic low tunnels	All cucurbits	4-5 months only for off-season production during winter months

6.1 TOMATO

Bed preparation

Firstly, soil clods are broken & soil is brought to fine tilth by digging. Beds of 15 cm height and 100 cm width are prepared leaving 50 cm footpath between the beds. In heavy soils mix sand or decomposed rice husk up to 25% of volume is required for proper aeration in the root zone. Disinfection of growing beds with solar radiation in summer helps in killing of harmful organisms, fungal spores, bacteria, nematodes and weeds. During the process the temperature rises up to 60-70^{o}C. In North India during June – July the beds drenched using 4 per cent formaldehyde (@ 4 liters/sq m) and the beds are covered with polyethylene (400 gauge) sheet. All the doors and ventilators are closed. After four days of formaldehyde treatment, the polyethylene cover is removed and the doors and ventilators are opened. The beds are hoed repeatedly everyday to remove the trapped formaldehyde fumes completely before transplanting.

Fertilizer application

Well decomposed organic manure @ 10-15 kg per square meter of the bed is added and mixed thoroughly before fumigation. Commercial fertilizers containing 19:19:19 (N:P:K) are applied @ 7 g per sq m to the growing beds after fumigation. Two furrows 10 cm deep are made adjacent to the planting rows in the growing bed, the fertilizer mixture is applied and the furrows are closed. Prasanna *et al.* (2018) reported that the mode of application influences the bio-fertilizing efficacy of cyanobacterial bio-film formulations in chrysanthemum varieties under protected cultivation.

Transplanting

For better establishment of seedlings, irrigate the beds up to field capacity before transplanting. 20-25 days old, uniform in size 25-30 cm in height & vigorous seedlings are selected for planting. The seedlings are removed from the trays by applying slight pressure on the bottom of the individual cells. Seedlings are planted in the centre of the holes made in the polythene mulch film so that the seedlings do not touch the mulch film. Beds are irrigated daily with a rose-can till the seedling establishment. If the humidity is low, the foggers are run to increase the RH level. The beds are drenched with copper oxy chloride (@ 3 g/lit) if seedling mortality due to damping off is observed (Singh *et al.*, 2007).

6.2 CAPSICUM

Bed preparation

Leveling of beds is important for better irrigation and other intercultural operations. Bed to bed distance should be 1.5 meters. Height of the bed should be 20 cm. Width of the bed is 100 cm leaving 50 cm path in between. Row to row spacing on bed is kept 30 cm with plant to plant distance 40 cm (Singh and Gupta, 2011).

Solarization of growing beds

Disinfection of beds is done after soil preparation and application of vermicompost. Soil it wetted thoroughly with formalin 4 % solution @ 4 lit./sq m. The soil surface is covered with white and transparent polythene sheet (100 micron thickness). During process the temperature raises upto 60-70^{o}C. This process helps in killing harmful organisms, fungal spores, bacteria and nematodes and weeds (Berke, 2000).

Nursery raising

Seedlings are raised in pro trays having drainage holes at the bottom. The growing media includes sand + vermi-compost + sterilized coco peat (1:1:1). Seeds are planted single in each cell. The emerging seedlings are drenched with Copper oxychloride solution @ 3 g/lit. The seedlings are provided nutrition by drenching them with 0.2 per cent, 19:19:19 (N:P:K) plus trace elements at 15 days after germination. To prevent insect infestation, the seedlings are sprayed using Imidacloprid (0.03 ml/lit) or Acephate (0.75g/lit) or. Drenching the seedlings with Carbendazim (0.1%) solution on the day of planting is required for avoiding damping off and better establishment. The seedlings are hardened by gradually reducing the frequency of irrigation and exposing them to sunlight (Singh and Gupta, 2011).

Transplanting

The healthy and disease free seedlings of 30-35 days old, 8-10 cm height with 5-6 leaves are used for transplanting. Optimum time of seedlings planting is August- September on raised beds. Planting should always be done in the evening. Irrigation is given by rose can immediately after planting till plant establishment during the first week.

6.3 PARTHENOCARPIC CUCUMBER

Bed preparation

Leveling of beds is important for better irrigation and other intercultural operations. Bed to bed distance should be 1.5 meters. Width of the bed is 100 cm. leaving 50 cm path in between. Height of the bed should be 20 cm, row to row spacing on bed is kept 30 cm with plant to plant distance 45 cm.

Solarization of growing beds

Same as above in tomato and capsicum

Nursery raising

Seedling are raised in 48 cell pro trays having drainage holes at the bottom. The growing media includes sand + vermicompost + sterilized coco peat (1:1:1). Seeds are planted single in each cell. The emerging seedlings are drenched with Copper oxychloride solution (@3 g/lit). The seedlings are provided nutrition by drenching them with 0.2 per cent, 19:19:19 (N:P:K) at 15 days after germination. To prevent insect infestation, the seedlings are sprayed using Imidacloprid (0.03 ml/lit) or Acephate (0.75g/lit). Drenching the seedlings with Carbendazim or Ridomil (0.1%) on the day of planting is beneficial for avoiding damping off and provide better establishment.

Fertilizer application

Well decomposed organic manure @ 10-15 kg per square meter of the bed is added and mixed thoroughly before fumigation. Commercial fertilizers containing 19:19:19 (N:P:K) are applied @ 7 g per sqm to the growing beds after fumigation. Two furrows 10 cm deep are made adjacent to the planting rows in the growing bed, the fertilizer mixture is applied and the furrows are closed. Kaur *et al.*, (2019) reported that the microbial inoculants enhancing soil nutrient availability in cucumber under protected cultivation.

Transplanting

The healthy and disease free seedlings of 20-25 days old, 8-10 cm height with 5-6 leaves are used for transplanting.

7. CANOPY MANAGEMENT

Training and pruning is an important aspect of vegetable production in greenhouse (Kumar and Singh, 2015). Vining crops like cucurbits can grow several to many meters long or tall by the end of the crop. For these crops, the training systems we use can impact productivity and canopy maintenance. In addition to proper training, plants are frequently pruned to maintain predictable growth. Most of the prunings techniques relate to “source and sink” plant physiology. Simply, the sources produce and sinks consume. If one part of a plant is growing vigorously, some other part may not be. To maintain the productivity and quality of vining crops including cucumber, tomato, pepper and eggplant training and pruning is essential (Cheema *et al*., 2006).

7.1 TRAINING

The growth habit, fruit bearing pattern and seed yield in cucurbits and solanaceous vegetables are greatly affected by source and sink relationship. In tomato, the growth habit can be determinate, semi-determinate or indeterminate. The indeterminate types are preferred for hybrid seed production under the greenhouse (Vidyadhar *et al.*, 2014). Indeterminate tomato is vining plants that continue to extend in length throughout the growing season and also continue to set and ripen fruit throughout the growing season. Seed production in determinate or semi determinate varieties is less popular and not preferred inside greenhouse (Cheema *et al*., 2006). Usually first to fourth cluster at each branch are selected for emasculation for hybrid seed production. The training and pruning is a regular process in greenhouse tomato crop (Mangal and Jasmin, 1987), hence a careful attention is always helpful in high seed yield. Each branch is trained on plastic string hanging from an overhead GI wire trellis support system 3m above the ground level. So that the branches do not break due to weight of the fruits & foliage. Tying of the branches is start from one month after transplanting before the tendrils appearance at regular interval. The plants are tied carefully in order to avoid damage or breakage to the growing parts (Babik, 1987).

7.2 PRUNING

Pruning is the proper and judicious removal of plant parts such as shoots, spurs, leaves, roots or nipping away of terminal parts etc. to correct or maintain tree structure and increase its usefulness (Babik, 1987). Pruning in sweet pepper is generally limited to the shoots that grow on the stem beneath first branching, or some of the weak side shoots. Pepper leaves have a slightly low level photosynthetic efficiency and therefore a large area of active leaves is required to produce sufficient dry matter (Berke, 2000). Under protected condition, the stem structure of pepper is too weak to take the load of the foliage and fruit, hence pruning of pepper is necessary. Pepper plants trained upright by allowing two main branches after removal of first terminal bud. It should be done in a way to expose the leaves to the maximum light and the canopy must always be ventilated. Brinjal has an upright growth habit; hence the horizontal strings fixed on side rows of the plant for providing support to them. A good pruning system deals with the removal of the side shoots up to the first flower appearance, allowing two branches to expand from the terminal flower node, followed by periodic removal of shoots from the inner part of the plant. And removal of the oldest suffices to allow good air exchange and a balanced framework of plants.

Tomato plants in greenhouse are spaced at 60 x 45 cm and are pruned to retain two stem per plant. Pruning starts 20 to 30 days after transplanting of seedling at weekly interval. The main stem of tomato branches into two after the first flower cluster. Suckers form in the axils between the leaves and the suckers are removed (Vidyadhar *et al.*, 2014). A strong main stem is developed by removing all suckers below the first flower cluster. Only two branches are retained and all other branches and suckers developing at the base of the stem are also removed. For pruning, the complete sucker is removed at the base or the tip of the sucker is pinched off ((Babik, 1987 and Mangal and Jasmin, 1987).

Cucumber requires a support system to grow vertically by means of its tendrils. The plants are trained upwards retaining two branches for better interception of light. The strings are hang down from wire stretched at height of 1.5 to 2.0 m. The main stem is pruned to 25 cm and two sturdy laterals are allowed to grow. Weak and unproductive lateral branches should be removed. The older leaves that are touching the ground surface are removed periodically in order to diminish the fungal infections and pest accumulation. Leaves are retained to a length of about 1.5 – 2.0 m on the stem from the growing tip at any stage of growth.

7.2.1 Long fruited varieties

In long fruited cultivars of cucumber, the side fruits on the main stem are removed up to a height of 60-70 cm. After that the fruits are allowed to set on the main stem up to a height of 2 or 3 meter. The side shoots up to 2 m length are not allowed. Above 2 m length, 3 branches are allowed to develop. The fruits are allowed to set up to first 2-3 nodes. Irregular shaped fruits and old leaves are removed to improve fruiting.

7.2.2 Short fruited varieties

In short fruited cultivars of cucumber, the side shoots of the main stem are removed up to a height of 40-50 cm. Further pruning is done in any of the following ways:

1. Side shoots are pruned to 1 fruit/leaf and the fruits on the main stem are removed.
2. Side shoots are pruned to 1 fruit and 2 leaves and the fruits on the main stem are also removed.
3. Side shoots are pruned to 1 fruit and 2 leaves and the fruits on the main stem are allowed to develop.
4. Side shoots are pruned to 1 fruit and 2 leaves up to 1 m. and pruned to 2 fruits and 3 leaves up to 2 m. The fruits on the main stem are removed.

7.2.3 Parthenocarpic varieties

In parthenocarpic cucumber varieties, one single stem is allowed from the starting of the plant and the fruits are allowed on the main stem only.

Some seed crops of such varieties are possible under greenhouse are watermelon, muskmelon and summer squash.

7.3 WATERMELON (*Citrullus lanatus*)

The main stem is trained vertical along with 3-4 strong branches with the help of strings. The first female flower is pinched off if it develops below 8-10 nodes on the main stem. 2-3 fruits are allowed to develop between 12 to 25 nodes. Growing tip of each branch after 2nd or 3rd node is pinched off. For small-fruited cultivars, 4-5 fruits are allowed to develop per plant. A support is provided to the developing fruits using nylon net bags if the insect pollination has been used in the protected structures.

7.4 MUSKMELON (*Cucumis melo*)

In muskmelon, the single stem training is the common and plants are trained upright. All the branches below 6-8 nodes are removed and the female flowers are retained on branches emerging from 9 to 16 nodes on the main stem. The tips of the branches are pinched off after fruit set by retaining 2-3 leaves per branch. The top of main stem is pinched out after 25 nodes. In double stem training system, the main stem is pinched off at the 2nd leaf stage. And the plants are trained straight with 2 main branches. The secondary branches appearing on main axis are pinched off after the first fruit set or two leaves afterward. Maximum 3 to 5 fruits are allowed per plant for optimum growth. The tips should be pinched off up to 20 to 25 nodes of two main branches. The fruits should be allowed to retain the middle portion the plant. In muskmelon, the duration of seed production can be doubled by this way to increase the seed yield.

7.5 SUMMER SQASH (*Cucurbita pepo*)

In summer squash, the main stems and branches are short, thus for making the plant bushy any training and pruning are not required. However, the older leaves are removed for proper aeration.

7.6 WINTER SQUASH (*Cucurbita maxima*)

In winter squash, the stems are long and needs upright training. The main stem is pinched off at 4 nodes and allowing two strong branches to develop. Two fruits are allowed on each branch between 12-16 nodes. The main branches are pinched off at 30 nodes. A support is provided with a nylon net bag to each developing fruit.

8. VARIETIES AND HYBRIDS

8.1 TOMATO (*Lycopersicon esculentum* Mill.)

Indeterminate tomato varieties are suitable for protected cultivation under polyhouse. The hybrids are gaining popularity because they are more productive, produce more uniform fruit compared to inbred lines (Hanson *et al.*, 2001)

Indeterminate types –

- **Pusa Ruby** - Released by IARI, New Delhi. It is an early growing variety, fruits have a yellow stem end, slightly furrowed with uniform ripening. It is suitable for sowing both in spring-summer and autumn-winter seasons.
- **Avtar** - Early-maturing, is very vigorous and resistance to Tomato Yellow Leaf Curl Virus (TYLCV). Its fruits are red to red orange, high round, medium-sized and weighs 55 to 60 grams each, and are ideal for shipping.
- **Pant Bahar** - The plants are bushy and profusely branched. Fruits are flattish round, medium in size with 5-6 locules, slightly ridged and uniform red at maturity.
- **Marglobe –** Indeterminate in nature, fruits large, round with green stem end, smooth and juicy. It is late in maturity. It is an old heirloom variety with natural disease resistance that is an ancestor of many hybrid varieties. Its name was derived from its ancestors the 'Globe' and 'Marvel' tomatoes. Yield: 280-300 q/ha.

- **Arka Vikas** – A pure line selection from as American Variety Tip-Top. Fruits medium large (80-90 g), oblate with light green shoulder, which develop deep red on ripening. Bred for fresh market. Adapted to both rainfed and irrigated conditions. Yields 35 t/ha in 140 days.
- **Arka Meghali** - A pedigree selection (F8) of the cross Arka Vikas x IIHR 554 Plants semi-determinate. Narrow dark green leaves with good canopy. Fruits medium (65 g.), oblate with light green shoulder. Deep red fruits. Suitable for fresh market. Bred for rainfed cultivation Suitable for kharif season. Duration 125 days. Yield 18 t/ha.
- **Arka Saurabh** - A pure line selection from a Canadian Breeding line V-685 Plants semi-determinate. Broad light green leaves with good canopy. Fruits medium large (70-80g). round with light green shoulder. Deep red firm fruits with nipple tip. Bred for both fresh market and processing. Suitable for rabi season. Duration 140 days. Yield 30-35 t/ha.
- **Naveen-** Indeterminate, vigorous, early fruit bearing habit, wider adaptability. Fruit: Medium sized, green shouldered oblong, fruits with excellent color. Average fruit weight 90-100g. Duration: 190-195 days. First harvest in about 70 days from planting.
- **Pusa Divya -** It is a cross between Long style x Roma. Plants are indeterminate, profusely branched; fruits thick skinned, round to oval; first picking in 80 days after transplanting. Average yield 350 q/ha.
- Sun-7611, Abiman, COTH-1, NDT-120 are suitable for protected cultivation.

Cherry Tomato

BR 124 (Holland), Pusa Cherry Type (IARI, Pusa), Olle, Seran, Regy

8.2 CAPSICUM (*Capsicum annum* var. *grossum* L.)

Following coloured capsicum hybrids are recommended for cultivation in North India.

Yellow fruited:

- **Orobelle –** It is a blocky F1 hybrid turning from green to yellow at maturity. It sets well under cold conditions. Fruit: Fruits are blocky, almost square (10 x 9 cm) with a medium-thick wall. Average fruit weight is 150 g.
- **Yellow Wonder –** Maturity from light- green to glden –yellow, the peppers grow on 22-26’’ sturdy, upright plants that set continuously. 4 inch thick walled peppers with amazing citrus-like flavor. Plants are vigorous and high-yielding, with fruits that ripen from lime-green to yellow. Harvest in 62-73 days from transplant. Capsicum Yellow is a winter season crop, can be sown directly from seed in February when the night temperature is 20-30^{0}C.
- **Golden Summer-** Golden Summers have an outstanding sweet, mild flavor. This bell pepper is lime green ripening to golden yellow and is 4-lobed. The Golden

Summer plant provides good foliage cover for the sweet bell peppers that are excellent stuffed or added to salads. Pinch off early flowers to encourage plant growth.

- **Swarna –** Strong and vigorous plants. Blocky to long fruit with thick and firm wall, attractive dark green colour, quickly turning to bright yellow. Fruit weight: 200-250 g.

Red fruited:

- **NS 280 -** Tall vigorous plants, broad leaves, strong plants fruits blocky 3 to 4 lobed, good firm, 10 x 8 cm in size, each fruit weighs 220-230 g, fruit are shiny, dark green in color and on maturity turn to red. This hybrid suits well for green house and protected net house cultivation.
- **Bomby -** Plant: Strong, sturdy, tall plant which requires staking. Early hybrid with good branching. Dense foliage provides adequate fruit shelter. Fruit: Dark green, glossy with average weight 130-150 g.
- **Tanvi –** Plant medium tall and medium spreading, fruit weight is 150-180 g. Very pleasing hybrid turn yellow after maturity. High yielding, excellent keeping quality.

Green coloured:

- **California wonder** - Open pollinated Variety, Large, bell shaped dark green fruit turning red on maturity. ideal for gardens and large containers. Relative days to maturity (DS): 70. Fruit colour: Green and fruit weight (g): 180-200. Fruit shape: Blocky 3-4 lobed
- **Indra** - Plant Medium tall, bushy plants having vigorous growth. Dark green leaves, dense foliage providing fruit shelter. Fruit Fruit is dark green, thick-walled and glossy with average weight 170 gm, length 10-12 cm, girth 10 cm having 3 - 4 lobes. Fruit setting starts in 50-55 days after transplanting.

8.3 CABBAGE (*Brassica oleracea* var. *capitata*)

- **Golden Acre –** Early growing variety with small round heads, color of the leaves is light green from outside and green from inside. Individual head weighing 1.0-1.5 kg, harvested within 60-65 days after transplanting. Late harvesting leads to heads cracking. Average yield is 20-24 t/ha.
- **Pride of India –**Early growing variety medium-large head weighing 1-1.5 kg, harvested within 70-80 days after transplanting. Average yield is 20-8 t/ha.
- **Copenhagen Market –** Late maturing variety, popular variety in West Bengal. Head is large in size weighing 2.5-3 kg each. Harvested within 75-80 days after transplanting.
- **Pusa Mukta –** Heads flattish round, medium sized with light green outer leaves, weighing 1.5-2.0 kg each. Tolerant to black rot disease. Average yield is 25-30 t/ha.
- **Pusa Drum Head –** Late season variety. The heads are large, flat, somewhat loose and drum shaped. Each head weighs 3-5 kg. Outer leaves are light green with prominent mid-rib. Requires long winter for a good crop, tolerant to black leg disease. Average yield is 50-54 t/ha.

8.4 KNOL-KOHL (*Brassica oleracea* var. *gongylodes*)

- **White Vienna -** It is an early maturing variety takes about 55–65 days to mature after transplanting. The plants are dwarf with medium green leaves and stem. The knobs are globular, light green, smooth and tender with delicate flavour. Its yielding potential is 175 q/ha .
- **Purple Vienna** - The knobs are purplish-blue with greenish-white flesh. It takes about 70 days to mature and more yield potential as compared to White Vienna.
- **King of North -** It is an early maturing variety. The plants are dark green with about 25 cm height and bear flattish-round knob. It matures in 60–65 days after transplanting.
- **Large Green** - The knobs are green, round and large-sized with small tops. These are usually tender and delicately flavored with white flesh. It is ready to harvest in about 75 days after transplanting. The average yield potential is 225–250 q/ha. It is very much suitable for cultivation under mid and high hills of western Himalayas.

8.5 CUCUMBER (*Cucumis sativus* L.)

Parthenocarpic cucumber is preferred under protected cultivation in order to avoid the use of pollinators due to its high cross pollination habit. Parthenocarpic cucumber gives good results under protected cultivation in Northern Indian conditions. The following varieties can be successfully grown in polyhouse condition:

- **Hilton -** Uniform green lustrous fruits & high fruit setting ability with earliness. recommended for protected cultivation. Plant vigour - strong, Maturity days (1st harvest after sowing) - 38-40.
- **Isatis -** Good plant vigor, good adaptability. Fruit length 18-20 cm. Good fruit setting & high yielding. Crispy and bitter free with uniform fruits and good tolerance to DM.
- **Kian** - Parthenocarpic beit alpha hybrid. Cylindrical, glossy, medium green colour fruits. Semi-multi fruited on main stem. Bears 2-3 fruits per node with Intermediate Resistance to Powdery and Downy Mildew.
- **Multistar -** Parthenocarpic Mini Cucumber with fruits of 16 to 18 cm long. Open plant type with relatively small leaves and multi fruit bearing. Dark green shiny fruits long, slightly ribbed and uniform cylindrical in shape. Perfect product for slicing and salads.
- **Delta star -** Suitable for summer, autumn and early spring cultivation. It has vigorous growth and is therefore suitable for longer cultivation. Has an open plant habit and produces dark green, slightly ribbed fruits with a fruit length of 16-18cm. Fruits have an excellent shelf life and good flavor.
- **Hasan–** Tender long attractive fruit with shiny whitish color. 1st Picking 40-45 days after sowing. Average Fruit Length - 22-25 cms with fruit Weight: 125-130gm. Execellent taste and keeping quality Non Spongy, High yielder.

- **Sunstar -** Open plant type with relatively small leaves and multi fruit bearing. Dark green shiny fruits are 17-19 cm long slightly ribbed. Uniform cylindrical in shape. Perfect product for slicing and salads.
- **Kingstar** - Kingstar is suitable for late autumn and early winter under net house and poly house

  Strong plant with less side shoots. Regular setting, 1-2 fruits per node. Average fruit length 16 - 18 cm.

9. EMASCULATION AND POLLINATION

Flowering in male and female parents is synchronized with the sowing time. In solanaceous vegetable crop, the emasculation of the perfect flower on the seed parent (female line) is done a day prior to anthesis, leaving the petals intact. Such petals turn yellow (in tomato), white (in sweet pepper) and purple or white (in brinjal) on the day of anthesis. Flowers with under developed reversed stigmas are pinched off. On the day of anthesis the fresh pollen from the desired plants of male parents is collected by a vibrator. Only ripen pollen are shed by vibrating the flower, such pollen grains have the highest viability (Vidyadhar *et al.*, 2015). Pollens are collected in a small cup or other container as per need. Pollination is carried by dipping the stigma into the pollen mass. In brinjal, the stigma is receptive a day prior to anthesis. Flower buds about one to two prior to opening chosen for emasculation (Zijlstra *et al*., 1991). For emasculation the sharp-pointed forceps are used to open the unopened bud from upper part, and then take out all the anthers carefully inside leaving only the ovary, petals and the style without damaging the style. The emasculated flower buds were covered with butter paper bags. The desired male parent from which pollen is to be collected is bagged on the previous day evening. Next day morning at 7 am the pollen are collected from the male plants before the anthers dehisce. The pollen was collected into small-sized vessels by vibrating the flowers. The pollination is done by dipping the stigma of emasculated flower into pollen mass kept in a suitable pollen container. It can also be done by sinking the tip of the finger into a pool of pollen and then touch the stigma with the pollen-covered finger (Vidyadhar *et al.*, 2015).

The sex expression in cucurbits is mainly monoceious, andromonoceious and gynoceious. The perfect flower on the seed parent in cucumber and muskmelon are emasculated a day prior to anthesis. It is not required in parthenocarpic varieties. On the other hand the perfect flowers of the watermelon are not emasculated, as the anthers do not produce the viable pollen. The emasculated flowers are bagged to avoid chance self-pollination. In monoceious, the female flower is bagged a day prior to anthesis. The desired male flowers are collected in the evening a day prior to anthesis and are kept in a moist polythene bag or collected early in the morning on the day of anthesis. Pollination is done by dusting pollen on the stigma of the main flowers. Pollination work starts at 7 am and completed by 9.30 am.

To avoid contamination by visiting bees the pollinated flowers are re-bagged. Pollination work continues upto 15 days in cucumber and muskmelon and up to 10 days in squash and watermelon. Emasculation and pollination requires 20-25 laborers/day/acre. Insect pollinators like honey bees are beneficial in cucurbitaceous vegetables under protected seed production. But careful management of the bees is required to avoid pollinators' destruction (Zijlstra *et al*., 1991). Similarly, in tomato, bumble bees are best pollinators among insects but they are not available in India. Hence, only option left is to use vibrators or electric bee or hand pollination in open pollinated varieties.

10. HARVESTING

The mature fruits in different vegetable crops are harvested at different stages. The stages of harvest in some of the important crops have been presented in Table 2.

Table- 2: Stage of harvest in different vegetable crops

S. No.	Vegetable crops	Stage of harvest
1	Tomato	60-65 days after pollination. Fruit colour complete red
2	Cucumber	30-35 days after pollination. Fruit skin colour – yellow or brown.
3	Pepper	60-65 days after pollination. Fruit skin colour – red or yellow.
4	Brinjal	50-55 days after pollination. Fruit skin colour yellow/yellowish brown.
5	Muskmelon	Full slip stage or when cracks develop at the junction of fruit peduncle
6	Squash	40-45 days after pollination. The peduncle is dried upto the base
7	Water melon	1. 55-65 days after pollination 2. The tendrils nearest to the fruit is dried upto the base 3. The fruits also produce dull sound when tapped with knuckles.

11. SEED EXTRACTION

In tomato, cucumber, muskmelon and watermelon, the seeds are extracted by fermentation method (Patil *et al*., 2014). The pulp is stirred several times in a day to sustain uniform fermentation and to avoid staining of seeds. Fermentation method also controls the seed borne bacterial canker in tomato. In tomato, the seed extraction from ripe fruit is done by fermenting the crushed fruits for 1-2 days. And then wash with water so that the seeds settle down on bottom and pulp and skin float which are easily separated. Seed extraction can also be done using commercial HCl @ 100 ml per 10 kg of tomato pulp. It takes only half an hour time after which the seeds are cleaned up and dried to specified moisture content. To produce 1 kg of tomato seed the quantity of fruit required from 160-210 kg depending on the variety. About 100-150 kg/ha tomato seed can be obtained.

In eggplant, the ripe fruits are cut into pieces and water is added for fermentation. Thereafter seeds are washed, sieved and dried. On an average 200-300 kg seeds can be obtained from a hectare of brinjal crop. Acid method can also be used for brinjal seed extraction.

In chilli and capsicum, the ripe fruits (turn red) are harvested and dried. For drying the fruits are spreads under the sun for 10-15 days depending upon the light intensity. The fruits can also be dried in hot air oven at about 54^{o}C in 2-3 days. Seeds are extracted by breaking the dried fruits by hand (Pickersgill, 1980). An axial pour vegetable seed extracting machine can also be used for seed extraction from tomato, brinjal and chilli fruits. The machine can extract brinjal seeds @ 1.8 kg per man hour, tomato seeds @1.25 kg per man hour and chillies @ about 3.0 kg per man hour. On an average about100-150 kg/ha of seeds in capsicum and about 200-300 kg/ha of seeds in chilli can be obtained.

In cole crops, the seed crop should be harvested when most of the pods turn yellow. After that the pods are dried and seeds are threshed out from the pods. On an average, seed yield of 400-500 kg/ha from cabbage, 300-400 kg/ha from cauliflower, and about 400 kg/ha of knol khol can be obtained. In cucurbits, the harvesting is done when fruits are fully mature or become dry (Patil *et al.*, 2014). The seeds are extracted by cutting the fruits longitudinally. In pumpkin, watermelon etc. seeds are embedded in the pulp and for these different methods are applied for seed extraction:

a) **Mechanical methods –** In the mechanical method machines like Axial Flow Vegetable Seed Extractor are used to split out the pulp from seeds.

b) **Chemical methods** - In this method commercial HCl is used to separate the pulp from seeds within 15-20 minutes. After that the seeds are washed in water and dried to prescribed moisture levels. From a hectare of seed crop, 100-300 kg bitter gourd seeds, 300-500 kg bottle gourd seeds, 300-400 kg luffa, pumpkin, cucumber & round melon seeds, 400-500 kg watermelon and 200-300 kg muskmelon seeds can be obtained.

12. RESPONSE OF INDIVIDUAL CROPS TO PROTECTED CULTIVATION

Tomato

Tomato requires a dry and relatively cool climate for high yield and good quality (Nicola *et. al.*, 2009). When the temperature goes below the 10°C, it causes problem of pollen bursting, while the higher temperature causes premature fruit drops (Singh *et. al.,* 2015). Mostly the lower temperature affected the crop production as there is problem with fertilization and ultimately less fruit yield. At high temperatures, fruits are often badly damaged or misshaped, while the red varieties be likely to become more orange. The temperature when rises above the 30°C, both the stigma and pollen grain may dry out, which causes poor fruit set (Nicola *et. al.*, 2009 and Harel *et. al.,* 2014). These problems can be overcome with the maintainenace of temperature in protected cultivation. Night minimum temperature is important, since a temperature below 21°C can cause fruit abortion (Naika *et al.*, 2005). The pollen germination rate increases with temperatures up to a point but over 37°C germination is greatly inhibited (Nicola *et. al.,* 2009).

In protected cultivation, the growing period can be extended for the whole year (Sandri *et al.*, 2002).

Cucumber

Cucumber production cultivated in Polyethylene bags using perlite, volcanic scoria and sand as substrates was better than soil production. Low-cost, naturally ventilated greenhouses were the most suitable and economical for year-round cucumber cultivation on the northern plains of India (Singh et. al., 2007).

Sweet pepper

Sweet pepper can be effectively grown under zero energy naturally ventilated greenhouse (Singh and Gupta, 2011).

Capsicum

It is a most extensively grown vegetable under green houses and gives higher returns (Harisha *et al*., 2019b).

Brinjal

With the development of parthenocarpic hybrids in brinjal, now it is possible to grow it under the protected conditions (Kumar *et. al.,* 2015).

13. INSECT-PEST MANAGEMENT IN VEGETABLES UNDER PROTECTED CONDITIONS

The warm, humid conditions and plentiful food under protected conditions provide an excellent, stable environment for pest growth. Often, the natural enemies that keep the pests under control outside are not present under protected conditions. For these reasons, pest situations often develop in the greenhouse more quickly and with greater severity than outside. The damage inflicted by arthropod pests on the greenhouse crops varies with the pest and season. The level of damage that can be tolerated is greatly dependent on the type of crop. In India, the insect-pests scenario under protected conditions is given in Table 3.

Table- 3: Insect-pests Scenario under protected conditions in India

Group	Insect and mite pests	Host	Distribution
Aphids	*Aphis gossypii*	Capsicum	Punjab, Delhi
	Myzus persicae	Capsicum	Punjab, Maharashtra
Caterpillars	*Helicoverpa armigera*	Capsicum, tomato	Punjab, Uttrakhand, H.P.
	Spodoptera litura	Tomato, capsicum, cucumber	Karnataka, Punjab, HP
Leaf-miner	*Liriomyza trifolii*	Tomato, cucumber	Karnataka, H.P.

Mites	*Polyphagotarsonemus latus* (yellow mite)	Capsicum	Karnataka, Punjab, Delhi, H.P.
	Tetranychus neocalidonicus	Cucumber	New Delhi
	Tetranychus urticae (Spider mite)	Tomato, capsicum, cucumber	H.P., Maharashtra
Whiteflies	*Bemisia tabaci*	Capsicum	Karnataka, Pumjab
	Trialeurodes vaporariorum	Tomato, cucumber, capsicum	H.P.and Nilgiri hills (TN)

13.1 PEST MANAGEMENT

13.1.1 Start with a clean production area

The first steps to take in a pest management are preventative, and starting with a clean production area is essential. Greenhouses can be fumigated or otherwise treated prior to establishing a new crop to help eliminate pest problems from previous crops. Proper pruning and removal of clippings and other debris from the growing area will eliminate some of the sites that harbor pests. Weed control in and around production areas eliminates alternate host plants for pests.

13.1.2 Select pest-free, quality plants

The selection of healthy seeds, cuttings or transplants is critically important. Carefully inspect all plants/seedlings brought into the greenhouse/production area. Discard, treat the infested plants and hold the remains infected seedlings in a quarantine area for a while. When possible, use pest-resistant or tolerant varieties to reduce the need for pesticides. Appropriate knowledgeable about the susceptibility to insect-pests of a particular plant species or cultivar will help you await problems throughout the production cycle.

13.1.3 Exclusion and mechanical methods

Exclusion, keeping insects out from entering the greenhouse, is a important key part of greenhouse insect management. Most of common pests that attack the crop are small, flying or windborne creatures that can easily be sucked into the greenhouse through cooling pads and ventilation fans or that can easily enter through other openings. Construction the greenhouse so that it is “bug tight” can help farmers can avoid many serious insect infestations. While building an insect-proof greenhouse requires additional planning and more expense, it is well worth it. One of the first steps in constructing an insect-proof greenhouse is to establish proper screening over air intake vents or cooling mats. Because many greenhouse insect pests are so small, it takes very fine screening to exclude them. Thrips are the smallest insect that needs to be screened out. For screening of trips a screen mesh of 81x81 is required. Apparently, screening that keeps out thrips ultimately keeps out larger pests, such as whiteflies and aphids. One of very important point to keep in mind when installing screening over cooling mats or intake vents is that such fine mesh screens greatly reduce the airflow. Therefore, if you install screening for insects exclusion, you may need to construct a special screen covered enclosures over the vents that support enough screen surface area to provide the necessary air flow. Greenhouse manufacturers and suppliers sell screening of various opening sizes and can provide information and guidance on proper installation to achieve the necessary airflow. In addition to properly screening air intake points, all the other possible entries to be sealed. Even in properly sealed and screened greenhouses, insect pests can enter or sucked into the greenhouse through the door as with workers come and go. Adding up an air-lock or enclosed porch over the door is an inexpensive and important way to prevent this kind of insect entry. Of course, once you have gone to the problem and expense of sealing and screening a greenhouse, it is important to properly maintain the exclusion devices. Repair tears or holes immediately, and clean screening to maintain airflow.

13.1.4 Mechanical methods

Mechanical methods for pest exclusion and suppression can be helpful.

a) Screens- Screens can exclude crop pests from the greenhouse. Insect-exclusion screens are sold with full instructions for proper use. When they are positioned in front of intake fan vents, be careful not to reduce air flow. Proper maintenance of exclusion devices is essential.

b) High pressure water sprays- The devices produce high pressure water sprays that can be effectively dislodge aphids and spider mites from host plants.

c) Sanitation- Sanitation is another major component of greenhouse pest management. Many major pests also take place on other crops or broadleaf weeds. That's why, it is important to avoid growing other host crops next to the greenhouse and to prevent profound growths of broadleaf weeds around the boundary of the greenhouse. Not letting weeds and volunteer plants grow inside the greenhouse, during either cropping or non cropping periods, is even more important, because such plants can serve as hosts for a number of insect-pests and can let pests survive inside the greenhouse during non crop season/periods. One of the most important points in sanitation is to begin with insect-free transplants and avoid bringing other plants into the greenhouse once you plant the crop. Serious infestations of insects or diseases can be introduced on new plants that are brought into the greenhouse or exchanged with other growers. It is best to avoid this entirely. If some new plants/seedlings are introduced, quarantine them in another location and strictly observe them for several days to be sure they are healthy or pest-free. Finally, keep the greenhouse clean and free of debris. Promptly remove pruned leaves and cull overripe fruit.

Scouting and early detection are critical to successful insect control. Purposefully inspect plants one to two times per week to check for developing insect problems. Do this by walking through the greenhouse, making random stops, and visually examining both upper and lower leaf surfaces as well as buds, blooms, and fruit for insect pests. Give extra attention to plants or areas that show unusual symptoms or appearance. Conduct regular inspections, paying particular attention to the underside of leaves. Try whipping portions of plants against off-white paper to dislocate small pests onto the paper. This method is useful in detecting hard-to-see pests such as spider mites and thrips. In the greenhouse, regularly inspecting/monitoring plants that are highly attractive to certain pests can be useful for detecting the low populations of pests. Many insect infestations initiate in isolated spots within the greenhouse but quickly multiply if not controlled. Because many insects and mites are so small, a 10–20x hand lens is an important tool to use when scouting. Also be alert for insect pests when performing routine maintenance procedures, such as pruning, training, or harvesting. There are a number of pest-management tools you can use in addition to visual scouting. Yellow sticky cards from greenhouse supply companies can help detect whiteflies and many other greenhouse pests early. Pheromone traps available for tomato pinworms can allow critical early detection if you use them according to directions and replace the lure as required.

d) Trapping- Light traps, yellow sticky traps and sticky-surfaced pheromone traps attract and kill certain insect pests. In and around the production area, place yellow sticky traps to help detect early movement of adult thrips, whiteflies, adult leafminer flies, aphids and fungus gnats. Put into practice control measure programs when significant numbers of pests or related damage are first detected. However, they do not provide absolute control. These devices are best suited to monitor pest population densities over time and to detect infestations early. They can also be used to evaluate the impact of management practices.

e) For best results:

(a) Use the same brand of yellow sticky trap throughout the inspection/monitoring period so you can document an accurate image of relative insect population densities.

(b) Change sticky traps weekly and count pests/card or per area (i.e., pests/ square inch of card).

(c) In the greenhouses, use one sticky trap per 10,000 square feet and place them at least 150 feet apart.

(d) Hang traps just above the plant over the center of the crop, and also in doorways and near vents.

f) Pheromones- Pheromones are natural chemicals produced by animals to signal each other. There are mainly three basic types of pheromones.

1. Aggregation - The pheromones attract many individuals together; for example, at a site where food is plentiful.

2. Sex pheromones – The pheromones attract one sex of a species to the other sex.

3. Trail pheromones – The pheromones are deposited by walking insects, such as ants, so others can follow. Synthetic pheromones imitate these natural chemicals. They are used to attract pests into traps, interrupt mating and monitor pest populations

13.2 Consider all management tactics

Consider the toxicological, economic (worker_safety, pesticide residue and phytotoxic potential) and environmental effects of all control options. When pesticides are necessary, select the most target-specific, least toxic, most effective and affordable material.

13.2.1 Cultural management

Many cultural practices can be helpful to reduce insect populations. Maintaining weed control and not bringing other plants/seedlings into the greenhouse were discussed above in the sanitation section. Pruning lower leaves, lower fruit clusters are another helpful measure in disease management. This can also help control insects by removing large numbers of developing leaf miners and whiteflies. But growers are practicing biological control need to keep in mind that excessive leaf removal can hamper with biological control efforts by removing parasitized pests before the parasites emerge. Managing irrigation to avoid leaks and excessive moisture helps control fungus gnats.

13.2.3 Biological Control

The term "biological control" refers to the use of natural enemies to restrain pests. Biological control strategy includes the conservation, augmentation and importation of natural enemies. Biological control can be a viable alternative to using insecticides in greenhouse and works especially well with using bumble bees for pollination. Successful biological control requires careful, accurate pest identification, frequent scouting, knowledge of the pest biology, knowledge and understanding of the complete biology of the bio control agents used, and careful selection and timely release of bio control agents. One key to successful bio-control is to understand that it is not meant to eliminate all insect pests. Low levels of pests should be present to provide food for the biological control agents. It is important to start releases of biological control agents when pest populations are small to keep them from reaching damaging levels. Several suppliers specialize in developing and producing predatory and parasitic insects and mites, together with other biological control agents, for use in greenhouses. If you are interested in using this approach, contact suppliers to learn details about which species are available, recommended release rates, specific environmental conditions under which the agent performs best, frequency of release, cost, and other information. Remember that biological control agents are living organisms, and the quality of the biological control agents can differ between sources. Success of bio control frequently depends on careful management of environmental conditions, especially humidity and temperature. Certain species of predators or parasites execute best under certain conditions, and in some other cases different strains of the same species are accessible for different conditions. One of the major factors disturbing success of biological control efforts is insecticide use. For example, you can’t conduct a successful biological control program against whiteflies if long-residual, broad-spectrum insecticides are being used regularly in the greenhouse to control other pests. The biological control attempt must target all major pests likely to occur in the greenhouse. When insecticide sprays are requisite, carefully select products compatible with any biological control agents being used. Providentially, a number of insect growth regulator (IGR) and bio-pesticide type products meet this requirement. Biological control tactics is an environmentally safe method and is the basis for some integrated pest management programs.

13.2.4 Conservation- Pesticides kill beneficial predators, parasites and pathogens as well as pests. They can cause rapid resurgence of pests or outbreaks of secondary pests that were initially suppressed. Using nonchemical/biological control methods, or pesticides that destroy only the target pest, protects natural enemies. Some easily seen predators are lacewings, spiders, lady beetles, rove beetles, syrphid flies, flower flies, ground beetles, hover flies, true bugs (including big-eyed bugs, damsel bugs and minute pirate bugs), predatory mites and even fire ants. Though, many important natural enemies are rarely seen, such as flies and parasitic wasps (more than 8,500 species), nematodes, fungi and pathogenic bacteria.

13.2.5 Augmentation- Natural enemies can be released all at a time or over time to suppress pests to keep their numbers low. Also, the environment can be regulated to favor natural enemies. Releases of natural enemies in greenhouse for controlling certain pests can be very effective and interiors capes such as the two-spotted spider mite controlled by predacious mite releases. Outside releases are affected by unpredictable environmental conditions. Additionally, if a second pest is unaffected by the released enemies, pesticides used to control the second pest often eliminate the natural enemy of the first pest.

The application of microorganisms in a way similar to conventional pesticides is a form of augmentation. These types of products are referred to as "microbial insecticides." Several products are available contain varieties of the bacterium *Bacillus thuringiensis,* which controls certain beetles, caterpillars and flies, but does not affect other arthropods. Microbial insecticides are comparatively slow acting and are most efficient if applied when pest numbers are low and pests are in early stages of development.

13.3 Chemical method

Insecticides are the last resort in any integrated pest management system. Though, insecticide use is often needed to keep pest populations from accomplishment damaging levels. When using any pesticide in the greenhouses, read and follow all label instructions. Be sure to be dressed in appropriate protective equipment because pesticide exposure can be larger in enclosed areas. Using appropriate respirators is especially important when making any pesticide applications in greenhouses. Also take care to use appropriate dose. Applying pesticides at excessive doses can result in plant injury and other problems. Most of the insect pests of greenhouse crops occur on the undersides of leaves, and you will not get full control unless you spray on the bottoms of the leaves. Since pest populations are often highest on the lower and older leaves, it is especially important to be definite to treat the undersides of lower leaves. Using sufficient spray volume and taking the time necessary to treat the leaf undersides systematically, especially lower leaves, is important to achieving good control with insecticide sprays.

13.3.1 Broad spectrum- Broad spectrum insecticides destroy a wide variety of insects, generally by affecting a system common to all, such as the nervous system. These "broad spectrum" pesticides are common purpose killers used when numerous kinds of insects are a problem. Examples of broad spectrum insecticides comprise pyrethroids and those containing acephate, diazinon, chlorpyrifos and carbaryl.

13.3.2 Target-specific- Target-specific or narrow spectrum insecticides are much more selective to certain pests or groups of pests. Use these type of insecticides when you wish to destroy only one insect pest and not other beneficial insects. For example, chitin inhibitors influence insects only at certain stages in the expansion of their exoskeleton. Growth regulators are still more specific. They affect only insects that have particular hormones. Chitin synthesis inhibitors interfere only with the growth and molting of immature insects. Chitin is the major structural chemical in an insect's body wall. An immature insect dies the next time it tries to molt when it treated with a chitin inhibitor. For example, the cyromazine-containing products, which only affect certain fly larvae.

Insect growth regulators (IGRs) imitator an insect's natural juvenile hormone. They hamper with certain normal processes and avoid immature insects from becoming reproductive adults. Growth regulators act slowly and their effects include twisted wings, abnormal molting, loss of mating behavior and sometimes death to embryos in eggs. Because Insect growth regulators attack a growth process found only in insects, there is a great margin of safety for humans and other vertebrates. An example is kinoprene-containing products which influence primarily sucking insects.

13.3.4 Short-term vs. residual- Pesticides are also vary in how long they last. Some shatter down quickly into nontoxic by-products. These short-term chemicals are best when the pest will not come back and when long-term exposure could damage non target plants or animals. For example, short-term insecticides a lot are used in homes and dwellings where people and household animals might be exposed. Examples of short term residually active products are those containing insecticidal soap, resmethrin or pyrethrins.

Other pesticides remain active killers for a long time. These remaining chemicals are very useful for a constant pest problem, if used where they will not become an environmental or health hazard. Examples of long residually active products are those contain pyrethroids, chlorpyrifos or imidacloprid.

13.4 DISEASE MANAGEMENT

Diseases caused by bacteria, fungi, and viruses can quickly destroy a crop of greenhouse when conditions are favorable. However, if a combination of recommended disease management practices is used as part of an integrated pest management (IPM) program, diseases can be successfully managed. Biological, cultural, environmental, sanitation, and chemical management practices may all be necessary since no single practice effectively manages all diseases affecting the crop.

13.4.1 Steaming

Steam is the primary method of soil sterilization in greenhouse industry prior to the emergence of soil fumigants. Steam heat is the highly effective and environmentally safe method. Equipment and fuel costs for steaming are expensive, however, and treatment between crops is labor and time consuming. These are the principal reasons many growers shifted to soilless culture. There are three methods of steaming in common use:

1. Tarping an area and piping in steam for 6-7 hours, heating and sterilizing the topmost 8 inches of soil.
2. Pumping steam into the subsurface drainage pipes, sterilizing the top 2 feet of the soil.
3. Negative pressure steaming, where the pumps pull steam applied at the surface through pipes obscured 2 feet deep and 10 feet apart.

13.4.2 Solarization

Soil solarization is the process of tarping the moist soils with polyethylene to trap solar radiation and raise soil temperatures to a level, which is lethal to most of pathogens and weed seeds. Solarization is most valuable when applied for at least 30 days in midsummer. Two layers of polyethylene, separated by fillers (i.e. pvc pipes) spaced every few feet to generate an air space, increases the effectiveness of solarization. Solarization in the greenhouses is a verified means of soil sterilization, and is practiced worldwide in Japan, Greece, Israel, France, Italy, Belgium, Spain and Portugal, in addition to the United States and Canada. Solarization can also be used to pasteurize sand or soil planned for potting media, or to treat used media. A simple technique developed in Florida, is to fill a black plastic trash bag with media, which is then sealed in a transparent plastic bag. The double-wrapped media is placed in open on asphalt or concrete medium and spread to a uniform depth of 3 inches.

As long as the scrap bag received one full day of sunshine in summer (April through August), the temperatures reached or exceeded 113°F for more than 2 hours. The temperature, which was monitored with a thermometer inserted into the media, was considered the least treatment period for plant-parasitic nematodes. This method yields about 24 liters of media.

13.4.3 Biological Management

Biological management, through the use of disease resistant varieties, is the most economic and effective method of handling several significant diseases. Compared to the 1970s when the commonly grown varieties did not have disease resistance, most modern greenhouse crop varieties are resistant to one or more of the diseases that used to be limiting factors in production. The disease-resistance package (the combination of all disease resistance present) in a particular variety is often listed on seed packages and in seed company catalogs or websites. Disease-resistance codes are used to indicate to which diseases a particular variety has resistance. For example, L may stand for leaf mold resistance, while TSWV typically stands for tomato spotted wilt virus resistance. Consult the company’s key of disease-resistance codes for code definitions. Heirloom varieties, which are favored by some greenhouse tomato growers, generally do not have resistance to disease. Biological products are available for use in managing diseases of greenhouse tomatoes. These products work best when use begins before the appearance of disease.

13.4.5 Cultural Management

Cultural management refers to the practices connected to the production of the crop. This type of management creates conditions that do not favor disease development. Because a greenhouse is a protected system, it is possible to manipulate the environment in the greenhouse. This includes the temperature as well as the relative humidity. Regulating the relative humidity inside greenhouse is critical since moisture is the main factor influencing plant infection by the fungi responsible for leaf mold, gray mold and timber rot. RH must be above 90 percent for spore germination and disease to occur. Most of bacterial diseases also need high relative humidity. Control of relative humidity is particularly important when greenhouses are tightly sealed to conserve energy. Warm air holds more moisture than cool air. Thus, during warm fall and spring days, the air inside the greenhouse picks up moisture. As the air cools in the evening, its moisture-holding capacity drops. When this happens, the dew point is reached and moisture (condensation) begins to form on plant surfaces. Condensation can be reduced or eliminated by practicing the following methods:

- When the heat comes on in the late afternoon, keep the ventilators open about 1 inch or keep the exhaust fans running on low capacity. This allows cold, dry air to enter the greenhouse and warm, moist air to leave. The cold, drier air that enters the greenhouse is heated or further dried. After 8 to 10 minutes, close the ventilators and turn the fans off. Warm, dry air now exists in the greenhouse.
- Moving air in the greenhouse helps reduce moisture on plant surfaces. The horizontal airflow structure or the overhead polyethylene ventilation tube structure keeps temperatures stable and decreases cold spots where compression is likely.
- When a greenhouse is very humid, exchange the air one or more times during the night. Greenhouse supply companies trade controls that turn on the fans at automatic times during the night. Temperature control is also important. For example, temperatures no lower than 70°F limit development of gray mold. *Pythium* root rot and FCRR also thrive in cooler temperatures. Pith necrosis appears to be most severe when plants are over fertilized with nitrogen. It is likely that *Pythium* root rot might be more of a problem if the roots are injured by high soluble salt levels. Certain pruning methods increase wounding and leave tissue that is highly susceptible to Botrytis (gray mold) infection attached to the stem. Fewer stem lesions develop when petioles are cut or broken close to the stem than when they are removed 1 or 2 inches from the stem.

13.4.6 Sanitation Management

Most growers/farmers view sanitation as an important method of effective disease management. Unfortunately, not all growers accomplish a strict sanitation routine.

Before beginning a new crop:

- Remove plant debris. Plant debris can serve as a source of inoculums (any part of a pathogen that is infectious; e.g., bacterial cell, fungal spore) for future disease outbreaks and can also harbor insects that transmit pathogens. Debris removed from the greenhouse should not be placed outside the greenhouse nearby and should be placed downwind from the greenhouse. It is best if the debris is removed from the site.

- Do not use again the growth containers, such as poly bags and rockwool slabs, or growth medium from which the diseased plants were removed. In greenhouses with a nutrient film technique (NFT) system or a modified NFT system, use a suitable disinfectant to disinfest buckets and other materials before planting the next crop. Remember to completely flush the system following treatment to remove disinfectant that could be poisonous to plants.
- Disinfect the greenhouse by spraying all surfaces with a suitable disinfectant. Research has revealed that fungal spores may be carried over from season to season in dirt on greenhouse support beams. When producing transplants:
- Use disease-free seeds.
- Use sterile growth media and containers.
- Remove and destroy the seedlings that do not look normal.

After crop establishment:

- Set up a clean-up room where the hands and shoes (via footbath) can be sanitized and cleaned before entering and after exiting the greenhouse. Use any practice available to prevent introducing pathogens into the greenhouse.
- Restrict the use of tobacco products if ToMV-susceptible varieties are being grown.
- Frequently disinfect tools and other equipment with a suitable disinfectant. Many disinfectants are available. Information on choosing the best disinfectant and how to properly use various disinfectants can be found in Information Sheet 1955 Choosing a Disinfectant for Tools.
- Maintain a “clean strip” around the outside of greenhouse to reduce populations of aphids, thrips and other insects that could be sources of virus introduction.
- Consider by insect-barrier screens to cut down on the movement of aphids, thrips and other possible virus-carriers into the greenhouse.
- Observe plants continuously for any evidence of disease growth. Promptly remove diseased plants, and eradicate foliage that may be critically diseased or no longer contributing to plant growth. Destroy diseased plants and plant debris or carry them far enough away downwind from the greenhouse so that they will not be a source of inoculums to reintroduce the pathogen(s) into the greenhouse.

13.4.7 Chemical management (fungicides)

The need for weekly application of fungicide decreases if cultural, biological and sanitation practices. However, it may be necessary to use fungicides as part of an integrated disease management program to successfully manage disease. When using fungicides, remember, the label is the law. You must read product labels before use, and you must follow the label directions. Many fungicides are labeled for use on greenhouse crop. When using fungicides to manage disease, it is important to rotate (alternate) fungicide groups as part of a resistance management program. Each group of fungicides uses a specific biochemical mode of action to attack a pathogen. The chance of a pathogen becoming resistant to a particular fungicide increases if products with the same mode of action are used repeatedly. For this reason, it is important to alternate fungicide applications with fungicides that have different modes of action. Fungicides are arranged into groups based on their mode of action. These groups, designated by the Fungicide Resistance Action Committee (FRAC) are assigned FRAC codes (e.g., M3, 3, 11). These FRAC codes are normally clearly indicated on the product label. Rotation of fungicides should be based on the FRAC codes (groups) rather than by the product name or the active ingredient of a fungicide since different products may use the similar active ingredient or interrelated active ingredients that have the same mode of action.

14. SEED YIELD

The seed yields of different vegetables under protected conditions have been presented in Table 4.

Table- 4: Seed yield in different vegetable crops under protected conditions

S. No.	Vegetable crops	Seed yield (kg/ha)
1	Brinjal	200-400
2	Tomato	150-200
3	Cucumber	450-500
4	Muskmelon	250-300
5	Pepper	150-200
6	Squash	500-700
7	Water melon	200-300
8	Chilli	200-300
9	Cabbage	400-500
10	Cauliflower	300-400
11	Bitter gourd	100-300
12	Bottle gourd	300-500
13	Musk melon	200-300
14	Water melon	400-500

15. BENEFITS OF SEED PRODUCTION UNDER PROTECTED CONDITIONS

1. Off-season seed production is possible in several vegetables.
2. All the year round vegetables seed can be produced by avoiding the season.
3. Under protected structure high seed yield can be obtained from small area.
4. Virus free quality seed can be produced even during rainy or post rainy season.
5. Provides the best opportunity for organic seed production in vegetables.
6. Uniform establishment of seedlings leads to quality seed production.

7. Early fruiting in seed crops leads to advancement in seed production.
8. More fruit setting take place due to congenial climatic conditions under protective structure provides long duration for fruit setting.
9. The maintenance of genetic purity of different varieties/lines can be achieved by growing them under a adjacent greenhouse without giving isolation distance particularly in cross-pollinated vegetables.
10. Handling of crops is very easy during winter season.
11. Seed production can be possible even if soil salinity is high by using soil-less media for cultivation.
12. In case of parthenocarpic varieties of cucumber, seed production is only possible under protected conditions.
13. Several vegetables seed crops are possible under a protected structure in short duration of one year.
14. Crop is protected from heavy rains, storms, high temperature and viral disease transmitted by insect vectors like white flies etc.
15. In protected area there is less chances of physical contamination as the protected area always remain neat and clean so objectionable weed or diseased plants etc. are under check.

16. CONSTRAINTS

1. The cost of seed production is normally high as compared to open field.
2. The seed production job is highly technical and labour intensive.
3. The maintenance of the pollination under protected conditions is quite difficult.
4. Sometimes soil borne fungus becomes a severe problem for crop production.
5. High cost and non-availability of various components are the two major limiting factors in the adoption of polyhouse technology for commercial seed production.
6. Lack of awareness among farmers pertaining to potentials of protected vegetable seed production and lack of major research programme on protected vegetable seed production are other limiting factors.

17. PROSPECTS OF PROTECTED CULTIVATION OF VEGETABLES IN INDIA

In India, there are a number of opportunities of vegetable seed production under protected structure in various agro-climatic zones. Raising of vegetable nursery in protected structures/green house has several benefits such as easy to manage, off seasonality, and protection from abiotic and biotic stresses. Such as plastic low tunnel technology for off-season cultivation of cucurbits in the northern plains of India has the great potential for the future. Walk-in tunnel can also be used on a large scale for growing off-season nursery for healthy seedlings and vegetables cultivation in northern plains or hilly regions during winter months when the temperature is very low. For virus and pesticide free seed of tomato, chilli, sweet pepper and okra cultivation during rainy season or late rainy season, insect proof net houses can be used on a large scale. Low cost greenhouses can be used for protected vegetable seed production good and quality vegetables production (Harisha *et al*., 2019b). Protected vegetable cultivation is a boon to cold dessert of the country where this technology is suitable for commercial cultivation for several vegetables and production during frozen winters when nothing can be produced outdoor. In temperate areas vegetable growers can use low cost protected structures for raising early crops to increase their income in addition to the farmers can get double income by producing quality vegetable seed under protected conditions. The potential of protected vegetable seed production to meet the demand of quality seed should not be over looked. Protected seed production provides many fold advantages over open field vegetable. This technology is highly productive, acquiescent to automation, conserves fertilizer, water and land. It is also environmental friendly and does not require much difficulty. In this century, protected vegetable seed production is likely to be a common commercial practice, not because of its potential but out of its sheer necessity. Net house + plastic mulch + fertigation is best options for scaling out vegetable protected cultivation among farmers for large number of crops like tomato, capsicum, brinjal and cucurbits (Singh, 2019). Presently, China is the world leader in protected cultivation with an area of around 3.5 million hectares out of which nearly 96% is only being used for commercial cultivation of fresh vegetables and hybrid seed production of vegetables. Although, a simultaneous growth like China, has also been observed in other developing countries of Indian and African sub-continent for the use of protected cultivation technologies, but the success rate varied significantly (Singh and Choudhary, 2019). Off-season vegetable production under protected cultivation provides the best way to enhance the production and quality of vegetables along with the remunerative price to the growers (Tomar *et al*., 2019).

CONCLUSION

Though India is the largest producer of vegetables in world next to only China, its requirements of vegetables are rapidly increasing because of its continuous increasing population. The rapid industrialization and urbanization is gradually decreasing the cultivated land. The demand of fresh and quality vegetable under shrinking land area forces the policy maker to think beyond open field cultivation. For maximum utilization of available land and to enhance the productivity as well as to minimize the use of harmful pesticides, protected structures offers immense scope for the farming community of India. Adverse climatic conditions, vegetables crop potentials, agro-inputs availability, small land holdings, increasing demand of high quality vegetables and to fulfil the dream of doubling farmers income necessitate adoption of the protected cultivation of vegetable crops for year round seed production of the different vegetable crop is the need of the hour. Effort should be made to minimise the initial investment of establishment of protected structures. Encouragement of low cost protected structures with natural ventilation must be encouraged. The market should be connected with the availability of crop in the protected structure for maximum financial return. Government support as well as intervention of NGOs for financial help and arrangement for skill development programme on quality seed production under protected cultivation will help to increase the area under protected cultivation and ultimately improve the seed quality. Supply of improved package of practices agronomic and genetic principles for good quality seed production under protected cultivation through leaflets, farmers training will help to create more awareness about the protected cultivation among the farmers.

REFERENCES

Babik J. 1987. Effect of pruning and decapitating on the earliness of tomatoes grown in heated plastic tunnel. Horticultural Abstract, 57:26-34.

Berke Terry. 2000. Hybrid Seed Production in Capsicum. Journal of New Seeds, 1: 49-67. 10.1300/J153v01n03_02.

Cheema DS, Dissanayake DMC and Geeta B. 2006. Seed vigour as influenced by truss position in tomato. Seed Research, 34(2): 221-2.

DACFW. 2018. Horticultural Statistics at a Glance (2018). Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India. p. 490.

Damyanovic MZ, Markovic J, Zdravkovic and Milic B. 1992. The effect of cultivar and training method on earliness and total yield of greenhouse tomato. Sravemena Polgobrivreda, 40 (1-2): 85-93,

Hanson P, Chen JT, Kuo CG, Morris R and Opeña RT. 2001. Suggested cultural practices for tomato. http://www.avrdc.org/LC/tomato/practices.html. 11/12/2008.

Harel Danny, Fadida Hadar, Alik Slepoy, Gantz Shelly and Shilo Kobi. 2014. The Effect of Mean Daily Temperature and Relative Humidity on Pollen, Fruit Set and Yield of Tomato Grown in Commercial Protected Cultivation. Agronomy, 4: 167-177. https://doi:10.3390/agronomy4010167.

Harisha N, Tulsiram J and Joshi Amritha. 2019a. Techno-Economic Analysis of Vegetable Production under Protected Cultivation in Kolar district of Karnataka. Agricultural Science Digest - A Research Journal, 39. 10.18805/ag.D-4930.

Harisha N, Tulsiram J, Joshi Amrutha, Chandargi DM and Meti SK. 2019b. Cost and Returns of Vegetable Production under Protected Cultivation in Kolar District of Karnataka, India. International Journal of Current Microbiology and Applied Sciences, 8: 1120-1129. 10.20546/ijcmas.2019.808.131.

Jensen Merle. 2002. Controlled environment agriculture in deserts, tropics and temperate regions - A world review. Acta Horticulturae, 578. 10.17660/ActaHortic.2002.578.1. [Online]. Available: https://www.actahort.org/books/578/578_1.htm.

Kaur Simranjit, Kanchan Amrita, Prasanna Radha, Ranjan, Kunal, Ramakrishnan, Balasubramanian, Singh Awani and Shivay Yashbir. 2019. Microbial inoculants as plant growth stimulating and soil nutrient availability enhancing options for cucumber under protected cultivation. World Journal of Microbiology and Biotechnology, 35. 10.1007/s11274-019-2623-z.

Koundinya AVV and Kumar P. 2014. Indian Vegetable Seeds Industry: Status and Challenges. International Journal of Plant, Animal and Environmental Sciences, 4. 62-69.

Kumar N and Singh G. 2015. Protected cultivation of parthenocarpic brinjal (*Solanum melongena* L.). International Journal of Agriculture Innovations and Research. 4(1) :105-06.

Mangal JL and Jasmin AM. 1987. Response of tomato varieties to pruning and plant spacing under plastic house. Haryana Journal of Horticultural Science, 16 (3-4): 248-52.

Max Johannes, Horst Walter, Mutwiwa Urbanus and Tantau Hans-Jürgen. 2009. Effects of greenhouse cooling method on growth, fruit yield and quality of tomato (*Solanum lycopersicum* L.) in a Tropical Climate. Scientia Horticulturae, 122: 179-186. 10.1016/j.scienta.2009.05.007. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0304423809002568.

Mishra GP, Singh N, Kumar H and Singh SB. 2010. Protected Cultivation for Food and Nutritional Security at Ladakh *Defence Science Journal*, 61(2) :219-225. https://doi:10.14429/dsj.60.343.

Naika S, Van Lidt de Jeude J, De Goffau M, Hilmi M. and Van Dam B. 2005. Cultivation of tomato. production, processing and marketing. In: B. Van Dam (ed.), Digigrafi, Wageningen, The Netherlands.

Negi VS, Maikhuri RK, Rawat LS and Parshwan D. 2013. Protected cultivation as an option of livelihood in mountain region of central Himalaya, India. International Jouranl of Sustainable Development and World Ecology, 20(5) :416–425. https://doi:10.1080/13504509.2013.799103.

Nicola Silvana, Tibaldi, Giorgio and Fontana E. 2009. Tomato Production Systems and Their Application to the Tropics. Acta horticulturae, 821: 27-34. https://doi:10.17660/ActaHortic.2009.821.1.

Nguyen T, Borgemeister C, Max J and Poehling HM. 2009. Manipulation of Ultraviolet Light Affects Immigration Behavior of Ceratothripoides claratris (Thysanoptera: Thripidae). Journal of Economic Entomology. 102(4): 1559-66. [Online]. Available: https://academic.oup.com/jee/article-abstract/102/4/1559/2199279.

Patil Kalyanrao, Tomar BS and Singh Balraj. 2014. Effect of stage of harvest and post harvest ripening on hybrid seed yield and quality in bottle gourd. Indian Journal of Horticulture, 71: 428-432.

Pickersgill B. 1980. Some aspects of interspecific hybridization in Capsicum. Proceeding of the VIth Meeting "Eucarpia Capsicum Working Group". 1-5.

Pimpini F, Gianquinto G, Babbo G and Xodo E. 1987. Effect of protective structures and pinching on the earliness of table tomato in the greenhouse. Colture Protette 16(8/9): 63–73.

Prasanna Radha, Saxena Garima, Singh Babita, Ranjan Kunal, Buddhadeo Rishi, Velmourougane Kulandaivelu, Ramakrishnan Balasubramanian, Nain Lata, Singh Mam, Hasan Murtaza and Shivay Yashbir. 2018. Mode of application influences the bio-fertilizing efficacy of cyanobacterial biofilm formulations in chrysanthemum varieties under protected cultivation. Open Agriculture, 3: 478-489. 10.1515/opag-2018-0053.

Sandri MA, Andriolo JL, Witter M and Dal Ross T. 2002. High density of defoliated tomato plants in protected cultivation and its effects on development of trusses and fruits. Horticultura Brasileira, 20(3): 485-489.

Singh Balraj and Choudhary Santosh. 2019. Prospects of Protected Vegetable Cultivation in Arid and Semi-Arid Regions of India. In: Training Manual on Skill Development Course on Protected Cultivation of Vegetable Crops. (HG Prakash *et al*., Eds.), C. S. Azad University of Agriculture & Technology, Kanpur - 208002 (U.P.), India. pp 18-23.

Singh Balraj and Sirohi NPS. 2006. Protected cultivation of vegetables in India: problems and future prospects. Acta horticulturae, 710: 355-358. 10.17660/ActaHortic.2006.710.38. [Online]. Available: https://www.actahort.org/books/710/710_38.htm.

Singh Balraj and Gupta Ramwant. 2011. Performance of sweet pepper (Capsicum annum) varieties and economics under protected and open field condition at Uttarakhand.. Indian Journal of Agricultural Sciences, 81: 973-975.

Singh Balraj and Kumar M. and Sirohi NPS. 2007a. Protected Cultivation of Cucurbits Under Low-Cost Protected Structures: A Sustainable Technology for Peri-Urban Areas of Northern India. Acta horticulturae, 731: 267-272. https://doi:10.17660/ActaHortic.2007.731.36.

Singh Balraj and Tomar B. 2015. Vegetable seed production under protected and open field conditions in India: A review. Indian Journal of Agricultural Sciences. 85: 1251–9.

Singh Balraj, Yadav HL. Kumar M and Sirohi, NPS. 2007b. Effect of plastic plug-tray cell size and shape on quality of soilless media grown tomato seedlings. Acta horticulturae, 742: 57-60. 10.17660/ActaHortic.2007.742.7.

Singh Brahma. 2019. Protected cultivation of vegetables in India: An overview. In: Training Manual on Skill Development Course on Protected Cultivation of Vegetable Crops. (HG Prakash *et al*., Eds.), C. S. Azad University of Agriculture & Technology, Kanpur - 208002 (U.P.), India. pp 01-08.

Singh J, Nangare DD, Meena V, Bhushan B, Bhatnagar PR and Sabir N. 2015. Growth, quality and pest infestation in tomato under protected cultivation in semi-arid region of Punjab. Indian Journal of Horticulture. 72(4): 518-22. https://doi:10.5958/0974-0112.2015.00095.X.

Sringarm Korawan, Max Johannes, Saehang Suchart, Spreer Wolfram, Kumpiro Siriya and Müller Joachim. 2013. Protected Cultivation of Tomato to Enhance Plant Productivity and Reduce Pesticide Use. [Online]. Available: https://www.researchgate.net/publication/258098888.

Tomar BS, Singh Jogendra and Jat GS. 2019. Low Tunnel Technology for Off- Season Cucurbits Cultivation. In: Training Manual on Skill Development Course on Protected Cultivation of Vegetable Crops. (HG Prakash *et al*., Eds.), C. S. Azad University of Agriculture & Technology, Kanpur - 208002 (U.P.), India. pp 24-26.

Trivedi Ajaya and Singh VK. 2015. Potential for Improving Quality Production of Horticultural Crops Under Protected Cultivation. In: National Workshop cum-Seminar on Eemerging Prospects of Protected Cultivation in Horticultrural Crops under Changing Climate, ICAR-Central Institute of Subtropical Horticulture, Lucknow, 22-23 December. pp71-75.

Vidyadhar Bontha, Tomar BS and Singh Balraj. 2014. Effect of truss retention and pruning of berry on seed yield and quality of cherry tomato (*Solanum lycopersicum* var *cerasiforme*) grown under different polyhouse structures. Indian Journal of Agricultural Sciences, 84: 1335-41.

Vidyadhar Bontha, Tomar BS, Singh Balraj and Behera Tusar. 2015. Effect of methods and time of pollination on seed yield and quality parameters in cherry tomato grown under different protected conditions. Indian Journal of Horticulture, 72. 10.5958/0974-0112.2015.00011.0.

Wani KP, Singh PK, Amin A, Mushtaq F and Dar ZA. 2011. Protected cultivation of tomato, capsicum and cucumber under kashmir valley conditions. Asian Journal of Science and Technology, 1(4): 56-61.

Zijlstra Sierd, Purimahua Coen and Lindhout Pim. 1991. Pollen Tube Growth in Interspecific Crosses between Capsicum Species. HortScience, 26. 10.21273/HORTSCI.26.5.585.