Protected Cultivation of Horticultural Crops

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Training Manual

Protected Cultivation of Horticultural Crops

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Training Manual

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Protected Cultivation

of

Horticultural Crops

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1. Protected Cultivation Technology

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Production of vegetables and flowers is significantly influenced by the seasonality and weather conditions. The extents of abundance and deficiency in production cause considerable fluctuations in the prices and quality of vegetables and flowers. Vegetable production, at present, is also characterized by a strong dependence on chemical plant protection with its all-inherent environmental and health hazards, both, for the grower and the consumer. Striking a balance between all-season availability of high quality vegetables with minimum environmental impact, and still to remain economically competitive in this time of globalization, is a major challenge for the modern technology of crop production.

The crop productivity is influenced by the genetic characteristics of the cultivar, growing environment and management practices. Under open field cultivation, while the other factors could be taken care of, it is not possible to effect control on the environment around the plant. The plant's environment can be specified by five basic factors, namely, light, temperature, humidity, carbon dioxide and nutrients. The main purpose of protected cultivation is to create a favourable environment for the sustained growth of plant so as to realize its maximum potential even in adverse climatic conditions. Greenhouses, rain shelters, plastic tunnels, mulches, insect-proof net houses, shade nets etc. are used as protective structures and means depending on the requirements and cost-effectiveness. Besides modifying the plant's environment, these protective structures provide protection against wind, rain and insects.

Protected cultivation offers several advantages to produce vegetables and flowers of high quality and yields, thus using the land and other resources more efficiently. This becomes relevant to growers in India who have small land holding, say less than one hectare. They would be interested in a technology, which helps them to produce more crops each year from their land, particularly during off-season when prices are higher. However, growing vegetables under protected conditions requires comparatively high input cost and good management practices, which have direct bearing on the economic viability of the production system. Even if the protective structures are cost effective, proper planning, management and attention to details are needed to achieve maximum benefits. Growing vegetables and flowers under location-specific suitable structures may accrue substantial benefits even to small growers.

1. Definition:

- Protected cultivation is the modification of the natural environment to achieve optimum plant growth. Modification can be made to both the aerial and root environment to increase crops yields, extends the growing season and permit growth during periods of the year not commonly used to grow field crops.
- Protected cultivation may also indicate comprehensive system of controlled Environmental agriculture in which all aspects of the natural environment are modified for maximum plant growth and economic return.

2. History:

Structures for protected crop production were in use several centuries ago in northern Europe. Early structures were simply the pits covered with sheets of transparent material, probably mica, to provide protection to food crops. By the early 17th century, structures of stone and glass were being used as orangeries, which were structures for protected cultivation of citrus. During the 18th century, commercial production of food crops, cut flowers and ornamental plants in glasshouses commenced. By the early 1900s glasshouse designs had evolved to a level at which traditional designs of today were in use and little further evolution in the designs occurred.

The most significant breakthrough in greenhouse designs came about with the development of plastic technology. Polyethylene polymer was first developed in the 1930s and came into agricultural use in the early 1950s in the form of plastic films and pipes for water conveyance including sprinkler and drip irrigation. New kinds of plastic, like polyvinyl chloride, polypropylene and polyesters were developed in later years, which were cheaper, more durable, and opaque or transparent as required for greenhouse covers and several other applications.

3. Protective structures/methods

The kinds of protective structures for crop production range from simple provisions such as rain shelters, shade houses, mulches, row covers, low tunnels, cloches to greenhouse structures with passive or active climate control. While it would not be possible to describe each of the above in detail, a brief description of some of these is given below.

3.1 Greenhouses

A greenhouse is quasi-permanent structure, covered with a transparent or translucent material, ranging from simple homemade designs to sophisticated pre-fabricated structures, wherein the environment could be modified suitable for the propagation or growing of planats.. Materials used to construct a greenhouse frame may be wood, bamboo, and steel or even aluminum. Coverings can be glass or various rigid or flexible plastic materials. Depending on the covering material, different terminology have been used in the context of greenhouse structures as mentioned below:

Glasshouse : A greenhouse with glass as the covering material is called as glasshouse.

Polyhouse : It is a greenhouse with polyethylene as the covering material.

3.1.1Plant environment and greenhouse climate

A plant grows best when exposed to an environment that is optimal for that particular plant species. The aerial environment for the plant growth can be specified by the following four factors:

i) Heat or temperature
ii) Light
iii) Relative humidity
iv) Carbon dioxide

While plants have precise optimum environmental conditions for best growth, most are tolerant to variations in these conditions within some limits. However, permanent damage would occur when they are exposed to conditions outside these limits. At the same time, plants are subject to attack by pests and diseases.

Greenhouse crop production provides protection against adverse environmental conditions and allows pests and diseases to be excluded or controlled. Besides providing a protective enclosure, a greenhouse also acts as a 'heat trap'. It admits solar radiation and converts this energy into heat by raising the temperature of the greenhouse air. While this is the basis of the greenhouse's ability to perform its tasks, it also affects other environmental factors.

Environmental conditions inside the greenhouse can be modified suiting to the potential growth of plants. The extent of climate modification will, however, depend on the design of greenhouse and is generally related with its cost. Higher the capability of greenhouse to modify its climate, higher is the cost of its construction.

The way in which a greenhouse gets heated when exposed to sunlight is similar to heating of the earth's surface and its adjacent atmosphere. When solar radiation reaches the earth, a small portion is reflected back into the space while the remainder is absorbed at the surface raising its temperature. In the same way, when solar radiation reaches the greenhouse cover-surface, a small amount (normally 15-20%) is reflected back from the surface while the remainder is transmitted to the interior. Plants, soil and other objects absorb most of this transmitted radiation and remainder is reflected as shown in figure 1. The absorbed radiation raises the temperature of absorbing surfaces and objects with the heat energy being immediately transferred to the greenhouse air by convection and evaporation thereby increasing the temperature and humidity.

Greenhouses lose heat in three ways:

i) Warm air moves out the greenhouse and is replaced by cooler outside air.
ii) Heat is transferred through the covering material itself.
iii) Heat is lost through the soil / floor.

Increasing the temperature of the growing environment in a greenhouse is unavoidable, but it is also the most important function of a greenhouse. Enhanced temperatures accelerate plant growth, and allow sustaining plant growth even when outside ambient temperatures are unfavourably low. However, during summers, inside temperatures rise higher than the optimum levels and, therefore, cooling/ventilation provisions are necessary.

Most plants grow better within 60 - 85% relative humidity (RH) of air. Low RH increases the evaporative demand on the plant, while high RH can depress this demand inhibiting the uptake of nutrients, particularly of calcium. In general, the RH inside the greenhouses is higher than the outside, mainly due to transpiration load. Effective ventilation is required to control higher RH levels.

In most parts of the country, solar radiation is not a limiting factor for plant growth. Light control inside the greenhouse can be affected conveniently either by shading or by supplementary lighting whenever required. Growers in northern

India should, however, be careful in monitoring light levels in winters especially during prolonged foggy conditions. In peri-urban areas, particulate pollutants get deposited on the plastic roof thereby reducing the light transmission significantly. This problem is compounded in winters. In such conditions, it is necessary to wash the roof frequently to maintain adequate light levels inside the greenhouse.

Plants use carbon dioxide from the atmosphere for photosynthesis. Carbon dioxide concentration inside the greenhouse in the early morning is always higher than the outside. With the onset of sun, this level quickly depletes and goes down the normal level during the day if adequate air exchanges are not maintained. Carbon dioxide enrichment is generally accomplished by burning suitable fuels like propane.

3.1.2 Type of greenhouses

The greenhouses design and cost range from a simple plastic walk-in tunnel costing about Rs.100/- per sq. meter to a climate-controlled, saw-tooth greenhouse with automatic heating, ventilation and cooling, costing more than Rs. 3000/- per sq meter. The selection of the greenhouse design should be determined by the grower's expectations, need, experience, and above all its cost-effectiveness in relation to the available market for the produce. Obviously, cost of greenhouse is very important and may outweigh all other considerations.

Greenhouses are classified in different shapes, which also determine their cost, climate control and use in terms of crop production. Commonly used structural designs are briefly described below:

Gable: This is the most basic structure similar to a hut-like construction and was perhaps the first version of a greenhouse with glass as the covering material. The roof-frame can be inclined at any angle to present an almost perpendicular face to the sun to minimize losses due to external reflection. The structure also allows large openings in the side-walls and at the ridge for high rates of natural ventilation. Modern gable-shaped greenhouses are multi-span units with bay widths of 6-12 meters.

Gambrel: These structures are similar to the gable but have high strength to withstand high wind loads during storms. This design is more suitable where wood or bamboos are to be used for the greenhouse construction.

Skillion: In this kind of structure, the roof consists of a single sloping surface. This is because the greenhouse is built as the southward extension of a building with a solid wall on the northern side. Such greenhouses have the advantage of low structural requirements.

***Curved-roof*:** The semi-circular tunnel greenhouse structures appeared with the introduction of polyethylene film as the covering material. These structures, besides being most simple and easy to construct, have the advantage of high strength with a relatively light frame due to inherent strength of the curved arch. But these structures have the disadvantage of poor ventilation efficiency since the curved roof is not amenable to the incorporation of ridge ventilators.

In an attempt to improve the ventilation efficiency of curved roof greenhouses, raised arch type of structures have been adopted. This design has vertical side-walls, which permit high head room and improved ventilation due to the wind velocity.

Saw-tooth: In these structures, the roof consists of a series of vertical surfaces separated by a series of sloping surfaces, all of which are pitched at the same angle and facing in the same direction. The vertical surfaces consist entirely of ventilating area. These types of greenhouses are most efficient from ventilation point of view. Such greenhouses are also suitable for multi-span structures. Orientation of saw-tooth greenhouses can also be used as a means of maximizing natural ventilation. By facing the open vertical ventilation areas away from the wind, airflow over the greenhouse roof creates a negative pressure, which facilitates in sucking out warm greenhouse air. However, this air dynamics relies on the premise that there are large ventilation areas in the greenhouse walls on windward side.

3.1.3 Covering materials of greenhouses

As mentioned earlier, the purpose of a greenhouse covering is to allow sunlight to pass through it so that the energy is retained inside . Glass was the main covering material in the early greenhouses. With the introduction plastic materials, there are now several alternatives available for greenhouse coverings. A brief description of greenhouse covering materials is given below:

Glass: A clean, transparent provides the maximum light transmittance to the extent of 90%. However, being heavier in weight, it requires elaborate structure for adequate support. It is brittle and can break with minimum shock or vibrations resulting in high maintenance costs.

Acrylic: This material has long service life, good light transmittance (80%), moderate impact resistance, but prone to scratches. It has a high coefficient of expansion and contraction. Being inflammable and costly, it is not a preferred material.

Polycarbonate: It is available in single or double wall sheets of different thickness. A new polycarbonate sheet has good light transmittance of about 78%, but reduces with age. It has excellent impact resistance and low inflammability. High cost limits its use on large scale.

Fiberglass reinforced plastic panels (FRP): These plastics consist of polyester resins, glass fibers stabilizers etc. It has a initial light transmittance of about 80% and has high impact resistance with a service life ranging from 6-12 years. Good quality FRP materials for greenhouse coverings are not quite assured.

Polyethylene: A clear, new polyethylene sheet has about 88% light transmittance. Its higher strength and low cost have made it most popular replacement to glass. An ultra-violet (UV) stabilized plastic sheet can have a service life of 3 years. These sheets are generally available in 7 and 9 meter widths with 200 micron (0.2 mm) thickness.

3.2 Plastic low tunnels /row covers

These structures are laid in open fields to cover rows of plants with transparent plastic film stretched over steel hoops of about 50 cm height spaced suitably along the rows. Polyethylene film of 30-40 micron thickness, without UV stabilization, is used which is perforated in situ as the season gets hotter. Row covers used in vegetable production have different purposes in temperate and tropical regions. In cold conditions, they are used to conserve warmth, stimulate germination and early growth, protect plants from frost injury, and improve the quality of the crops. Other beneficial effects, such as maintaining soil structure, and protecting crops from the attacks of birds and pests, can also be expected.

The main advantage of these covers in northern India is to grow vegetables, especially cucurbitaceous crops, ahead of normal season in winters. Experiments on muskmelon have proved it a highly profitable proposition. The muskmelon seedlings could be transplanted under such covers in the last week of January. The crop growth was sustained during the cold period. Temperature profile inside the cover indicated a difference of about 7°C averaged over 24-hour cycle. This rise in temperature provided necessary warmth to sustain the growth of plants.

In hot season, however, materials used as row covers need to have adequate permeability to air and moisture, to prevent the accumulation of excessive heat inside the covers. The covering materials used in summer are woven polyester wind-break nets, cheese-cloth, and insect-proof screens. These types of covers are generally laid over the planted rows without the support of steel hoops, and are also called as floating covers. To provide adequate space, the seedlings are planted in the furrows and the covers are laid over the ground. But such planting should only be adopted in light textured soils having high infiltration rates.

3.3 Mulching

Mulching is done to cover the soil around plants with a protective material, which may be organic or synthetic. Organic mulches, like leaves, sawdust etc. add nutrients and humus to the soil as they decompose, improving its tilth and moisture holding capacity. Synthetic or plastic mulches have various beneficial effects on crop production. Transparent polyethylene mulch raises the soil temperature. This effect derives mostly from the suppression of latent heat loss through evaporation. The mean difference in soil temperature between transparent film mulched and bare soil in early February in Delhi was observed to be 5°C in the top 7 cm of soil where most of the root zone of young muskmelon existed. It increased the plant growth by about 15% during the same period.

Mulching conserves the soil moisture and fertility. The former is higher with black plastic than under the transparent plastic. Mulching prevents the leaching of fertilizer, because it acts as a physical barrier to rainfall, thereby conserving the fertility. Black polyethylene film also gives effective weed control by cutting down solar radiation by more than 90%, resulting in etiolated growth and the eventual death of weeds under the film. Transparent film, on the other hand, has little effect on weed control unless the film is coated with weedicides.

Plastic mulch is also effective in the control of pests and diseases. Silver-colored film is used as mulch to suppress the increase in soil temperature and to control pests and diseases. The silver color acts as a repellent to aphids, which transmit viruses. On the other hand, yellow colored mulches attract insects, which could be killed easily. Muskmelons, tomatoes, peppers, cucumbers, squash, eggplant, watermelons and okra are vegetable crops that have shown significant increases in earliness, yield, and fruit quality when grown on plastic mulch.

3.4 Shade houses

Shade nets are perforated plastic materials used to cut down the solar radiation and prevent scorching or wilting of leaves caused by marked temperature increases within the leaf tissue from strong sunlight. These nets are available in different shading intensities ranging from 25% to 75%. Leafy vegetables and ornamental greens are recommended to be grown under shade nets whose growth rates are significantly enhanced compared to unshaded plants when sunlight is strong.

3.5 Net houses

Shade house and net house are often synonymously used but more correctly a net house is enclosed with perforated screen primarily to act as a barrier for the entry of insects and pests. .Insect-proof nylon nets are available in different intensities of perforations, ranging from 25 mesh to 60 mesh. Nets of 40 or higher mesh are effective means to control entry of most flying insects and save crop from diseases. These structures permit early planting of tomatoes and capsicum without the risk of vector. Higher mesh size, however, reduces the air exchange of the structure. UV- stabilized nets are now available which have a longer life.

A simple bamboo framed greenhouse suitable for North-East region where bamboo grows in plenty. Preference for local materials should be given if the construction is cost-effective in long run.

A simple wooden framed, saw-tooth design of naturally ventilated greenhouse for raising nursery. Walk-in tunnel and raised-arch type of greenhouses are easy to build in low cost. The walk-in tunnel has poor ventilation and thus of limited annual use with plastic cover. Its annual use can be enhanced by replacing the plastic cover with insect proof net during hot season. The raised arch structures have better ventilation and can be used almost year around for crop production. The orientation of both the structures should be North-South lengthwise.

World Scenario

Total Greenhouse area acreage nearly 6, 23,302 ha. Green house vegetable production area is 4, 02,981 ha. Vegetable area under soilless/ hydroponic culture systems is around 95,000 ha .Around 115 countries are using this technology for growing vegetables commercially. The Netherlands is the traditional exporter of greenhouse grown flowers and vegetables all over the world. With about 89,600 ha under cover, today, the Netherlands has many of the largest greenhouses in the world.China (81,000ha), Spain (70,400ha), South Korea (47,000ha), Japan (36,000ha) &Turkey (33,500ha) are the leading countries. The development of greenhouses in Gulf countries is primarily due to the extremity in the prevailing climatic conditions. Israel is the largest exporter of cut flowers and has wide range of crops under greenhouses (15,000 ha) and Turkey has an area of 10,000 ha under cover for cultivation of cut flowers and vegetables. In Saudi Arabia cucumbers and tomatoes are the most important crops contributing more than 94% of the total production. The most common cooling method employed in these areas is evaporative cooling. Egypt has about 1000 ha greenhouses consisting mainly of plastic covered tunnel type structures. In Asia, China and Japan are the largest users of greenhouses. The development of greenhouse technology in China has been faster than in any other country in the world. With a modest beginning in late seventies, the area under greenhouses in China has increased in recent years. The majority of greenhouses use local materials for the frame and flexible plastic films for glazing. Japan has more than 40,000 ha under greenhouse cultivation of which nearly 7500 ha is devoted to only fruit orchards. Greenhouses in Japan are used to grow wide range of vegetables and flowers with a considerable share of vegetable demand being met from greenhouse production.

National Scenario

- Technology was existed for commercial purposes in 1960s.
- Installation of glasshouse at DRDO, Field Research Lab, Leh in 1964

- Thrust came only in the mid 1980′s with the emergence of the industries manufacturing U.V. stabilized Low Density Polyethelene (L.D.P.E.).
- Technology got extended in temperate regions with the development of the indigenous low cost greenhouses technology.
- In India, the area under protected cultivation is presently around 25,000 ha while the greenhouse vegetable cultivation area is about 2,000 ha (Sabir 2013).
- Maharashtra and Karnataka leading states. Hilly regions offer potential, Himachal Pradesh taking lead (3rd)
- Maharashtra and Gujarat had a cumulative area of 5,730.23 hectares and 4,720.72 hectares, respectively under the protected cultivation till 2012

Protected Cultivation Advantages:

- Higher yield
- Better quality
- Off-season production
- Assured and early production
- Least pesticide residues
- Controlled pollination
- Vagaries of weather
- Easier plant protection
- Weed free cultivation

Protected Cultivation Constrains:

- Basic cost and operational cost very high
- Irregular power supply
- Little work on designing in different locations
- Cladding material quality/availability
- Lack of technical knowhow
- Lack of indigenous technology (Zone/region)
- Lack of suitable varieties / hybrids for greenhouse cultivation
- Exotic seeds very costly
- Poor performance of indigenous varieties

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2. Designing Greenhouse

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Green house

A greenhouse is a framed or inflated structure covered with a transparent or translucent material in which crops could be grown under the conditions of at least partially controlled environment and which is large enough to permit a person to work within it to carry out cultural operations.

Selection of site for Greenhouse:

Following things are taken into account

1. The selection Site should be free from pollution.
2. Water should be available regularly
3. Supply of electricity (Three phase) should be regular
4. Soil should be properly leveled and drained
5. Poly house should be near to road side means proper approachable road must be there to go to poly house
6. Some space should be there nearby for further extension
7. Expertise and labors should be available when required.

Factor affecting site selection

- Sunlight
- Topography of land
- Climate
- Available water
- Land-use prediction
- Accessibility of the site
- Room for Expansion
- Soil
- Labour Supply
- Market
- Electricity

Sun light

- The structure should be away from the building and trees to avoid obstruction from sun light.
- The greenhouse should be located where it gets maximum sunlight. The first choice of location is the south or southeast side of a building or shade trees.
- The next best sites are southwest and west of major structures, where plants receive sunlight later in the day. North of major structures is the least desirable location and is good only for plants that require little light.
- Sunlight all day is best, but morning sunlight on the east side is sufficient for plants.
- Morning sunlight is most desirable because it allows the plant's food production process to begin early; thus growth is maximized.

Topography of land

- It determines the amount of work and expense that will be required to provide good surface drainage and efficient transportation.
- Levelled ground
- Good drainage is another requirement for the site. When necessary, build the greenhouse above the surrounding ground so rainwater and irrigation water will drain away.

Climate

- The construction depends on the local climatic conditions (intensity of sun radiation, humidity, rainfall, temperature, wind velocity, snow fall, land slide ,avalanche etc.)

Available water

- Water is one the most frequently overlooked commodities in the establishment of a green house.
- Before site selection, the available source of water should be tested for quality and quantity.
- Water pH should be between 5.5 to 7 & electric conductivity of water should be 0.01 to 0.1

Land –Use Prediction

- Laws of local government are subject to change .They affect planning and Development of green house industry. Therefore one should know them in detail of past development and local laws of the area for future direction and assessment

Electricity

- Naturally ventilated greenhouse may not need any power supply
- For greenhouse electrical appliances, such as motor fans, lights, and other equipment we need assured electrical power for uninterrupted operations
- An auxiliary generating system should be available to cope with the failure of regular electrical supply

Greenhouse Orientation

- In a free-standing greenhouse, more sunlight is available in winter in an east-west oriented greenhouse
- A freestanding greenhouse should have its long axis perpendicular to the wind direction
- In multi-span greenhouses, the gutter should be oriented north south
- In naturally ventilated greenhouse, the ventilators should open on the leeward side.

Basic Design Considerations

Functional design parameters:

- Light transmission
- Crops
- Size of operation
- Environmental control requirements
- Frame material
- Glazing material

Structural design: The most important function of the greenhouse structure and its covering is the protection of the crop against hostile weather conditions (low and high temperatures, snow, hail, rain and wind), diseases and pests. It is important to develop greenhouses with a maximum intensity of natural light inside. The structural parts that can cast shadows in the greenhouse should be minimized. The different structural designs of greenhouse based on the types of frames are available. A straight side wall and an arched roof is possibly the most common shape for a greenhouse, but the gable roof is also widely used. Both structures can be free standing or gutter connected with the arch roof greenhouse. The arch roof and hoop style greenhouses are most often constructed of galvanized iron pipe. If tall growing crops are to be grown in a greenhouse or when benches are used, it is best to use a straight side wall structure rather than a hoop style house, this ensures the best operational use of the greenhouse. A hoop type greenhouse is suitable for low growing crops, such as lettuce, or for nursery stock which are housed throughout the winter in greenhouses located in extremely cold regions. A gothic arch frame structure can be designed to provide adequate side wall height without loss of strength to the structure (Fig.10). Loads in designing the greenhouse structures include the weight of the structure itself and, if supported by the structure, loads of the equipment for the heating and ventilation and water lines. Greenhouse structures should be designed to resist a 130 km/h wind velocity. The actual load depends on wind angle, greenhouse shape and size, and the presence or absence of openings and wind breaks.

The ultimate design of a greenhouse depends on the following aspects: (i) The overall structural design and the properties of the individual structural components. (ii) The specific mechanical and physical properties which determine the structural behavior of the covering materials. (iii) The specific sensitivity of the crop to light and temperature to be grown in the greenhouse. (iv) The specific requirements relevant to the physical properties of the covering material. (v) The agronomic requirements of the crop.

Covering materials: The following factors are to be considered while selecting the greenhouse covering material i.e., light, transmission, weight, resistant to impact, and durability to outdoor weathering and thermal stability over wide range of temperatures. Before selecting the covering material, two important points should be taken into consideration: the purpose for which greenhouse facility is intended and service life of material. In temperate regions where high temperatures are required, the covering material with high light transmission and far IR absorption must be selected. Also the loss of heat by conduction should be minimum.

Covering material	**Life span**
1. Glass and acrylic sheet	20 years
2. Polycarbonate and fiberglass-reinforced polyester sheet	5-12 years
3. Polyethylene	2-6 months
4. Polyethylene stabilized for UV rays	2-3 years

The ideal greenhouse selective covering material should have the following properties:

(i) It should transmit the visible light portion of the solar radiation which is utilized by plants for photosynthesis.

(ii) It should absorb the small amount of UV in the radiation and convert a portion of it to fluoresce into visible light, useful for plants.

(iii) It should reflect or absorb IR radiation which are not useful to plants and which causes greenhouse interiors to overheat.

(iv) Should be of minimum cost.

(v) Should have usable life of 10 to 20 years.

The following materials commonly used to build frames for greenhouse are

(i) Wood, (ii) Bamboo, (iii) Steel, (iv) Galvanized iron pipe, (v) Aluminum and (vi) Reinforced concrete (RCC). The selection of above materials was based on their Specific physical properties, requirements of design strength, life expectancy and cost of construction materials.

Wood: Wood and bamboo are generally used for low cost polyhouses. In low cost polyhouses, the wood is used for making frames consisting of side posts and columns, over which the polythene sheet is fixed. The commonly used woods are pine and casuarina, which are strong and less expensive. In pipe-framed polyhouses, wooden battens can be used as end frames for fixing the covering material. In tropical areas, bamboo is often used to form the gable roof of a greenhouse structure. Wood must be painted with white color paint to improve light conditions within the greenhouse. Care should be taken to select a paint that will prevent the growth of mold. Wood must be treated for protection against decay. Chromated copper arsenate and ammonical copper arsenate are water based preservatives that are applied to the wood that may come into contact with the soil. Red wood or cypress (natural decay resistance woods) can be used in desert or tropical regions, but they are expensive.

Galvanized iron (GI): Aluminum, steel and reinforced cement concrete GI pipes, tubular steel and angle iron are generally used for side posts, columns and purlins in greenhouse structure, as wood is becoming scarce and more expensive. In galvanising operation, the surface of iron or steel is coated with a thin layer of zinc to protect it against corrosion. The commonly followed processes to protect against corrosion are: (i) Hot dip galvanising (hot process) process: The cleaned member is dipped in molten zinc, which produces a skin of zinc alloy to the steel. (ii) Electro-galvanising (cold process) process: The cleaned member is zinc plated similar to other forms of electro-plating The galvanising process makes the iron rust proof, to eliminate the problem of rusting of structural members. Aluminum and hot dipped GI are comparatively maintenance free. In tropical areas, double dipping of steel is required, as single dip galvanising process does not give a complete cover of even thickness to the steel. Aluminum and steel must be protected by painting with bitumen tar, to protect these materials from corrosion, while these materials contact with the ground. Now-a-days, the greenhouse construction is of metal type, which is more permanent. RCC is generally limited to foundations and low walls. In permanent bigger greenhouses, floors and benches for growing the crops are made of concrete.

Glass: Glass has been traditional glazing material all over the world. Widely used glass for greenhouse are: (i) Single drawn or float glass and (ii) Hammered and tempered glass. Single drawn or float glass has the uniform thickness of 3 to 4 mm. Hammered and tempered glass has a thickness of 4 mm. Single drawn glass is made in the traditional way by simply pulling the molten glass either by hand or by mechanical equipment. Float glass is made in modern way by allowing the molten glass to float on the molten tin. Coating with metal oxide with a low emissivity is used for saving of energy with adequate light transmittance. Hammered glass is a cast glass with one face (exterior) smooth and the other one (interior) rough. It is designed to enhance light diffusion. This glass is not transparent, but translucent. Tempered glass is the glass, which is quickly cooled after manufacture, adopting a procedure similar to that used for steel. This kind of processing gives higher impact resistance to the glass, which is generally caused by hail. Glass used as a covering material of greenhouses, is expected to be subjected to rather severe wind loading, snow and hail loading conditions. The strength mainly depends on the length/width ratio of the panel and on the thickness of the panel, but the most widely used thickness is 4 mm.

Polyethylene film: Polyethylene is principally used today for two reasons- (i) Plastic film greenhouses with permanent metal frames cost less than glass greenhouses and (ii) Plastic film greenhouses are popular because the cost of heating them is approximately 40% lower compared to single-layer glass or fiberglass-reinforced plastic greenhouses. The disadvantages are : these covering materials are short lived compared to glass and plastic panels. UV light from the sun causes the plastic to darken, thereby lowering transmission of light, also making it brittle, which leads to its breakage due to wind. A thermal screen is installed inside a glass greenhouse that will lower the heat requirement to approximately that of a double-layer plastic film greenhouse, but this increases the cost of the glass greenhouse. Polyethylene film was developed in the late 1930s in England and spread around the middle of this century. Commonly used plastic for greenhouse coverings are thermoplastics. Basic characteristics of thermoplastics are: (i) thermoplastics consists of long chain molecules, soften with heating and harden with cooling and this process is reversible and (ii) thermoplastics constitute a group of material that are attractive to the designer for two main reasons: (a) Thermoplastics have the following specific physical properties- stiffness, robustness and resilience to resist loads and deformations imposed during normal use and (b) It can readily be processed using efficient mass production techniques, result in low labour charge. The main reason to use polyethylene year round for greenhouse covering is due to presence of UV-inhibitor in it. Otherwise it lasts for only one heating season. UV-inhibited plastic cover may last for a period of 4 to 5 years. UV-grade polyethylene is available in widths up to 15.2 m in flat sheets and up to 7.6 m in tubes. Standard lengths include 30.5, 33.5, 45.7, 61 and 67 m. Some companies provide custom lengths upto a max. of 91.5 m. Condensation on ploythene film is a big problem. Condensation causes disease development, development of water logged condition and oxygen deficient inside the greenhouse. Condensation reduces light intensity within the greenhouse. To avoid this problem, anti-fog surfactant, which discourages condensation, is built into the film or panel. Warm objects, such as plants, the greenhouse frame and soil radiate IR energy to colder bodies at night, which result in loss of heat in greenhouse. Since polyethylene is a poor barrier to radiant heat, it is formulated with IR-blocking chemicals into it during manufacture, will stop about half of the radiant heat loss. On cold and clear nights, as much as 25% of the total heat loss of a greenhouse can be prevented in this way and on cloudy nights only 15% is prevented. UV-stabilised polyethylene, on an average, transmits about 87% of photosynthetically active radiation (PAR) into the greenhouse. IR absorbing polyethylene, reduces radiant heat loss, transmits about 82% of photosynthetically active radiation (PAR) into the greenhouse. The amount of light passing through two layers of a greenhouse covering is approximately the square of the decimal fraction of the amount passing through one layer. Eg. When 87% passes through one layer of UV-inhibited polyethylene, only 76% (0.87 x 0.87) passes through two layers. Similarly, when 82% passes through one layer of IR-absorbing polyethylene, only 67% (0.82 x 0.82) passes through two layers.

Polyvinyl chloride film (PVC films): PVC films are UV light resistant vinyl films of 0.2 to 0.3 mm and are guaranteed for 4 to 5 years respectively. The cost of 0.3 mm vinyl film is three times that of 0.15 mm polyethylene. Vinyl film is produced in rolls upto 1.27 m wide. Vinyl films tend to hold a static electrical charge, which attracts and holds dust. This in turn reduces light transmittance unless the dust is washed off. Vinyl films are seldom used in the United States. In Japan, 95% of greenhouses are covered with plastic film, out of which 90% are covered with vinyl film.

Tefzel T2 film: The most recent addition of greenhouse film plastic covering is Tefzel T2 film (ethylene tetrafluoroethylene). Earlier, this film was used as covering on solar collectors. Anticipated life expectancy is 20 years. The light transmission is 95% and is greater than that of any other greenhouse covering material. A double layer has a light transmission of 90% (0.95 x 0.95). Tefzel T2 film is more transparent to IR radiation than other film plastics. Hence, less heat is trapped inside the greenhouse during hot weather. As a result, less cooling energy is required. Disadvantage is that, the film is available only in 1.27 m wide rolls. This requires clamping rails on the greenhouse for every 1.2 m. If reasonable width strips become available, the price is not a problem, because a double layer covering will still cost less than a polycarbonate panel covering with its aluminum extrusions, and will last longer, and will have much higher light intensity inside the greenhouse.

Polyvinyl chloride rigid-panel: Initially, PVC rigid panels showed much promise as an inexpensive covering material (almost 40% of cost of long lasting fiberglass reinforced plastics), has the life of 5 years. After commercial application, these panels indicated that the life expectancy was much shorter, less than 2 years. This is undesirable factor, because the cost of PVC panels was 4 to 5 times that of polyethylene film and they required much more time to install. Now-a-days, PVC rigid panels are not in use.

Fiberglass-reinforced plastic (FRP) rigid panel: FRP was more popular as a greenhouse covering material in the recent past. Advantage of FRP is that it is more resistant to breakage by factors, such as hail or vandals. Sunlight passing through FRP is scattered by the fibers in the panels, as a result the light intensity is rather uniform throughout the greenhouse in comparison with a glass covering. Disadvantages with these are the panels subjected to etching and pitting by dust abrasion and chemical pollution. Based on the grade, the usable life period of FRP panel varies. Some grades give 5 to 10 years, while better grades can last up to 20 years. FRP panels are flexible enough to conform to the shape of quonset greenhouses, which make FRP a very versatile covering material. FRP can be applied to the inexpensive frames of plastic film greenhouses or to the more elaborate frames of glass type greenhouses. The price of FRP greenhouse lies between that of a plastic film greenhouse and that of a glass greenhouse. But the cost is compensated by the elimination of the need for replacement of film plastic in every year or alternate years. Corrugated panels were used because of their greater strength. Flat panels are used occasionally for the end and side walls, where the load is not great. It is available in 1.3 m width, length up to 7.3 m and in a variety of colours. The total quantity of light transmitted through clear FRP is approximately equivalent to that transmitted through glass, but diminishes in relation its color. For greenhouse crops in general, only clear FRP permits a satisfactory level of light transmission (88 to 90%). Colored FRP has found a limited use in greenhouses intended for growing houseplants that require low light intensity and in display greenhouses for holding plants during the sales period. FRP has advantage over glass is that, it cools easily. FRP greenhouses require fewer structural members since sash bars are not needed.

Acrylic and polycarbonate rigid-panel: These panels have been available for about 15 years for greenhouse use. The panels have been used for glazing the side and end walls of plastic film greenhouses and retrofitting old glass greenhouse. Acrylic panels are highly inflammable, where as polycarbonate panels are non- flammable. Acrylic panels are popular due to their higher light transmission and longer life. Acrylic panels are available in thickness of 16 and 18 mm, and have 83% of PAR light transmission. Acrylic panels cannot be bent, but the thinner panels can be bent to fit curved- proof greenhouses. These panels are also available with a coating to prevent condensation drip. Polycarbonate panels are preferred for commercial greenhouses due to lower price, flame resistance and greater resistance to hail damage. Polycarbonate panels are available in thickness of 4,6, 8, 10 and 16 mm. These panels are also available with a coating to prevent condensation drip and also with an acrylic coating for extra protection from UV light.

Design criteria of construction For locating the greenhouse

For locating the greenhouse, a piece of land larger than the grower's immediate need should be acquired. The ultimate size of the greenhouse range should be estimated. Area should then be added to this estimated figure to accommodate service buildings, storage, access drives and a parking lot. The floor area of service buildings required for small firms is about 13% of the greenhouse floor area, and it decreases with the increase in size of the firm. On an average, service buildings occupy 10% of the growing area. The service building is centrally located in a nearly square design of the firm, which minimizes distance of movement of plants and materials. Doors between the service buildings and the greenhouse should be wide enough to facilitate full use of the corridor width. Doors at least 3.1 m wide and 2.7 m high are common. It is good to have the greenhouse gutter at least 3.7 m above the floor to accommodate automation and thermal blanket and still leave the room for future innovations.

Construction of glass greenhouses: Glass greenhouses have an advantage of greater interior light intensity over plastic panel and film plastic covered greenhouses. Glass greenhouses tend to have a higher air infiltration rate, which leads to lower interior humidity, which is advantageous for disease prevention. On the other hand, glass greenhouses have a higher initial cost than double-layer film plastic greenhouses. While comparing the price of a glass greenhouse to a film plastic greenhouse, one needs to take into account the initial purchase price of each as well as the cost of re-covering the film plastic greenhouse every three to four years. Several types of glass greenhouses are designed to meet specific needs. A lean-to-type design is used when a greenhouse is placed against the side of an existing building. This design makes the best use of sunlight and minimizes the requirements for roof supports. It is found mostly in the retail industry. An even-span greenhouse is one in which the two roof slopes are of equal pitch and width. By comparison, a un-even-span greenhouse has roofs of unequal width, which makes the structure adaptable to the side of a hill. This style is seldom used today because such greenhouses are not adaptable to automation. Finally, a ridge-and-furrow design uses, two or more A- frame greenhouses connected to one another along the length of the eave. The sidewall is eliminated between greenhouses, which results in a structure with a single large interior. Basically, three frame types are used in glass greenhouses, which are wood frames (6.1 m in width), pipe frames (12.2 m in width) and truss frames (15.2 m in width). Latest glass greenhouses are primarily of the truss frame type. Truss frame greenhouses are best suited for prefabrication. All-metal greenhouses proved cheaper to maintain since they required no painting. At present, virtually all glass greenhouse construction is of the metal type. The structural members of the glass greenhouse cast shadows that reduce plant growth during the dark months of the year. Aluminum sash bars are stronger than wooden ones; hence wider panels of glass can be used with aluminum bars. The reduction in materials and the reflectance of aluminum have given these metal greenhouses a great advantage over wooden greenhouses in terms of higher interior light intensity. Glass greenhouse construction of today can be categorized as high profile or low profile. The low profile greenhouse is most popular in the Netherlands and is known as the Venlo greenhouse. The low profile greenhouses uses single panels of glass extend from eave to ridge. The low profile greenhouse slightly reduces exposed surface area, thereby reducing the heating cost, but more expensive to cool. The high profile greenhouses require more than single panel to cover the eave to ridge. A problem with this design is the unsealed junction between pieces of glass in the inner layer. Moisture and dust may enter between the layers and reduce light transmission.

Construction of pipe framed greenhouses: The choice of construction of pipe framed greenhouses often favors low initial investment and relatively long life. Galvanized mild steel pipe as a structural member in association with wide width UV- stabilized low density polyethylene (LDPE) film is a common option of greenhouse designers.

Material requirement:

The structural members of greenhouse are

- hoops
- foundation
- lateral supports
- polygrip assembly
- end frame

Protected Cultivation of Horticultural Crops
Arvind Singh, Surender S Dhankhar and KK Dahiya (Eds)
CCS HAU, Hisar, 2015, pp 17-24.

3. Protected Cultivation of Cut Flowers

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In the modern High tech methods, flowers are grown in protected conditions. The quality of flowers produced is superior, because inside climate or microclimate such as temperature, light, ventilation etc. is controlled.

The rose is one of the oldest flowers having been grown for over 7000 years. It is the most favorite gift on special occasions, like Birth Days, X-MAS, Day, Happy New Year, and Valentine's Day.

Planting material and rootstock

The cuttings can be made for growing in the most suited system depending on the variety and purpose with following advantages of behaving as mini plants; no grafting is required and easy propagation.

Table 1.1 characteristics of rootstocks used for the commercial rose growing.

Species / Botanical name	Characteristics
ROSACANINA *Canninainermis*	Produces large number of suckers,inclined to drop the leaves in Northern Europe, do not show stress symptom in excessive heat and give resistance against powdery mildew.
INDIAN ROSE *Rosa indica* var. major	Good for sandy soils and high pH and it thrives best in warm climate. Produce longer and stronger stems than *with good* colour flowers
ROSA NATAL BRIAR *Rosamanetti*	This is more sensitive to virus, establish very slow and is not suitable for warmer climates and thrives well in warmer and hot climate.

Varieties

At present more than hundred popular varieties of cut roses are grown all over the world and hundreds of the new varieties (Table 1.2) are checked each year. The characteristic of some of the well known rose varieties are given below:

Table 1.2 Rose varieties popularly grown in India as commercial cut flowers

Varieties	Seasonal availability	Existing markets
Cora, Corvetti, Diplomat, Esacada, Femma, Filmstone,First Red, Grand Gala, Kiss, Konfetti, Lambada, Laser, Movies Star, Nicole, Noblesse, Osiana, Papillon, PareaPavrotte,Passion ,Pink Prophyta, Ravel, Rodeo, Rossini, Sacha, Samura,SandyFemma,Sangaria,Skyline, Spinks Starlight,Texas, Sublime, Temptation, Monte Carlo, First Red, Tineke, Vivaldi, Soledo,Susanne,	Northern India: Oct. to May Southern India : Year round Western India : Year round	Europe (Germany, Holland, Italy, Switzerland), Japan, Australia and Singapore

Soil and growing media

If the roses are to be grown in the soil with fertigation schedules the optimum soil conditions required should be ideal with the which are deep (80 cm) sandy loam having 6.5 pH with 1.2 to 1.5 EC. Rockwool, perilite, sponge, coco-fine fiber and thermo-foam are some of the inert soilless media used in agriculture. Various organic mediums like cocopeat, peat-moss, composted manure and other organic mixtures are active in absorbing and releasing fertilizers and are very strong buffers. Chemical changes in such medias are slow and need less frequent monitoring of fertigation. In general the roses are planted under soilless culture having coco-peat and perlite and vermiculite mixture of 80: 10:10 ratio in double layer tray and the amount of fertigation required is decided by achieving 30-50% drainage rate. When water quality is good, a rinse with lesser percentage of drainage is sufficient. The excess water is drained all the way to sides and collected through drain to be used in the open fields.

Climate and greenhouse requirement

I) Radiation : High and full without shading at the canopy level of plants.

ii) Day temperatures : 24º-26ºC

iii) Night temperatures : 18ºC

iv) Relative humidity : 85 %

v) CO_2 : 1000 ppm

Planting, bending and development of bush

Planting

2 rows per bed @ 0.40 m (from row to row) and 20 cm spacing. The bed should be ridged to the extent that the roots are aerated. Planting density is kept depending upon the varieties and types ranging from 7 to 14 plants per sqm that can be planted to cover the population of 70,000 to 1,40,000 plants per ha.

De-shooting and bending

Sprouting of the buds just below the flower and leaf should be removed regularly because being between shoot and leaf lead to the small buds. Dead shoots are removed immediately. Otherwise they serve as a good surface for fungi.

Bending

Leaf is the source of the food. Therefore, a balance between the source (assimilation) and sink (dissimilation).In three month old plants bending induce the cytokine which encourage the sprouting of shoots to increase the production surface and framework of the plant into a young bush. Then after the unproductive and thin shoots are regularly bended. Picking flowers at the height of 40 to 80 cm.

Fertilizers and micro nutrients

The fertilizer concentrations required for fertigation of mature roses in greenhouse during winter and summer seasons as given in the table 1.3.

Table 1.3 Requirements of nutrition by rose grow under fertigation system

Nutrient	Concentration (ppm)	
	Summer	Winter
Nitrogen (N)	100-120	150-160
Ammonium (N- NH_4)	20-25	20-15
Nitrate (N-NO_3	80-100	130-140
Phosphorous (P-PO_4)	20-25	30-35
Potassium (K)	120-140	160-170

Post harvest management

A flower harvested at the tight bud stage has long vase life. Picking stage determines the keeping quality of the flower which differs among the varieties. Prematurely harvested bud will bend by the neck even if placed in water. After picking of flowers they should be placed in clean water treated with a mild bactericide and kept in a cool chamber at around the 10 ^{0}C until they are packed for cooled storage before transit.

Packing and storage of rose is an important as after pre-cooling is must to retain the quality in and freshness for longer time. The cut roses are packed dry in the standard boxes of 122 cm x 51 cm x

30.5 cm (48” x 20” x 12”) size and wet packing of the rose curt stems is done in the boxes of 33 cm x 33 cm x 56 cm (13” x13” x 22”) size and stored at –0.5 to 2 ^{O}C in preservative. However, the roses should be stored even while transit as dry pack at the temperature –0.5 to 0 ^{O}C.

Plant protection

Plant protection is very crucial in rose production. The recommendations of pesticides for controlling different pests and diseases as prescribed in Israel are given in the table below:

Table1.4 Control of different insects, pest and diseases in roses

Insect / pests	Controller	Controlling dose
Spidermites (*TetranychusUrticae) &* (*T. Cinnabarinus*)	Vertimec (Abamectin) Dinobuton (Acarex), Insect proof net	0.007 to 0.07 % spary 0.07 to 0.05 % spary 50 mesh net
Caterpillars	Monocrotophos, Confidor	0.01 % spary 0.01 % spary
Aphids	Monocrotophos Insect proof net	0.01 % spray 50 mesh net
Diseases		
Rose dieback (*Lasiodiplodia Spp.)*	Benomyl (Benlate), Captan (Marpan).	0.1 % spray 0.2 to 0.5 % spray
Rust (*Phragmidium Sp*.)	Mencozeb, Triforine (Saparol)	0.2 to 0.5 % spray
Downy Meldew (*PernosporaSparsa*)	Mencozeb, Metaxyl (Rydomil)	0.5 % spray
Rose, Powdery Meldew (*SphaerothecaPannosa)*	Sulphur, Dichlofluanid, Fenarimol (Rubigan)	99 % vapour, Sulphur 70 % dust 60 % dusting

2. Chrysanthemum

Introduction

In 1997, there were 635 million DFL worth of Chrysanthemum sold in the Dutch market alone. Next of the rose the chrysanthemum has been the most important cut flower in Holland. Holland has only 17% share in the total world production. More than 15 lakh stems are grown in an average in 1 hectare of chrysanthemum. A winter flash may have a yield of 40-50 flowers per square meter.

The cut flower chrysanthemum varieties popular in the International market are of single types and these are called margaritas. The colours of which are different as per the colour inside and outside the disk. Some the popular varieties are:

Rosalis (red)	Leman’s (red)
Paragon (white)	8210 (pink)
Yellow Paragon (Yellow standard)	Snowdone White (white standard)
Reagan cherry (red)	Reballet (pink)
Reagan Lemon (yellow)	Dark splender (red)
Greeno (green)	Bartiz(spider)
Tigro (light orange)	Sunney (yellow)
Tikro(white)	Vesuvio (spider)
Reagan Orange (orange)	Yellow Venn (spider)

Preparation of the Field

Soil should bewell plowed by disk, furrowed, mixed with manure if any and bed are made 1 m wide and 10-25 cm elevated form the soil.

General Physiology

Chrysanthemums are short day (SD) plants which mean that flower bud initiation and flower development are controlled by the day length. The chrysanthemum crop can be programmed accurately by the application of cyclic lighting and blackout treatments. The former induces vegetative growth (extension of stems) and the latter induces generative or flower bud development. Most of the chrysanthemums grown as cut flowers need a short day period of less than 13 hours out of 24 for satisfactory flower initiation. Temperature is a very important factor in the flowering process. Low night temperature result in more vegetative growth, taller plants, delay in flowering, longer pedicels, sturdier plants and more intense flower colors. For nursery raising the mother plants should be grown at night temperature not lower than 18^oC.

RH, CO_2 and relative humidity

The rate of growth and development is determined by four environmental factors a) light b) RH c) CO_2 and temperature as discussed above. The light Light is absorbed by the leaf pigment called chlorophyll. The amount of light absorbed is very important for the formation of sugars. These sugars are converted into more complex plant building materials like cellulose and proteins. Enrichment of CO_2 levels in the air to 600-900 ppm is recommended in closed environment. However , the relative humidity extremes beyond 60-75 % should be avoided. Low atmospheric humidity levels encourage high transpiration and respiration rates resulting in hard and dark growth.

Growth control

Growth inhibitors are the most common among the growth regulators used in chrysanthemum. Alar, Dagide& B9 are most widely used. Alar 64% at the strength of 3 gr. per liter in a volume of 50 liters is sprayed ten and twenty days after the beginning of the SD period.

Fertigation

At early stages of establishment overhead sprinklers are recommended. After 3 days drip fertigation must be started. Five cubic meters of water with 60:60:60 ppm of N: P: K should be applied.At the vigorous growth stage 5-6 m^3 of water with 100:10:100 of NPK is used. After the stage of marble size flower bud is achieved fertigation is shifted towards KNO_3 only. At the stage of flower colour appearance all fertilizer application is stopped.

Post harvest management

1. Harvest the stems at the full length of the stem. In the packing house the flowers are sorted for heavy stems of 70 – 80 cm and lighter stems of 60 cm.
2. Chrysanthemum has a very rigid and long shelf life and mild bactericides like sodium hypo-chloride solution is used in the water saturating period in the store rooms and refrigerators.

Plant protection measures

Insect and pests

S.N.	Insects/pest	Nature of damage	Control
1	Leaf minor	It makes tunnels in leaves	Metasystox 0.1 %
2	Red spider mite	It create white net all around the leaves ,, flower and colonies under the leaf where it feed and leaf die	Vertimec 0.07%, Dicofol 0.1%, Metasystox 0.1% and Polytrin 0.1%
3	White fly	Feed on aphids for sugary material secreted by its body and carry spores of fungus and other diseases	Pyriproxyfen 0.2 %
4	Thrips	suck the sap of leaves and buds on the under surfaces	Confidor 0.1 % Monocrotophos 0.1%
5	Catterpillar or *Helicoverpa*	Cut and eat the whole leaves and buds and even flower petals	Confidor 0.4 % Metasystox 0.1 %
6	Aphids	favors fungal infection on the leaves	Carbosulfan 0.2 5 %

7	Sodoptera and cut worms	Cut the leaves , buds and flowers	Metasystox 0.1 % Endosulfan 0.25 %

3. Gerbera

Introduction

Gerberas s has became popular world wide as used in the gardens, mixed containers, patio pots, or traditional containers for use as holiday and seasonal gifts. In fact, much of the production today in Europe and Japan is for cut-flowers. In US, California and Florida are the leading states in the production of cut flowers and tissue-cultured stock. The majority of cut gerberas, however, come from Columbia and surrounding countries in South America, with substantial quantities coming from the Netherlands. In India too a large cultivation in South India is booming to filled up the growing demand in mega cities like Delhi, Mumbai etc.

Varieties

The varieties which stands at present in the market for considerations like ease of shipping, long-lasting quality for different seasons-for example, orange and red for fall and winter and yellow, pink, and salmon for spring and summer can be preferred for growing are Kozac, Binaca, King Alexender, Lady Lifring, True Love Disk, Queen Victoria, Sangaria, Tara, Sunsett, Ornello, Diablo, Twiggy, Thalasa, Himalaya, Savana, Sanvi etc.

Climatic requirements

Gerbera require partial shade i.e by shade net or if grown in naturally ventilated greenhouse with light alkaline sandy soil having pH 6.5 to 7.0 and 1.2 to 1.5 EC. Temperature of 12 – 16 ^{O}C in night and 22-24 ^{O}C in day and the relative humidity of 60 to 85 % is required for producing best quality flowers.

Propagation and planting

Gerbera seeds which there are 6,000 to 8,000 seed per ounce, are expensive, delicate, and sensitive to germinating conditions. Considering that the crop requires 14 to 18 weeks from seed to flower, many small- to medium-sized growers order established, plug-grown seedlings from specialist propagators. Recommended sowing media varies, but most consists of 40 to 60 percent peat and 40 to 60 percent perlite with a 5.8 to 6.0 pH.

Potting media and irrigation

Potting media used for gerberas should be loose and well drained with a high percentage of organic matter. Many growers use 50 to 80 percent peat with perlite, vermiculite, calcine clay, or course sand added for the remaining percentage. Dolomite limestone should be added to a pH of 5.8 to 6.0. Super phosphate at 9 kg per cubic meter and micronutrients at the manufacturers' recommended rates are also added. After potting, place the plants pot-to-pot where they will receive the maximum amount of light. Gerberas can be watered and fertilized overhead for about 4 weeks before they must be placed at final spacing.

Fertilization

Many sources recommend applying a low-ammonium, balanced fertilizer such as 15-16-17 (peat-lite special) or 15-15-18 on a constant liquid fertilization basis. Young plants should be fertilized with 100 to 150 ppm nitrogen for the first 2 to 3 weeks. This rate should be increased to 150 to 200 ppm nitrogen during the winter months or 200 to 250 ppm nitrogen during the summer months. Adjust the nitrogen application rate based on plant growth. Excessive nitrogen can cause the foliage to overgrow and hide the flowers

Table 4.1 Plant Analysis Guidelines for Gerbera Daisy (Dry Weight Basis)

Table . Nutrient and fertilizers

Nutrient.	Concentration (percentage)	Nutrient	Concentration (ppm)
N	1.50 to 3.50	B	20 to 60
P	0.20 to 0.50	Cu	6 to 50
K	2.50 to 4.50	Fe	50 to 200
Ca	1.00 to 3.50	Mn	40 to 250
Mg	0.20 to 0.70	Zn	25 to 200

Growth control

B-Nine is the growth retardant of choice for gerbera growers. Apply the first application as a foliar spray 10 to 14 days after potting to the final container at 2,500 ppm. B-Nine at 1,000 to 1,500 ppm can also be applied in the plug stage when seedlings have 4 to 5 mature leaves. The number of applications depends on the season, cultivar, and pot size (Table 2). A second application of B-Nine may be desirable at 2,500 ppm during the hot summer months, depending on light levels and watering practices. Do not apply B-Nine in the last 4 weeks before flowers open because flower size and shape may be adversely affected.

Post harvest care

The flowers are cut /detached from the base. The heal of the stalk is cut 2-3 cm from the base and kept in chlorinated water and packed individually by wrapping heads in polyethylene. The bunches are made tying 10 or 20 flower per bunch. The flowers are kept in fresh water with 10 % sugar solution in buckets and stored at 2-4 OC temperature until they are sold.

Plant protection

Insects like Leaf miners, spider mites, cyclamen mites, whiteflies, aphids, and thrips are the main insect pests of gerberas and among the diseases , the powdery mildew, Phytophthora (crown/root rot), Botrytis, impatiens necrotic spot virus, and bacterial blight are the main disease problems of gerberas.

4. Carnation

It is one of the most beautiful and commercially important flower crops. It occupies third rank in the world cut flower trade. Carnation being originated in South France have sweet fragrance with varying colours like red, yellow, salmon, pink, purple, orange, white, bicolour, stripped in white and fancy combinations. Because of the strong emphasis on quality on both the export and domestic markets, commercial production of spray and Sim (standard) carnations should be considered only as a greenhouse crop. However a third group of carnations, the “GIPSY”series, has been developed during the early 1990s and has potential as a winter-grown crop.

Botany and varieties

Carnation has two major groups i.e. spray and sim / standard carnations. The spray carnations include strain of border, picottes (with colou petal margins). Margerrete and chaubad types are popular in India for ease of cultivation in open field conditions. However the standard carnations are perpetual , large flowered with long stems and have great commercial value and called “Sim Carnations”. These can be multiplied by cuttings during winter months in the Northern plain and in summer in N-E hilly areas. The major varieties popular in the market are mentioned as under :

Spray types	White Elegance, Red Baron, Scarlet Elegance etc.
Standard / Sim types	Willium Sim, Arthur Sim, Dustry Sim, Shocking Pink, White Scarlet, Harvets Moon, Tangerine Sim, Skipper, Icardi, Riffi, Calibra, White Giant, Red Desi, Caberatt, Domingo, Yellow Solor, Dower Solor, Cherry Solor, Gydina, Nivah, Garbo, Amador and Salva etc.

Climatic requirements

To achieve the best production, greenhouses should provide maximum light interception. Side walls should be no less than 1.8 m and glazed to the foundation not more than 30 cm from the ground. Modern glass and aluminum structures are considered superior. The recent trend is for high-walled structures (4m), but some compromise between light transmission, heat retention and costs. For example, a polyethylene greenhouse or tunnel is less optimal for light transmission and heat retention, but is much cheaper. Carnations are best grown at an even temperature, as fluctuations accentuate calyx splitting. Accurate environmental control is required to maintain the following parameters :

Temperatures 1	2°C (night) and 24°C (day).
Ventilation	at least 20% of the floor area.
Light	supplementary lighting should also be made.
Soil	sandy loam soil with 6.0 to 6.5 pH

Propagation and planting

Carnations are commonly propagated by cuttings (Sim types). Seed can be sown in 1 m wide and 15 cm high raised bed at 1 cm depth of sterilized soil during Aug-Sept in the plains and Feb-March in the N-E hills and seedling usually gets ready after 8 weeks. Standard carnation are propagated by terminal 8-10 cm long cuttings with 3-5 pairs of leaves in sterilized sand beds at 2 cm depth with Rootex No. 2 or Seradix- B after powder dip after drenching in 0.1 % Bavistin solution for good results. Planting can be done in 1m wide beds at 15 x 15 , 15 x 20, 20 x 20 cm apart from plant to plant and row to row spacing with stacking and supporting net at 15 or 20 cm spacing column net. About 60,000 to 1,00,000 cutting can be planted in an acre. A planting density of 24 plants per net square meter is recommended for standard carnations.

Pinching and disbudding

Pinching of the terminal bud is important in carnation to promote the lateral buds usually done when plants reaches at 5-6 leaf pair stage may be at 45 days after planting and 5-6 goods shoots are allowed to produce desired flower bud and rest are disbudded leaving only the buds having diameter of 10-15 mm . in spray type the central bud is removed to get large no of buds.

Growing media and fertilizers

A range of media containers can be used from trays to planter bags, filled with growing media such as soil, peat, scoria, pumice or rock wool. Before trying soil-less media, seek advice from experienced carnation growers who use it. However, the experience points to the levels of N and K around 4.0% as most favorable should be used to apply in standing crops in addition to following recommendations.

FYM	5-6 tons per acre is mixed in soil as basal application
NPK	30-40g +15-20g +25-30g per sqm.
Foliar spray	2:1:1 NPK mixture @ 3g per liter at 15-20 days interval

Harvesting of flowers

For local market, carnations should be cut when some of the flowers are fully open and the first petals are at an angle of 90° to the calyx. For export they should however be picked somewhat tighter at the paint brush stage. The vase life will be determined by the harvesting stage - if picked too tight they will not open properly, and if picked too open they will not last very long in the vase. For optimum vase life, only 1-2 flowers per stem should be open. Harvesting is best carried out in the morning when the flowers are cool and turgid, and should never be done in the heat of the day. Many growers still harvest by accumulating an armful of flowers as they move along the row. A far better method is to use small carts with detachable liners.

Plant protection

Insect / pests

Sr.No.	Insect / pests	Nature of damage	Control
1	Red spider mite	Suck the sap from leaves, stem , buds and flower petals	Malathion 0.1 % Kelthane 0.2 %
2	Aphids	Suck the plant sap	Endosulfan 0.2%
4	Caterpillars	Cut and chew the leaves and soft buds	Parathion 150 g per 100 sqm

Diseases

Sr.No.	Insect / pests	Nature of damage	Control
1	*Fusarium* wilt	Yellow and wilting of leaves	Vapan 200g / sqm
2	Bacterial wilt	Root rot and gray green leaves	Sterilize soil
3	Slow wilt	Slow death of plant	Soil sterilization
4	*Alternaria dianthi*	Leaf spots and branch rots	Captan 0.2 %
5	*Botrytis* blight	Blight of flowers	Zineb 0.2 %
6	Rust / *Uromyces*	Small blisters on the leaves	Zineb 0.2 %

Protected Cultivation of Horticultural Crops
Arvind Singh, Surender S Dhankhar and KK Dahiya (Eds)
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4. Vegetable Crop Production under Protected Conditions

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In spite of considerable progress achieved during the last three decades in horticulture production in India, the average productivity of different horticultural crops is quite low as compared to the best yields at national and world level, indicating the scope to enhance the yield in different horticultural crops by many fold along with its quality especially in vegetables. This is because of an appealing gap between potential yield and the actual yield of various vegetable crops. For many vegetable crops, the yields realized are even less than 50 % of their potential yield. Sometime the farmers who grow their horticultural crops during main season are even not getting back their cost of production, but the prices of the same horticulture produce are very high during off season. Several biotic and abiotic stresses are the major limiting factor for several horticultural crops for their outdoor production during rainy and post rainy season especially for vegetables. The increasing demand of off-season and high quality vegetables in various markets of the big cities has calls the attention of the vegetable growers for diversification from traditional way of vegetable production or from general agriculture.

Protected cultivation of horticultural crops offers the best choice for diversification in agriculture production for a number of reasons. Production of crops under protected conditions has great potential in augmenting production and quality of vegetables, flowers and in some fruit crops in main and off season and maximizing water and nutrient use efficiency, under varied agro climatic conditions of the country. This technology has great potential especially in peri urban agriculture in near future, since it can be profitably used for growing high value vegetable crops like, tomato, cheery tomato, colored peppers, parthenocarpic cucumbers, flowers like cut flowers, chrysanthemum, lilium fruits like strawberry, grapes etc. and for off season cultivation of vegetables and their healthy and virus free seedlings.

Protected cultivation in partially modified environment structure is useful in combating both biotic and abiotic stresses that limit the productivity and quality of horticultural crops. This requires careful planning and attention to detail, including timing of production and harvest to coincide with high market prices, choice of varieties adopted to the off season environment, and able to produce economical yields of high quality produce etc.

Large number of farmers, who are living in peri urban areas of the country can successfully diversify their traditional agriculture by adopting or using various levels of protected cultivation technologies for production of horticultural crops looking to their resources, availability of emerging market of usual and unusual off season horticultural produce, year round demand of high value vegetables like slicing tomatoes, coloured peppers and parthenocarpic cucumbers etc. High quality nursery raising in vegetables is the other area, where complete diversification in the traditional system of nursery raising is required. All kind of protected technologies may not be economical and useful to the farmers in India, because of their very high initial, running and maintenance cost, but some protected technologies are simple and highly profitable under Indian conditions and more specifically for peri-urban areas, which can be adopted by Indian farmers for production of different horticultural crops in the following manners.

1. High quality vegetable seedling production under protected conditions

To ensure high productivity and high quality of the produce, raising of high quality seedlings through use of good quality seeds at right time and at a appropriate place is one of the cheapest but most important way. Most of the Indian farmers are raising their vegetables flowers and fruits like papaya seedlings under open field conditions, which is always inferior in quality, as the seedlings are infected with virus when raised in open during rainy and post rainy season. On one side soil borne fungus and nematodes create severe problem for raising the seedlings in soil media in open fields during hot summers and rainy season but on the other hand the very high cost of hybrid seeds in vegetables has also warranted the farmers to improve or change their traditional nursery raising method to increase the productivity and quality of vegetables. Protected nursery raising in vegetable crops has already become a full scale industry in several European countries, Israel, USA, Morocco, Turkey, Japan and China. Under this system seedlings are raised in plastic pro-trays in artificial soil-less media in especially designed greenhouses or other protected structures. A large number of virus free healthy seedlings of different vegetables can be raised in a small area of green house in plastic pro-trays by using soil-less media for growing vegetables either for main season or for their off season cultivation. With the use of this technology it is now almost possible to raise healthy vigorous seedlings of different cucurbits, otherwise it was not possible in the traditional system of nursery raising. The farmers or unemployed agriculture graduate youths of our country can very successfully start nursery raising as a small scale industry in major vegetable growing pockets of the country. By this way the vegetable growers will get the virus free or off-season healthy nursery as per their requirement and it will also generate some employment in agriculture sector. Therefore, this is the first and most important step for diversification in horticulture through protected vegetable cultivation.

2. Off-season cultivation of vegetable crops under plastic low tunnels

In most parts of our country the farmers are growing various vegetables during their main season of cultivation, but the prices of those vegetables are very low and sometime the vegetable growers are even not getting back the cost of cultivation of the vegetables. But the same vegetables are sold on very high price during off-season in several cities of our country. The demand of off-season vegetables is increasing day by day in several big and medium sized cities of the country, which provide wide scope of diversification in vegetable production through off-season cultivation of vegetables mainly the cucurbits in peri-urban areas of the country. Plastic low tunnel technology is a simple and profitable technology for off-season cultivation of cucurbits during the winter season in northern plains of our country. Crops like summer squash can be grown as a complete off-season crop, whereas other cucurbits like muskmelon, round melon, bottle gourd, cucumber, bitter gourd, watermelon can be advanced by 30-40 days over their normal growing season.

Plastic low tunnels are flexible transparent coverings that are installed over single or multiple rows of vegetables to enhance the plant growth by warming the air around the plants in the open field during winter season when the temperature is below 10^0c. Plastic low tunnels are often used to promote the growth of plants during the period of winter season. Low tunnels are supported above the plants by using hoops of GI wire and a clear or transparent plastic of 30-50 micron is covered/stretched over the hoops and the sides are secured by placing in soil. The plastic is vented or slitted during the growing season as the temperature increase with in the tunnels. The farmers can grow different varieties of summer squash (round fruited, long fruited) which is a emerging crop along with cultivation of netted muskmelon varieties in place of traditional varieties. Bitter gourd and round melon are two other crops with increasing demand and which usually fetches very high price during off-season and can be grown successfully by using the plastic low tunnel technology. This technology is highly suitable and profitable for the farmers living in northern plains of India.

If the vegetable growers are not so resourceful to use plastic low tunnels, they can advance these cucurbits even under their open field cultivation. For advancing these crops, first seedlings of these crops are raised under protected conditions in plastic pro-trays in artificial media. Because under this system of nursery raising the root development of the seedlings is vigorous so that there are no chance of damage to the root or shoot parts of the seedlings. After raising the seedlings these cucurbits can be directly transplanted in open after 10-15th of February, when there are no further chance of frost in northern plains of India. By this way these crops can be advanced by 25-30 days over their normal and traditional system of cultivation by seeds.

3. Use of insect proof net houses and low cost playhouses for production of vegetable crops:

Usually the farmers are growing their vegetable crops like tomato, chilli, sweet pepper, okra etc under open fields. But during rainy and post rainy season it is very difficult to grow these crops successfully due to leaf curl and yellow vein mosaic and other viruses, respectively. These viruses are mainly spread by insect vectors like whitefly or aphids. The population of white fly after on start of monsoons is very high and it remains in the environment uptomid November depending upon the temperature. The farmers are using several insecticides for several sprays to control these vectors, even they could not control these vectors and their tomatoes, chilli or okra crops are highly infected with viruses. The second most common and most severe problem in tomato, brinjal and okra is the fruit borer against which also the growers are using huge amount of insecticide even they are unable to control this insect. The only way to control the virus and fruit borer is to put a mechanical barrier between the crops and open environment and this is possible with the use of insect proof net of 40 or 50 mesh size in form of net houses or insect proof net covered walk in tunnels. By this way the growers can directly reduce the use of insecticides and they can grow virus free crops of tomato, chilli, sweet pepper and okra during rainy or post rainy season. But for growing these crops under insect proof net houses, it is pre-requisite to raise virus free healthy seedlings of these crops either in the greenhouse or by covering the nursery beds with insect proof net. The farmers can erect these insect proof net houses by using half inch size GI pipes after bending them in half circle shape. Other insect proof net houses can also be made by covering all sides and top with insect proof net of 40 or 50 mesh, but the net should be UV stabilized. Under these net house crops like sweet pepper, tomato chilli or okra can be grown successfully without infestation of viruses or other insects like fruit borer etc. and the growers can save the huge amount spent on pesticides.

Low cost polyhouses are the other structures, which can be used successfully and efficiently for off-season vegetable production or for virus free healthy nursery raising purposes. These low cost polyhouses can be erected by using GI pipes of 1.0 and 1/2 inch. The 1.0 inch pipe is useful erecting the side walls upto 6-7 feet in height and on the top the ½ inch size bended GI pipes are fixed in the 1.0 inch size pipes. The width of these structures is 5 to 5.5 feet. The top of the structure is covered with plastic of 180-200 micron, whereas the sidewalls are first covered with insect proof net of 40 or 50 mesh up to 5-6 feet height from the ground after placing it in soil and a rollable plastic is fixed over the net. During summer one can roll the all side plastic for cross ventilation in the structure and it can be opened during the winter season to increase the inside temperature of the structure. These structures can be used for off-season or virus free cultivation of vegetable or for year round virus free healthy nursery raising of different vegetables. These structures can be made within Rs. 100-110 per m^2 cost and the farmers themselves can made these structures according to their requirement.

4. Growing vegetable crops under naturally ventilated greenhouses:

Naturally ventilated greenhouses are the protected structures where no heating or cooling devices are provided for climate control. These are simple and medium cost greenhouses which can be erected with a cost of Rs.500-600 sq. meter and these greenhouses can be used successfully and efficiently for growing year round parthenocarpic slicing cucumber, off season muskmelon, tomato and sweet pepper crops for 6-7 months duration. These structures are having a manually operated cross ventilation system as and when required. Looking to the year round, increasing demand of high quality parthenocarpic slicing cucumber in upmarkets of the metro and other big cities of the country, this is one of the most suitable and profitable crop for cultivation under naturally ventilated green houses in peri-urban areas of the country. Three successful crops of cucumber can be grown in a naturally ventilated greenhouse in a period of one year. Muskmelon is the second crop, which can be successfully cultivated for its complete off-season availability, which can fetch very high price of the off-season produce in the up markets of the metro and other big cities of the northern parts of the country.

5. Diversification in agriculture through green house cultivation of high value vegetables around big cities

High value vegetables like slicing tomatoes, cherry tomatoes and coloured peppers are three crops which can be grown for long duration (10-12 months period) under climate control greenhouse conditions. In metro cities like Delhi there is year round demand of these high quality vegetables in the up markets viz. five star hotels, shops of embassies or high commissions of various countries situated in Delhi. They are ready to pay very high price for the high quality produce, therefore, it may be a profitable venture only if this technology is adopted around metro cities of the country. Although the initial and running cost of the climate controlled greenhouse is very high and greenhouse vegetable production is a highly intensive enterprise requiring substantial labour and 24 hour-a-day commitment, which restrict the adoption of this technology. But now the time has come when the vegetable growers around metro cities can use the green house technology for cultivation of high value vegetables for high profits.

Keeping in view the increasing demand of off season and high value vegetables, fruits and flowers in several big cities of the country, there is a urgent need for diversification from the traditional way of agriculture by production of horticultural under different protected conditions for increasing their productivity and quality for getting high returns. Nursery raising under protected cultivation can be adopted as a small scale industry in major vegetable growing areas of the country by unemployed youths who are graduate in agriculture or post graduate in horticulture.

Protected Cultivation of Horticultural Crops
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5. Vegetable Seed Production under Protected Structures

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India is the second largest producer of vegetables in the world and produced 162.62 million tones fresh vegetables from the 9.20 million hectares (NHB-2014-15). The average productivity i. e 14.14 tones/hectare of vegetables is lower than that of many developed countries. The low productivity of vegetables could be attributed to the limited availability of quality seed especially of hybrid seeds for large-scale production. India is also the second largest produce of hand pollinated hybrid seeds in vegetables among the Asian countries, next only to China. The higher cost of the hybrid seed is prohibiting in the popularization of hybrids among the small farmers. The seed production cost of high value vegetables crops could be minimized by growing them in the protected structures and enabling to harvest higher the seed yield and better quality /planting value.

Challenge in open field condition:

- Healthy seedling rising
- Management of isolation
- Parental line seed production
- Promotion of hybrid seed production
- Short growing period
- Poor seed yield
- Poor seed quality
- Reduced storability

Why we go for protected cultivation?

Now in days population is increasing sharply and due to modernization or infrastructure work is increasing day to day, agricultural land is becoming less and less. Also world water resources are fast diminishing. The one and only answer to this problem is application of new technique/technology in agriculture. Greenhouses have proven to be a reliable solution to achieve these goals; however, protected agriculture has the potential to lead to serious problems. Therefore the main benefit of protected cultivation is,

- ✓ Environmental conditions can be controlled e.g. lighting, temperature, humidity.
- ✓ Plants can be grown in places where plants cannot normally grow.
- ✓ Plants can be grown out of season or allows a longer growing season.
- ✓ Less impact on the surrounding environment through efficient land and resource utilisation.
- ✓ Crops can be grown at greater densities leading to higher yields.
- ✓ Harvesting does not depend on weather.

- ✓ Control of crop disease may be more effective as infection may be restricted to a single glasshouse/ polytunnel.

Recently there was a technical shift towards the production of high quality hybrid seeds in protected structures such as net houses, low cost net cum polytunnels for production of hybrid seeds of cucurbits and solanaceous vegetables where as fan and pad cooled green houses for the production of hybrid seed of high value vegetables like sweet pepper, hot pepper, indeterminate tomato, melon and cucumbers.

How protected cultivation can satisfy market demands?

Protected cultivation allows farmers including those having small farms to produce more crops each year from their land, particularly during the off-season, when prices are higher. High value plants and vegetables which are in seasonal demand by the consumer such as salad crops in summer or soup ingredients in winter can be grown locally without the need for high transport costs. There is a big demand by consumers for locally grown fruit and vegetables which supports the local economy by keeping money in the area and creating local jobs, as well as the national economy by reducing unemployment and the amount of expensive imports of fruit and vegetables

Type of structures suitable for seed production:

There are various protected structures viz; climate controlled greenhouses, semi-climatic controlled greenhouses, naturally ventilated greenhouses, insect proof net-houses, walk-in-tunnels, low cost poly-houses and plastic low tunnels etc are the major structures.

1. Climate and semi-climate controlled green houses; these structures could be utilized for seed production of high value vegetables being long growing period and more yield. Otherwise the growing period is shorter under open field conditions. The high value vegetables, which are suitable for growing in such structures, include slicing tomatoes, cherry tomatoes, sweet peppers, parthenocarpic cucumbers etc. The major constraint for using this type of structure is that the basic or initial cost of fabrication and running cost of such greenhouses is very high which increases the seed cost as compared to seed produced under other structures or under open field conditions, but yield and quality of seed under such structures is always very high.

2. Naturally ventilated greenhouses; can be used for seed production of tomato, sweet pepper, cucumber including parthenocarpic cucumber, summer squash, muskmelon etc. However, the duration and seed yield are less compared to climate controlled or semi-climate controlled greenhouses.

3.Insect proof net-houses; can be utilized commercially for seed production of sweet pepper, tomato, brinjal and other vegetables like cucurbits etc. These structures can be used to protect the crops against viruses and other insects like fruit bores during rainy and post rainy season. The seed yield is always less compared to all kind of greenhouses but the cost of production is also very less compared to greenhouses.

4.Walk-in-tunnels; can be used commercially for seed production of cucurbits like muskmelon, watermelon, summer squash, bottle gourd, bitter gourd etc and even for off-season crop can be protected against low temperature injury (Dec-mid Feb) in north Indian plains.

5. Walk-in-tunnels, plastic low tunnels and even rain shelters; are suitable for raising seed crops of onion, French bean, garden pea etc. especially in hills where their seed maturity coincides with the rains.

Plastic low tunnels can be used commercially for off-season seed production of cucurbits. The basic purpose is to advance the seed crops, which is not possible under open field conditions of northern plains of India. The details of protected structures, duration of seed crop has been shown in table 1.

Table 1 Kind 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
1.	Climate controlled greenhouses	Tomato, cherry tomato, sweet pepper (one crop),
		Cucumber (three crops)
2.	Semi-climate controlled greenhouse	Tomato, cherry tomato, sweet pepper (one crop),
		Cucumber (three crops)
3.	Naturally ventilated greenhouses	Tomato (one crop)
		Sweet pepper (one crop)
		Cucumber (three crops)
		Muskmelon (two crops)
		Summer squash (two crops)
4.	Insect proof net-houses	Sweet pepper (one crop)
		Tomato (one crop)
		Cucumber (two crops)
5.	Walk-in-tunnels	Muskmelon (one crop), Watermelon (one crop) and other cucurbits
6.	Plastic low tunnels and Rain shelters	All cucurbits

Factors affecting the selection of structures:

The selection of structures to be utilized for seed production depends on the type of seed crop and local environmental conditions like sunlight, maximum and minimum temperature, wind speed, humidity, rainfall, snowfall etc. Simple plastic covered net houses may be enough to produce hybrid seeds in rainy or winter seasons in many parts of south India. But it is difficult to raise sweet pepper seed crop in summer months in such net house because of very high temperature and very low humidity inside the net house. Incase of fan and pad cooled green house sweet pepper seed production can be taken up throughout the year. Plastic houses with top ventilation can be used for seed production of temperate vegetable crops in the hills of north India. Computer controlled European type high tech glass house are very expensive and economically not viable for seed production under north Indian conditions.

Considerations for quality seed production under protected conditions:

Raising of seedlings (Nursery growing):

In order to produce healthy / off season seedlings that are free from the infestation of insect and diseases, the net house or low tunnel net house or climate controlled nursery structures can play important role. The seedlings of various cucurbits can be grown for seed production during January in north India which otherwise not possible to grow early seed crop in open field condition. Similarly, the production of seedlings of brinjal free from shoot borer and leaf miner could be organized during the onset of rainy season by growing in net houses. The virus free seedlings of tomato and chilli can be produced over the beds during rainy and autumn season by covering the nets.

Seedling establishment and crop growth:

The seedlings of cauliflower cultivar Pusa Sharad raised in soil less media under high tech nursery structures showed more than 95% establishment of seedling and uniform growth under open field condition than the field grown seedlings where the establishment was only 78%.

Maintenance and multiplication of self incompatible line for hybrid seed production:

In case of cauliflower, there is problem of maintaining and multiplication of potential self-incompatible lines for the production of F_1 hybrid seed. Temporary elimination of the self-incompatibility with the use of CO_2 gas has solved this problem. For this purpose, the self-incompatible line is planted in a greenhouse and bees are allowed to pollinate the crop when it is bloom. Then keeping the greenhouse closed tightly, within 2-6 hours of pollination, it is treated with 2-5% CO_2 gas which allows successful fertilization by temporarily eliminating the self-incompatibility

Maintenance and multiplication temperature sensitive vegetables:

Asparagus, sweet potato, pointed gourd and ivy gourd are sensitive to low temperature. The propagating materials of these vegetables can be well- maintained during winter season before planting their cuttings in early spring-summer season for higher profit.

Seed production practices in protected structures:

Seed production of parental lines and HSP of Pumpkin cv PH-1 in net house:

The seed production of pumpkin consisting two part- first, multiplications of parental line and second hybrid seed production. The seed production in open field condition has a greater risk of virus infestation and spreading of Downey mildew disease in moist environment which ultimately reduce the seed yield as well as seed quality. The growing of parental line in open field, an isolation of 1000 m is essentially pre requisite of pumpkin cultivation. The high incidence of red pumpkin beetle in early growth period, fruit fly at fruit development stage and fruit rot during maturation period are the major challenges in organizing successful seed production programme of parental line. The sharp rise in temperature during fruit development in May greatly influence the fruit set, fruit development, seed yield and quality produce Therefore, seed production in net house gives higher yield with higher fruit weight, fruit length, total number of seed etc. The disease incidence chance is also very low in net house due to this seed quality become high when compared it with open field condition.

Seed production of parental lines and HSP of bitter gourd in insect proof net-house:

Bitter gourd is the most important cucurbitaceous vegetable crop widely cultivated in Tamil Nadu, Uttar Pradesh, Maharashtra, Kerala and Karnataka States. In North Indian condition, the severe attack of Downey mildew disease limit the success of seed production in open field condition. Therefore insect proof net-house has gain popularity for HSP in bitter gourd among farmers. In net house , the plant produce more number of fruits, higher fruit weight, more number of seeds , higher seed yield etc. The physical property of seed viz. Seed length, Seed coat weight, Cotyledon weight also higher in net house in compared with open field condition.

Hybrid seed production of summer squash in insect proof net-house:

Summer squash are warm-season crops. They grow best during hot weather and cannot tolerate frost. Plants are usually killed by one hour or more of frost (temperature below 0°C, 32°F). Therefore, planting in the field when soil temperatures are high enough for good germination and all chance of frost has passed. For early summer squash production, plastic mulch and/or row covers will raise soil temperatures and provide some frost protection. But cultivation in insect proof net house gives higher yield with fewer Incidences of diseases (Squash mosaic virus and Powdery mildew).

Hybrid seed production of cucumber in net house:

Cucumber (*Cucumis sativus*) a member of the Cucurbitaceae family, are susceptible to damage from wind and susceptible to severe disease, pest attack when growing in open field conditions. In net house condition, vine length and number of leaf nodes were significantly more as compared to open field condition. The vine length, number of leaves, fruit weight, fruit length and fruit width were higher under insect proof net house compared to open field. The seed yield/fruit, seed yield/plant and total seed yield can also get higher in insect proof net house in respect to open field condition. The seed quality attributes, viz. germination percentage, seedling length, seedling dry weight, vigour index I and II and seed moisture content immediately after harvest has superior in insect proof net house in comparison to open field conditions. So Hybrid seed production of cucumber in net house is beneficial for farmers.

Cherry Tomato Seed Production under Protected Conditions:

Cherry tomato (*Solanum lycopersicum var. cerasiforme*), a wild relative of slice tomato, is one of the emerging tropical vegetable crop under protected cultivation. The site selected for for construction of protected structures should be slightly elevated so that it will get good air movement and ventilation. Cherry tomato is self pollinated crop, so isolation distance-For OPV seed production- 50 m and 25m (F & C) from one variety to another variety and for Hybrid seed production - 200m and 100m (F&C).Separate block system for both male and female parent should be adopt to avoid contamination and 5 m distance should be maintain within the block. Seedlings were raised inside the high-tech nursery in the disinfected multi-celled plastic plug tray cells. Plug tray should be filled with well-decomposed and sterilized soil less media, consisting a mixture of cocopeat, vermiculite and perlite in the ration of 3:1:1 (on a volume basis). :- Pruning of all internal branches (suckers) was done, to encourage a single leader. It was done early in the day when plants are turgid but dry and also suckers were snapped out easily from leaf axils results a clean wound that heals easily. In the polyhouse, good ventilation does not occur and it is very difficult to rear the bumble bees so pollination through Air blower method between the 10:00 a.m. to 11:00 a.m. will give best result in terms of seed setting, yield and seed quality. The better performance of seed quality and yield were recorded when plants were retained upto 5 truss/plant. The stage of harvest is an important factor that influences the seed yield and quality in many crops having indeterminate growth habit. Hence, harvesting at 65 DAS will give best result in terms of seed yield and seed quality attributes .Overall we can say that cherry seed production under subtropical conditions (north India) should be organized under semi-environment controlled polyhouse and pollination with air-blow method at 11:00 am should be practiced for higher seed yield and quality.

Operation followed under protected cultivation:
Training and pruning

Source-sink relationship affects the growth habit, fruit bearing pattern and seed yield in cucurbits and solanaceous vegetables. In tomato, the growth habit can be indeterminate, semi-determinate or determinate. The indeterminate varieties/hybrids are preferred for hybrid seed production inside the greenhouses. Such plants can be grown over a long period and produce a number of fruit trusses. Indeterminate tomato varieties are staked and trained upright. Pruning of side branches is done to maintain single stem or maximum double stem. Seed production of determinate or semi-determinate varieties is less popular and not preferred under greenhouse conditions. Usually first to fourth cluster at each branch are selected for emasculation in case of hybrid seed production. In single stem, terminal pinching is carried out after 6 to 10 clusters. Lateral shoots are removed regularly. Defoliation of leaves commences at the time of setting of fourth cluster only. The training and pruning is a very regular process in greenhouse tomato crop hence a careful attention is always helpful in high seed yield.

Pruning in sweet pepper is normally limited to the shoots that grow on the stem below the first branching, or to some of the weak side shoots. Pepper leaves have a rather low level of photosynthetic efficiency and consequently a large area of active leaves is necessary to produce sufficient dry matter. Pruning is done only in few cases where the growth is luxuriant. Under protected cultivation, the stem structure of pepper is often too weak to take the load of the fruits; hence there is a need to train the plant. Pepper plants should be trained upright by allowing two main branches after removal of first terminal bud in a way to expose the leaves to the maximum light, the canopy must always be ventilated. The sweet pepper seed crop can be grown for a period of 9 to 10 months depending upon the climatic conditions of the area. The eggplant has an upright growth habit, hence horizontal strings fixed on either side of the plant row are enough to support them. A good pruning system consists of removing the side shoots upto the position of first flower appearance, allowing two branches to develop from the first terminal flower node, followed by periodic removal of shoots from the inner part of the plant and removal of the oldest leaves suffice to allow good air exchange and a balanced framework of plants.

Cucumber requires a supporting system in order to grow vertically by means of its tendrils. Plastic or fiber strings are useful for training. They hang down from wire stretched at height of 1.5 to 2.0 m. Pruning operations are summarized here under needs regular and careful attention for cucumber seed crop.

Long- fruited cultivars*:* The side shoots and fruits on the main stem are removed up to a height of *60-70* cm. The fruits are then allowed to set on the main stem up to a height of 2 or 3 meter. Side shoots up to 2 m length are not allowed. Above 2 m length, three branches are allowed to develop. The fruits are allowed to set up to' first 2-3 nodes. Miss shaped fruits and old leaves are removed to improve the aeration.

Short-fruited cultivars: The fruits and side shoots of the main stem are removed up to a height of *40-50* cm. Further pruning is done as follows:

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

Parthenocarpic varieties; In gynoceious or parthenocarpic cucumber varieties, one single stem is allowed from the beginning of the plant and fruits are allowed on the main stem only. Three seed crop of such varieties are possible under greenhouse conditions in a period of one year.

Muskmelon; The single stem training is the commonest system. The plants are trained upright. All branches below 6-8 nodes are removed. Female flowers are retained on branches emerging from 9 to 16 nodes on the main stem. After fruit set the tips of the branches are pinched off retaining 2-3 leaves per branch. The top of the main stem is pinched off after 25 nodes. In double stem training system, the main stem is pinched off at the second leaf stage and the plants are trained upright with 2 main branches. The secondary branches appearing on each of the 2 main axis may be pinched off after the first fruit-set or two leaves afterwards. Maximum 3 to 4 fruits are allowed per plant for optimum growth. The tips of the two main branches are pinched off up to 20 to 25 nodes. The middle portion of the plant should be allowed to retain the fruits. After harvesting first 3 to 4 fruits, further fruits may be allowed to set. In muskmelon, the duration of seed production can be doubled by this way to increase the seed yield.

Watermelon; The main stem is trained upright along with 3-4 strong branches with the help of plastic strings. The first female flower, if it develops below 8-10 nodes on the main stem, is pinched off. In the middle portion of the plant 2-3 fruits are allowed to develop between 12 to 25 nodes. The growing tip of each branch after 2^{nd} or 3^{rd} node is pinched off. For small-fruited varieties, 4 fruits are allowed to develop per plant. The developing fruits are provided a support using nylon net bags if insect pollination has been used in the protected structures.

Summer squash; The main stems and branches are short, thus, making the plant bushy. And ad such does not require any training and pruning. The older leaves are, however, removed for proper aeration. The winter squash has long vines and needs upright training. The main stem is pinched off at 4 nodes allowing two strong branches to develop. Two fruits are allowed to set on each branch between 12-16 nodes. The main branches are pinched off at 30 nodes. Each developing fruit is provided with a support using a nylon net bag.

Emasculation and pollination

The synchronization among the parental lines is managed by staggered sowing time. In solanaceous vegetables, the emasculation of the perfect flower on the seed parent is done a day prior to anthesis, leaving the petals intact. Such petals turn yellow (in tomato), purple or white (in brinjal) and white (in sweet pepper) on the day of anthesis. Flowers with under developed inverted stigmas are pinched off. A vibrator collects fresh pollen from several plants of male parents on the day of anthesis. Since only ripen pollen are shed by vibrating the flowers, such pollen have the highest viability. Pollen is collected in a small cup attached to a finger ring or other container as per need. Pollination is done by dipping the stigma into the pollen mass. Half of the calyx of pollinated flowers is removed to distinguish it from un pollinated flowers. In eggplant, the stigma is quite receptive a day prior to anthesis. Hence, emasculation and bud pollination can be done simultaneously, a day prior to anthesis, which is quite successful. Since the bees do not visit the emasculated flowers in solanaceous crops, bagging of emasculated flowers is not necessary. Pollen grains can be stored for a long period i.e. 1 to 2 months at 0^0C using silica gel for their proper drying.

The sex expression in cucurbits is mainly monoecious, andromonoecious and gynoecious. The perfect flowers on 'the seed parents' in muskmelon and cucumber are emasculated a day prior to anthesis that is not required in parthenocarpic varieties. The perfect flowers of watermelon on the other hand are not emasculated, as the anthers do not produce viable pollen. The emasculated flowers are bagged in order to avoid chance self-pollination. In monoecious plants, the female flowers are bagged a day prior to anthesis. The male flowers are either collected in the evening a day prior to anthesis and are kept in a moist polythene bag or collected early in the morning (5 am) on the day of anthesis. Pollination is done on the day of anthesis by dusting pollen on the stigma of the female flowers. Pollination work commences at 7 am and completed by 9.30 am. Pollinated flowers are rebagged to avoid contamination by visiting bees.

Pollination work continues-up to 15 days in muskmelon and cucumber and up to 10 days in watermelon and squash. Emasculation and pollination work requires 20-25 laborers/day/acre in case of muskmelon and cucumber. Pollination and bagging in watermelon and squash requires 12-15 laborers per day/acre. Insect pollinators like honey bees (*Apis melifera* or *Apis indica*) are largely used in cucurbitaceous vegetables under protected seed production but proper and careful management of the pollinators is required to avoid pollinators destruction. Similarly, in case of tomato, 'bumble bees' are the best pollinators among insects but they are not available in India. Hence, only option left is to use electric bee or vibrators or hand pollination in open pollinated varieties.

Advantages; Seed production under protected structures has many fold advantages that are given below.

1. Off-season seed production of high value cucurbits is possible
2. Seeds of vegetables can be produced all the year round by avoiding the season.
3. Higher seed yield / unit area can be obtained
4. Productions of diseases free seedlings during rainy or post rainy season.
5. Provides the best opportunity for organic seed production of vegetables.
6. Uniform establishment of seed crops leads to quality seed production.
7. Early fruiting leads to advancement in seed production.
8. More fruit setting due to congenial climatic conditions under protection provides long duration for fruit setting.
9. Different cross pollinated crops/varieties belonging to same family/crop can be grown in adjacent greenhouses for seed production without any problem of isolation distance.
10. Handling is very easy during winter season.
11. Seed production is possible even if soil salinity is high using soil-less media.
12. Seed production of parthenocarpic varieties of cucumber is only possible under protected conditions.
13. More number of seed crops is possible under a protected structure in of one year.
14. Crop is protected from heavy rains and viral disease transmitted by insect vectors like white flies etc.
15. Since the protected area is always kept neat and clean thus objectionable weed or diseased plants etc. remains under check.

Limitations; The protected structures are capital intensive, required technical expertise and demand more labour, hence the production is high. It is also difficult to maintained use the pollinator's efficiently. Occasionally, the soil borne fungus becomes a severe problem for crop production.

Protected Cultivation of Horticultural Crops
Arvind Singh, Surender S Dhankhar and KK Dahiya (Eds)
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6. Drip Irrigation and Fertigation in Horticultural Crops

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Irrigation is an important aspect for horticultural crops in arid and semi arid regions. Proper supply of water and nutrients to plants is essential to ensure timely maturity, desired yield and acceptable fruit quality. Drip irrigation is one of the most efficient methods of water and nutrient application to horticultural crops and is being promoted to enhance water productivity and nutrient use efficiency amid concerns over water availability and environmental degradation. It is a method of irrigation (Fig. 1) where water is carried through a pipe system to the point of application and water is applied in the form of droplets at targeted spots (root spread area), leaving some of the space between the crops as dry.

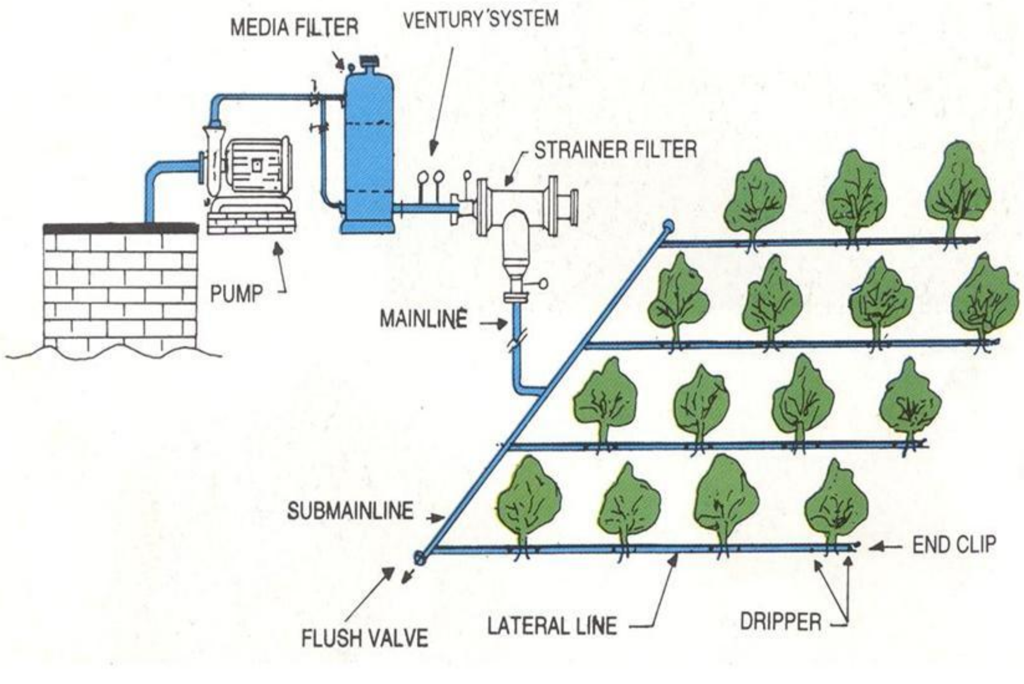


Figure 1: Typical drip irrigation system

Drip irrigation has been recommended for adoption for widely spaced crops such as orchards, vegetables and field crops like cotton and sugarcane. Many areas are experiencing water scarcity due to limited availability. Rising food demand is expected to continue to further increase pressure on water resources. Water management experts increasingly agree that the most effective long term strategy for dealing with water scarcity is the improved productivity of existing water resources i.e. harvest more food from limited water resources. Thus, adoption of water-saving strategies for efficient water use in agriculture is very important.

Water saving in drip irrigation method is due mainly to the controlled application of water in limited part of the total field, as compared to surface and sprinkler irrigation methods. Due to the manner in which water is applied by drip irrigation system, only a portion of the soil surface and root zone of the total field is wetted. Limited wetting of soils also means limited exploitable zone for water and naturally available nutrients that plant grown with drip irrigation can utilize necessitating frequent water and nutrient applications. As a consequence, the system must be more reliable since failure margins are very narrow and mistakes are more difficult to overcome. Once reliability of the system is ensured, limited wetted zone of plants under drip irrigation system helps to increases the effectiveness of the water and minerals supplied to the plants. Proper knowledge of the concepts of water and nutrient availability is essential to achieve the highest return from the investments made in drip irrigation systems.

Irrigation: Assessment of water requirement of the crop/plant under consideration is essentially an important step for the design and operation of any irrigation system. The importance of quantification of water requirement can be gauged from the fact that, despite the irrigation practices being used since time immemorial, experiments are still continuing to assess water requirement of different crops. Traditionally, irrigation systems apply a known depth of water based on moisture storage capacity of soil and frequency of application is decided based on consumptive use rate of the crop. Under drip irrigation system, frequency of application is a management decision depending on operational aspect of the system as well as crop response to the frequency of water application and water holding characteristics of the soil.

In general, any water deficits that reduce plant transpiration also decrease the production of biomass in all crops. However, for many tree crops where the fruit is the economic product, a reduction in biomass production does not always result in a parallel reduction in fruit production. It has long been known that fruits from trees grown under water deficits tasted better than those from fully irrigated trees. More recently, research results have suggested several advantages of deficit irrigation including improved fruit quality (for specific fruits) coupled with water savings. Nevertheless, some quality parameters, such as fruit size or appearance, may be negatively affected. Basically, there are two methods to implement deficit irrigation for a crop: (1) by reducing the amount of irrigation water applied, and (2) by increasing the period between irrigation cycles. Both strategies are easy to implement with drip irrigation.

Tree transpiration demand under a given climate is governed by its growth habit (evergreen vs. deciduous), canopy size and architecture, developmental stage, and stomatal behaviour. For most species the horizontal projection of their canopies seldom covers more than 70-75 percent of the ground. This is because their growth is often controlled by pruning to allow mechanization and to achieve a more even distribution of direct solar radiation to fruiting branches. As per the standard procedure crop consumptive use requirements for a mature orchard is estimated as [maximum value is considered for deciding design flow rate of the system]

$$ET_c = K_c \times ET_0 \qquad (1)$$

Where, ET_c: maximum evapotranspiration from a crop; K_c: crop coefficient; and ET_0: reference evapotranspiration. Typical K_c value for large mature citrus tree varies from 0.65 to 0.75 (Doorenbos and Pruitt, 1977). The peak water requirement of some of the fruits crops is given in Table 1.Under mulching evaporation component of ET may reduce by 50 to 80 % and transpiration increase by 10 to 30 %. Accordingly, the reported value of K_c should be reduced by 10 to 30 % if mulching is practiced.

Table 1. Peak water requirement (WR_{peak}) of different crops (adapted from EPC design manual)

S.No.	Crop	Spacing (m x m)	WR_{peak} (L/day/plant)
1	**Grapes**	1.8 x 1.2	10-12
		2.5 x 1.8	18-20
		2.5 x 2.5	24
		2.5 x 3.0	30
2	**Pomegranate**	3.0 x 3.0	30-40
		3.7 x 3.7	40-50
		4.5 x 4.5	70-75
3	**Guava**	4.5 x 4.5	70-80
		5.5 x 5.5	100-120
		7.5 x 7.5	120-130
4	**Mango/ Sapota / Chiku**	7.5 x 7.5	120-140
		9.0 x 9.0	150-170
5	**Orange / Lemon / Citrus**	4.8 x 4.8	75
		5.5 x 5.5	85
6	**Ber**	3.0 x 3.0	30
		3.7 x 3.7	55
7	**Banana**	1.8 x 1.2	22
		1.8 x 1.8	25
		1.5 x 1.5	22
8	**Papaya**	1.5 x 1.2	18
		2.1 x 2.1	20

For an orchard of incomplete cover crop consumptive use requirements is estimated as

$$ET_c = K_c K_r ET_0 \qquad (2)$$

Where K_r is a reduction coefficient relating the ET of an orchard of incomplete cover to that of a mature orchard and is related to the horizontal projection of the tree shade (ground cover) (Table 2).

Drip irrigation results into substantial saving of water, particularly during the initial stages of crop growth. Suggested water requirement for kinnow under drip irrigation is given in Table 3.

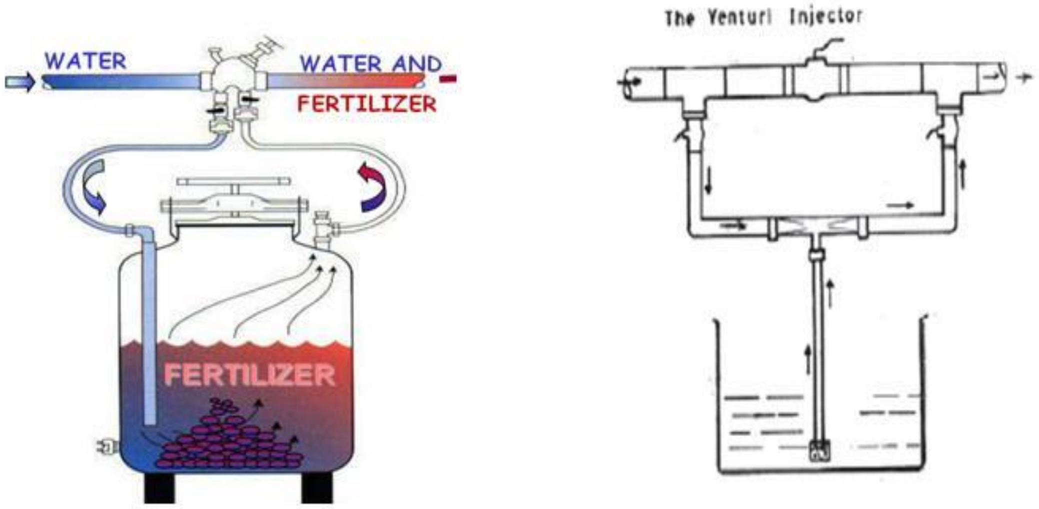
Table 2. Values of reduction coefficient (K_r) suggested by different authors

Ground cover (%)	Reduction coefficient (K_r)		
	Keller & Karmeli	**Freeman & Garzoli**	**Decroix CTG REF**
10	0.12	0.10	0.20
20	0.24	0.20	0.30
30	0.35	0.30	0.40
40	0.47	0.40	0.50
50	0.59	0.75	0.60
60	0.70	0.80	0.70
70	0.82	0.85	0.80
80	0.94	0.90	0.90
90	1.00	0.95	1.00
100	1.00	1.00	1.00

Table 3. Amount of water (litre/day/plant) to be applied to drip irrigated Kinnow

Month	Average canopy coverage (%)/Age of the plants (Yrs)				
	10 (0-2)	20 (3-4)	30 (5-6)	40 (7-8)	50 (9 & above)
Jan	3	6	9	12	15
Feb	6	12	18	24	30
March	9	18	27	36	45
April	13	26	39	52	65
May	16	32	48	64	80
June	17	34	51	68	85
July	13	26	39	52	65
August	12	24	36	48	60
September	11	22	33	44	55
October	8	16	24	32	40
November	5	10	15	20	25
December	3	6	9	12	15

Fertigation: Fertigation is the application of required fertilisers/plant nutrients (water soluble) with the irrigation water at a slow and controlled rate to meet the nutritional requirements at different stages of crop growth. Conventionally, whole of the fertilizer amount required by a particular tree is applied in two to three splits. Under Fertigation, the required amount of fertilizers can be applied in 10-15 or more splits depending upon the nutritional requirement at different stages of crop. With fertigation, plants can receive small amounts of fertilizer early in the crop's season when plants are vegetative. The dosage is increased as fruit load and nutrient demands grow and then decreased as plants approach the end of the crop's cycle. This gives plants the needed amounts of fertilizer throughout the growth cycle, rather than just a few large doses. Fertigation results in comparable or higher yields with substantial saving in fertilizer as compared to conventional. The right combination of water and nutrients is the key for high yield and quality of produce.



(a) (b)

Figure 2: Fertigation method (a) Fertilizer tank and (b) Venturi injector

Fertilizers (liquid or water soluble) can be injected into the drip system using either of the following three methods: (i) Fertilizer tank: part of the water flowing into the system is passed through a tank containing fertilizer and resulting solution again joins the main flow (Fig. 2a) or (ii) Venturi: A venturi is installed in a shunt pipe parallel to the main line and creating enough suction to such the fertilizer solution into the system (Fig. 2b) or (iii) **Fertigation pump**: A positive displacement pump is used to inject fertilizer solution into the mainline.

The main criteria to decide the amount, type and time of fertilizer application are: nutrient demand of the plants - total as well as at different growth stages; fertility status of the soil; physico-chemical properties of the soil; fertilizer characteristics - nutrient content and its form, solubility, convenience and cost of the available fertilizer material and irrigation water quality. A knowledge of nutritional requirement of different crops (Table 4) is very essential for successful fertigation.

Table 4: Nutrient removal (kg/ha) by some fruit crops,verified on 29-10-2015)

Crop	**Yield (t/ha)**	**N**	**P_20_5**	**K_20**
Apple	25	100	45	180
Banana	40	250	60	1000
Citrus	30	100	60	350
Grape	20	170	60	220
Mango	15	100	25	110
Papaya	50	90	25	130
Pineapple	50	185	55	350

It is important to understand that the total nutritional requirement of the fruit trees may not be affected by the irrigation method. However, it is common practice under surface irrigation to add the required fertilizers in 2-3 splits, whereas fertilizer application may scheduled in large number of splits as per the needs of fruit trees while practicing fertigation. For instance for Guava plants it is common practice under surface irrigation to apply half of the required nutrients (N, P_2O_5 and K_2O) in the month of February while the other half is applied in the month of July/August). On the other hand the same total amount of nutrients can be applied in weekly variable doses under fertigation (Table 5).

Table 5: Typical tentative fertigation schedule (g/ha/week) for Guava plants under drip irrigation (~275 plants per ha)

Age of plant (yrs)	Nitrogen (N)				Phosphorus (P_2O_5)				Potash (K_2O)			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
1	390	590	590	390	140	200	200	140	215	315	315	215
2	775	1160	1160	775	275	415	415	275	425	625	625	425
3	1160	1750	1750	1160	415	615	615	415	640	950	950	640
4	2340	1810	2340	1565	815	540	815	540	1275	850	1275	850
5	2925	1950	2925	1950	1015	675	1015	675	1590	1065	1590	1065
6	3500	2340	3500	2340	1140	765	1140	765	1590	1065	1590	1065
≥7	4375	2925	4375	2925	1275	850	1275	850	1590	1065	1590	1065

Nitrate nitrogen, sulphate sulphur and Boron are very prone to leaching in light or sandy soils and hence be applied in smaller amount with more frequent fertigation. Ammonium Nitrogen, potassium, calcium, magnesium and Molybdenum are moderately prone to leaching while phosphorus, copper, iron, Manganese and zinc are resistance to leaching. Micronutrients such as iron, zinc, copper and manganese are fixed in the upper layers of fine clay soils and little if any may be available to the feeding roots. Thus it is difficult to correct deficiency by soil applications. The use of foliar sprays is the most effective and quickest method for correcting such deficiencies.

The selected fertilizer must contain the required nutrient in available form to the plants or in that form which is readily converted to available form (Urea is readily converted to available form). Plants absorb nitrogen either as ammonium or nitrate, phosphorus in the form of orthophosphate and potassium in the form of K^+. The selected fertilizer must be completely soluble in water and should remain in solution, at least up to the end of application time. The selected fertilizer must not react adversely with the irrigation water and another fertilizer, if it is used in conjunction with other fertilizer. Mixing of fertilizer solutions that contain calcium with solutions containing phosphates or sulfates be avoided when the pH in the solution is not sufficiently acidic.

Other important considerations for irrigation and fertigation include:

- Fertigation frequency, in most situations, is not as important as a correct amount of application of nutrients to the crop during a specified period. On very sandy soils, more frequent fertigation might be necessary to avoid leaching losses. During rainy season, a bulk injection of larger amount of fertilizer might be needed to fertilize a crop when no water is required.
- Phosphorus should not be introduced into the drip lines if soluble Fe ions are present in the water. Once iron phosphate precipitates occur, flushing the system with nitric acid to dissolve the chemical precipitates is the only way to remove the precipitates from the irrigation lines.
- The performance of a micro-irrigation system may rapidly deteriorate if it is not routinely maintained by checking for leaks; backwashing and cleaning filters; periodic line flushing; chlorinating; acidifying (if necessary) and cleaning or replacing plugged emitters.
- Post installation system monitoring is essential to ensure optimum performance/ sustainability. Therefore, select a dealer with capability to provide professional/technical service.
- Check the wetted area at the surface for different plants. Any variation in the area of wetted surface, for fields with uniform soil types, indicates non uniform water application thereby indicating the need for some remedial measures.
- Drip irrigation system may not prove to be effective if it is to be used for old orchards previously being rainfed or being irrigated with surface methods. Micro sprinkler (35-250 lph), bubbler (270-480 lph) or basin irrigation may be more suitable for such old orchards having spread root system. However, drip irrigation system may be more suited and economical for newly grown orchards or high density orchards.

Protected Cultivation of Horticultural Crops
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7. Environment/Climate Control System in Greenhouses

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All greenhouse cultivation systems, regardless of geographic location, consist of fundamental climate control components, are depending on their design and complexity, and then can provide a greater or lesser amount of climate control, and subsequent plant growth and productivity.

Light: Light is essential for photosynthesis, the amount of natural light available is influenced by both the length of the day and the intensity of the light. Day length in turn is a function of region and latitude.

Greenhouse, have a problem of less light, since the plastics covering invariably reduces the light transmission, except in regions where the days are longer than the nights.

Light is used as an energy for conversion of Carbohydrates to sugars.

In white light photo synthesis increases with increasing illumination level unless it is limited by some other factor.

Radiation, Environment and Plant Growth

Sr. No.	Wave length (u m)	Spectral band (nanometer)	Identification UV	Plant effect	% Solar radiation
1.	0.115-0.28 0.28-0.315 0.315-0.400	280 280-315 315-400	UV (C) UV (B) UV (A)	Phytotoxic Detrimental Induces Dwarfness	9.293
			Visual		
2.	0.400-0.510 0.510-0.610 0.610-0.700	400-500 510-610 610-700	Blue green Yellow Red	Strong photosynthesis Low photosynthesis Strong photosynthesis	41.476
			Infra-red		
3.	0.700-2.00	700-2000	Infra-red	Plant elongation Seed Germination Photoperiodic Reversal of red light effect	42.720
4.	2.00-5.00 5 to 10 0.488	Above 2000	Infra-red	No. effect on photosynthesis converts into heat.	6.023+

Ultra Violet Stabilised Film absorbs all U.V. radiations, which are not conductive for plant growth:

Photosynthesis is maximum between 6000 to 60,000 Lx meters.

During summer the intensity of light would be around 3, 00,000 Lx meter, hence shading is highly necessary to reduce the light intensity.

Temperature

Temperature is the most important variable of the greenhouse climate that can and needs to be controlled. The majority of plants grown in greenhouses are warn-season species and are adapted to average temperatures in the range 17-27˚C, with approximate lower and upper temperature limits of 10˚C and 35˚C. If the average minimum outside temperature is below 10˚C the greenhouse is likely to require heating, particularly at night.When the average maximum outside temperatures during the day: however, if the average maximum temperature exceeds 27-28˚C then artificial cooling may be necessary. The maximum greenhouse temperature should not exceed 30-35˚C for prolonged periods.

Humidity

The second important variable of the greenhouse climate is humidity, which has traditionally been expressed in terms of relative humidity. Relative humidity within the range 60-90% is suitable to plant growth. Value below 60% may occur during ventilation in arid climates, or when plants are young with small leaves, and this can cause water stress. Serious problems can occur if the relative humidity exceeds 95% for long periods, particularly at night as this favors the rapid development of fungus diseases e.g. *Botrytis cinerea.* Maintaining the VPD above some minimum value helps to ensure adequate transpiration and also reduces disease problems. During the day, humidity can usually be reduced using ventilation. However, at night, unless the greenhouse is heated, the internal and external temperatures may be similar and if the external humidity is high; reducing the greenhouse humidity is not easy.

The limited supply of energy caused a significant increase in energy prices; the energy use of greenhouses has become a major economic and research issue. There are mainly two ways to increase the energy efficiency :a) reduction of the energy input into the greenhouse system and b) increase the production per unit energy. The major challenge is to find ways which meet both needs: improved energy efficiency combined with an absolute reduction of the overall energy consumption and related CO_2 emission of the greenhouse industry.

Clearly there are numerous technologies for greenhouse system which can be adopted by the growers enabling a better and more efficient climate control and energy use. However, many obstacles and constraints remain to be solved. High-level technology is out of reach for most of the growers because their cost is too high compared to the modest investment capacity of these growers.

Climate Control

Ventilation Cooling and Shading

Getting rid of the heat load is the major concern for greenhouse climate management in hot climate conditions. This can be realized by: (1) reducing incoming solar radiation; (2) removing the extra heat through air exchange; and (3) increasing the fraction of energy partitioned into latent heat.

Shade screens and whitewash are the major existing methods used to reduce the income of solar radiation; greenhouse ventilation is an effective way to remove the extra heat through air exchange between inside and outside, when outside air temperature is lower; and evaporative cooling is the common technique to reduce sensible heat load by increasing the latent heat fraction of dissipated energy. Other cooling technological solutions are available (heat pump, heat exchangers), but are not yet widely used, especially in the Mediterranean countries, because investment cost is yet very high.

Ventilation

One of the simplest and effective ways to reduce the difference between inside and outside air temperature is to improve ventilation. If the greenhouse is equipped with ventilation openings both near the ground and at the roof, then this type of ventilation replaces the internal hot air by external cooler one during the hot sunny days with week wind. The external cool air enters the greenhouse through the lower side openings while the hot internal air exits through the roof openings due to density difference between air masses of different temperatures causing the lowering of temperatures in the greenhouse.

Sufficient ventilation is very important for optimal plant growth, especially in the case of high outside temperature and solar radiation, which are common conditions during summer in Mediterranean countries. In order to study the variables, determining the greenhouse air temperature and to decide about the necessary measures for greenhouse air temperature control, a simplified version of the greenhouse energy balance is formulated.

The necessary ventilation rate can be obtained by natural or by forced ventilation. For effective ventilation, ventilators should, if possible, be located at the ridge, on the side walls and the gable. Total ventilator area equivalent to 15-30% of floor area was recommended by White and Aldrich (1975). Above 30%, the effect of additional ventilation areas on the temperature difference was very small.

Systems like exhaust fan; etc. can supply high air exchange rates whenever needed. These are simple and robust systems and significantly increase the air transfer rate from the greenhouse and allow maintaining inside temperature to a level slightly higher than the outside temperature by increasing the number of air changes. The principle of forced ventilation is to create an air flow through the house. Fans suck air out on the one side, and openings on the other side let air in. Forced ventilation by fans is the most effective way to ventilate a greenhouse, but consumes electricity. It is estimated that the annual needs for electrical energy for greenhouse ventilation is about 100.00 kWh per greenhouse ha.

Some key elements are: Ventilation fans should develop a capacity of about 30 Pa static pressure (3 mm on a water gauge), should be located on the leeside or the lee end of the greenhouse and the distance between two fans should not exceed 8-10 m. Furthermore, an inlet opening on the opposite side of a fan should be at least 1, 25times the fan area. The velocity of the incoming air must not be too high, in the plant area; the air speed should not exceed 0, 5 meter per second. The openings must close automatically when the fans are not in operation.

The obstruction offered byinsect-proof screens (fine mesh screens) to flow through the openings results in air velocity reduction and higher temperature and humidity as well as an increase of the thermal gradients within the greenhouse.

Shading

The entry of unwanted radiation can be controlled by the use of shading or reflection techniques. Shading can be obtained by various methods such as by the use of paints, external shade cloths, use of nets (of various colours), partially reflective shade screens and water film over the roof and liquid foams between the greenhouse walls. Shading is not the ultimate solution to be used for cooling greenhouse, because it affects the productivity. However, in some cases, a better quality can be obtained from shading. One of the most used methods adopted by growers due to its low costs is white painting, or whitening the cover material. The use of screens has progressively been accepted by growers and has gained, through the last decade, a renewed interest as shown by the increasing area of field crops cultivated under screen houses while roof whitening, due to its low cost, is a current practice.

The whitening applied onto a glass material enhanced slightly the PAR proportion of the incoming solar irradiance, thus reducing the solar infrared fraction entering the greenhouse.

This characteristic of whitening could represent an advantage with respect to other shading devices, especially in warm countries with high radiation load during summer. Another advantage of whitening is that it does not affect the greenhouse ventilation, while internal shading nets.

2.1.3. Evaporative cooling

One of the most efficient solutions for alleviating the climatic conditions is to use evaporative cooling systems, based on the conversion of sensible heat into latent heat be means of evaporation of water supplied directly into the greenhouse atmosphere (mist of for system, sprinklers) of through evaporative pads (wet pads).

- Fog system can be high (40 bars) or low (5 bars) pressure systems. High pressure systems produce droplets of 10-30 µm while low pressure systems produce droplets with diameter higher than 200 µm. High pressure systems are more effective that low pressure.
- The nozzles of the fog system should be located at the highest possible position the greenhouse to allow water evaporation before the water drops to crops on the ground.
- During the operation of the fog system a vent opening of 20% of the maximum aperture should be maintained.
- The pad material should have high surface, good wetting properties and high cooling efficiency. A suggested padthickness in 200 mm. It is very important that there are no leaks in the pad where the air can pass through without making contact with the pad.
- The pad area depends on the air flow rate necessary for the cooling system and the permissible surface velocity over the pad. Average face velocities are 0.75-1.5 meter per second. The pad area should be about 1 m^2 per 20-30 m^2 greenhouse area. The maximum fan-to-pad distance should not be more than 40 m.
- Fans should be placed on the lee side of the greenhouse. If they are on the windward side, an increase of 10% in the ventilation rate will be needed. The distance between the fans should not exceed 7.5-10 m, and the fans should not discharge towards the pads of an adjacent greenhouse less than 15 m away.
- When starting the cooling system, the water flow though the pad should be turned on first to prevent the pads from clogging. When stopping the cooling system in the evening, the fan should be turned off before the water flow through the pad.
- A basic air flow rate of 120-150 m^3 per m^2 greenhouse area per hour will permit satisfactory operation of an evaporative cooling system.

Heating

Greenhouse heating is essential even in countries with temperate climate in order to maximize crop production in terms of quantity and quality and thus to increase the overall efficiency of greenhouse. Heating costs not only have a critical influence on the profitability, but in the long term may also determine the survival of the greenhouse industry. Apart from the costs problems associated with high energy consumption, heating is associated with environmental problems through the emission of noxious gases.

Heating for anti frost protection

In these greenhouses heating was used to protect crops from freezing. It is also used to keep air temperature in greenhouse in levels above critical thresholds for condensation control. Usually a unit heater is enough. Other useful recommendations for heating a greenhouse in order to avoid freezing of plants are:

- To back the north wall to an existing structure such as a house or outbuilding. This rear wall offers extra wind protection and insulation.

- Use water to store heat (a sample passive solar heating system). We can use barrels or plastic tubes filled with water, inside the greenhouse to capture the sun's heat. The heat accumulated during the day will be released at night when temperatures drop.
- Insulate your greenhouse. If your greenhouse is constructed of plastic, insulate with a foam sheet. These sheets can easily be placed over the structure at night and removed during the day. Also install an additional layer of plastic to the interior of the green house for added insulation.

CO_2 enrichment

Inside an un-enriched greenhouse, the CO_2 concentration drops below the atmospheric level whenever the CO_2 consumption rate by photosynthesis is greater than the supply rate through the greenhouse vents. The solution is to increase the ventilation rate through forced air, to improve design and management of the ventilation system, or to provide CO_2 enrichment to enhance crop photosynthesis under the low radiation conditions. Enrichment reportedly increases crop yield and quality under a CO_2 concentration of 700-900 µmol mol^{-1}. One of the main restrictions is the short time duration available for an efficient use of CO_2 enrichment, due to the need to ventilate for temperature control .The fact that greenhouse have to be ventilated during a large proportion of the daytime makes it uneconomical to maintain a high CO_2 concentration during the daytime. However, some authors advise supplying CO_2 even when ventilation is operating to maintain the same CO_2 concentration in the greenhouse as outside and enriching to levels of about 700-800 µmol mol-1 during the periods when the greenhouse is kept closed, usually in the early morning and the late afternoon.

Optimal CO_2 enrichment depends on the margin between the increase in crop value and the cost of providing the CO_2 gas. Attempting to establish the optimal concentration by experiment is not feasible because the economic value of enrichment is not constant but varies with solar radiation through photosynthesis rate, and with greenhouse ventilation rate through loss of CO_2. The optimal CO_2 set point depends on several influences: the effect of CO_2 on the photosynthetic assimilation rate, the partitioning to fruit and to vegetative structure, the distribution of photosynthate in subsequent harvests, and the price of fruit at those harvests, as well as the amount of CO_2 used, greenhouse ventilation rate and the price of CO_2. The reduction in production caused by depletion is comparable to the reduction resulting from the lower temperature caused by ventilation to avoid depletion, compensating the effect of depletion is much cheaper than making up the loss by heating. The two principal sources of CO_2 for enrichment are pure gas and the combustion gases from a hydrocarbon fuel such as low sulphur paraffin, propane, butane or natural gas.

Dehumidification

Condensation is a symptom of high humidity and can lead to significant problems, including germination of fungal pathogen spores, including Botrytis and powdery mildew. Condensation occurs when warm, moist air in a greenhouse comes in contact with a cold surface such as glass, fibreglass, plastic or structural members. Condensation can be a major problem and it is unfortunately one which, at least at certain times of the year, is almost impossible to avoid entirely.

How to dehumidify greenhouse?

- Combined used of heating and ventilation systems
- Absorption using a hygroscopic material
- Condensatoin on cold surfaces
- Forced ventilation usually with the combined used of a heat exchanger
- Anti-drop covering materials

The use of anti-drop covering materials is an alternative technology for greenhouse dehumidification. (The "anti-dripping" films that contain special additives which eliminate droplets and form instead a continuous then layer of water running down the sides) The search for anti-drip cover materials has been mainly focused on the optical properties of the cover materials.

When to dehumidify?

Dusk: Reduce humidity to 70-80% as night falls to prevent condensation.

Dawn: Reduce humidity to prevent condensation, and jumpstart transpiration as the sun rises.

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8. Artificial Media

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Growing the horticultural crops in the media other than the soil is called soil-less media. Generally, field soils are unsatisfactory for the production of plants in the containers because they do not provide proper aeration, drainage and water holding capacity required by the plants. Therefore, to improve these conditions several soil-less media have been developed and utilized in vegetable production. Due to relatively shallow depth and limited volume of the container, growing media must be amended to provide the appropriate physical and chemical properties necessary for the plant growth.

The containers of various shapes and sizes with drainage holes are required for soil-less culture and the system is called container system. The containers are filled with desired sterile mix and placed in the double row in the greenhouse. Transplants are produced in a soil-less mix, such as peat / vermiculite or rockwool and transplanted into the containers. The soil-less mix usually contains some fertilizer to start the plants. Containers are irrigated and fertilized through a drip irrigation system in which a polyethylene pipe delivers water and fertilizers down the double row of containers and each containers is irrigated from the emitter. The culture ensures easy handling, sterilization of new media is necessary, reduction in the risk of spread of water borne pythium root rot in the greenhouse, and the capacity of a butter for water and fertilizer in case of power outages.

Advantages

1. Growers who do not have their own field are also able to grow vegetables other crops.
2. It has wide adaptability to produce vegetables in greenhouses, kitchen gardens, in the houses and in the areas where suitable soil areas are not present.
3. Soil-less culture media is free from pathogens and nematodes.
4. It provides good aeration and drainage.
5. Nutrient control: complete analysis of soil-less culture media is possible, which economizes the fertilizer use.
6. Labour economics: Less handling time, sterilization, weeding, fertilizer application and watering.
7. The light weight of soil-less substrates reduces the cost of transportation.

There are different soil-less media, which are used for the cultivation of vegetable crops in greenhouse and they are as follows:

a. Peat: It consists of the remains of aquatic, marsh bog or swamp vegetation, which has been preserved under water in a partially decomposed state. Composition of different deposits varies widely, depending upon the vegetation from which it is originated, state of decomposition, mineral nutrient and degree of acidity. It is very stable source of organic material that holds a great deal of water and air. It does not decompose quickly.

Peat is quite acidic (pH 3.5 – 4.0) and limestone is added to adjust the pH. Younger and light coloured peat does a better job of providing air space than does older and darker peat. Peat is the most widely used soil-less medium because of its wide availability and relatively low cost.

b. Perlite: Pertile is grey-white silicaceous material of volcanic origin mined from lava flows. The crude ore id crushed, screened and heated in furnaces where the small amount of moisture in the particles change to steam, exploding the particle to small, sponge like kernels. It is very light, weighing only 6 to 8 Ibs/cubic feet. The high processing temperature gives a sterile product. Perlite pieces create tiny air tunnels that allow water and air to flow freely to the roots. Water will adhere to the surface of perlite but it is not absorbed in to the perlite aggregates. It is neutral in pH and has negligible cation exchange capacity. Although costs are moderate but perlite is an effective amendment for growing media.

c. vermiculite: This is a micaceous mineral, which expands markedly when heated. Chemically, it is a hydrated magnesium-aluminium-iron silicate. It is very light in weight (6 to 10 Ibs/cu. ft.), neutral in reaction and insoluble in water. It has a near natural pH. Vermiculite is very desirable component of soil-less media because of its high nutrient and water retention, good aeration and low bulk density. It is generally not used with soil.

d. Sphagnum moss: commercial sphagnum moss is the hydrated remains of acid bog plants such as *Sphagnum pappilosum and Sohagnumpalustre.* I is relatively sterile and light in weight with high water holding capacity. It consists of water holding cells so as being able to absorb 10 to 20 times its weight of water. It also consists small amount of minerals.

e. Leaf mold: Among the leaf type, maple, oak, sycamore and elm are suitable for leaf mold. After the composting of leaves to 12 to 18 months leaf mold is ready for use. It may contain nematodes as well as weed seeds and noxious insects and diseases, so it should be sterile before use.

f. Bark: Bark is partially composted and screened material of plant origin. When bark is removed from logs, varying quantities of cambium and young wood are included. These materials decompose faster than bark and accentuate the nitrogen tie-up problem. It is beneficial to obtain bark from local sources to avoid cost of transport.

g. Rockwool: Rockwool is produced by burning a mixture of coke, basalt, limestone and possibly slog from iron production. The actual composition is approximately 60 % basalt, 20 % coke and 20 % limestone. It is formulated to prescribe higher density to provide the air and water holding requirement of plants. It is used in cubes for propagation and in slabs for finishing crops. Insulation and acoustical-grade rock wool is suitable for plant growth. The granular form has very high available water and aeration properties. Although slightly alkaline, it is not buffered and has negligible CEC. It neither contributes nor holds nutrients to any extent.

h. Polystyrene form: It helps in bringing improved aeration and light weight to root substrate. It is white synthetic product containing numerous closed cells filled with air. It is extremely light, does not absorb water and has no appreciable CEC. It is neutral and thus, does not affect root substrate pH levels. Polystyrene can be obtained in beads or in flakes. Beads from 3 to 10 mm and flakes from 3 to 10 mm in diameter are satisfactory for pot plant substrate. It is highly resistant to decomposition.

i. Sand: Sand is a basic component of soil, its particle size ranges in diameter from 0.05 mm to 2.0 mm. fine sand (0.05 mm -0.25 mm) does little to improve the physical properties of a growing media and may result in reduced drainage and aeration. Medium and coarse sand particles are those which provide optimum adjustment in media texture. Although, sand is generally the least expensive of all inorganic amendments. It is heaviest which may result in prohibitive transportation cost. Sand is a valuable amendment for both potting and propagation media.

j. Rice hulls: These are by-product of the rice milling industry. Rice hulls are extremely light in weight and very effective in improving drainage. The particle size and resistance to decomposition of rice hulls and very similar. However, N depletion not much serious problem in media amended with rice hulls.

k. Calcined clays: Calcined clays are formed by heating montmorrillonitic clay minerals to approximately 690 C. the pottery like particles formed are six times as heavy as perlite. They have relatively high cation exchange as well as water holding capacity. It is very durable and useful amendment. This inorganic soil amendment is generally used to increase the number of large pores, decrease water holding capacity and improve drainage and aeration.

l. Bagasse: Bagasse is a waste by-product of sugar industry. It may be shredded and / or composted to produce material which can increase the aeration and drainage properties of container media. Because of its high sugar content, rapid microbial activity results after the incorporation of bagasse into media. This decreases the durability and longevity of bagasse and influences nitrogen levels. Although bagasse is readily available at low cost (usually transportation), but its use is limited.

m. Coco-peat: it is a by-product of coconut husk. After grinding the husk, coco-peat is ready. Now a days it is commercially used in the pot cultivation of vegetables in the polyhouse. After soaking in water, it swells 15 – 18 times more than that of its original weight. It is more suitable, cheaper as well as available in ample quality. It is available in loose form as well as in compressed bricks. Coco-peat is considered best in providing aeration, drainage and life to media.

n. Sawdust and shavings: These are by-product of lumber mills. These materials decomposes at a faster rate than bark and because of its wider C:N ratio (1000:1) a greater amount of nitrogen is tied up in the root substrate. Saw dust is composted with additional nitrogen for one month to increase the quantity of nitrogen. It continues to decompose during use in pots or greenhouse benches. It is close to neutral in pH when thoroughly composted.

Media preparation and fumigation

Soil mixes used for greenhouse production of potted plants and cut flowers are highly modified mixtures of soil, organic and inorganic materials. When top soil is included as a portion of the mixture, it is generally combined with other materials to improve the water holding capacity and aeration of the potting soil. Many greenhouses do not use topsoil as an additive to the soil mixes, but rather use a combination of these organic and inorganic components as an artificial soil mix. When managed properly as to watering and fertilization practices, these artificial mixes grow crops that are equal to those grown in top soil.

Media preparation for greenhouse production

The media used in greenhouse generally have physical and chemical properties which are distinct from field soils.

- A desirable medium should be a good balance between physical properties like water holding capacity and porosity.
- The medium should be well drained.
- Medium which is too compact creates problems of drainage and aeration which will lead to poor root growth and may harbour disease causing organisms.
- Highly porous medium will have low water and nutrient holding capacity, affects the plant growth and development.
- The media reaction (pH of 5.0 to 7.0 and the soluble salt (EC) level of 0.4 to 1.4 dS/m is optimum for most of the greenhouse crops).
- A low media pH (<5.0) leads to toxicity of micronutrients such as iron, zinc, manganese and copper and deficiency of major and secondary nutrients while a high pH (>7.5) causes deficiency of micronutrients including boron.
- A low pH of the growth media can be raised to a desired level by using amendments like lime (calcium carbonate) and dolomite (Ca-Mg carbonate) and basic, fertilizers like calcium nitrate, calcium cyanamide, sodium nitrate and potassium nitrate.
- A high pH of the media can be reduced by amendments like sulphur, gypsum and Epsom salts, acidic fertilizers like urea, ammonium sulphate, ammonium nitrate, mono ammonium phosphate and aqua ammonia and acids like phosphoric and sulphuric acids.
- It is essential to maintain a temperature of the plug mix between 70 to 75ºF. Irrigation through mist is a must in plug growing. Misting for 12 seconds every 12 minutes on cloudy days and 12 seconds every 6 minutes on sunny days is desirable.
- The pH of water and mix should be monitored regularly.

Pasteurization of greenhouse plant growing media

Greenhouse growing medium may contain harmful disease causing organisms, nematodes, insects and weed seeds, so it should be decontaminated by heat treatment or by treating with volatile chemicals like methyl bromide, chloropicrin etc.

Agent	Method	Recommendation
Heat	Steam	30 min at 180° F
Methyl bromide	10 ml/cu. ft. of medium	Cover with gas proof cover for 24-48 hr. Aerate for 24-28 hr before use.
Chloropicrin	(Tear gas) 3-5 ml/cu. ft. of medium	Cover for 1-3 days with gas proof cover after sprinkling with water. Aerate for 14 days or until no odour is detected before using.
Basamid	8.0 g/cu.ft. of medium	Cover for 7 days with gas proof cover and aerate for atleast a week before use.
Formalin	20 ml/l of water (37%)	Apply 2 l/cu.ft. cover for 14 to 36 hr and aerate for at least 14 days.

Disinfection of the growing media can also be achieved by fungicides or bactericides

Fungicides and their effect on a few fungi

Chemical	Rate of application	Effect against
Captan	2 g/l of water	*Pythium, Fusarium, Rhizoctonia and Phytophthora. Some extent to root and stem rot, white mold,black rot, crown rot and damping off.*
Metalaxyl + Mancozeb (Ridomil MZ 72 WP)	1 g/l of water	*Pythium*, *Phytophthora*, *Fusarium* and other soil borne pathogens

Temperature necessary to kill soil pests

- 115°F for water molds (*Pythium* and *Phytophthora*)
- 120°F for nematodes
- 135°F for worms, slugs and centipedes
- 140°F for most plant pathogenic bacteria
- 160°F for soil insects
- 180°F for most of weed seeds
- 200°F for few resistant weed seeds and plant viruses

Fumigation in greenhouse

Physical propagation facilities such as the propagation room, containers, flats, knives, working surface, benches etc. can be disinfected using one part of formalin in fifty parts of water or one part sodium hypochlorite in nine parts of water. An insecticide such as dichlorvos sprayed regularly will take care of the insects present if any. Care should be taken to disinfect the seed or the planting materials before they are moved into the greenhouse with a recommended seed treatment chemical for seeds and a fungicide –insecticide combination for cuttings and plugs respectively. Disinfectant solution such as trisodium phosphate or potassium permanganate placed at the entry of the greenhouse would help to get rid off the pathogens from the personnel entering the greenhouses.

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9. Integrated Pest Management in Greenhouses

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Greenhouse production of horticultural crops is a profitable business; nevertheless plants will be attacked by pests at some point in time. In protective environment, pest situation often develops more rapidly and with greater severity than outdoors. Due to rapid multiplication of insect pests, sucking pests in particular, growers often resort to repeated sprays of chemical pesticides, leading to pesticide residues, environmental degradation and pest resurgence coupled with mortality of natural enemies and non target organisms. Under such conditions, good agricultural practices (GAP) coupled with integrated pest management (IPM) are advocated as comprehensive solution. Integrated pest management is a sustainable approach to manage pests by combining cultural, mechanical, biological and chemical tools in a way that minimizes economic, health and environmental risks. The IPM is based on the principle that it is not necessary to eliminate all the pests but to suppress the pest population to a level at which these pests do not cause significant losses. Integrated pest management is adaptable to all greenhouse grown crops and involves specific techniques to manage pests. These techniques are:

- Sanitation
- Exclusion
- Cultural control
- Regulatory control
- Pest identification and life stages
- Mechanical control
- Physical control
- Biological control
- Use of bio-rationals
- Chemical control

Sanitation

Sanitation is key for controlling pests in greenhouses. The goal of sanitation is to eliminate all possible sources of the pest. The following practices should be used to keep the greenhouse tidy.

- A green house should be thoroughly cleaned before planting a new crop. Collect and destroy all leftover roots and debris after the final harvest leaving no chance of any stage of insects.
- Clean or sterilize the greenhouse to make it an insect free. Wash the walls, stem cracks and crevices and fumigate with appropriate broad spectrum insecticides. Also sterilize the media, troughs, trays, tools etc.
- During hot weather close the empty greenhouse for week to eradicate the pests.
- Avoid planting outdoor crops near greenhouse because they serve as host for insect pests and diseases. Follow weed control measure within and around (10-30 feet area) the greenhouse.

- Continue the sanitation practices throughout the growing period as well. The pruned material and over ripe fruits should be immediately disposed off.

Exclusion

Preventing insect or mite pests from entering the greenhouse is easier than attempting to kill them after they have entered the greenhouse. This includes temporary quarantine and inspection of all plants upon arrival from other greenhouses, and regular monitoring of stock plants used for propagation. Carefully inspecting new plants before placing them into a greenhouse can minimize problems with insect and mite pests. Insect proof screening physically excludes the entry of light weight, airborne insects like aphids, whiteflies, and thrips from the greenhouse through doors, cooling pads, and ventilation units. For greenhouses that are covered with plastic, the use of ultraviolet absorbing plastics can reduce insect problems.

Cultural control

Cultural control includes deep summer ploughing, use of resistant varieties, intercropping etc.

- **Deep summer ploughing:** Deep ploughing after harvesting and then closing the doors of greenhouse kills the soil inhabiting stages (pupae) of various insects.
- **Use of resistant varieties:** Managing pests with host plant resistance is not only economic but safer to environment as well. Varieties such as Nun 3020, Orobelle and Indira are tolerant to mites in sweet pepper. Similarly varieties GS-600, R-144, Delphi and Astoma of greenhouse tomato and Satis and Nun 9729 of cucumber are also tolerant to mites.
- **Intercropping:** Intercropping breaks the standard mono-cropping and limits the infestation of insects. Diverse cropping system besides frustrating adult insects from egg laying also deters the adult insects from damaging the crops due to emission of volatile allelochemicals by certain crops. Intercropping of marigold is also helpful as trap crop in cabbage, while as a repellent against plant parasitic nematode.

Regulatory control

It includes inspection of foliage and flowers (scouting) and the use of insect traps (monitoring) for detecting presence, and estimation of pest population.

- **Scouting:** Scouting procedures for most greenhouse grown crops are based on visual observations and are used to provide estimates of the pest population in protected environment. Scout the entire greenhouse in a consistent uniform pattern. Inspect the entire plant, including the soil surface for the presence of arthropod pests.
- **Monitoring:** It is a relative method of insect population estimation where no direct observations on the plants for the presence of insect-pests are needed. However, the pest population is estimated with the help of attractant traps. For whiteflies, aphids, thrips and leaf miner adults, yellow sticky cards are an excellent supplement to pest observation in the protected environment. Additionally, for thrips, blue coloured sticky traps can also be used. The traps are placed in a grid pattern and 1-2 yellow sticky cards per 100 square meter of floor area are used.

Pest identification and life stages

Identifying insect or mite pests, various stages and the number of each species in a greenhouse requires diligence, but this information is critical in order for greenhouse producers to adopt an appropriate control measure and avoid using unnecessary and inappropriate pest control material such as an insecticide or miticide.

Mechanical control

Mechanical control methods such as hand picking and use of sticky trap reduce the pest buildup. Some insects like tobacco caterpillar lays eggs in groups and newly emerged larvae feed gregariously. So collection and destruction of such eggs and larvae can minimize the pest population build up to a greater extent. Using yellow sticky trap reduce the pest population of various insect pests like whitefly, aphid, thrips etc., considerably.

Physical control

Physical methods of pest control involve manipulation of temperature, humidity, use of energy etc. Daily misting to maintain relative humidity of >90 % reduce the thrips and mite attack. Sprinkler irrigation system reduces mites build-up. Give hot water treatment to planting material or steam sterilization of planting beds.

Biological Control

Practically every crop pest has its natural enemies in the form of parasitoids or predators. The biological control involves a large scale multiplication and liberation of such agents, or creating conditions under which the naturally occurring agents can act effectively. Use of specific predators and parasitoids in greenhouse ecosystem to manage pests forms the basics of biological control. But to be effective, biological control must be well planned and begun when the target populations are low. In field situations, some very outstanding successes have been achieved by using biocontrol agents, but the method suffered a set-back owing to the large-scale and indiscriminate use of insecticides.

Beneficial organisms commercially available for greenhouse pest management

Beneficial organism	**Pest controlled**
Parasitic wasps, *Encarsia formosa*	Whiteflies
Parasitic wasps, *Aphytis melinus*	Scales
Leafminer parasite, *Dacnusca sibiriica* and *Diglyphus isaea*	Serpentine leaf miners
Predatory mites, *Amblyseius californicus, Phytoseiulus longipes* and *P. persimilis*	Spider mites
Predatory mites, *Amblyseius cucumeris* and *A. mckenziei*	Thrips
Lady beetles, *Coccinella septempunctata* and *Cryptolaemus montrouzeri*	Various soft-bodied insects and eggs
Green lacewings, *Chrysoperla carnea*	Various soft-bodied insects and eggs

Use of biorational

These include plant products such as neem and bio-pesticides such as nuclear polyhedrosis virus and *Bacillus thuringiensis,* and non chemicals such as insect growth regulators.

Neem products

These insecticides are based on extracts from the tropical and subtropical neem tree, *Azadirachta indica*. Azadirachtin, the most commonly used material, is derived from the oil of neem tree seeds. It acts as an insect growth regulator, insect feeding deterrent, repellent, oviposition inhibitor, sterilant, and/or direct toxin. The other material derived is the clarified hydrophobic extract of neem oil, which suffocates and desiccates insects and mite pests. Neem oil has contact activity only so thorough coverage of all plant parts is important.

Microbials

These are insecticides containing micro- organisms such as bacteria, virus or fungi that cause diseases of insects. They are usually very specific for the targeted insect pest and are slow-acting, typically requiring repeat applications. *Bacillus thuringiensis* (*Bt*) and nuclear polyhedrosis virus (NPV) are used against the larval stage of moths (caterpillars). *Beauvaria bassiana* is a fungal pathogen or entomopathogenic fungus used against aphids, mites, thrips and whiteflies.

Insect growth regulators

Insect growth regulators, (IGRs) are used to kill the young (immature) stages of plant feeding insects including mealybugs, scales and whiteflies etc. Insect growth regulators regulate insect development and are typically placed into three general categories: juvenile hormone mimics or analogs, ecdysone antagonists, and chitin synthesis inhibitors. Juvenile hormone mimics, or analogs, inhibit development and cause insects to remain in an immature stage, thus preventing insects from completing their life cycle. Ecdysone antagonists disrupt the molting process of insects by inhibiting metabolism of the molting hormone ecdysone. Chitin synthesis inhibitors interfere with enzymes during the molting process that stimulate the synthesis and formation of chitin, an essential component of an insect's exoskeleton. As a result, insects fail to reach adulthood because they die in an immature stage, or they mature into sterile adult females.

Chemical Control

Due to their easy accessibility, sure and quick action against the target pests, chemical control still remains first choice of farmers. Under protected environment, in order to avoid the contamination of produce from pesticide residues, insecticide resistance and resurgence of insect pests, the insecticides should be used judiciously considering certain aspects like persistency and waiting period of pesticides and economic threshold level. The following steps are recommended when using any pesticides:

- Insecticide should be chosen considering the picking interval and waiting period. Also, the insecticides should be quickly alternated with their counterparts from different groups, so as to avoid development of resistance in target pests. Growers should be aware of the insect pest biology and appropriate sprayer and nozzle.
- Judicious use of pesticides is essential in terms of dosage, frequency, time and schedule.
- Proper application is most important steps in pest control efforts.

Greenhouse Insect and Mite Pests

Major insect and mite pests of greenhouse crops include aphids, thrips, whiteflies, caterpillars, leaf miner and mites. In addition to damaging the crop, some insects also act as vector of various viral diseases.

Insect-pests scenario under protected environment in India

Group	Insect and mite pests	Host	Damaging symptoms
Aphids	*Aphis gossypii*	Capsicum	Cause stunting growth with curled, twisted or distorted leaves and deformed fruits. Also excrete honeydew on foliage, stems and fruits allow the growth of black sooty moulds. Heavily attacked leaves can turn yellow and eventually wilt. Aphids feeding on flower buds and fruits may cause malformation.
	Macrosiphoniella sanborni	Chrysanthe-mum	
	Macrosiphum luteum	Orchid	
	Myzus escalonicus	Strawberry	
	Myzus persicae	Capsicum, Gerbera etc.	
	Toxoptera aurantii	Orchid	
Thrips	*Thrips tabaci*	Gerbera	Thrips suck the cell sap from leaves, flowers, buds and young fruits of a crop. Feeding causes flower or leaf buds to abort or emerging leaves to become distorted. Heavily infested leaves have a mottled or silvery appearance.
	Thrips palmi	Gerbera	
	Scritothrips dorsalis	Rose	
Whiteflies	*Bemisia tabaci*	Gerbera, capsicum etc.	Both the nymphs and adults of whitefly feed on plant cell sap and causes yellowing of leaves,
	Trialeurodes	Tomato,	

	vaporariorum	cucumber, capsicum, gerbera, and more than 30 hosts	defoliation, stunting and distortion of plant growth. As a byproduct of feeding honeydew is excreted and that alone can be second, major source of damage
Caterpillars	*Spodoptera litura*	Rose, tomato, capsicum, cucumber etc.	They are mainly foliage feeders, but occasionally damage fruits. Skeletonize the leaf surfaces and devoured the entire plants.
	Helicoverpa armigera	Capsicum, tomato, carnation	Tomato fruit borer feed on blooms, as well as immature and mature fruits. Heavy infestations of these caterpillars can destroy the crop.
Leaf-miner	*Liriomyza trifolii*	Tomato, cucumber, chrysanth-emum, gerbera, and many ornamentals	Larvae mine into the tender leaves in zig-zag manner and scrape chlorophyll making winding trials on leaves in distortion of leaf lamina and retardation of growth.
Mites	*Tetranychus urticae* (Spider mite)	Tomato, capsicum, cucumber, carnation, gerbera etc.	Heavy infestations of the two-spotted spider mite produce fine webbing which may cover the entire plant. Generally they feed on the undersides of leaves, giving the upper leaf surface a speckled or mottled appearance. Leaves of mite-infested plants may turn yellow and dry up, and plants may lose vigor and die when infestations are severe. Yellow mite infested leaves become distorted and often curl inward; foliage may become darker than that of healthy leaves.
	Tetranychus neocalidonicus	Cucumber	
	Tetranychus cinnabarinus	Carnation	
	Polyphagotarsonemus latus (yellow mite)	Capsicum	
	Stenotarsonemus fragariae	Strawberry	

Management

Aphids

- In greenhouse conditions aphid population can be kept under control by using beneficial insects such as lady bird beetles, wasps, lacewings and other insects.
- Spray the crop with malathion 50 EC or dimethoate 30 EC @ 2 ml/litre of water.

Thrips

- Prevent the thrips from flying or moving into the greenhouse using small mesh screens.
- Daily misting and a relative humidity of 90% or higher reduce the population of thrips and mites.
- Use blue sticky trap to attract the adults.
- A predacious mite (*Neoseulus cucumeris*) can be very effective but it must be released over a period of several weeks to control thrips.
- Spray the plant with malathion 50 EC @ 2 ml/litre or cypermethrin 25 EC @ 1 ml/3 litres of water.

Whiteflies

- New crop should not be planted in or near greenhouse that currently have a whitefly problem.
- Seedling growers should take extra precautions to keep the seedling free of whiteflies.
- Sanitation should always be practised and infested plant parts should be destroyed.
- Use nitrogen and irrigation judiciously.
- Remove alternate weed host *Abutilon indicum*
- Use yellow sticky traps regularly which reduce the menace of whitefly.
- Use the parasitic wasp (*Encarsia formosa*) in greenhouse.
- Use plant product such as neem as repellent of whitefly.
- Spray malathion 50 EC @ 2 ml/litre of water during active period.

Tobacco caterpillar

- Remove and destroy all plant residues after final harvest of the crop.
- Collect and destroy the eggs and smaller larvae of this pest.
- Use pheromone traps @15/ha.
- Spraying of SNPV @ 500-600 LE/ha when larvae are not more than one cm long is suggested.
- Spray the plants with malathion 50 EC @ 2 ml/litre of water.

Tomato fruit borer

- Prevent the entry of adult moths into the greenhouse through large openings by covering the doors and by poly sheets or mesh.
- Release egg parasitoids such as *Trichogramma chilonis* in greenhouses.
- Spray the formulation of bioagents, *Bacillus thuringiensis* @ 500 g a.i./ha of greenhouse at 10 days interval.
- Spray HNPV of 500-600 LE/ha to eliminate the already existing larvae.
- Foliar spray of cypermethrin 25 EC or fenvelerate 20 EC @ 1 ml/litre of water is also recommended.

Leaf miner

- Adopt preventive measures to avoid the establishment of leaf miners.
- Release natural enemies in the greenhouse. e.g. *Diglyphus* spp.
- In severe infestation, spraying of dimethoate 30 EC or oxydemeton methyl @ 2 ml/litre of water can be done.

Spider mite

- Follow prevention and sanitation measures.
- Sprinkler irrigation system is found detrimental to mites and aid in control and in delaying build up of mite population.
- Predacious mites like *Amblyseius longispinous* can be released to control mites if the infestation is light.

Spray the plants with malathion 50 EC @ 2 ml or Prempt 20 EC 1.5 ml per litre of water.

Protected Cultivation of Horticultural Crops
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10. Diseases Management of Crops in Protected Cultivations/Greenhouses

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In India green house technology is still in its nascent stage. The area under green/poly house cultivation, in the end of 2011 was about 2000 hectares. Maharashtra, Uttarakhand, Karnataka and Jammu & Kashmir are the major states having cultivation of crops under green house. All these crops have high productivity in green houses due to reduction in competition, healthy environment, better nutrient management, increased surface area and longer crop duration.

Green house cultivation is a form of protected cultivation which has some level of control over plant microclimate to alleviate one or more of abiotic stress for optimum plant growth. The green house technology is more than 200 year old and Europeans were considered the pioneers in this field. Later with the advent of plastic during World War II a new phase in the glass house technology emerged. The world’s total greenhouse area is more than 307,000 ha which includes both plastic and glass poly houses. There are more than 50 countries in the world where cultivation of crops is undertaken on a commercial scale under cover. Green houses permit production of crops even in areas where winters are severe and extremely cold as in Canada and Russia, and also in areas where summers are extremely intolerable as in Israel, UAE, and Kuwait. Country wise area under green house crop production is a detailed below

Country	**Area under greenhouse production**
USA	>400 ha
Spain	25,000 ha
Italy	18,500 ha
Netherlands	89,600 ha
Israel	15,000 ha
Egypt	1000 ha
China	48,000 ha
Japan	>40,000 ha
South Korea	>21,000 ha

A greenhouse is generally covered with transparent material such as polyethylene, glass or polycarbonate. Depending upon the clading material and its transparency major fractions of sunlight is absorbed by the crops and other objects. These objects in the greenhouse in turn emit long wave thermal radiation for which cladding material has lower transparency with the result solar energy is trapped and resist the temperature inside the greenhouse (Nimje and Shyam, 1991).This is known as greenhouse effect. This rise in temperature in greenhouse is responsible for crop forcing in adverse climate. During winter month’s loss of trapped temperature should be minimized whereas, during summer months air temperature in greenhouse is to be brought down by providing cooling device or ventilation.

Greenhouses were initially built in areas with long, cold seasons to produce out-of season Vegetables, flowers and ornamental plants. Northern Europe is the paradigm of pioneering areas of greenhouse cultivation. Greenhouses protect crops against cold, rain, hail and wind, providing plants with improved environmental conditions compared to the open field. In greenhouses, crops can be produced out-of-season year-round with yields and qualities higher than those produced in the open field. Greenhouses have also allowed the introduction of new crops; normally foreign to the region (Germing, 1985).There are two basic types of greenhouse. The first type seeks maximum control in an environment to optimize productivity. In Europe, optimal conditions for year-round production are provided in the glasshouses of The Netherlands, Belgium, the UK and Scandinavia. The other type of greenhouse, which is very common throughout the Mediterranean area, provides minimal climatic control, enabling the plants grown inside to adapt to suboptimal conditions, survive and produce an economic yield (Enoch, 1986; Tognoni and Serra, 1989; Castilla, 1994). The ideal and stable environment with warm, humid and abundant food under green house provides an excellent platform for the development of diseases often more than field conditions. Most pathogens cannot be excluded from the greenhouse environment, for example airborne spores enter through doors and screens; soilborne pathogens enter through dust or contaminated soil on shoes, tools, or equipment; and many pathogens are introduced on seeds or contaminated propagating materials. Zoosporic pathogens get entry through irrigation water, and insects transmit both fungal inoculum and viruses. The optimum conditions like temperature, light, and fertilizer not only maximize plant growth but also favourable for pathogens. Moreover, warmth and humidity, due to the water vapour transpired by the plants and the lack of air exchange with the outside, provide ideal conditions for foliar pathogens such as Botrytis and powdery mildews. Because of high energy costs, ventilation is often reduced to prevent loss of heat. Disinfested soil or soilless substrates such as peat or rock-wool lack the microbial diversity and biological buffering present in a natural soil.

Preplant Sanitation for Disease Management

House Preparation

After harvesting of the previous crop remove as much of the previous crop debris as possible. This debris must not be discarded in a dump pile adjacent to the production site because plant pathogens can overseason in plant debris. All houses should be cleaned of all fallen plant debris and surfaces cleaned free of soil, media, etc. Production systems that have had incidence of root and stem diseases should be rigorously sanitized. Passive solarization during the noncropping period in summer is very much beneficial. Structures can be sealed completely after wetting media, surfaces etc. The temperatures generated will assist in the eradication of pathogens and other pests in the production area. All air intakes should be covered with insect-proof screens and soil-proof screens. Houses should be inspected for possible entry points of unsterile soil or insect vectors of plant viruses. Land adjacent to the production houses should be maintained by frequent mowing. Appropriate weed control is needed if weed population is high.

Media Preparation

Incidence of soil borne diseases should be carefully recorded. Infested bags or rhizosphere and adjacent soil should be discarded immediately after plant death. Infested media in troughs should either be discarded or sterilized. New media should be mixed upon disinfested concrete slabs to avoid exterior soil contamination. Trough structures should be thoroughly disinfested prior to being refilled. All troughs should be sterilized between crops depending on the house design, available sterilant products. In soil bed production system in the greenhouse soil should be solarized between cropping seasons.

Water Source

Where persistent soil borne diseases problems occurred even after soil sterilization, a possible source of infection may be irrigation water. Water from deep wells and tap water are usually free of this risk of pathogen intrusion. Also sump location should be checked, since surrounding land should be pitched away so there is no possibility of back flushing soil into the sump during heavy rains.

Tool and Surface Cleanup: Soil fungi can survive in dried soil on tools between seasons and certain viral and bacterial pathogens survive on hand tools between crops. Tools used for pruning, media transport, pollinating etc., should be disinfested between cropping seasons. Areas destined to contact tools or transplants should also be treated with a disinfestant.

Transplant Production

Transplant quality is extremely important for taking healthy crop. For the production of transplant only certified or disease free seed, protrays, and fresh sterile media should be used. Dropping one transplant onto unsterile soil can contaminate this plant with propagules of soil borne pathogens. Transplants should be produced in a separate greenhouse from ongoing crop production to minimize worker contact with these plants. Isolation of transplants will reduce the likelihood of disease spread from production areas.

Production Sanitation for Disease Management

Recommended sanitation steps that have been found successful in reducing the infection are given below:

1. To avoid the entry of wind-carried insects, soil etc directly from the outside in the production area, an 'air lock' type entrance to each production house is must.
2. Use of foot baths to prevent unsterile soil from being carried into the production space.
3. Restricted access by visitors to production and transplant houses.
4. Raising transplants at a height of at least 1 feet above the ground to minimize dust or splashing soil contamination of plants.
5. Prohibition of bidi, cigarette, and chewing tobacco use by workers involved in production areas, so as to minimize contamination by viruses present in tobacco.
6. Rigid hand-washing/scrubbing rules for personnel involved in pruning, pollinating, tying, or harvesting activities.
7. Filters on all air intakes to restrict air-blown soil and vector-insect entry.
8. Rigid vegetation control around the periphery of houses to avoid insect and pathogen buildup on weeds.
9. Periodic tool, pathway, and bench surface treatment with disinfestants.

Production areas should be examined for the initial symptoms of disease during routine crop maintenance activities. The earlier a disease is found and identified, the more effective removal of infected plant parts will be to stop or slow disease progress. For disease identification and suitable management options, growers should contact the nearest KVK or Govt. extension specialist or private agency that specialized in disease diagnosis.

Reuveni *et al*, (1989) observed a reduction in the number of infection sites of *B. cinerea* on tomato and cucumber when a UV-absorbing material was added to polyethylene film to increase the ratio of blue light to transmitted UV light. Blue photo selective polyethylene sheets have been suggested for their ability to reduce grey mould on tomato (Reuveni and Raviv, 1992) and downy mildew on cucumber (Reuveni and Raviv, 1997). Green-pigmented polyethylene reduced the conidial load and grey mould in commercial tomato and cucumber greenhouses by 35–75%. *Sclerotinia sclerotiorum* on cucumber, *Fulvia fulva* (Cooke) Cif. (= *Cladosporium fulvum* Cooke) on tomato and cucumber powdery mildew were also reduced. The influence of greenhouse structures and covers on greenhouse climatic regimes may have strong consequences for pests and their natural enemies, as they have for diseases. In high-tech greenhouses, regulation of temperature and water pressure deficit enables the creation of conditions less favorable to pathogens and, in some cases, more favorable to bio control agents. The use of heating to limit development of a number of pathogens is well known. Soil borne pathogens such as *Pythium and Rhizoctonia* can quickly grow and spread. The use of high root temperatures in winter grown tomatoes in rock wool offers a non-chemical method of controlling root rot caused by *Phytophthora cryptogea* Pethybr. & Lafferty. The high temperature was shown to enhance root growth while simultaneously suppressing inoculums potential and infection, and, consequently, reducing or preventing aerial symptoms. Careful control of the temperature also proved important in the case of hydroponically grown spinach and lettuce, in which it prevented or reduced attack by both *Pythium dissotocum* Drechs. and *Pythium aphanidermatum* (Edson) Fitzp.. Attacks of *P. aphanidermatum* on nutrient film technique (NFT) grown lettuce in Italy were related to the high temperature (>29°C) of the nutrient solution. Root rot was inhibited by reducing the temperature below 24°C. Hydroponic systems (rockwool, nutrient film, or ebb and flow) present another set of disease problems. In this closed recirculating system, zoosporic pathogens can easily spread in the water system

Considerations of biocontrol in green houses: The protected nature, expensive crops and microclimatic conditions in the green house make it rather imperative to suitably alter the disease management strategies as per the requirements. There is lack of specific chemicals suited for green house conditions. Due to high registration and development costs and the lack of return on investment act as deterrents to chemical companies in registering products for the relatively small greenhouse market. Containment of toxic fumes from pesticides are hazardous to green house workers. Workers are at greater risk of fungicide exposure in the greenhouse because of the intensive nature of crop management. Most fungicides require a re-entry period before the workers can return to a treated crop and there is a harvest interval, a period of time between the last application and harvest. Moreover, many greenhouse crops are continuously harvested and therefore cannot use most fungicides. Due to frequent harvesting and direct table value of the produce, pesticides with lower waiting periods only can be used. Breakdown, weathering, and wash-off of chemicals on the leaves or in substrates are all lower in greenhouses than in the field, so fungicides may have a longer residual activity. Finally, the development of fungicide resistance in the pathogen may be exacerbated by the intensive use and limited choice of fungicides in the greenhouse. There is increasing societal concerns about the environmental and health effects of fungicides. Large sprayers cannot be used in green houses due to the limitation of space.. Therefore, the grower must be extra careful in the long range planning, selection, use and application of pesticides in green house crop cultivation systems. That's why agriculture in greenhouses and protected structures offers a unique niche for the development and use of biological control agents

Suitability of biological control for greenhouses:

Of the commercial biocontrol products over half have applications in nurseries or greenhouses and many were specifically developed against the soil borne pathogens *Pythium and Rhizoctonia*, which are major greenhouse pathogens. The use of biocontrol is more prevalent in greenhouse and protected structures than in field crops, even though greenhouses account for only 0.02% of the area used in agriculture. Some of the very conditions that favor disease also favor the management of diseases with biological control agents. Environmental conditions such as temperature and relative humidity can be tightly controlled. Like the pathogen, biocontrol agents are also sensitive to environmental conditions, and an unfavorable environment in the field has been cited as a reason for failure or inconsistent performance. Conditions in the greenhouse can be optimized for the biocontrol agent. For instance, biocontrol agents of powdery mildews are much more efficient when relative humidity can be maintained above 80%, a condition that is easily monitored under glasshouse conditions.The biological vacuum in soil substrates can also favor the establishment of biocontrol agents, provided they are applied before pathogen introduction. Logistics and economics of applying biocontrol agents in the greenhouse

Products registered for biological control of soil borne pathogens: Several formulations of either of the fungi *Gliocladium-Trichoderma* or the bacteria *Pseudomonas and Bacillus* have been widely used for biocontrol of soil borne pathogens. These products are not only registered *as* biofungicides but also used as plant strengtheners. In European countries, plant strengthen include inorganic compounds such as SiO_2, $NaHCO_3$, organic constituents such as compost, homeopathic compounds, and some containing microorganisms such as *Trichoderma harzianum,Bacillus subtilis, Pseudomonas, and Pythium oligandrum.* Details of available biocontrol agents for green houses are as follows:

1. ***Coniothyrium minitans:*** *Coniothyrium minitans* is a mycoparasite which destroys sclerotia of *Sclerotinia sclerotiorum and S. minor.* It is used for the control of *Sclerotinia wilt of* lettuce in greenhouse and rape in the field. *C. minitans* reduced the sclerotial populations at the soil surface, survived at least 39 weeks at a density of 104–105 CFU/g, and spread to infect sclerotia in control plots.

2. ***Gliocladium virens (Trichoderma virens):*** It is a soilborne fungi, developed for control of *Pythium ultimum and Rhizoctonia solani* in soilless mixes. The fungus produces two fungitoxic compounds, glioviren and gliotoxin compounds.

3. ***Trichoderma harzianum:*** *T. harzianum reduces Fusarium* crown and root rot of tomatoes grown in potting mix containing *T. harzianum* and transplanted into the field. In greenhouse trials, *T. harzianum* controlled *R. solani in poinsettia, geraniums, and Catharanthus,* and *Pythium on geraniums, impatiens, and petunias.* It inhibits the pathogens by mycoparasitism via production of chitinases, ¼ 1-3 glucanases and ¼ 1-4 glucanases,antibiotics, competition, solubilization of inorganic plant nutrients, induced resistance, and inactivation of the pathogen’s enzymes involved in the infection process.

Streptomyces griseoviridis: This culture is marketed in Europe and USA, under the name of Mycostop. It was originally isolated from sphagnum peat and was tested as abiocontrol agent against Fusarium wilt of carnations in commercial greenhouses.

5. ***Gliocladium catenulatum:*** It is a mycoparasite effective against damping-off, seed rot**,**root rot, and wilt pathogens. It is sold as a wettable powder that can be applied to the soil,roots, or foliage. In glasshouse trials with ornamental bedding plants, application by incorporation into the growing mix or drench reduced damping-off caused by *Pythium* and *Rhizoctonia.* In some cases, G. catenulatum was as effective as the fungicides. propamocarb or tolclofos.

6. **Non-pathogenic *Fusarium oxysporum:*** It is effective against Fusarium wilt diseases on carnation, tomato, cyclamen, and Fusarium crown and root rot on tomato. Mechanisms of action include competition for carbon, direct competition with pathogenic strains, and induction of host defenses.

7. ***Bacillus subtilis var. amyloliquefaciens:*** Several strains of **B. subtilis** tested on cucumber and tomato against *Pythium aphanidermatum and Phytophthora nicotianae* in a series of greenhouse trials. It shows growth promotion effect on corn and radish. *FZB C* and *G strains of B. subtilis produced*

Biological control of greenhouse diseases in India: In India, integrated pest management research has not matched the progress and problems of plant protection at large and green house cultivation in particular. *Trichoderma harzianum* and *T. viride* are the most common fungal bioagents used for suppression of soil borne plant pathogens. *Pseudomonas fluorescens,* used as addendum to FYM, effective against *Fusarium oxysporum, Pythium* spp, *Rhizoctonia solani*,Phytophthora spp., *Sclerotium rolfsii* and nematode parasites. The following table shows important diseases of green house crops in India and their biocontrol.

Diseases Crops Management

Diseases	Crops	Management
Powdery mildew	Capsicum, cucumber	*Bacillus subtilis (10g/l)*
Downy mildew	Cucumber	*Bacillus subtilis* (10g/l)
Fusarium wilt	Tomato, cucumber	*Trichoderma* spp. (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2)
Damping off	Capsicum, cucumber	*Trichoderma spp*. (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2)
Fruit rot	Tomato	*Bacillus subtilis* (10g/l)
Root knot nematode	Capsicum, cucumber, tomato	*Trichoderma spp*. (10g/m^2), *Pseudomonas fluorescens* (10ml/m^2)

Biopesticide	**Biocontrol organism**	**Target pathogen / disease**	**Crop**	**Formulation**	**Application method**
AQ 10	*Ampelomyces quisqualis*	Powdery mildew	Cucurbits, grapes, tomatoes, Ornamentals, strawberries	Spore powder	Spray
Sporodex	*Pseudozyma flocculosa*	Powdery mildew	Cucumber, tomato,Rose	Spore powder	Spray
PlantShield, Trichodex, Top shield	*T. harzianum*	*Gray mould*	*Vegetables and* ornamentals		
Ketomium	C. *globosum, C.cupreum, Colletotrichum*	Leaf spot	vegetables	Spore powder	Spray
Cease	*Bacillus subtilis*	*Anthracnose,* powdery mildew, leaf Spot, *gray* mould (*Xanthomonas, Pseudomonas)*	Vegetables and ornamentals	Spore suspension	Spray
Serenade *Cercospora*	*Bacillus subtillus*	Powdery mildew, downy mildew, leaf spot, Early and late blight,	Cucurbits, grapes, vegetables, ornamentals	Spore powder	spray
Bio-save	*Pseudomonas syringae*	Gray mould	Ornamentals and vegetables	Pellets (bacterial Cells)	Spray
Blight Ban	*Pseudomonas fluorescens Erwinia amylovora*	Russet inducing bacteria	Strawberry and tomato	Wettable powder (bacterial cells)	Spray

Stress Management in Capsicum

I. Physiological disorders:

I. Blossom end rot
II. Sunscald
III. Fruit cracks
IV. Fruit splitting
V. Fruit color spots
VI. Misshapen fruit

Blossom End Rot (BER)

l BER can be caused by reduced absorption and translocation of Ca into the fruit.l Ca deficiency can be due to low Ca in media, excessive salinity or moisture fluctuations in the media.

Management: Avoid the conditions of moisture stress or conditions of reduced transpiration. Weekly foliar applications of calcium nitrate can have a significant impact on reducing the amount of BER

Fruit Cracking: Characterized by the appearance of very fine, superficial cracks on the surface of the capsicum fruit. Ruptures on the cuticle at blossom end is Radial cracking or all over the fruit surface is Russeting. Fruit cracks may be due too high relative humidity (over 85%) Sudden changes in weather conditions (from hot sunny weather to cool cloudy weather or vice versa) or thick walled fruits(>8mm).

Management : Avoid high humidity. Use thin walled fruit varieties

Fruit Splitting: The development of large cracks in the fruit is a direct response to high root pressure. Factors that contribute to the development of high root pressure directly impact fruit splitting.

Management: Adjust the timing of the last watering in the day so as not to water too late. Eliminate any night watering cycles.

Color Spots: Yellow spots can occur on the outer surface of the fruit. High incidences occur in summer and in plants grown in high densities with high levels of N.

Management: Avoid capsicum varieties susceptible to this disorder

Diseases of Capsicum and their Management

Damping-off: Caused by species of *Pythium and Rhizoctonia solani.*· Common in soil grown crops. In pre-emergence damping-off areas in nursery are seen where no seedlings have emerged. Damping-off in young, emerged, seedlings is seen as a toppling over of the seedlings when root systems are destroyed by the fungi.

Management: Maintain proper sanitation practices in greenhouse.Provide optimal soil temperature, watering etc. to the plants. Avoid the conditions where young plants are stressed.

Fusarium stem and Fruit rot: Caused by *Fusarium solani.* Soft, dark brown or black lesions on the stems at nodes or wound. Black water-soaked lesions may also develop around the calyx, eventually spreading down the sides of the fruit.

Management : Clean greenhouse and good sanitation practices. Maintain good air circulation and avoid high relative humidity conditions (above 85%). Avoid wounding fruit and excessive wounding to the stems.

Gray mould: caused by ***Botrytis sp.*** Water-soaked spots that rapidly expand into large yellowish-green or grayish-brown. Irregular lesions on fruit that are soft and spongy in texture. Velvet-like fungus mycelium and spores are produced on the lesion surface under cool and humid conditions. The fungus produces overwintering structures called *sclerotia* in addition to other types of spores.

Management : Prestorage dry heat treatment.Hot air treatment at 38ºC for 48-72 h or Hot water treatment at 50 ºC to 53 ºC for 2 to 3 min.

Leaf spot: caused by *Colletotrichum capsici.* Leaves have necrotic areas.Small or large lesions on leaves and fruits.Stems and petioles may be girdled, and necrosis of inflorescences causes dieback and shrivelling.

Management: Use fungicide@0.2% Mancozeb , 0.1% Blitox 50 (copper oxychloride),0.1%

Anthracnose: caused by *Colletotrichum capsici* . Seed born. Water-soaked lesions on fruit that become soft and slightly sunken. Concentric rings within the fruit spots.

Management: Avoid alternate host and infected plant debris in polyhouse.Optimize the humidity in polyhouse.

Bacterial soft rot: caused by *Erwinia carotovora.*The fleshy fruit peduncle is highly susceptible and is frequently the initial point of infection.Initially, the lesions on the fruit are light to dark-colored, water-soaked, and somewhat sunken. The affected fruit hang from the plant like a water-filled bag.

Management

Use chlorinated wash water to reduce populations of soft rot bacteria and to reduce the risk of infection during washing. Allow fruit to dry thoroughly. During packing and storage, the fruit should be kept clean and maintained in a cool, dry place.

Pepper Mild Mottle Virus (PMMV): Symptoms include the development of obvious bumps on the fruit as well as color streaking and green spotting as the fruit matures. Fruit tend to have pointed ends and may also develop sunken brown areas on the surface.

Management: The virus is spread by the routine handling of the young plants, especially at transplanting. Do minimum mechanical activities during cultivation. Grow resistant varieties.

Tobacco Mosaic Virus: The symptoms of infection first appear on the leaf as a necrosis along the main veins accompanied by wilting and leaf drop. New growth on the plants may exhibit mosaic symptoms as well as distorted growth.

Management: Use disease-free seed. Grow resistant cultivars. Destroy any infected plants.

Tomato Spotted Wilt Virus: The virus is spread primarily by thrips, particularly the western flower thrips. Leaves get blackish-brown circular spots, or tan spots bordered by a black margin. Fruit gets orange to yellow spots surrounded by a green margin.

Management: Control the virus is by controlling the thrips vector through insecticides. Do weed control to minimize the population of thrips and virus.

Common diseases of greenhouse Tomato:

Gray mold: Caused by the fungus *Botrytis cinerea*.A light-gray fuzzy growth that appears on stems and leaves. Soft rot of the stem end of the fruit can also occur. Most severe in greenhouses with moderate temperatures, high humidity and stagnant air.

Management: Increasing ventilation and air circulation to reduce humidity levels can be helpful, as well as timely fungicide applications.

Powdery mildew: Caused by the fungus *Oidium neolycopersici*. Common in humid greenhouses with poor air movement.White patches on the upper surface of leaves, defoliation as the spots develop into brownlesions.

Management: Increase air circulation and spacing between plants.Fungicide sprays also can be effective if used when symptoms are first noticed.

Management of Bacterial wilt diseases of solanaceous crops:

- Use disease free tubers and seeds.
- Treat tubers with streptocycline 500 ppm concentration.
- Grow bacterial wilt resistant varieties of following crops –
- Brinjal: Arka Keshav (long type), Arka Nidhi (long type), Arka Neelkanth (long type),

- Pusa Anupam (round type)and Hissar Shyamal (round type), Singnath.
- Tomato: Palam Pink, Palam Pride and F1 7711, Arka Rakshak, Arka Abha, Swarna Sampada
- Chilli: Surajmukhi
- Disinfecting the cutting knives with suitable bactericide.
- Avoidance of surface water for irrigation, cutting of potato seeds and education.
- The incidence of wilt diseases in tomato was reduced by applying panchagavya which contains 20 ml of cow ghee, 50 ml each of cow milk, and curd, 40 ml of cow urine,400g of cow dung, 20 g of common salt and 10g bakers yeast.

Biocontrol agent *Pseudomonas fluorescens* and *Bacillus subtilis* found effective to control the disease.

- Crop rotation is not effective as the pathogen can survive for a long period (several years) in the soil and also attack a wide range of crops and solanaceous weeds. Crop rotation 2-3 years with wheat and *Crotolaria juncea.*
- Do not grow crops in soil where bacterial wilt has occurred.
- Rogue out wilted plants from the field to reduce spread of the disease from plant to plant
- Control root-knot nematodes since they could facilitate infection and spread of bacterial wilt
- Where feasible, extended flooding (for at least 6 months) of the infested fields can reduce disease levels in the soil.
- Soil amendments (organic manures) can suppress bacterial wilt pathogen in the soil Good results have been encountered by using biofumigation as soil treatment for bacterial wilt.
- Application of bleaching powder 12 -15 kg/ ha in the furrow during transplanting/ sowing tubers in the field.
- Actigard (acibenzolar-s-methyl) has shown to be effective, but only when inoculum densities are low.
- In India, CRA 66 rootstocks were used in grafting of tomato to reduce bacterial wilt in tomatoes (Tikoo, 1979). Several Hawaiian lines (Hawaii 7996-7998) have been identified as suitable candidates for resistance to bacterial wilt. This technique could be a very valuable tool for eliminating bacterial wilt in tomato, pepper, and eggplant production systems.

Sr. no.	Disease	Crop	Symptom	Management
1	Powdery mildew	Capsicum cucumber	Leaves, buds and stem are cover with white powdery coating. Affect leaves curl upwards	WettableSulphur(2g/l) Hexaconazole(0.5ml/l
2	Damping off/ Post damping off	Tomato, capsicum	Failure of seedling emergence from the soil results in patchy appearance of seedlings stand in the nursery in early stages of growth. (Pre-emergence) toppling over of infected seedlings at any time after their emergence from the soil resulting in mortality of the seedlings.	Soil solarization of nurserybed,Metalaxyl (1gm/l),Trichoderma (10gm/m2), Carbendazim(1gm/l)+ Captan (2gm/l)
3	Rootknot nematode	Tomato, capsicum	Root nodulation/galls on the roots	Drenching with Carbofuran (6g/m2)
4	Fusarium wilt	Tomato, capsicum	Yellowing and drooping of plants, wilting of leaves, stunting and browning of vascular system.	Metalaxyl (1gm/l), Trichoderma (10gm/m2)
5	Late blight	Tomato, capsicum	It is characterized by the appearance of brown dead areas on leaves, which initially appear as faded green patches and later turn into brownish blacklesions spreading rapidly during wet weather. Within 3-4 days of wet weather whole plant may get blighted	Ridomil (2.5ml/l), Mancozeb(2.5ml/l)
6	Buck eye rot	Tomato	Spots on tomato fruit mark with pale brown, concentric rings resembling slightly the marking on a buck eye.	Ridomil (2.5ml/l), Mancozeb(2.5ml/l) Copperoxychloride(3g/l)
7	Septoria leaf spot	Tomato	The spots appear as small, water soaked, more or less circular spots in outline and show definite brown colored margins with grey centers.	Mancozeb(2.5ml/l) Copper oxychloride (3g/l)
8	Bacterial wilt	Tomato, capsicum	Sudden drooping of leaves, without yellowing resulted in wilting of the plants.	*Pseudomonas fluorescens (10g/m2),*Bleching powder(300g/200m2), Streptocycline(0.1g/l)+ Copper oxychloride(3g/l)
9	Blossom End Rot (Calcium deficiency	Tomato	Lesions appears at blossom end of the fruit. The affected portions of the fruit become sunken, leathery and dark colored.	Calcium Carbonate (5g/l)

Diseases of Roses:

Die-back: This is the most serious of the rose disease in India. Earlier reports suggest that this disease was caused by fungus *Diplodia rosarum* Fr.As the term die-back implies, the disease causes the death of the plant from top downwards. The disease starts from the pruned surface of the twigs. Initially it may be observed to the extent to a few centimeters below the pruned end, but in the severe cases, the disease spreads further and kills the entire plant. Soil drenching with 2 g/l bavistin, benomyl or demosan, has also been reported to control the disease. Spraying with 0.2% captan or 0.2% mancozeb or 0.2% copper oxychloride immediately after pruning and then twice at 10 days interval is also effective for controlling dieback of rose

Black spot: This disease is caused by *Diplocarpon rosae* Wolf.This disease is also called leaf blotch, leaf spot, blotch and star sooty mold. Characteristics black spot 2-12 mm in diameter develops on upper leaf surfaces. These leaf spots are circular or irregularly coalescent with characteristic feathery, radiate, fibrillose margins of sub-cuticular mycelial strands. The infected leaves as they are observed should be clipped off and burnt. Preventive sprays of ferbam (0.1%) at fortnightly intervals, benlate or bayleton (0.1%) applied just before the appearance of the spots helps in managing the disease. Bavistin (0.1%) was found most effective fungicide against leaf spot caused by *Diplocarpon rosae*.

Powdery mildew: It is a major disease of the rose all over the world caused by *Sphaerotheca pannosa* var. *rosae* (Wallr) Lev.The disease affects all the aerial parts of the plant, though the leaves are found to be affected more. The younger leaves get curled, exposing the lower surface and such leaves are likely to be purplish than the normal leaves raised blister like areas develop in these leaves, which becomes coated with the white powdery growth of the fungus.

Common Diseases of Gerbera and their control measure

Powdery mildew (*Erysiphe cichoracearum*): The infection causes white powdery coating on the foliage. The plants should be lightly irrigated by drip irrigation system so that they can be protected by excessive humidity. Destroy the affected plants and the leaves. This disease can be controlled by spraying fenarimole (0.5ml /litre) or Dianocab (0.3 ml/litre).

Collar rot (*Phytophthora cryptogea*): The infection occurs just at the soil surface on the collar portion of the stem. In some cases the leaves turn yellow and the entire plant wilt. The disease can be controlled by drenching the soil in the root zone of the plants either with metalaxyl or with contact fungicide such as captan and copper oxychloride @ 0.2 mg/l.

Root rot

Several fungi namely *Phythium, Sclerotium rolfisii and Rhizoctonia solani* affect the root system of gerbera. Sterilizing the soil before planting and regular application of fungicide like copper oxychloride @ 0.2 mg/l to soil may help in controlling the disease.

Diseases of *chrysanthemum*

1) Root rot (*Pythium* spp or *Phytophthora* spp.): In this disease, the infected plant suddenly wilt the plant parts like roots, stems, leaves.

Control measures

i) Provide good drainage conditions to prevent water logging.

ii) Soil drench with thiram or captan or mixture of both at the rate of 2.5 g/m^2 area prevents the infection.

iii) Mancozeb, Metalaxyl and Fosetyl- also used for control.

2) Leaf spot (*Septoria chrysanthemella*): Greyish brown spots appear on leaves which turn yellow surroundings. When flowering starts, the infection occurs on flower buds, which rot completely. The disease spreads from down to upwards.

Control measures

i) Spraying with mancozeb at fortnightly interval helps in controlling the disease.

ii) Burning and destroying of infected leaves.

iii) Spray of Copper oxychloride (0.2%).

3) Wilt (*Verticillium dahliae*): The leaves turn yellow to grey and the branch or whole plant wilts gradually. It may occur due to a number of diseases, disorders or even just lack of water.

Control measures

i) Solarization of soil by using black polythene mulch during summer months.

ii) Soil treatment with Dithane M-45 (0.2%)

iii) Dipping of rooted cuttings in Benomyl suspension before planting. iv) Use of resistant varieties.

4) Rust (*Puccinia* spp): It is serious disease especially in the early spring. Brown spores appear in the underside of the leaves. Severely infected plants become very weak and fail to bloom properly.

Control measures

i) Sanitation and clean cultivation prevent the disease.

ii) Early removal of infected leaves.

iii) Dusting plants either with sulphur and other fungicides such as Zineb, Captan, etc. can be used.

5) Powdery mildew (*Oidium chrysanthemi*): There is powdery coating on the leaves appear. It may lead to defoliation.

Control measures: Use of Sulphur fungicides or Carbendazim.

Viral disease

Chrysanthemum stunt: - Overall reduction in plant size, foliage become pale in colour, flower may open prematurely. Disease occur diving pinching. This disease occurs during pinching.

Control measures: Use of cuttings from virus free plants.

Protected Cultivation of Horticultural Crops
Arvind Singh, Surender S Dhankhar and KK Dahiya (Eds)
CCS HAU, Hisar, 2015, pp 73-74.

11. High-Tech Nursery Raising of Vegetable Crops

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The Increasing susceptibility of vegetables to various biotic and abiotic stresses and very high cost of hybrid seeds have warranted the attention of vegetable growers to improve their nursery raising technology. Nowadays, high tech nursery has become full-fledged industry. For, protected cultivation. For successful protected cultivation seedling should be raised in high tech nursery only .High- tech nursery can be established as a small- scale industry in major vegetable growing areas especially in peri – urban areas.By this way the vegetable growers can get virus free, healthy and off season seedling as per their requirement generating extra employment to rural youth.

Plug – Tray Nursery raising

Vegetable seedlings or nursery can be raised in a number of containers. Plastic trays are standard ones used worldwide. Generally, plastic trays or portrays having different sizes of cells are used for raising seedlings. Generally, plastic trays or portrays having different sizes of cells are used for raising seedlings. These trays helps in proper germination , provide independent area for each seed to germinate , reduce the mortality rate , maintain uniform and healthy growth of seedlings , are easy in handling and storing, reliable and economical in transportation . These nursery trays may be fixed in thermocol base trays having same number and size of cavities before filling media. If thermocol base is not available only trays placed on floor or firm base may be used. Mostly artificial soilless media is used for raising healthy and vigorous seedlings in plastic portrays . Mainly three ingredients- cocopeat, vermiculite and perlite are used as root medium for raising nursery. These ingredients are mixed in a 3:1:1 ratio before filling in plastic portrays.

Root Medium

Coco peat: It is completely free from infestation of any pest or pathogen. It is commonly used as a medium for raising nurseries of vegetables and ornamental plants.

Perlite: It is light rock material of volcanic origin . it is essentially heat – expended aluminium silicate rock. It improves aeration and drainage . Perlite is neutral in reaction and provides almost no nutrients to the media.

Vermiculite: It is heat expended mica. It is very light in weight and has minerals for enriching the mixture (magnesium and potassium) for enriching the mixture as well as good water holding capacity. Neutral in reaction (pH), it is available in grades according to sizes.

Sowing and after care:

Seeds true to type and of good quality should be purchased fresh for each growing season. seeds are usually planted in shallow depth after pressing the media with finger in a gentle way into the potting plugs or cells which filled with media. After sowing of seed, a thick layer of vermiculite is given to cover for better germination as this media has water holding capacity. These portrays are kept in germination room at optimum temperature for early and better germination. Water is applied after sowing of seeds in each tray. Hundred percent humidity is maintained and when level comes down irrigation is applied. For raising good and healthy seedlings, optimum EC of irrigation water should be 1.6 to 1.7 with pH of 6.6 to 6.7.

Nutrients are applied in form of water soluble N:P:K (1:1:1) @ 140 ppm once a week through the fine sprinkler to maintain the uniformity .

Hardening of vegetable seedlings before transplanting in the main field is very essential for reducing transplanting shock and also to have better crop stand. Plants should be gradually hardened or toughened by acclimatizing them to anticipated growing conditions of fields, at least a week before planting them in main field. This is done by slowing their rate of growth to prepare them to withstand such as chilling, drying winds, shortage of water or high temperature. Generally, seedlings of all vegetables become ready for transplanting 28-30 days after sowing in plug tray.

Advantages of high tech nursery raising:

- Seedling can be raised under adverse climatic conditions where , it is not possible otherwise.
- Healthy seedlings can be raised.
- There is no chance of soil-borne fungus or virus infection to seedling as the nursery is grown in soilless sterilized media.
- Drastic reduction in mortality in transplanting of seedlings as compared to traditional nursery raising.
- Early / offseason planting is accomplished by raising such nursery.
- Easy transportation
- Weed free
- Better root development
- Approximate cost of nursery raising in a year is 3 to 4 lakhs and net profit of 4 to 6 lakh / 1000 m^2
- In this technology seed rate can be reduced to the 30 -40%as compared to open field.
- Saving the fertilizer and water of use of plug tray nursery.

Protected Cultivation of Horticultural Crops
Arvind Singh, Surender S Dhankhar and KK Dahiya (Eds)
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12. Hydrophonics

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Geoponics: The terms geoponic and geoponics refer to growing plants in a normal soil.

Disadvantages

- Presence of disease, insect and weeds in the soil.
- Excessive nutrient level could leach into local ground water tables or accumulate in the soil surface.
- Flooding of irrigation water cause high water table which reduces aeration and thereby, prevent root growth.

Hydroponics is a technology for growing plants in nutrient solutions (water and fertilizers) with or without the use of artificial medium (e.g., sand, gravel, vermiculite, rockwool, peat, coir, and sawdust).

Historical Background

- The technology was first reported in scientific literature in 1600 (Weir, 1991)
- Woodword grew mint plants without soil in England in 1669
- The term "hydroponics" was proposed by Setchell, based on the Greek word hydro (water) and ponos (working)
- Gericke was first person who used the term 'hydroponics' in 1929
- Nutrient solution was first developed by Sachs and Knap in 1938
- In India hydroponics was first introduced at Kalimpongin Darjeeling (WB) in 1947
- Cooper *et al*. developed the NFT in 1966
- Jensen and Collins developed Aeroponics in 1985

Advantages of hydroponic culture over soil culture (geoponics)

- Provide a controlled chemical composition of nutrient solution.
- There is no soil colloids present to immobilize any of the nutrients through adsorption.
- The frequent replacement of culture solution prevents the accumulation of toxic organic decomposition products.

- The growth of bacteria and fungi is minimized which may otherwise may cause diseases.
- Free from soil borne diseases and weeds
- Natural calamities such as floods, drought, erosion etc, can be avoided.
- This system can assume high yield with good quality produce.
- It allows the culture of greenhouse vegetables in areas where soils are not suitable for vegetable production.

Disadvantages

- This high-tech system calls for a higher investment compared to other commercial methods of cultivation.
- It requires huge investment and some basic knowledge of chemistry, plant physiology and crop botany has deferred many from adopting this technology.
- Slight mistake in calculating exact requirement of fertilizers may end up with deficiencies or toxicities in the crop**.**

Hydroponics Production Systems

Closed systems: The nutrient solution is re-circulated, continuously providing the nutrients that the plant requires.

Open systems: In open system the solution is discarded after use instead of recycling.

Type of Hydroponics

(i) Solution culture:

The plants are raised in pure nutrient medium containing only the desired elements. The pyre or any other clean hard glass vessels are used as containers and for plant support special engineered structures are required. To protect the roots from direct light and to check algal growth in the nutrient solution, the containers are covered o their outer surface with black paper. The aeration for the roots is provided with the help of vacuum lines which continuously keep on providing fresh filtered air to the nutrient solution. There are several culture media available but Knop's Sach's and Hoagland's media is commonly used.

(ii) Rockwool culture:

Rookwool is an inert, porus, sterile growing medium made from rocks that are heated at high temperature and made into thin fibres. The resulting fibres can be turned into slabs or bags as a loose rookwool for bag culture. The small cubes of rookwool are used for starting transplants. Slabs are packaged in white or white-on-black polyethylene sleeves. Slabs are laid in two rows and irrigated by micro irrigation with one emitter per plant. The rookwool slabs can be reused for up to three seasons. Rookwool culture has many advantages viz., ease of handling, installation and media removal, high water holding capacity, more precise control of nutrients and good air circulation. The major disadvantages of rookwool are the need for a leachate collection system and the need to replace the media every two or three season.

(iii) Nutrient Film Technique (NFT):

It is a type of 'water culture' system in which the bare roots are continuously bathed in a flowing nutrient solution. True NFT consists of growing plants in a shallow plastic-lined trough in which nutrient is flowed continuously. Roots spread out over the width of 12 inch channel and are continuously bathed in a thin film of flowed oxygenated nutrient solution. Channels are on a slope to allow the nutrient solution to flow from one end of the channel to the other and collected for return to the sump tank. Nutrient solution is pumped continuously from the sump tank back to the channels. Nutrient are added to the solution as needed and the solution may be replaced periodically to reduce the build-up of salts and disease organisms. In NFT system, channels and plants are arranged in the greenhouse similar to rookwool culture. It is expensive to install and require high degree of management and experts to operate the system to ensure correct irrigation and fertilization. The vegetable crops are adoptable to NFT system are tomato, cucumber.

The major problem of this system s high probability of quick recirculation of disease organism like pythium within the greenhouse. Management of nutrient concentration and pH of the solution is highly labour intensive and there is no water holding capacity in the event of power failure**.**

(iv) Aeropnics:

It involves the growing of plants in a trough or container in which roots are suspended and sprayed with a nutrient mist. The rooted plants are placed in a special type of box with computer controlled humid atmosphere. It is relatively new production system used especially for research purposes.

(v) Fogponics:

Fogponics is an advanced form of aeroponics which uses water in a vaporised form to transfer nutrients and oxygen to enclosed suspended plant roots. Using the same general idea behind aeroponics except fogponics uses a 5-10 micron mist within the rooting chamber and as use for a foliar feeding mechanism.

(vi) Aquaponics:

Aquaponic**s** refers to any system that combines conventional aquaculture (raising aquatic animals such as snails, fish, crayfish or prawns in tanks) with hydroponics (cultivating plants in water) in a symbiotic environment. In normal aquaculture, excretions from the animals being raised can accumulate in the water, increasing toxicity. In an aquaponics system, water from an aquaculture system is fed to a hydroponic system where the by-products are broken down by nitrification bacteria into nitrates and nitrites, which are utilized by the plants as nutrients, and the water is then re-circulated back to the aquaculture system.

Protected Cultivation of Horticultural Crops
Arvind Singh, Surender S Dhankhar and KK Dahiya (Eds)
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13. AgroMeteorological Information System - AgroMet InfoSys

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Information can be identified as the cornerstone to successful farming in the 21st Century. Agricultural producers already know that information is important and valuable. In the last decades several changes occurred in the field of agriculture and forestry. In the industrialized countries a specific attention has been devoted to the quality of products and to the environmental safety. On the other hand, in developing countries, due to the huge population increase, a strong need of food commodities exists along with a concern to maintain the sustainability of the system and reduce the danger of desertification and land degradation. In any case, the perspectives of climatic changes due to the global processes highlight the issues of forecasting the impacts of agricultural practices and on the environment. Currently, sensible changes in the general circulation pattern have occurred, both atmospheric and oceanic, as well as in the energy balance of the surface and in the increase of extreme events in temperate areas. In the meantime the world policy and economy changed to a more global perspective and relevant efforts have been made in the research of new technologies. Earth observation from space, progress in the field of computer science, information technology via the Internet system, development of electronic devices for monitoring environmental parameters, numerical meteorological models, crop models and seasonal climatological models for climate prediction, improved substantially our ability to measure, compute and control the natural processes Despite such improvements, our capacities did not develop at the same rate because of several reasons, i.e. difficulties in adapting to such rapid changes both in terms of mentality and of professional skills, lack of innovative organization and the poor capability to face new situations and possibilities. In particular in the agrometeorological sector, it is now time to shift from a philosophy of "agrometeorological bulletin" to a more innovative concept of "Meteoinformation System for Agriculture".

Agrometeorological Bulletins:

Agrometeorological information is part of the continuum that begins with scientific knowledge and understanding and ends with evaluation of the information. The meteorological bulletins for agriculture were thought, since the fifties, to give information concerning the main meteorological parameters such as sunshine, temperature, wind, rainfall and evaporation for a better crop management to the farmers and/or extension services. But since then, some indications have come from international agencies, such as WMO and FAO, to integrate this information with biological data on crops, on the related pests etc.

The guide to agricultural meteorological practices (WMO 1981) prepared by the WMO Commission for Agricultural Meteorology (CAgM), underlines in each chapter how agricultural meteorology depends on the combination of meteorological and biological data as well as on the agricultural practices. There must be relevant inputs and knowledge of soil science, plant physiology, plant pathology and biometeorological interrelationships etc for a skillful agrometeorologist.

Disseminating agrometeorological information is part of a process that begins with scientific knowledge and understanding and ends with the evaluation of the information. But, in order for this information to be useful, it must be accurate, timely, and cost-effective. To improve the production and the dissemination of information to agriculture in a useful manner, the following questions should be addressed:

- To whom is the information directed?
- -What is the utility of the information in relation to the decisions to be taken?
- Is the time of delivery coherent with the time for the adoption of decisions?
- Is the way of information diffusion adequate to convey it at the right time to the users?
- Is the language adopted understandable by the relevant category of users to whom the information is directed?
- Is it correct to produce a bulletin or is it better to think about an "agrometeorological information system"?

Each person responsible for the agrometeorological division in a meteorological service should ask himself this kind of question to plan the preparation of a bulletin or to check whether the current one is efficient enough.

Agrometeorological Information System:

The term ‘agrometeorological bulletin’ should be changed for two main reasons:

- The users of a bulletin could be various groups with different information needs; hence there should be the opportunity to prepare various kinds of "bulletins". Therefore it is more appropriate to talk about an Agrometeorological Information System;
- The bulletin evokes the idea of a printed document, but in many cases the use of other means are necessary to reach the targeted group, such as radio broadcasting or television.

The first step is to define the targeted group to be reached. The main groups identified are the following:

- Decision makers and the outreach services for agriculture and environment
- Farmers and
- Businessmen

Decision makers: The decision-makers are interested in monitoring the agricultural season to help the farmers in adverse years and to provide agroclimatological information for agricultural planning

Another important information for the decision makers is on extreme events causing damages to the agricultural system or to the environment, as in the case of hurricanes, extreme droughts, floods, frosts, strong winds, very intense rainfall etc. In that case, the users need to know the area affected and the intensity of the phenomena.

Farmers: The farmers are interested:

a) Before the beginning of the season, to know the characteristics of the season in order to plan, where possible, which crops to grow?

Examples of the Agrometeorological Information System

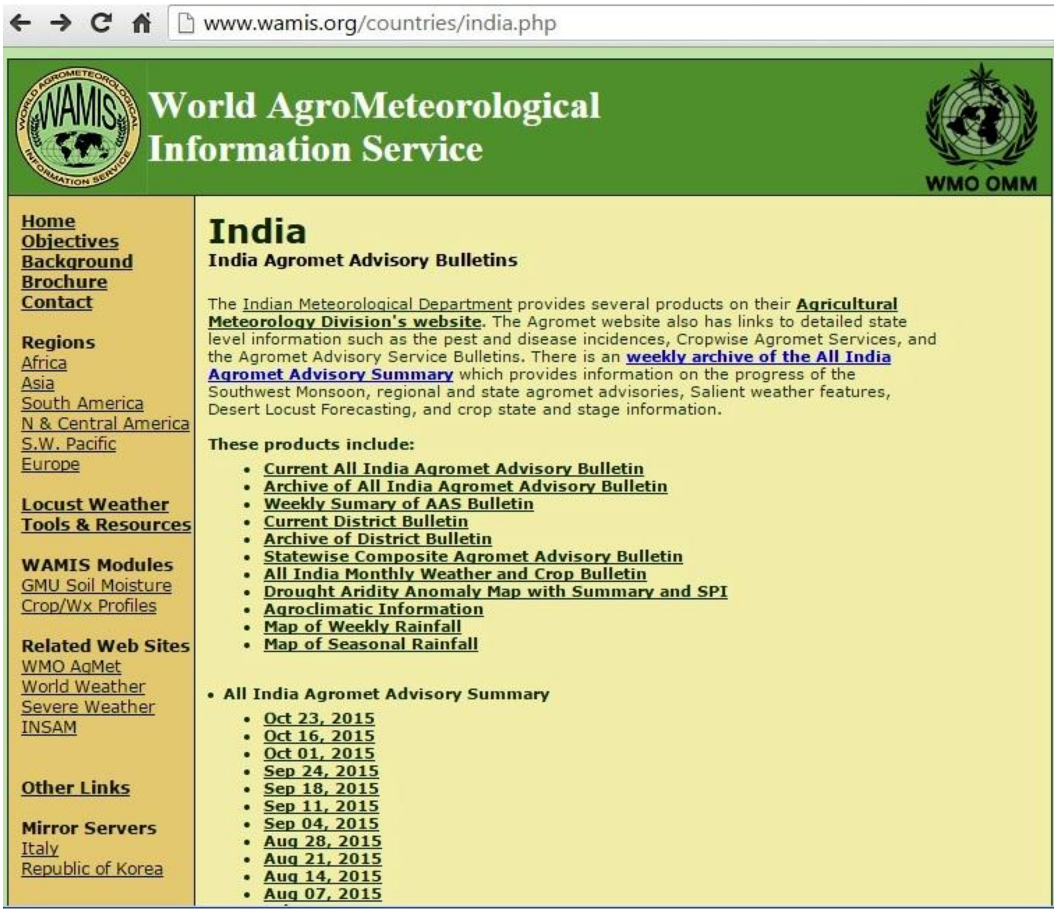

Figure 1. World AgroMeteorological Information Services (WAMIS)
http://www.wamis.org/

Nowadays, progress in the seasonal climatology combined with the earth observation from space of the sea surface temperature, brings the time closer when this will be possible operationally for many areas;

b) During the season, the farmers require information which allows them to take decisions in terms of crop management, whether to sow or not, to spray or not, to irrigate or not and if the decision is made to irrigate what should be, the amount of irrigation etc.

The information to be delivered to the farmers should be punctual, sufficiently precise in space, coherent with the available options and already in an agricultural technical language. For example, it is less important to indicate the temperature or the amount of rainfall, but it is essential to communicate whether the farmers should sow or not.

In preparing the advice, the agrometeorologists should keep in mind the following issues:

- ✓ which options the farmers have in relation to the information delivered;
- ✓ the required accuracy in time and space of the information;
- ✓ how to translate the meteorological or climatological information into a crop management information;
- ✓ how to estimate the value of the advice.

Businessmen: The businessmen are interested mainly in the prices. The prices of the main commodities are related to the production on a regional and international level in such a way, that the balance among various markets would lead to an adjustment of the local market. Nevertheless, their focus is on comparing the current year production with the past years and the information has to be available some time in advance of the harvest.


www.crida.in:82/contingencyplanning/

CRIDA

ICAR - Central Research Institute for Dryland Agriculture

Online Crop Contingency Planning

Citation

District level contingency plans cover contingency strategies to be taken up by farmers in response to major weather related aberrations such as delay in onset and breaks in monsoon causing early, mid and late season droughts, floods, unusual rains, extreme weather events such as heat wave, cold wave, frost, hailstorm and cyclone. Read More

State: Haryana District: Hissar Drought Contingency: Terminal Drought

Major Farming situation	Normal Crop	Crop management	Rabi Crop planning
Light textured sandy soils susceptible to wind erosion	Pearl millet	1. Remove every third row for green fodder. 2. Make ridge and furrow for rain water harvesting. 3. Life saving irrigation if available. 4. Foliar spray of urea 2% solution under rainfed condition.	Field preparation for rabi crop sowing during first fortnight of October Sowing of Mustard (RH-30, RH -819, RB-24, RB 50 RH- 781 and Varuna) and Chickpea (C-235, H-208 and HC- 1) during second fortnight of Oct.
Light textured sandy soils susceptible to wind erosion	Pearl millet + Greengram/Mothbean (Intercropping 8:4 or 6:3)	1. Remove every third row for green fodder. 2. Make ridge and furrow for rain water harvesting. 3. Life saving irrigation if available. 4. Foliar spray of urea 2% solution under rainfed condition.	Field preparation for rabi crop sowing during first fortnight of October Sowing of Mustard (RH-30, RH -819, RB-24, RB 50 RH- 781 and Varuna) and Chickpea (C-235, H-208 and HC- 1) during second fortnight of Oct.

Figure 2. ICAR-Central Research Institute on Dryland Agriculture (CRIDA)

http://www.crida.in/

Establishing an AgroMet System:

The problems faced by agrometeorologists are often related to the fact that the resources available for this sector are rather limited. It could be argued that the system should be drawn assuming that all the resources are available as in a theoretical situation. This approach, which is usually followed, is not realistic and it is advisable indeed to organize the system keeping the real situation in mind, with its constraints and possibilities, trying to adapt to such situation in the best way. The work of an agrometeorologist is often very difficult because he is alone, he has no indications on how to operate, and he has to take his own decisions without any technical help. Furthermore, the background of knowledge in meteorology and climatology, in crop science and in computer science has to be very large and comprehensive to achieve any practical result.

The Internet can accomplish this since vast amounts of timely information can found with one click of a mouse button. Additionally, the Internet can play a vital role in the training of agrometeorologists by providing useful knowledge to a large number of people in a cost-effective manner. Fortunately today the technologies can help substantially in solving problems which once were impossible to solve. However, to tackle with these technologies, a modern agrometeorologist needs greater skills than before. Steps to prepare the AgroMet Sys would be:

- Definition of users and their needs;
- Division of the country in units coherent with the needs of the users (administrative etc.);
- Choice of the crops relevant for the users;
- Determination of the appropriate information for the users in relation to the available options;
- Division of the units in climatological homogeneous sub-units;
- Establishment of the method to convert the climatological and meteorological data;
- Evaluation of the data available concerning weather, climate, ancillary data, crops, etc and their accuracy in time and space;
- Establishment of the methods to convert the data at the requested scale of time and space;
- Preparation of the software to make the chain of data processing more automatic;
- Definition of the way to deliver information (Email, radio, TV, World Wide Web, etc).

Approaching Steps of an AgroMet InfoSys:

Data collection: AgroMet InfoSys needs real time meteorological data in every application, especially in the case of advice to the farmers (satellite images, remote sensing data, Normalized Vegetation Index curves and software like DB and GIS etc are essentials).

Climatic database: An important tool for the agrometeorologist is the climatic database for a representative number of years. The climatic classification can be done using a matrix of temperature and rainfall with the average/ total monthly data for 30 years (if possible) and a cluster analysis program in order to group the zones with similar values.

Crop monitoring: Crop monitoring can be carried out for two main reasons, namely for early forecasting of crop yields, and providing advice to the farmers in order to help them in decision-making.

All these systems, from the simple ones to the more complex, require a good knowledge of the ecophysiology of the crop, i.e. the response of the crop, as well as the ecophysiology of the variety of each crop. A good knowledge of the common agricultural practices in the area and of the environmental factors is also required.

To analyze the relationships between the crops and the environmental factors, consideration of the following questions could be useful:

- ✓ How long is the growing season?
- ✓ In which period the sowing date does occur?
- ✓ What should be the temperature and soil moisture thresholds for germination?
- ✓ How many phenophases are there along the growing periods?
- ✓ Which phenophase is more sensitive to the meteorological parameters?
- ✓ Which are the more frequent adverse events (droughts, high temperatures, storms, strong winds, pests and diseases, cold, frosts, floods)?
- ✓ How much water does the crop need for each phenophase?
- ✓ What is the average evapotranspiration during each phenophase?
- ✓ Which are the most important factors affecting the yield and the production?
- ✓ How much is the variation in yield between years?
- ✓ How can the minimum year and the maximum year be characterized from a climatic point of view?
- ✓ Can the principal causes of the variation be identified? What is the coefficient of reduction of the maximum possible yield for each phenophase?
- ✓ Which kind of management practices do the farmers use?
- ✓ How many possible options do they have during the growth periods (i.e. date of sowing, varieties, timing and amount of fertilizers, spraying for pests and diseases, timing of weeding, amount and scheduling of irrigation, timing of harvest etc.)?
- ✓ What are the possibilities for delivering agrometeorological information useful for decision-making? If yes, which kind of decision?
- ✓ Are the meteorological forecasts useful to take some decision?
- ✓ How much time is required before decision based on the information is delivered?
- ✓ Which should be the accuracy of the information on a spatial basis?

The development of an efficient agrometeorological information system is crucial in countries including India where agriculture is the basis of the economy. Nowadays, even if the available resources are quite limited, building a good service and delivering useful products to a variety of users is possible. To achieve this, the main condition is a proactive attitude of the agrometeorologists to tailor the information to the real user needs. The information must be prepared by agrometeorologists in a way that the majority of users will easily understand it. Then it can be adapted and sent to key communication outlets such as radio, television, newspapers, bulletins, specialized information networks and web sites for broad-scale as well as targeted dissemination.