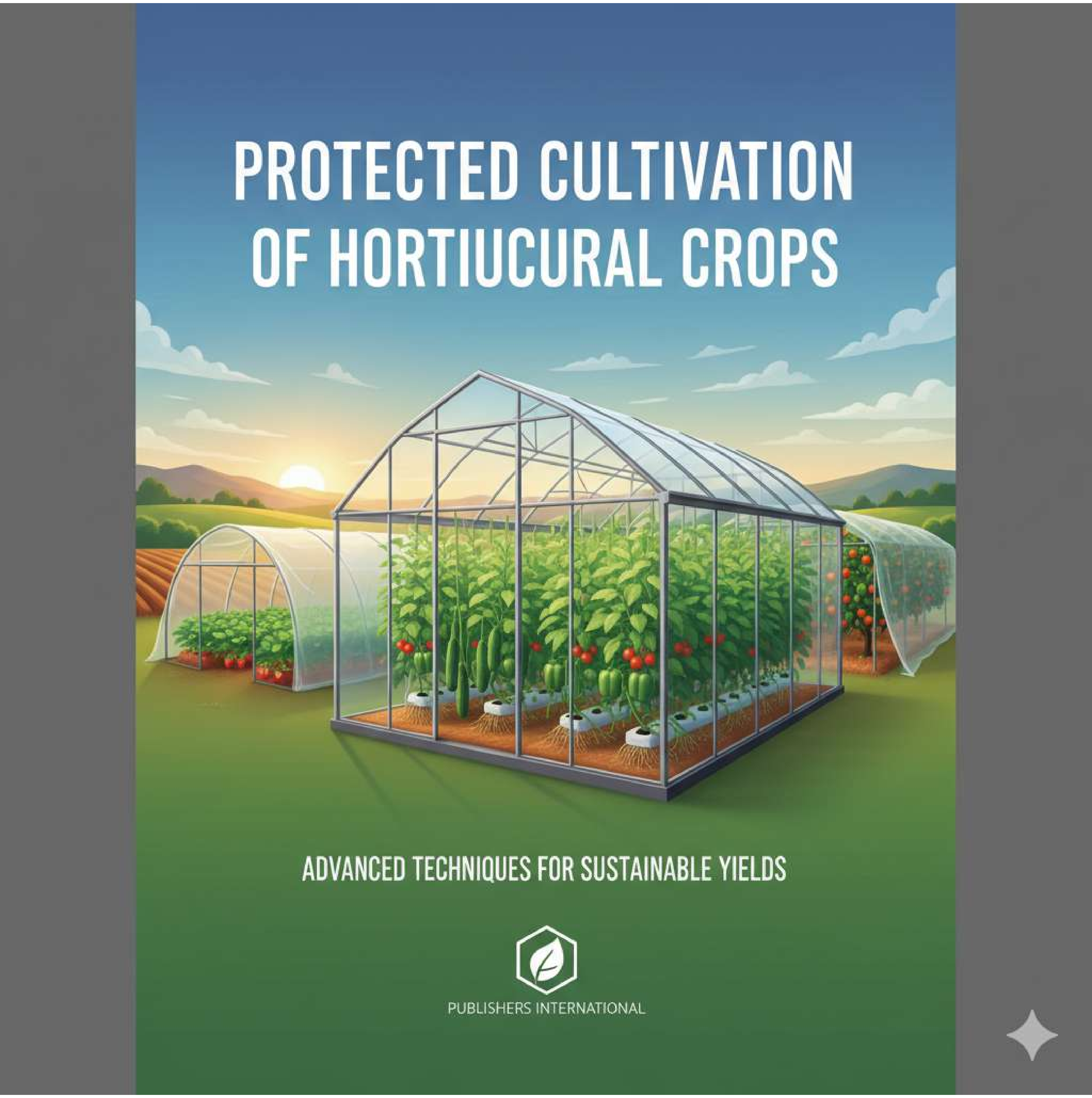
PROTECTED CULTIVATION
OF HORTIUCURAL CROPS
ADVANCED TECHNIQUES FOR SUSTAINABLE YIELDS
PUBLISHERS INTERNATIONAL

PROTECTED CULTIVATION OF HORTICULTURAL CROPS

Department of Horticultural crops

Compiled BY

Department of Horticultural crops

BIHAR AGRICULTURAL COLLEGE, SABOUR, BHAGALPUR

BIHAR AGRICULTURAL UNIVERSITY, SABOUR, BHAGALPUR -813210

PROTECTED CULTIVATION OF HORTICULTURAL CROPS

Chapter 1

Protected cultivation – Importance and scope, status of protected cultivation In India and World

After the advent of green revolution, more emphasis is laid on the quality of the agricultural product along with the quality of production to meet the ever-growing food and nutritional requirements. Both these demands can be met when the environment for the plant growth is suitably controlled. The need to protect the crops against unfavourable conditions led to the development of protected agriculture. Greenhouse is the most practical method of achieving the objectives of protected agriculture, where natural environment is modified by using sound engineering principles to achieve optimum plant growth and yield. Poly house cultivation has become an important policy of Indian Agriculture.

Protected cultivation practices can be defined as a cropping technique wherein the micro climate surrounding the plant body is controlled partially or fully as per the requirement of the vegetable / flower species grown during their period of growth. With the advancement in agriculture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged. Among these protective cultivation practices, Green house, Plastic house, Cloth house, Net house and shade house etc is useful for the Telangana State.

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

Greenhouses are the most common types of structures used for production of ornamental and vegetable crops under controlled conditions. These structures provide the potential to control all environmental parameters, although to varying degrees depending upon the design of the structure and its components.

Importance of Greenhouses (or) Specific Benefits of Greenhouses :

1. Crop is protected from cold, wind, storm, rain and frost.
2. Due to controlled conditions there is better germination, plant growth and crops mature faster.
3. Improved quality and quantity of produce with long shelf life.
4. Use of water is optimized and there is reduction in its consumption by 40 – 50 %.
5. Effective utilization of inputs.
6. Incidence of disease and pests is reduced or eliminated.
7. Crops can be grown throughout the year.
8. Best technology for commercial production of high value crops like flowers, medicinal plants, etc.
9. Can be used for solar drying of farm produce.
10. Involvement of labour force can be reduced.
11. Crop cultivation under inclement climatic conditions.
12. Certain crops cultivated year round to meet the market demands.
13. High value and high quality, even organic, crops grown for export markets.
14. Income from small land holdings increased several fold.
15. Successful nurseries from seeds or by vegetative propagation prepared as and when necessary.

16. More Self-employment opportunities for educated youth on farm.
17. Manipulation of microclimate and insect proof feature of the greenhouse for plant breeding and, thus, the evolution of new varieties and production of seeds.

Scope of Greenhouse in India :

The scope in Indian horticulture is tremendous. If popularly organized, the promising fields having wide scope for protected cultivation in India are

1. **Cultivation in problematic agro climate :** In India majority of uncultivated area is under problematic conditions such as barren, uncultivable fallow lands and deserts. Even a fraction of this area bought under greenhouse cultivation could produce substantial returns for the local inhabitants.
2. **Greenhouses around big cities :** The substantial demand persists for fresh vegetables and ornamentals around the year in big cities. Demand for off season and high value crops also exists in big cities. Therefore greenhouse cultivation can be promoted to meet the urban requirements.
3. **Export of horticultural produce :** There is a good international demand for horticultural produce, mainly the cut flowers. Promotion of greenhouse cultivation of export oriented crops will be of definite help towards export promotion. Ex. Cultivation of Gherkins in greenhouses around Hyderabad are exported to different countries.
4. **Greenhouses for plant propagation :** GH technology is being now a days considered as suitable approach for raising of seedlings and cuttings which require control environment for their growth. GH facility could increase the capacity of producing the plant material.
5. **Greenhouse technology for biotechnology :** Material generated through tissue culture are need to be propagated in control environment. The hydroponics or Nutrient Film Technique (NFT) are also required controlled environmental conditions for growing plants.
6. **Greenhouse for cultivation of rare and medicinal plants :** India has wide variety of medicinal herbs and rare plants like orchids which have been identified for large scale cultivation. The greenhouse could provide the right type of environmental conditions for the intensive cultivation of these plants.

Status of protected cultivation In World :

Greenhouse crop production is now a growing reality throughout the world with an estimated 405,000 ha of greenhouses spread over all the continents. There are more than 55 countries now in the world where cultivation of crops is undertaken on a commercial scale under cover, and it is continuously growing at a fast rate internationally.

In India, protected cultivation technology for commercial production is hardly three decades old (DRDO). In developed countries viz. Japan, Holland, Russia, UK, China and others, it is about two century old. China started protected cultivation in 1990's and today the area under protected cultivation in China is more than 2.5 m ha and 90 percent area is under vegetables. Israel is one country which has taken big advantage of this technology by producing quality fruits, vegetables, flowers, etc in water deficit area. Several thousand acres are now under glass in the United States and equally large area in England and Holland, where horticulture under glass was practiced over a century ago.

Status of protected cultivation In India :

India's first exposure to truly hi-tech protected farming of vegetables and other high-value horticultural produce came through the Indo-Israel project on greenhouse cultivation, initiated at the New Delhi-based Indian Agricultural Research Institute (IARI) in 1998, shortly after the establishment of diplomatic ties with that country. However, the Israleli experts left India in 2003 at the end of this five-year project, IARI continued to maintain the facility, calling it the Centre for Protected Cultivation Technology (CPCT). It has, in the past 10 years, managed to refine and upscale the system to reduce costs, besides designing greenhouse structures to suit local conditions. The area under greenhouse cultivation, reported by the end of 20th century was about 110 ha in India and world over 275,000 hectare. During last decade this area must have increased by 10 percent if not more. The states that have consistently expanded the area under protected cultivation for the period of 2007-2012 are Andhra Pradesh, Gujrat, Maharashtra, Haryana, Punjab, Tamil Nadu and West Bengal. Maharashtra and Gujrat had a cumulative area of 5,730.23 hectares and 4,720.72 hectares respectively under the protected cultivation till 2012.

Status of protected cultivation in Telangana :

At present (March 2018) There are about 1150 acres (917 farmers) of vegetables and flowers produced in Telangana under polyhouses. The major crops of tomato, cucumber, capsicum, gerbera, chrysanthemum, roses, accounted for 31 % of the total statewide vegetable and flower crop value. Currently, almost one-sixth of Telangana vegetables are produced on polythene mulch. Nearly 90 % of the polyethylene mulched crops are grown with drip irrigation.

Chapter 2

Greenhouse / polyhouse designs, different types of protected structures on soil and climate

Greenhouse type based on Shape :

1. **Lean-to Type Greenhouse :**
   A lean-to design is used when the greenhouse is placed against the side of an existing building. This design makes the best use of sunlight and minimizes the requirement of roof supports. The roof of the building is extended with appropriate greenhouse covering material and the area is properly enclosed.
2. **Even Span Type Greenhouse :**
   In this type, the two roof slopes are of equal pitch and width. This design is used for the greenhouse of small size, and it is constructed on levelled ground. Several single and multiple span types are available for use in various regions of India. For single span type, the sp- in general varies from 5 to 9 m, whereas the length is around 24 m. The height varies from 2.5 to 4.3 m.
3. **Saw Tooth Type Greenhouse :**
   These are also similar to the ridge and furrow type greenhouses except that, there is provision for natural ventilation. In this type, specific natural ventilation flow path develops in a saw tooth type greenhouse.
4. **Quonset Greenhouse :**
   In Quonset greenhouse, the pipe arches or trusses are supported by pipe purlins running along the length of the greenhouse. In general, the covering material used fQr this type of greenhouses is polyethylene. Such greenhouses are typically less expensive than the gutter connected greenhouses and are useful when a small isolated cultural area is required. These houses are connected either in free standing style or arranged in an interlocking ridge and furrow.

Greenhouse Type Based on Utility :

Classification of greenhouses can also be made depending on the functions or utilities. Of the different utilities, artificial cooling and heating of the greenhouse are more expensive and elaborate. Hence based on the artificial cooling and heating, greenhouses are classified as that uses active heating system and active cooling system.

1. **Greenhouses for Active Heating :**
   During the night time, the air temperature inside greenhouse decreases and to avoid the cold bite to plants due to freezing, some amount of heat has to be supplied. The requirements for heating greenhouse depend on the rate at which the heat is lost to the outside environment. Various methods are adopted to reduce the heat losses, namely, using double layer polyethylene, thermopane glasses (two layers of factory sealed glass with dead air space) or to use heating systems, such as unit heaters, central heat, radiant heat and solar heating system.
2. **Greenhouses for Active Cooling :**
   During summer season, it is desirable to reduce the temperatures of greenhouse than the ambient temperature, for effective crop growth. Hence suitable modifications are made so that large volumes of cooled air are drawn into fog cooling. This greenhouse is designed in such a way that it permits a roof opening of 40 % and in some cases nearly 100 %.

Greenhouse Type Based on Construction :

Based on construction, greenhouses can be Broadly classified as wooden framed, pipe framed and truss framed structures.

1. **Wooden Framed Structures :**
   In general, for greenhouses with span less than 6 m, only wooden framed structures are used. Side posts and columns are constructed of wood without the use of a truss. Pine wood is commonly used as it is inexpensive and possesses the required strength. Timber locally available, with good strength, durability and machinability also can be used for the construction.
2. **Pipe Framed Structures :**
   When the clear span is around 12 m, pipes are used for the construction of greenhouses. In general, the side posts, columns, cross-ties and purlins are constructed using pipes. Trusses are not used also in this type of greenhouse. The pipe components are not interconnected but depend on the attachment to the sash bars for support.
3. **Truss Framed Structures :**
   If the greenhouse span is greater than or equal to 15 m, truss frames are used. Flat steel, tubular steel or angle iron is welded together to form a truss encompassing rafters, chords and sturts. Sturts are support members under compression and chords are support members under tension. Angle iron purlins running throughout the length of greenhouse are bolted to each truss. Columns are used only in very wide truss frame houses of 21.3 m or more. Most frames are best suited for pre-fabrication.

Different types of protected structures based on soil and climate :

Poly house

The crops grown in open field are exposed to vivid environmental conditions, attack of insects and pests, whereas the polyhouse provides a more stable environment. Polyhouse can be divided into two types.

a) **Naturally ventilated polyhouse**
   These polyhouse do not have any environmental control system except for the provision of adequate ventilation and fogger system to prevent basically the damage from weather aberrations and other natural agents.
b) **Environmental controlled polyhouse**
   This type of polyhouse helps to extend the growing season or permits off-season production by way of controlling light, temperature, humidity, carbon-dioxide level and nature of root medium.

Shade House :

Shade houses are used for the production of plants is warm climates or during summer months. Nurserymen use these structures for the growth of hydrangeas and azaleas during the summer months. Apart from nursey, flowers and foliage which require shade can also be grown in shade houses. E.g. Orchids, These shade structures make excellent holding areas for field-grown stock while it is being prepared for shipping to retail outlets. Shade houses are most often constructed as a pole-supported structure and covered with either lath (lathhouses) or polypropylene shade fabric.

Net House :

Net houses are widely used as propagation structures in tropical areas, where artificial heating is not required and artificial cooling is expensive. In these areas, net houses may be constructed with roofs covered with glass or plastic film and its sides are covered with wire net. It provides necessary ventilation and maintains an ideal temperature for germination of seeds and subsequent growth of the seedlings. The roof of net house may be covered with gunny cloth or even with live plant creeper to cut off the solar radiant energy and to keep the house cool.

Polypropylene shade nets with various percentages of ventilations are used. Black, green, and white coloured nets are used, while black colours are the most preferred as it retains heat outside.

Growing rooms : A growing room is an insulated building from which natural light is usually excluded. In it, illumination is provided by artificial means. Growing rooms are now widely used commercially for the production of seedlings of bedding plants, tomatoes and cucumbers in most advanced countries. The seedlings are usually grown in trays or pots kept on benches.

The automatic greenhouse : Today, the modern greenhouses can be almost completely automated thus assisting propagation. For instance, by the use of thermostat, air and bed temperature can be maintained as per the requirement. Similarly, automatic ventilation allows the ventilators to open and close in relation to temperature. Even, automatic systems of irrigation are installed in the modern greenhouses and water is supplied to the plants through drip or trickle system to each pot or plant by individual nozzle of time switch.

Chapter 3

Different types of Cladding material involved in Green house/polyhouse Cladding

material : transparent material mounted on the walls and roof of a green house.

Rigid cladding material : cladding material with such a degree of rigidity that any deformation of the structure may result in damage to it. Ex. Glass.

Flexible cladding material : cladding material with such a degree of flexibility that any deformation of the structure will not result in damage to it. Ex. Plastic film.

Properties of ideal greenhouse covering material :

1. It should transmit the visible light portion of the solar radiation, which is utilized by plants for photosynthesis.
2. It should absorb the small of UV in the radiation and convert a portion of it into visible light useful for plants.
3. It should reflect or absorb IR radiation which are not useful to plants and causes greenhouse interiors to overheat.
4. It should be low cost.
5. It should have usable life of 10 to 20 years.

Covering material : they are of glass, fiberglass, or plastic. Each type has its advantages and disadvantages.

a. Glass – 90 % light transmission
b. Fiberglass – 90-95 % light transmission
c. Polyethylene – 65-75 % light transmission
d. Vinyl – 90 % light transmission

A) Glass :

Glass type greenhouses are the most traditional covering used. They may be constructed with slanted sides, straight and caves. Aluminium, glass buildings provide low maintenance and have aesthetic lines, as well as ensuring that you get a weather-tight structure. Pre-fabricated glass kits are available for easy installation by amateur gardeners. The disadvantages of glass are its fragile condition (glass break easily) and high costs.

B) Fiberglass :

Fiberglass greenhouses – they are light, strong and hail-proof. Be careful, though low quality fiberglass will discolour, thus reducing penetration of light. Using a good quality fiberglass will however make it as expensive as building a glass one.

C) Plastic :

Plastic greenhouses are becoming very popular for the following reasons :

i. Low cost (about 1/6 the cost of glass)
ii. Absorbs sufficient heat
iii. Low cost (about 1/6 the cost of glass)
iv. Fruits and vegetables and other plants under plastic are comparable in quality to that of glass-grown varieties.
v. Choice of polyethylene (PE), polyvinyl chloride (PVC), copolymers of these materials, and other readily available clear films.

1. **Polyethylene :**
   Commonly used plastic for greenhouse covering is thermoplastic. The basic characteristic is they soften on heating and hardens with cooling and the process is reversible. They are stiff, robust, resilience to resist loads and deformations. Polyethylene used for covering year round production have UV inhibitor in it otherwise last only one heating season. Standard length 30.5, 33.5, 45.7, 61.0 and 67.0 m. A polyethylene covering is colder than air inside greenhouse in winter due to which when warm air inside come in contact no time the water falls as beads over the plant. The wet foliage causes diseases and also the constantly wetted soil becomes waterlogged and oxygen deficient. With the water dripping problem, condensation also reduces light intensity within greenhouse usage of antifog surfactant is recommended.
2. **Polyvinyl chloride film :**
   UV resistant vinyl films of 0.2 and 0.3 mm thickness are guaranteed for 4-5 years respectively. This extended life of polyvinyl film is advantageous as compared to polyethylene which has only 1 or 2 years. But the advent of 4 year polyethylene the advantage of vinyl film has gone. The cost of 0.3 mm vinyl is 3 times that of 0.15 mm polyethylene. The vinyl films tend to hold a static electric charge due to which it attracts and holds the dust that reduces the light transmittance unless the dust is washed away. In Japan 95 % greenhouses are under plastic and within the group 90 % are covered of vinyl film.
3. **Polyester film :**
   Polyesters offers long life and are strong. Films of 0.13 mm thickness are used for roofs will last for 4 years, while 0.08 mm films are used on vertical wall have life expectancy of seven years. Although polyester having the higher cost as compared to polyethylene it offers the extra life expectancy. The advantage include light transmittance equal to that for glass. Polyester is still frequently used in heat retention screens because its high capacity to block radiant energy.
4. **Tefzel T^2 film (Ethylene tetra fluoro ethylene) :**
   It is the recent addition of plastic covering. This film was earlier used for transparent covering on solar collector. The life expectancy is 20 years or more. The light transmission is 95 % and is greater than that of any other covering material. Double layer will have about 90 % transmittance. It is more transparent to IR radiation so that less heat is trapped inside due to which the cost of cooling will be reduced. Disadvantage of Tefzel film is availability only in 1.27 m wide rolls which requires clamping rails on every 1.2 m.
5. **Fiberglass reinforced plastic rigid panel :**
   Most popular material in past. Life period varies with grade. Some grades give 5-10 years while better grades can last up to 20 years. Corrugated panels are used because of greater strength. Flat panels are used for side wall where load is not greater. Available width 1.3 m and length up to 7.3 m. Panels are flexible enough to conform to shape of Quonset greenhouse. Resistant to breakage by hails or Vandels.
6. **Acrylic and polycarbonate rigid panel :**
   Acrylic and polycarbonate films have been available for use since 15 years. The panels used for glazing the side walls and end walls of film plastic greenhouses and for retrofitting old greenhouses. Acrylic greenhouses are highly inflammable. Acrylic panels are popular due to high light transmission and longer life. Polycarbonate panels are for commercial greenhouses due to low price, flame resistance and resistance to hail damage. Available with coating to prevent condensation and also an acrylic coating for protection from UV light.

Chapter 4

Greenhouse design Structural

Design

Many types of greenhouse structures are successfully employed in protected agriculture, and each type has its own advantages and is well suited for a particular case. The different structural designs of greenhouse based on the types of farmers are available. A straight side wall and an arched roof (Fig. a) is possibly the most common shape for a greenhouse, but the gable roof (Fig. b) is also widely used. Both structures can be free standing or gutter connected with the arch roof greenhouse. The arch roof and hoop style (Fig. c) greenhouses are most often constructed of galvanized iron pipe bent into form by a roller pipe bender. 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 (Fig. d) 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 that are bound throughout the winter in greenhouses located in extremely cold regions. A Gothic arch frame structure to the structure. This form of structure, along with others, can be used as a single free standing greenhouse or as a large range of multi-span, gutter connected units.

The greenhouses are to be designed for necessary safety, serviceability, general structural integrity and suitability. The structure should be able to take all the necessary dead, live, wind and snow loads. The foundation, columns and trusses are to be designed accordingly. The greenhouse structures are to be designed to take up the loads as per design loads prescribed by the National Greenhouse Manufactures Association (NGMA of USA) standards – 1994.

The structure has to carry the following loads and is to be designed accordingly.

a) **Dead load :** Weight of all permanent construction, cladding, heating and cooling equipment, water pipes and all fixed service equipments to the frame.
b) **Live load :** Weights superimposed by use (include hanging baskets, shelves and persons working on roof). The greenhouse has to be designed for a maximum of 15 kg per square meter live load. Each member of roof should be capable of supporting 45 kg of concentrated load when applied at its centre.
c) **Wind load :** The structure should be able to withstand winds of 130 kilometer per hour and at least 50 kg per square meter of wind pressure.
d) **Snow load :** These are to be taken as per the average snowfall of the location. The greenhouse should be able to take dead load plus live load or dead load plus wind load plus half the live load.

The ultimate design of a greenhouse consists of a balance of the following aspects :

1. Overall structural design and the properties of the individual structural components.
2. Specific mechanical and physical properties, which determine the structural behaviour of the covering materials.
3. Specific sensitivity of the crop to light and temperature to be grown in the greenhouse.
4. Specific requirements relevant to the physical properties of the covering material.
5. Agronomic requirements of the crop.

Chapter 5
Environmental control in polyhouses

Control of greenhouse environment means control of temperature, light, air composition and nature of root media. Precise control of different parameters of greenhouse environment results in better timing of crops, higher quality crops, disease control to maximize economic returns and conservation of energy that optimizes energy inputs.

A. Temperature control :

The thermostat can be coupled to water circulating pump or exhaust fan for controlling the temperature inside the greenhouse. Bimetallic strip (differential expansion) or thin metal tube filled with liquid or gas (movement of tube due to change in volume of a gas or liquid) acts as sensors and cultivation a mechanical switch.

1. Ventilation

a) **Natural Convection :** A temperature difference is set between greenhouse temperature and ambient temperature and causes natural movement of air through roof vent provided in the roof.

b) **Forced Convection :** If the rate of heating of room temperature becomes higher than the rate of heat removal through roof vents then heat removal is possible only through forced convection in which fan is provided in greenhouse. The rate of heat removal depends on capacity of fan and its rpm.

2. Evaporative Cooling System

Developed to reduce the problem of excess heat inside the greenhouse.

a) Fan and Pad Cooling System :

Most common summer cooling system in greenhouses. A pad composed of excelsior (wood shreds) or cellulose material is placed vertically along one side of the greenhouse and exhaust fan an opposite side. Warm outside air is drawn in through the pad. Supplied water in the pad by the process of evaporation absorbs heat from the greenhouse and produces cooling effect. Khus-Khus grass mats can also be used as cooling pads.

b) Fog Cooling :

Fog or sprinklers can be used to cool green houses and maintain humidity but it is costlier than pad fan cooling. A high-pressure pumping apparatus generates fog containing water droplets with a mean size of less than 10 microns using suitable nozzles. These droplets are sufficiently small to stay suspended in air while they are evaporating and utilize the heat of greenhouse air. Fog is dispersed throughout the greenhouse, cooling the air everywhere. As the system does not wet foliage there is less scope of disease and pest attack.

Both types of summer cooling systems can reduce the greenhouse air temperature well below outside temperature. The fan and pad cooling system completer evaporation not taking place but fog system will have complete evaporation because of minute size water droplets.

A maximum night temperature of 13 to 15.5° C and a day temperature of 24° C are generally set to start the heaters and fans; respectively.

B. Relative Humidity control :

Humidistat coupled to water circulating pump or exhaust fan control the RH inside the fan and pad greenhouse. With the evaporative pad cooling system lowering the dry bulb temperature will generally rise the RH by 70-80 %. This is usually sufficient for crops such as carnation and chrysanthemum. The RH in Non-ventilated (NV) Greenhouse can be increased by providing foggers.

C. Light Intensity control :

In certain areas where natural illumination is absent or very low, illumination for plants may be provided by artificial sources. Incandescent bulbs generate excessive heat and are unsatisfactory in most instances. Fluorescent tubes are useful as the sole source of light for African violets, gloxinias and many foliage plants which grow satisfactorily at low light intensities. Excessive light intensity destroys chlorophyll even though the synthesis of this green pigment in many plants is dependent upon light.

D. CO_2 control :

The present, more sophisticated CO_2 generator control systems are based on CO_2 sensors. These sensors continually monitor the CO_2 level in the greenhouse and a single sensor can be connected to the several greenhouses by sampling tubes and air samples drawn by a pump. The signal from the sensor is used to control the CO_2 generator so that a constant CO_2 level can be maintained. Information from the single sensor with multiple sampling tubes is received by a computer, which in turn controls CO_2 generators in each greenhouse.

E. Controlling Light in Greenhouses :

1. **Light Quality :** In commercial greenhouse production, light quality is important when selecting a light source for supplemental photosynthetic lighting or photoperiod control. A broad emission spectrum within the 400 to 700 nm range is desirable especially when adding light to increase photosynthetic rate. Light sources being used to extend day length and create artificially long days must provide sufficient light in the red range in order to affect the phytochrome photoreceptor.

   Reducing the far-red light and increasing the blue light experienced by the plant results in shorter, darker-colored and stronger plant. Light quality can also affect the development of certain foliar diseases such **as Botrytis, Greenhouse glazings** have been developed with additives or pigments that filter certain wavelengths of light and allow for a shift in the relative ratios of wavelengths of light entering the greenhouse.
2. **Light Quantity :** The Light Level might need to be increased or decreased to maintain optimal levels. Different plant species have different optimal light levels. However, for a given species, plant spacing, nutritional level and plant age can affect light level. For example, the optimal light level for a tomato seedling is lower than that for a well established and actively growing tomato.

   A range of 32.2 to 86.1 klux is required by crops like cucurbits, capsicum, brinjal and sweet potato, while cabbage and potato require 21.5 to 86.1 klux.

Recommended Light Levels for Selected Plants in moles/m²/sec	
African violet	150 – 250
Foliage plants	150 – 250
Carnation, Chrysanthemum, Geranium, Cucumber, Lettuce and Strawberry	250 – 450
Roses and Tomato	450 – 750

Greenhouse shading methods : Two methods are commonly used to **reduce light levels** in greenhouses. The first is the application of a **shading compound** to the glazing. Retractable shade systems are being installed in many new greenhouses. These systems are placed in the gables of the greenhouse and are controlled by a computer that is in turn connected to a photometer (Light Meter). A desired light level can be programmed into a computer and the shade automatically pulled when light levels exceed the desired level. The shade will automatically be **retracted** when light levels fall below the desired level.

Stages of evolution of environmental control systems :

Stages of evolution of environmental systems are manual controls, thermostats, step controllers microprocessor and computers.

1. **Analog Control :** In this system proportioning thermostats or electric sensors are used to gather temperature information. Analog controls are costlier than thermostats, but offer better performance.
2. **Computerized environment control :** The amplifiers and logic circuit analogs have now been replaced by computerized environmental system, which involves mircroprocessors, which gathers information on a variety of sensor like temperature, humidity, light intensity, wind directions controls offer significant energy and labour saving and increases production efficiency in propagation. The deviations from the present levels of temperature and humidity can trigger alarms by the computer.

Chapter 6

Artificial lights, Automation in polyhouses Various methods

of Supplemental Lighting in Greenhouses

Before selecting a light source for greenhouse lighting, numerous factors should be considered. Among these are the

1. Total energy emitted by the lamp.
2. Efficiency (% of electrical energy converted to light energy).
3. Wavelength emitted (especially in the 400 to 700 nm wavelengths).
4. Cost, life expectancy (of bulbs and fixtures), and the fixtures required (including ballasts). Supplemental lighting during daylight hours to enhance photosynthesis is proved to be highly effective. Such lighting is more profitable in High Density Plantings, such as rooting and seedling beds and the production of young plants. Many types of lamps have been used in the greenhouse. Basically they fall into 3 groups

1. **Incandescent lamps (tungsten-filament) :-**
   These lamps are generally not used for supplemental lighting in greenhouses for photosynthetic purposes. A large portion of the radiation given off these lamps is in the form of infrared (heat). Because of this, their efficiency rating is only 7 %. Lamps range from 40 to 500 watts. Life span ranges from 750 to 1000 hours. In order to produce enough light for effective photosynthetic lighting, a large number of these lights would be required. This would require a large number of fixtures and would result in large amounts of heat being produced. Further, most of the visible radiation that these lamps produce is in the red and far-red wavelengths that cause plants to become tall and to have weak stems. However, because relatively low light levels are required for photoperiodic lighting, incandescent plants are suitable and commonly used for this purpose.
2. **Fluorescent lamps:-**
   These lamps are most commonly used in growth chambers and seed germination rooms. They are rarely used to produce crops in greenhouses. As with benefits the crop. These fixtures cost money, require additional wiring and block natural sunlight. Fluorescent lamps are more efficient than incandescent lamps (20 % efficiency) and provide their light over a broader spectrum (more in the blue region) than incandescent lamps.
3. **High Intensity Discharge (HID) Lamps:-**
   Now a days, the HID lamps are preferred types for the final stages of the crop growth in the greenhouse. These are the most commonly used lamps for supplemental lighting in greenhouses. As with fluorescent lamps, these lamps require ballasts that can be very heavy and generate significant amounts of heat. Reflectors are used to direct the light generated downward and to improve uniformity of light distribution. Numerous types off bulbs are available for use in HID lamps such as high pressure mercury, metal halide, low pressure sodium and high pressure mercury. The most commonly used HID system at present utilizes high pressure sodium lamps.
   a) **High-pressure mercury bulbs :** have emission spectrum similar to fluorescent lamps but with a greater concentration of their radiation being emitted in the red region. Light energy is produced by these lamps using a two-step process. First the filament gives off UV light. This UV radiation excites a phosphor powder in the tube. This powder fluoresces and gives off visible light. Because of this two-step process,

these lamps have an efficiency of only 13 % and have a lifespan of about 10,000 hours.

b) **High-pressure metal halide bulbs :** are the most common type of bulb used for supplemental lighting in greenhouses. They have a broader emission spectrum than low-pressure sodium bulbs and are cheaper than mercury bulbs. These bulbs have efficiency of 25 % and a lifespan of 24,000 hours.

Supplemental lighting is used for most crops but is particularly popular with Chrysanthemum and geranium stock plants, rose and plug seedlings. Light intensities of 3.2 to 6.5 klux at plant height are generally used for seedlings and ornamental plants, with 4.3 klux being the most common level. Intensities of 6.5 to 10.8 klux are used for vegetable crops.

Chapter 7

Types of Growing media, Soil preparation and substrate management in polyhouses for growing crops

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 cynamide, 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 75˚ F. 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.

Gravel culture :

Gravel culture is a general term which applies to the growing of plants with out soil in an inert medium into which nutrient solutions are usually pumped automatically at regular intervals. Haydite (shale and clay fused as high temperatures), soft – or hard-coal cinders, limestone chips, calcareous gravel, silica gravel, crushed granite and other inert and slowly decomposing materials are included in the term “gravel”. The more important greenhouse flowering crops include roses, carnations, chrysanthemums, gardenias, snapdragons, lilies, asters, pansies, annual chrysanthemum, dahlias, bachelor buttons and others.

Desirable nutrient level in greenhouse growth media :

Sr. No.	Category	Concentration (mg/l)			
		NO3	N	P	K
1	Transplants	75	125	10-15	250-300
2	Young pot and foliage plants	50	90	6-10	150-200
3	Plants in beds	125	225	10-15	200-300

Media ingredients and Mix

Commercially available materials like peat, sphagnum moss, vermiculite, perlite and locally available materials like sand, red soil, common manure/ compost and rice husk can be used in different proportions to grow greenhouse crops. These ingredients should be high quality to prepare a good mix. They should be free from undesirable toxic elements like nickel, chromium, cadmium, lead, etc.

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 7days with gas proof cover and aerate for atleast a week before use.

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.

Chapter 8

Types of benches and containers used in polyhouses Benching

If you intend to grow pot plants in a greenhouse, you probably need some benches. Benches enable you to raise plants off of the greenhouse floor, keeping them away from disease and often better light. A tiered system of benches usually provides more useable space than if you were to only use the floor. Benches can be made out of metal, wood or plastic, and are usually either slatted or solid in construction. The surface of a bench should drain freely. Wooden benches if not treated with preservative can rot, and may become infested with pests such as ants or mealy bug. Capillary matting (i.e. a continually moist, absorbent material, sold by some greenhouse companies) will help to reduce the need for watering if used on a bench, to sit pots on.

The duration of crop in greenhouse is the key to make the greenhouse technology profitable or the duration of production in greenhouses should be short. In this context, use of containers in greenhouse production assumes greater significance. The containers are used for the following activities in greenhouse production.

- Raising of seedlings in the nursery.
- Growing plants in greenhouses for hybrid seed production of flowers.
- Growing plants for cutflower production.
- Growing potted ornamental plants.

Advantages of containers in greenhouse production

- Increase in production capacity by reducing crop time.
- High quality of the greenhouse product.
- Uniformity in plant growth with good vigour.
- Provide quick take off with little or no transplanting shock.
- Easy maintenance of sanitation in greenhouse.
- Easy to handle, grade and shift or for transportation.
- Better water drainage and aeration in pot media.
- Easy to monitor chemical characteristics and plant nutrition with advanced irrigation systems like drips.

Advantages and disadvantages of different plant growing containers

Containers	Advantages	Disadvantages
Fiber block	Easy to handle	Slow root penetration Short life
Fiber tray	Minimum use of space	Hard to handle when wet
Single peat pallet	No media preparation Low storage requirement	Require individual handling Limited sizes can be handled
Prespaced peat pallet	No media preparation Limited to small sizes	
Single peat	Good root penetration	Difficult to separate
Strip peat pot	Good root penetration	Slow to separate

Portrays	Easy to handle Reusable	May be limited in sizes
Plastic pack	Easy to handle	Roots may grow out of container
Polyurethane foam	Easy to handle Requires less medium Reusable	Requires regular fertilization
Soil band	Good root penetration	Requires extensive labour
Soil block	Excellent root penetration	Expensive machinery
Perforated	Easy to handle	Requires regular fertigation
Plastic tray	Requires less medium Available in many sizes reusable	Roots may grow out of the container
Perforated	Less expensive	Less durable
Polyethylene	Reusable bags	Requires less storage space

Selectin of suitable containers depends upon the crop to be produced in greenhouse, plant characteristics like crop stage, duration, growth habit, root system, etc. Generally long duration, deep rooted and vigorous crop plants require bigger containers, compared to short duration, shallow and less vigorous ones. The containers provide optimum condition for germination of seed and growth and development of transplants.

Chapter 9

Irrigation and Fertigation management

Micro irrigation system is the best for watering plants in a greenhouse. Micro sprinklers or drip irrigation equipments can be used. Basically the watering system should ensure that water does not fall on the leaves or flowers as it leads to disease and scorching problems. In micro sprinkler system, water under high pressure is forced through nozzles arranged on a supporting stand at about 1 feet height. This facilitates watering at the base level of the plants.

Equipments required for drip irrigation system include :

i. A pump unit to generate 2.8 kg/cm^2 pressure
ii. Water filration system – sand/ silica/ screen filters

Water out put in drippers

a. 16 mm dripper at 2.8 kg/cm^2 pressure gives 2.65 litres/hour (LPH)/
b. 15 mm dripper at 1 kg/cm^2 pressure gives 1 to 4 litres per hour.

Screen filters : Stainless steel screen of 120 mesh (0.13 mm) size. This is used for second stage filtration of irrigation water.

Fertigation system :

In fertigation system an automatic mixing and dispensing unit is installed which consists of three system pump and a supplying device. The fertilizers are dissolved separately in tanks and are mixed in a given ratio and supplied to the plants through drippers.

Fertilizers

Fertilizer dosage has to be dependent on growing media. Soilless mixes have lower nutrient holding capacity and therefore require more frequent fertilizer application. Essential elements are at their maximum availability in the pH range of 5.5 to 6.5. In general Micro elements are more readily available at lower pH ranges, while macro elements are more readily available at pH 6 and higher.

Forms of inorganic fertilizers

Dry fertilizers, slow release fertilizer and liquid fertilizer are commonly used in green houses.

Slow release fertilizer

They release the nutrient into the medium over a period of several months. These fertilizer granules are coated with porous plastic. When the granules become moistened the fertilizer inside is released slowly into the root medium. An important thing to be kept in mind regarding these fertilizers is that, they should never be added to the soil media before steaming or heating of media. Heating melts the plastic coating and releases all the fertilizer into the root medium at once. The high acidity would burn the root zone.

Liquid fertilizer

These are 100 percent water soluble. These comes in powdered form. This can be either single nutrient to plant growth and results in steady growth of the plant. Fertilization with each watering is referred as fertigation.

Fertilizer Application Methods

1. **Constant feed**
   Low concentration at every irrigation are much better. This provides continuous supply of nutrient to plant growth and results is steady growth of the plant. Fertilization with each watering is referred as fertigation.
2. **Intermittent application**
   Liquid fertilizer is applied in regular intervals of weekly, biweekly or even monthly. The problem with this wide variability in the availability of fertilizer in the root zone. At the time of application, high concentration of fertilizer will be available in the root zone and the plant immediately starts absorbing it. By the time next application is made there will be low or non-existent. This fluctuation results in uneven plant growth rates, even stress and poor quality crop.

Fertilizer Injectors

This device inject small amount of concentrated liquid fertilizer directly into the water lines so that greenhouse crops are fertilized with every watering.

Multiple Injectors

Multiple injectors are necessary when incompatible fertilizers are to be used for fertigation. Incompatible fertilizers when mixed together as concentrates from solid precipitates. This would change nutrient content of the stock solution and also would clog the siphon tube and injector. Multiple injectors would avoid this problem. These injectors can be of computer controlled H.E. ANDERSON is one of the popular multiple injector.

Fertilizer Injectors

Fertilizer injectors are of two basic types: Those that inject concentrated fertilizer into water lines on the basis of the venture principle and those that inject using positive displacement.

A. **Venturi Principle Injectors**
   Basically these injectors work by means of a pressure difference between the irrigation line and the fertilizer stock tank.
   a) The most common example of this is the HOZON proportioner.
   b) Low pressure, or a suction, is created at the faucet connection of the Hozon at the suction tube opening. This draw up the fertilizer from the stock tank and is blended in to the irrigation water flowing through the Hozon faucet connection.
   c) The average ratio of Hozon proportioners is 1:16. However, Hozon proportioners are not very precise as the ratio can vary widely depending on the water pressure.
   d) These injectors are inexpensive and are suitable for small areas. Large amounts of fertilizer application would require huge stock tanks due to its narrow ratio.

B. Positive Displacement Injectors

1. These injectors are more expensive than Hozon types, but are very accurate in proportioning fertilizer into irrigation lines regardless of water pressure.
2. These injectors also have a much broader ratio with 1:100 and 1:200 ratio being the most common. Thus, stock tanks for large applications areas are of manageable size and these injectors have much larger flow rates.
3. Injection by these proportioners is controlled either by a water pump or an electrical pump.
4. Anderson injectors are very popular in the greenhouse industry with single and multiple head models.
   a. Ratios vary from 1:100 to 1:1000 by means of a dial on the pump head for feeding flexibility.
   b. Multihead installations permit feeding several fertilizers simultaneously without mixing. This is especially significant for fertilizers that are incompatible (forming precipitates, etc.) when mixed together in concentrated form.
5. Dosatron feature variable ratios (1:50 to 1:500) and a plain water bypass.
6. Plus injectors also feature variable ratios (1:50 to 1:1000) and operates on water pressure as low as 7 GPM.
7. Gewa injectors actually inject fertilizer into the irrigation lines by pressure.
   a. The fertilizer is contained in a rubber bag inside the metal tank. Water pressure forces the fertilizer out of the bag into the water supply.
   b. Care must be taken when filling the bags as they can tear.
   c. Ratios are variable form 1:15 to 1:300.
8. If your injector is installed directly in a water line, be sure to install a bypass around the injector so irrigation of plain water can be accomplished.

General Problems of Fertigation :

Nitrogen

Nitrogen tends to accumulate at eh peripherous of wetted soil volume. Hence, only roots at the periphery of the wetted zone alone will have enough access to Nitrogen. Nitrogen is lost by leaching and denitrification. Since downward movement results in permanent loss of NO3 – N, increased discharge rate results in lateral movement of N and reduces loss by leaching.

Phosphorous

It accumulates near emitter and P fixing capacity decides its efficiency. Low pH near the emitter results in high fixation.

Potassium

It moves both literally and downward and does not accumulate near emitter. It distribution is more uniform than N & P.

Micronutrients

Excepting boron, all micronutrients accumulates near the emitter if supplied by fertigation. Boron is lost by leaching in a sandy soil low in organic matter. But chelated micronutrients of Fe, Zn can move away from the emitter but not far away from the rooting zone.

Chapter 10

Use of polyhouses for Propagation and production of quality planting material

Greenhouse has been used long back by horticulturists as a mean of forcing rapid growth of plants and extending the growing season particularly in colder areas. There are being use for whole sale production and propagation of floricultural plants, nursery stock of fruit corps and vegetable crops. A greenhouse greatly extends the variety and scope of propagation. Many kinds of green houses are used for propagation but the most suitable type is the one that admits the maximum amount of light. This is important, particularly where most of the propagation is done in late winter and early spring. Good light conditions are essential for the steady growth of the seedlings. Experiments have shown that a greenhouse that runs from east-to-west is best for better light penetration in winter and early spring, and consequently preferable for raising seedlings at this time of the year. Moreover, it is important that the green houses should be well away from any kind of shade such as a tree or building, including other greenhouse. Some shelter, however, from north to northeast winds is desirable.

In India, construction of temporarily low-cost poly-houses is in fashion for raising nursery of fruit plant in off-season. Such low cost greenhouses are constructed either on wood or metal framework and are covered with polyethylene sheet of 0.10 to 0.15 mm thickness, which is resistant to ultra-violet rays. These houses are equipped with thermostat, cooler or an air conditioner or humidifier, etc for rigid control on temperature and humidity. Commercial greenhouses are usually independent structures of even span, gable-roof constructions, well proportioned so that the space is well utilized for convenient walk ways and propagating benches.

Hot Frames (Hot Beds) :

A hotbed is a bed of soil enclosed in a glass or plastic frame. It is heated by manure, electricity, steam, or hot-water pipe. Hotbeds are used for forcing plants or for raising early seedlings. Instead of relying on outside sources of supply for seedlings, you can grow vegetables and flowers best suited to your own garden. Seeds may be started in a heated bed weeks or months before they can be sown out of doors. At the proper time the hotbeds can be converted into a cold frame for hardening. Hot beds are small low structures, used for propagation of nursery plants under controlled conditions. Hot beds can be used throughout the years, except in area with severe winters, where their use can be restricted to spring, summer and fall. Seedlings can be started and leafy cutting rooted in hot beds early in the season. For small propagation operations, hot beds structures are suitable for producing many thousands of nursery plants, without the higher construction expenditure for larger, propagation houses.

Cold Frames :

The primary use of cold frames is in conditioning or hardening of rooted cuttings or young seedlings prior to field, nursery row or container planting. Cold frames can be used for starting new plants in late spring. When young, tender plants are first placed in a cold frame, the coverings are generally kept tightly closed to maintain a high humidity but as the plants become adjusted, the sash frames are gradually raised or ends of the hoop house to permit more ventilation and drier conditions. The installation of mist line or irrigation provision in cold frame is essential to maintain humid conditions.

Lath Houses :

Lath houses have many uses in propagation, particularly in conjunction with the hardening off and acclimatization of liner plants prior to transplanting and for maintenance of shade requiring plants. In mid climates, they are used for propagation, along with a mist facility and can be used as overwintering structures for linear plants.

Propagation frames :

Sometimes in a greenhouse, the humidity is not enough to allow satisfactory rooting in the leaf cuttings. In such cases, enclosed frames covered with glass or plastic material may be used for rooting of cutting. These frames are useful only on grafted plants as these retain high humidity during the process of healing. Large inverted glass can also be kept over a container having cuttings. Though, high humidity is required is such frames but ventilation and shading is necessary after the rooting process has started in the cutting.

Net House :

Net houses are widely used as propagation structures in tropical areas, where artificial heating is not required and artificial cooling is expensive. In these areas, net houses may be constructed with roofs covered with glass or plastic film and its sides are covered with wire net. It provides necessary ventilation and maintains an ideal temperature for germination of seeds and subsequent growth of the seedlings.

Bottom heat box :

It is a simple box for promoting rooting of cutting is difficult-to-root fruit plants like mango and guava. The most ideal temperature to be maintained in the box is 30 ± 2° C because at this temperature, cuttings of mango, walnut, olive and guava root easily and profusely. The initiation of rooting in cutting varies from species-to-species but in general, it takes 1-2 months for proper development of the roots.

Mist propagation unit :

The rooting of softwood leafy cutting under spray or mist is a technique now widely used by nurserymen and other plant propagators throughout the world. The aim of misting is to maintain humidity by a continuous film of water on the leaves, thus reducing transpiration and keeping the cutting turgid until rooting take place. In this way, leafy cuttings can be fully exposed to light and air because humidity remains high and prevents damage even from bright sunshine. Mist also prevents disease infection in the cuttings by way of washing off fungus spores before they attack the tissues. While the leaves in this process must be kept continuously moist, it is important that only minimum water should be used.

After rooting in the mist, hardening of the rooted cutting is important for better success in the field. When cuttings are rooted, misting should not cease abruptly as this may help in drying out of the young plants followed by scorching, instead, a weaving off process should be adopted in which misting is continued but the number of sprays/days gradually reduce. The way is to shift the rooted cutting to a greenhouse, fog chamber, and frames, maintained at higher temperature and low relative humidity. After phase-wise hardening only, the rooted cuttings are planted at permanent location or in the nursery.

Growing rooms :

A growing room is an insulated building from which natural light is usually excluded. In it, illumination is provided by artificial means. Growing rooms are now widely used commercially for the production of seedlings of bedding plants, tomatoes and cucumbers in most advanced countries. The seedlings are usually grown in trays or pots kept on benches.

Chapter 11

Greenhouse cultivation of Rose, Soil, Climate, Varieties, Propagation and Intercultural Operations

Normally one-year-old budded plants having at least 3 canes on rootstocks like *Rosa indica var. odorata* or *R. canina* or *R. manetti* are most ideal for greenhouse cultivation.

Cultivars : 'Golden Gates', 'Grand Galla', 'First Red', 'Kiss', 'Konfetti', 'Mercedez', 'Ravel', 'Noblesse', 'Vivaldi' and 'Starlite'.

Temperature requirement : The greenhouse temperature is generally maintained from 20˚ C or 21˚ C on cloudy days and 24˚ C – 28˚ C on sunny days. However, plenty of light, humid and moderate temperature ranging from 15˚ C to 28˚ C may be considered as optimum conditions for roses. Ideal humidity – 60-65 % and high RH results Powdery mildew and low RH causes desiccation and reduce flower quality, CO_2 level 1000 – 1200 ppm is favourable.

Growth media : Well drained soil rich in organic matter and oxygen is good for roses. Organic matter as high as 30 percent in the top 30 cm of the growing beds is preferred by many growers. The pH of the soil be around 6 to 6.5 with less EC.

Layout and Planting :

Raised beds are prepared, 5 beds each of 1.20 m width per 8 m bay. The width of path could be 0.40 m. There could be two rows of plants per bed. The lower number of rows per bed and higher number of paths allow better air circulation. Row to row distance could be 30 cm and plant to plant distance 17 cm. Each row of 24 m length could contain 140 plants so that planting density of 70,000 plants per hectare (7-13 plants/m^2). Planting may be done in the months of February to April and/or July to September in a phased manner.

Manuring :

Organic manures can required to be added so that top 30 cms. Of the soil has 30 % organic matter content. A dose of 15 kg. FYM per square metre has been incorporate in to beds.

Fertilizer Application :

Application of nutrients should be based on analysis of soil and plant.

Nitrogen and Potassium = 200 PPM

No. of applications = Twice a week for 7 months along with irrigation.

Phosphorus = Soil application @ 1.8 kg/m^2

Irrigation and drainage :

Rose plants require a lot of water, at least 6 mm/day i.e. about 60 cum/ha/day. A drainage line may be laid below the beds for disposal of excess water.

Cultural practices :

For proper growth of rose plant and high production special cultural practices are to be carried out as follows :

1. **Initial plant development / mother shoot bending :** If the young plant is allowed to flower immediately after planting there is serious risk that the important structural

frame work of the plant will be impaired. The various types of plants require different treatment. First flower is pinched after on month from the date of plantation so that 2 to 3 eyes bud will sprout on main branch to grow as branches and these branches in turn will form buds. When the plant attains this stage of growth, the mother shoot is to be bent towards the direction of path. This cultural operation in rose plants is done to be initiate bottom break ground shoot. The maximum leaf area is required to build up a strong root system. The mother shoot is bent nearer to the bud point.

2. **Plant structure development :** To develop more growing point and plant structure development plays an important role. After planting ground shoot will start growing from crown of plant. The weak ground shoot should be bent at ground level, for forming a basic and strong frame work of plant structure for production throughout their life cycle, the strong ground shoots should be cut at 5th five pair of leaves after four and half months from the date of plantation. The medium ground shoots should be cut 2nd or 3rd five of leaves.
3. **Bending in roses :** Bending helps in maintaining enough leaf area on the plants. The maximum leaf area is required to build up a strong root system. Leaves are important for producing carbohydrates. The mass of leaves is also known as the lungs of the plant. The buds growing suckers should be removed in check new growth on the bended stem. The buds should be removed from the bended stem in order to check the incidence of thrips and bud root (botrytis). Only weak and blind shoots are selected for bending. Bending breaks apical dominance of the plant. It is continuous process and hence carried out throughout the life cycle. Bending should be such that the most of the stems lay below horizontal. In summer season it is generally advised not to go for bending as it provides favourable condition for mite's incidence. Bending is done on 1st or 2nd five pair of leaves. One can also grow roses in green house without bending by keeping some blind shoots on plants in standing position for extra photosynthesis and uptake of water nutrients. While bending the stems, the care should be taken that the stem will not break and the leaves will not touch the soil on the bed.
4. **Disbudding :** Standard varieties are those with one flower on each stem. But as nearly all varieties produce some side buds below the center bud. These side buds have to be removed. The removal of these buds is known as disbudding. It should not be done too early or too late. If done too early it may harm leaves and if done too late then large wounds in the upper leaf axil can take place. When bud attain pea-size and show slight colour then it is right time to do disbudding. For most spray varieties, the center crown bud is to be removed. Disbudding is generally done on weak stem so that it can convert itself to thick stem and in future cuts can be taken. Thick stem produce strong sprouts whereas then stem gives out weak sprouts.
5. **Pinching :** Removal of unwanted vegetative growth from the axil of leaf below the terminal bud is called pinching. This helps to get good quality flowers and buds and avoids wastage of energy in the development of auxiliary bud if done at right stage and right time. It leads to apical dominance.
6. **Wild shoot (root stock) removal :** Wild shoots are the unwanted growth that take place at the union on the root stock. They should be removed at the earliest as these will deplete nutrients and checks growth and development of plant. They should not be cut but removed from its union by pressing it with thumb in order to check its further sprouting.
7. **Support of the plants :**

   The support system consists of bamboo/ GI pipes/ L' angles inserted on both sides of bed at the start and end of the bed. Post are placed at intervals of 3 m on both sides of the bed, along the sides of bed, fastened at the posts at 30 – 40 cm intervals are 14 guage GI wires or plastic string to support the plant. Between the wires across the bed, thin strings can be tied to keep the width of the bed constant. Support system makes intercultural operation easy and protects the buds from being damaged by not allowing the stems bend into the path.

8. **Pruning :** Stems are cut back leaving 4-5 nodes on the basic stock frame, removing all weak shoots and redirecting the wayward ones. This may be practised in a phased manner so that flowering takes place from September to March. Generally, flowering takes place 45 days after pruning.

Chapter12

Rose, harvesting, post-harvest management, Pest and

Diseases Harvest

The post-harvest management of roses starts with their harvest. Roses should attain the right stage for harvesting. If cut too early, flower miss reserve food and therefore, may not develop into full flowers. If cut too late, longevity diminishes. As such, roses should be cut just as the buds are opening, after the sepals have almost fully curled up and the colour is fully visible. In small flowered varieties and Floribundas, the flowers are cut just when they begin to open the cluster. The cutting may be done in the evening or early morning with long stem. The lower end of cut stems are immediately placed in clean plastic buckets containing a clean solution of 500 ppm citric acid or in chrysal – RVB. Thereafter, the buckets containing cut roses are brought to the grading and packing Shed/Hall. Flower yield of 250-350 stem/m^2 is considered to be ideal. Flower yield can be increased by spraying BAP 50-100 ppm before flowering flush.

Hydration :

Ideally, roses immediately after harvest should be graded, packed, precooled and despatched by refrigerated vehicle. In case of delay in grading and packaging flowers are shifted to the cold store. Before shifting to the cold store. Before shifting to the cold store, it is advisable to re-cut the stems, about 2 cm, above the previous level without removing lower leaves/thorns and again place them in clean containers in clean warm (40-48° C) water, adjusted with citric acid to pH 3.0 – 3.5. This treatment will prevent vascular blockage and hence neck drop.

Preservatives :

The followers are removed from the citric acid after 30-60 minutes (or when the leaves and petals are fully turgid) and put in the preservative solution. Thereafter, the flowers are shifted to the cold storage at 0 to 20 C. Roses may be kept for 4-5 days in a preservative solution in cold store, after that longevity may suffer. The composition of floral preservative is as under :

- Citric acid – 100-700 mg/litre
- HQC/captan – 16 mg/liter
- Sucrose – 20 mg/litre
- STS – 0.2 – 4 mM
- Cytokinin – 1.0 to 100.00 m.

Packing :

Packing comprises three steps : bunching, wrapping and packing. The head of roses are evened up and their stem tied with a rubber band into bunches in 10s, 20s, 25s, or 50s depending on the ultimate market. They are cut so that all the stems are of the same length. The bunches are placed in preservative solution and may be shifted to the cold store. They are brought back to the packing hall and the buds are wrapped and the bunches are sleeved in transport polyethylene. The wrap is a 15-20 cm. wide plastic strip which acts as a cushion for the buds. Many different cardboard boxes are used for packing. For long term transport it is best to use telescopic style boxes made of corrugated fibreboard. The size could be 100 cm x 45 cm x 22 cm. There may be 400 to 1000 stems per box and weight may vary from 14 to 18 kg/box.

Depending on the market, the box is either filled with one variety, one grade, or mixed colour one grade.

Pest and Diseases : The principal pests of roses are :

- Red spider mite
- Leaf rollers
- White fly
- Thrips
- Aphids
- Nematode

The principal diseases are :

- Powdery mildew
- Downy mildew
- Botrytis
- Pruning die back
- Black leaf spot

Control

The preventive spray programme with a volume of 1500 litres/spray at an average interval of once in a week is suggested.

The chemicals could be as under.

- Dithane M-45 0.6 gm/litre
- Metasystox 1.25 ml/litre
- Karathane 1.00 ml/litre

Chapter 13

Greenhouse cultivation of Carnation Soil, Climate, Varieties, Propagation and Intercultural Operation

Perpetual carnations – *Dianthus caryophyllus* *Family* : Caryophyllaceae

Carnation is an important flower crop having great commercial value as a cut flower due to its excellent keeping quality, wide array of colour and forms. It popularity ranks among the toop three cut flowers in the West.

There are two basic groups of Carnations traded within the international markets.

S. No.	Types of Carnation	Size and No. of flowers	Climate Suitable	Varieties
1	Standard carnation	Single big flower on stem	Cool climate	Master, Tanga, Sonsara, Laurella, Solar, Dakar, Raggio di Sole, Cabaret and Isac
2	Spray carnation	A bunch of flowers with smaller size	Warm climate	Bagatel, Cherrybag, Fantasia, Picaro, Ondelia, Sintomia and Macarena

Climatic requirement: Most of the varieties of carnation are photo-period insensitive. Ideal temperature requirement is about 10˚ C in the night and 23˚ C in the day with RH 50-60 %. High day and night temperature induce abnormal flower opening and calyx splitting. High light intensity with a 12 hour day length may produce top quality flowers. For better quality providing long days for short period (4-6 weeks) when 4-7 pairs of leaves, CO_2 level 750-1000 ppm found optimum on sunny days while 300-500 ppm on cloudy days.

Bed Preparation :

Carnation may be grown in raised bed of soil. This would allow 72 % utilization of land.

Top width – 90 cm, Bottom width – 100 cm, Height – 45 cm, Pathway – 50 cm.

Planting Distance : Plant to Plant distance : 15 cm and Row to Row distance : 15 cm.

Planting : Rooted cuttings are planted at shallow depth. Deep planting will results in foot rot. Plant density of 20-30 plants/m^2 is optimal (1.5 – 2.0 lakh/ha). Can be planted round the year under greenhouse environment.

Fertilizer dose : A nutritional dose of 40 g N, 20 g P_2O_5, and 10 g K_2O is ideal. Liquid feeding of carnation plants with nutrient levels of 190 ppm N and 156 ppm K, 1 ppm B with each irrigation water results in high grade carnation.

Tank	Day	Fertilisers	Dose/Plant
A	Monday and Thursday	Ammonium nitrate	3g
		KNO_3	5g
		MAP	2g
		$MgSO_4$	2.5g
		B	1g
B	Tuesday Friday	KNO_3	5g
		$CaNO_3$	8g

Wednesday and Sunday – only water

- Ca deficiency – weak stem with small flowers
- B deficiency – calyx splitting and bud abortion

Irrigation : Overhead sprinkling is quite effective and economical than soil surface irrigation. At bod appearance stage, over-head sprinklers should be replaced with soil surface system. 20 litre/m^2 (twice a week)

Cultural Practices :

For proper growth of carnation plant and high production special cultural practices are to be carried out as follows :

1) **Support System :** Both spray and standard carnation produce weak and lanky stems hence must be supported with 4 to 5 layers of support netting. Lack of support system may cause lodging of stems. Nets of mild steel wire or nylon wires can be used. Nets of mild steel is expensive but last long. 4 to 5 layers of wire nets are required during the growth period of the plant. Spread the first support net i.e. 7.5 cm x 7.5 cm on top of the beds before planting. When the plants starts to grow, the net should be lifted by 5 to 7 cm above ground. The wire should be support with iron poles. The poles should be placed at a distance of 3M along bed length.
2) **Pinching :** Removal of unwanted vegetative growth form the axil of leaf below the terminal bud is called pinching, this helps to get good quality flowers and buds and avoids wastage of energy in the development of auxiliary bud if done at right stage and right time. It leads to apical dominance.
   There are generally two methods of pinching as follows:
   a. Single pinch method
   b. Pinch and half method
      Single pinch method :
      First pinching is done after 3 to 4 weeks from date of plantation, when the plants are well established. Apex shoot is pinched on the 5th to 6th pair of leaf (nodes). This method is adopted in order to produce maximum number of flowers during September to March when the demand for flowers in the market is high.
      Pinch and half method :
      This method helps to get continuous production. After one month of 1st pinching, second pinching is done only on half of the lateral shoot by leaving three pairs of leaves on the shoots. First the unpinched shoot will grow and produce flowers. Later on pinched shoots will grow and produce flowers.
3) **Disbudding :** Standard varieties are those with one flower on each stem. But as nearly all varieties produce some side buds below the center bud, those need to be removed. The removal of these buds is known as disbudding. It should not be done too early or too late. For most spray carnation varieties, the centre crown bud in many cases is also to be removed.
4) **Weeding and loosening of the soil :** This operation is done with the help of long handed weeding hook (khurpi). It is helpful for removal of weeds, breaking the top layer of algae and to facilitate better air circulation in soil, this is to be done very carefully to avoid damage of active roots.
5) **Calyx banding :** Reduces calyx splitting. Placing a rubber band or 6 mm wide clear plastic tape is used around the calyx of the flowers which have just start opening. This operation is referred as ‘Calyx banding’.

Chapter 14

Carnation, Harvesting, Post-Harvest Management, Pests and Diseases

Harvest:

Carnation flowers mature in 4-5 months period. Standard cultivars are harvested at "Paint Brush" stage with half-open flowers, or almost fully open flowers. Spray cultivars are harvested when there are 2 fully open flowers on the stem. Standard carnations can also be harvested at the stage of mature, large but tight buds with calyxes filled with petals or buds with petals just beginning to appear on the upper portion (i.e. at "cross" stage). Such buds may be stored under dry condition for 5-6 months (except yellow colour varieties). Flowers partly open when harvested at the star stages with petals emerging about 0.5 cm above calyx, may be stored upto 8 weeks. Flowers destined for storage should be free from diseases and pests. Harvesting should be done in the early morning and/or in the late afternoon, and they should not be wet at harvest. Immediately after harvesting flowers should be placed in a bucket of clean water inside the green house and transported to the grading hall.

Yearly production of 300-400 flowers/m^2 is ideal and economical.

Flower Preservatives :

All cut flowers auction centres in Western Europe require flowers to be pretreated with Silver Thiosulphate Solution (STS) or some other floral preservatives. The preservatives promote longevity and quality of cut flowers. They are mainly composed of sugar, germicide, STS, weak acid and growth substances. Concentration of preservative are indicated below :-

i. 8-Hydroxquionoline sulphate or Hydroquionoline citrate 200-600 ppm
ii. STS – 0.2 – 4 mM.
iii. Cytokinin – 10-100 ppm.
iv. Sugar – 0.5-2 %
v. Citric acid – 50-100 ppm.

Packing :

Packing comprises three stages : bunching, wrapping and packing.

The exact number of stems stipulated per bunch i.e. 5, 10, or multiples of 10 pieces should be tied with a rubber band at the base of the stem. The branches may be wrapped in paper. Plastic promote fungal attack. However, wrapping is not essential.

Many different cardboard boxes are used for packing. For long-term transport, it is best to use telescopic style boxes made of corrugated fibreboard. Boxes must be strong enough to support the weight of at least 8 full boxes placed on top of one another under conditions of high humidity. Special boxes equipped with a container for water in which flowers are held in a vertical position have been developed in the West. The end of flowers can also be placed in absorbent cotton saturated with water and enclosed in waxed paper or polyethylene foil (0.004-0.006 mm. thick) which permits air exchange. All gaps inside the boxes should be filled with shredded paper. Boxes are during forced air cooling must have vents on either side. Total vent size should equal 4-5 % of the area of the end wall of the box.

Pre-cooling :

After packing, the flower should be pre-cooled as soon as possible. Since temperature reduction from flowers is a rather slow process and metabolism may continue even at a low temperature, the heat from the freshly harvested flowers needs to be removed rapidly before shipping or storage. Pre-cooling is that rapid removal of field heat to bring the produce temperature down to or near to its subsequent storage or shipping temperature.

Precooling units are available that can cool from 4 to more than 100 boxes of flowers in less than 1 hour as against the requirement of 12-24 hours if the boxes are stalked.

The pre-cooling equipments can be installed in cold store or a separate pre-cooling chamber can be constructed alongside cold store. In the present model separate built-in pre-cooling and cold store units, which would be kept in grading shed have been suggested. Of the various methods of pre-cooling, forced air cooling is considered as the best for cut flowers. This operates by forcing cold aid through boxes which have vents at each end.

One of the vents at each end of the box is connected to a hold in the wall of the chamber with suction. The speed of the air flow may bring down the temperature of the flowers to the air temperature in the cold room is less than an hour. The suction is switched off as soon as the temperature of carnation flowers is near 0˚ C. The humidity must be maintained at high level (90-95 %).

Plant Protection

Disorder : Calyx splitting : which is a well known problem in carnation production is caused by the formation of a large number of petals or by lateral buds inside the calyx at low temperatures.

- Cultivars with too many petals are susceptible to calyx splitting.
- Due to fluctuation in temperature and environmental conditions also influences calyx splitting.
- B deficiency will also leads to calyx splitting.

  Measures :
  1. Selection of cultivars that are less prone to splitting.
  2. Regulation of temperature and maintenance of optimal fertilizer level can minimize this disorder.
  3. This can also be reduced by placing a rubber band or 6 mm wide clear plastic tape is used around the calyx of the flowers which have just start opening. This operation is referred as 'Calyx banding'.

Diseases : Pythium, Phytopthora rot, Fusarium wilt, Fusarium stme rot, Alternaria blight, Grey mold.

Pests : Aphid, Mealybug, Spidermite, Thrips, Whitefly

Control :

1. Soil Sterilisation – Chloropicrin
2. Dithane – 0.6 gm/litre
3. Metasystox – 1.25 ml/litre
4. Karathane – 1.00 ml/litre

Volume of preventive spray – 1500 litre/spray and frequency is 50 sprays/year i.e. once in a week.

Chapter 15

Greenhouse cultivation of Chrysanthemum, Soil, Climate, Varieties, Propagation and Intercultural Operations

Chrysanthemum are among the top two best selling cut flowers in international trade. It is number one flower in China and Japan. In India it has been recognized as one among the five important commercially potential flower crops.

Cultivation Structures :

Polyhouse

Greenhouse with 25 % shade net

Types : Sprays and Standards

Chrysanthemum are broadly classified into 3 groups on the basis of their response to temperature. Thermozero varieties flower at any temperature ranging 10-27˚ C but most consistently at a constant 16˚ C night temperature. Thermopositive varieties require higher temperature (27˚ C) for bud initiation and lower temperature inhibit completely. Thermonegative varieties flower at any temperature between 10 and 27˚ C, but flowering is delayed at higher temperature. Most promising cultivars in the international trade are Snow Ball, Snow Don White, Mountaineer, Sonar Bangla, Bright Golden Anne, and Chandrama among large flowering tyeps while Ajay, Birbal Sahani, Lehmans, Nanako, and Sonali Tara in case of small flowering types as sprays are most common.

Temperature :

16-25˚ C for vegetative growth

16-18˚ C for flower induction

Optimum night temperature – 15˚ C

Optimum day temperature – 25˚ C

Light requirement : 70,000 Lux or 3000-10,000 foot candles and minimum of 10 foot candles light required to prevent premature flower bud formation.

CO_2 requirement : 750-1500 ppm

Relative Humidity : 75 % optimum

Day length : Short and day neutral varieties are there however only photosensitive varieties (Short day plants) are grown in greenhouse for continuous production throughout the year. During vegetative phase day length more than 12 hours is required whereas for reproductive phase day length is less than 12 hours and night length should be more than 13 hours.

Growing Media : pH of the soil around 6.5 with EC 1-1.5, well drained and aerated. Soil less media used is Rock wool and it can be sterilized by water steam or fumigation.

Propagation Method : Rooted terminal stem cuttings or micro propagation

Supporting : Various methods can be used to support chrysanthemum so that they will grow erect. The most satisfactory system of supporting is welded wire mesh of either 12.5 x 12.5 or 15 x 15 cm are used.

Plant Density : 15 to 20 x 15 -20 cm for plants that will be pinched (64 plants/m^2)

10 to 15 x 10 – 15 cm for plants that will be grown as single (32 plants/m^2)

July-August is ideal time of planting chrysanthemum in North India. However, if controlled photoperiod facilities are available planting can be done round the year.

Irrigation : Sprinkler irrigation from planting for every 7-10 days interval and gradually reduce the number of applications. Drip irrigation resorted at the end of sprinkler irrigation with fertilizer 2-3 drip lines for each row of bed with drippers placed at 30 cm.

Nutrition : 25-50 ppm of N, 5-10 ppm P, 20-40 ppm K and 100-150 ppm Ca

a) Planting to thinning : Fertigation : 20 : 20 : 20 – 150 ppm
b) Thinning to darkening : N-90 ppm, P-50 ppm, K-150 ppm
c) Darkening to buds : N-150-200 ppm, P-50 ppm and K-200-300 ppm
d) Buds to harvesting : N-150 ppm, P-50 ppm and K-250 ppm

Intercultural Operations :

1. **Pinching :** It encourages side branching.
   - **a) For standards :** Pinching is not done if only one central bloom is desired on the main shoot. Single pinch is done if two flowers are desired and double pinch is done for 4 flowers.
   - **b) For sprays :** Two pinchings are followed to encourage lateral growth. 1^{st} pinching is done at 4 weeks after planting and 2^{nd} pinching is done 7 weeks after planting.
2. **Thinning :** Following pinching several side shoots develop and these must be limited depending on the amount of space that is allows per plant.
   Standards : 2-3 stems
   Sprays : 3-4 stems
   Thinning operation is done 10-15 days after pinching.
3. **Deshooting :** It is done to remove side shoots which arise from axil of shoots for obtaining few flowers of better quality and size. In standards regular deshooting is done to produce single flower on single stem.
4. **Dis-budding : For Sprays :** As soon as the buds separated from one another, the central bud is pinched out to improve the spray shape. It is done between 2^{nd} and 3^{rd} week before harvesting. It is done to improve the size and quality of flower. For standards : Incase of standards side buds are removed to improve the size and quality of central bud.
5. **Induction of flowering (Block cloth treatment) :** Under natural long days (from late spring to early fall), short days can be created by blocking out all light with black plastic or cloth. Many growers use black cloth to provide short days to induce flowering of chrysanthemum.

Chapter 16

Chrysanthemum, Harvesting, Post-Harvest Management, Pest and Diseases Harvesting

For singles 11-15 weeks after planting are ready for harvesting

For singles 13-19 weeks after planting are ready for harvesting

Spray types are to be harvested when the central flower is opened or three out side flowers have opened with surrounding flower buds are well developed. Standards are harvested before the central florets are fully opened or the standards can be harvested in unopened stage i.e. when the inflorescences are 5-10 cm in diameter.

Decorative types – petals in centre of top most flower fully developed

Standard – outer rays florets ceased to elongate and few unfurl

Pot mums – Flowers half to fully open

Yield : considering 70 % growing area Standards may yield – 2.5 – 4.0 lakh/ha and sprays – 1.5 to 1.75 lakh/ha.

Grading : depend on Stem length, colour and diameter of flower

In USA generally SAF (Society of America Florists) Standards are followed

Packaging :

Standard chrysanthemum placed in sleeves packed in display boxes (91 x 43 x 15 cm). Placed in boxes as per grades and bulk packing sprays 10, 15, 20 stems placed in sleeves. Six sleeves 3 at each end packed in each box measuring 80 x 50 x 30 cm.

Post Harvesting Handling: After harvesting placed in cool and clean water. Stems should be cut at equal distance (90 cm for the standards). The lower one third of the foliage on the stem is stripped off. Then the flowers can be graded, bunched. The 250 g bunch has been used widely for the spray types but bunches weighing 450 g are common. Less than 5 stems per bunch is not acceptable to most of retailers. The bunches are to be packed in plastic sleeves. The stem length need not be over 75 cm for most purposes. Precooling at 4˚ C for 12-20 hours, before grading has to be done to remove field heat.

Storage : Can be stored at 1˚ C for 3 weeks in preservative solution like HQC or STS 0.1 %.

Aphids :

Damage by aphid's results in loss of vigour, yellowing and premature leaf fall and stunted growth of attacked plants.

Control : Spraying of Monocrotophos @0.05 % or Phosphamidon @0.02 % at 15-20 days interval.

Thirps :

Damaged flowers look discoloured, withered and dried due to scorching. Severe infestation adversely affects quality and quantity of flower production.

Control : Spraying with Monocrotophos (0.04 %) twice or thrice at 15 days interval controls thrips population.

Although the list of diseases that may attack chrysanthemum is long, mums are relatively trouble-free.

- Leaf Spot
- Rust
- Wilt
- Powdery Mildew
- Ray Blight
- Ray Speck
- Gray Mold

Spray the following chemicals weekly once chlorothalonil, mancozeb, nyclobutanil, propiconazola r thiophanate methyl

Chapter 17

Greenhouse cultivation of pot plants Gerberas

B.N. : *Gerbera jamasonii* Family : Asteraceae Important flower grown through out world.

Introduction :

Gerbera is a very attractive, commercial cut flower successfully grown under different conditions in several areas of the world as well as in India and meeting the requirements of various markets. This flower is originated in Asia and South Africa. Gerbera jamesonii has been developed through cross breeding program.

Varieties :

There are many multi coloured varieties of Gerbera developed through tissue culture. Jaffa, Sangria, Rosula, Oprab, Romona, Salina, Tecora and Starlight.

Climate :

Bright sunshine accelerates the growth and quality of the flowers, however, in summer this flowers needs diffused sunlight. Gerbera plants grown in locations with insufficient light will not bloom well. Temperature day 22-25˚ C, Night 12-15˚ C, Optimum 23˚ C. Below 12˚ C above 35˚ C will affects bud initiation. Optimum humidity – 75-80 % and required light intensity is 400 w/m^2 450 or 600 FC. Optimum CO^2 – 700 ppm (0.07 %)

Soil :

Red lateritic soils are good for Gerbera cultivation at it is having all the essential qualities that an ideal soil should have. Planting medium should be well drained-porous soils with pH – 6.5 – 7.0 are highly suitable. Well decomposed FYM, Sand and coconut coir pith 2 : 1 : 1 used for preparation of raised beds. After fumigation with formaldehyde, the raised beds are prepared on which Gerbera plants are planted.

Bed Preparation :

Top width – 60 cm

Bottom width – 70 cm

Height – 45 cm

Path way – 40 cm

Planting Distance :

Plant to Plant Distance - 30 cm

Row to Row Distance – 30 cm

Planting density – 8-10 plants/sq.m.

Planting Material :

Division of clumps and tissue culture plants are used as propagating material. Plants should not be less than three months old. At the time of planting the tissue culture, plant should have at least 4 to 5 leaves. Gerberas are planted on raised bed in two rows formation. Zigzag plantation system is mostly preferred. While planting 65 % portion of root ball should be kept below ground and rest of the portion i.e. 35 % should be kept above the ground for better air circulation in the root zones.

Manures and Fertilizers :

Organic manures are required to be added so that top 30 cm of the soil has 30 % organic matter content. Application of nutrients should be based on analysis of soil and plant. 20 : 20 : 20 NPK @ 1.5 g/L once in two days for first three months and at flowering – 5 : 8 : 35 NPK @ 1.5 g/L on alternate days.

Cultural Practices :

1) **Weeding and Raking of soil :** Weeds take the nutrients of the plants and affect the production. Hence, they should be removed from the bed. Due to daily irrigation, the surface of the gerbera bed becomes hard hence raking of soil is done with the help of a raker. It increases soil aeration in the root zone of the plant. This operation should be done regularly, may be twice in a month.
2) **Disbudding :** Removal of inferior quality flowers at the initial stage after plantation is called disbudding. The normal production of gerbera plants starts after 75-90 days from the date of plantation. Production of flowers starts 45 days after plantation but initial production is of inferior quality, hence these flowers should be removed from the base of the flowers stalk. This helps in making the plant strong and healthy.
3) **Removal of old leaves :** Sanitation helps in keeping the disease and pest infestation below the economic threshold level. The old, dry, infested leaves should be removed from the plant and burst outside the greenhouse or dumped in to a compost pit. This practice allows producing good, healthy new leaves and better aeration in the crops.

Irrigation : Gerbera plant water requirement is 500-700 ml/plant/day 4.5 to 6 litres/m^2 and Avoid excess watering.

Pest and Diseases :

The principal diseases of Gerbera are –

- **i.** Pythium
- **ii.** Sclerotinia
- **iii.** White rust
- **iv.** Rhizoctonia
- **v.** Fusarium

Major insect pests of the rose are

- i. Red Spider Mite
- ii. Aphids
- iii. Thrips
- iv. White fly

Control :

The preventive spray programme with a volume of 155 litres/spray at an average interval of once in a week is suggested.

The chemicals could be as under –

a) Dithane M-45 0.6 gm/litre
b) Metasystox 1.25 ml/litre
c) Karathane 1.00 ml/litre

Harvesting :

Disbudding done at 75 days after planting and the first flowers may be harvested after 75-90 days after planting. Flowers of most of the varieties (single types) are ready to be picked when 2-3 whorls of stamens have entirely developed and out 2-3 discs perpendicular to stalk. Some varieties are picked little riper, especially the double types. Skilled labours are required for harvesting of gerbera cut flowers. After harvesting the flowers should be kept in bucket containing chlorinated water. Flowers are very delicate hence they should be carefully handled otherwise can be damaged and their quality get deteriorated. For harvesting gerbera no secateurs are required and are done by naked hands, 200 flowers/m^2/year (6-7 plants) – 85 % first grade.

Grading : Graded based on Stalk length 45-55 cm and flower diameter – 10-12 cm Packing : Harvested flower heads are capped with – Polythene sleeve (small polythene bag) and such 10 flowers are made in to one bunch which are tied with rubber band. 500 flowers are packed in CFB boxes 98 x 30 x 12 cm.

Chapter 18

Greenhouse cultivation of Orchids, Soil, Climate, Varieties, Propagation and Intercultural Operations

Introduction :

Orchids are considered as the most beautiful flowering plants for the exquisite beauty of the flowers, variety of fragrance, brilliance in colour, unusual shapes, variation in form and attractive growth habits. There are about 24,000 species and 32,000 hybrids of orchid.

Development of new hybrids and commercial production of cut flowers in orchids are expanding rapidly in the USA, Europe, Thailand, Malaysia and Singapore. There is immense scope for improving orchids in India, because large number of species are native to this country and many of them have already proved to be important parent plants and contributed in the production of several outstanding hybrids in the world. Due to the diversity of environmental condition in India, it is possible to grow all types of orchids in suitable places without the control of environment. Thailand is the largest producer of tropical dendrobium, Vanda cut flowers. Significant quantities are now being produced by Srilanka and Singapore.

Varieties : Laura (Bicolour), Lady (Bicolour), Venus (Pale purple) and Royal pink Forest is the natural habitat of orchids. More or less similar environment can be created by growing the plants in greenhouse and protecting them from direct scorching sun, dry wind and by maintaining high humidity.

Warm Climate Orchids :

Orchids which suit warm climate condition and can be successfully grown in ordinary greenhouse include the numerous hybrids of Cattleya, Dendrobium, Onicidium, Phalaenopsis, Rhynchostylis and Vanda, Orchid species producing beautiful.

Orchid House and its climate management :

A free standing flat-roof orchid house shaded by spit bamboo or wooden batten is recommended for housing of orchids suitable for warm climate. The temperature range suitable for most of those orchids is 65 to 85˚ F. For satisfactory growth of orchids, atmospheric humidity should not be less than 30 percent at night and 70 to 80 percent during the daytime. Monopodial orchids like Vanda, Phalaenopsis require high humidity, whereas sympodial type e.g. Cattleya, Laelia or those with leathery leaves need less humidity. The atmospheric humidity will increase if small tanks or lily pools are located inside the orchid house and the floor space is covered with sand, soil, etc. instead of concrete. Free circulation of air is needed for the orchids to grow and flower and light intensity ranging between 1500 to 2000 foot candle in midday is good enough for most of the orchids.

Propagation : By seed and vegetative

1. **Seed Sowing and Care of Seedlings :-**
   Seedpod of orchid grow after fertilization, and ripens in six months to one year. After ripening the seeds are collected and stored in a cool and dry place or in a desiccator. Millions of powdery seeds are released from each pod and they contain little or no food to nourish the embryo. Under natural condition, the seeds germinate when they find a right pocket of decaying vegetable matter on the trees.
   Seeds of orchids are germinated and seedlings grown in culture media containing agar, inorganic nutrients and sugar. Disinfected seeds are sown in sterilized flasks containing agar-nutrient media and the seedlings grow for 8 to 12 months before they are transferred.
   The seedlings are removed from the flask and planted in the community pots, 7 to 10 cm in diameter which bold about 20 to 25 small plants. The compost used for seedlings in the community pot is a mixture of equal parts of the finely chopped tree fern and dust-

free crushed bark or moss. A shady but well aerated location in the greenhouse will promote the growth of seedlings. In the community pot, the seedlings are watered daily and during the summer months they may be sprayed with water two to three times a day.

With the increase in size and vigour, each plant is transferred in a small pot, using the same compost recommended for larger plants, but at this stage they benefit by feeding with the weaker concentration of fertilizer solution.

2. **Vegetative Propagation :-**

Besides multiplication by seeds, commercial method of vegetative propagation of hybrids of Cymbidium, Phalaenopsis and Cattleya is done by **meristem culture** and large number of plantlets develop from a small piece of growing apex. **Offsets** develop from Dendrobium and some Epdiendrum, which can be detached and planted in small pots.

Air layering is practised on the monopodial types like Vanda. A slant cut is given halfway in the stem and wrapped with sphagnum moss. When roots are noticed in the moss, the upper portion of the plant with is detached and potted.

Potting and Compost/Media :

A vigorous and healthy root system often indicates good vegetative growth of the plants, which largely depends on the pot compost. Ideal rooting media will provide high degree of porosity and ensure adequate oxygen for root respiration. Water should drain out freely through the media and it should be resistant to rapid decomposition and decay.

Depending on the growth habit. i.e. terrestrial or epiphytic, orchids are potted in a wide variety of media and compost. Epiphytes like Cattleya, Epidendrum, Phalaenopsis Vanda, Dendrobium, Rhynochostylis, etc., are planted on a very light rooting media, consisting of various kinds of tree fern fibre or on larger pieces of hard charcoal.

Watering and Spraying :-

As orchids are grown in a light and porous compost, watering is very important. Atmospheric humidity influences evaporation of moisture from the compost and orchids, in general, prefer high relative humidity. In a dry and well ventilated atmosphere, damping down of the floor of the greenhouse, frequent overhead sprinkling of water will increase the humidity. But in high humid atmosphere watering should be less frequent. Alkaline water is injurious to orchids and slight acidic water or at pH up to 7 should be used.

Newly potted plants should not be watered very frequently but the compost is kept moist by fine spraying. As new root emerges and growth starts, the plants need more frequent watering and it should be decreased again after flowering. Fine spraying of water is also very beneficial to plants during the period of growth or on warm dry days.

Nutrients :-

It has been observed that growth and flowering or orchids are improved markedly by the application of fertilizers in liquid form and a number prepared fertilizers are available. A balanced feed on nitrogen, phosphate and potash in the ratio of 10 : 12 : 10 and very small amount of magnesium, calcium, manganese, iron, boron and zinc has been found very effective on a large numbers of species and hybrids. For mature and flowering plants. Two table spoonful of the above fertilizers mixed in 10 litres of water is sprayed once a week, while a more dilute solution is used on seedlings. Leaves and rooting media should be thoroughly sprayed with the fertilizer solution.

Lecture 19 : Orchids, Harvesting, Post Harvest Management, Pest and Diseases

Harvesting : Stage of cutting is when the bottom 8 flowers are fully open.

Yield : 6 stems/plant 180-200 stems/m^2

Grading and Packing : They are graded according to stem length

Grade Name	Stem Length (cm)
Super long	>55
Long	45-54
Medium	35-44
Short	Upto 35

Grade Name	Stems/carton	Size of carton (cm^2)
Super long	400	38 x 39 x 75
Long	400-500	38 x 39 x 75
Medium	500	38 x 39 x 75

Storage : Stored at temperature more than 10 C. Dendrobium is sensitive to Ethylene. So Ethylene absorbent sachets should be used.

Diseases and Pests :-

Orchids are less subjected to the attack of pests and disease. Scale insects, mealy bugs, green fly, thrips, red spider and snails may cause considerable damage, if they are not controlled in time. Application of Rogor 2 ml or Malathion 2 ml/L water is very effective to keep the orchids free from pests.

Die-back is a serious disease which starts in rhizome and if left unattended, it spreads to other plants in the orchid house. Orthocide 50 and Cossan are recommended for controlling fungus diseases on orchids. Virus infection is also common in several species and varieties of orchids. Sometimes black spots appear on leaves and flowers turn yellow and drop off. This is not caused by fungus but due to faulty culture like over-watching insufficient ventilation, too much of light or very dry atmosphere.

Cleanliness of the greenhouse and regular attention to the plants are very important to keep the plants free from diseases and pests.

Chapter 20

Greenhouse cultivation of Anthurium Anthurium

Anthurium andreanum Family : Araceae

Genus anthurium consist of 500-600 species, out of which 10-15 are known to vtrade. The cultivated species are grouped in **two**

1. **Flowering group :** Anthurium andream, A. bakeri, A. brownie, A. ferrierense and A. ornatum.
2. **Foliage group :** A. corrugatum, A. crystallium, A. holtoniaum and A. penduratum.

Qualities of a good anthurium cultivar :

1. The plant should have short inter nodes, be compact and produce suckers profusely.
2. Capable of producing more number of flowers/plant/year.
3. The spathe should be bright, showy, heart shaped with plenty of blisters.
4. Spadix should be parallel to the spathe and shorter than spather (For easy packing and more number of plants)
5. The flower stalk should be long generally **5 times** more than length of Spathe and resistant to common pests and diseases. Basically, anthurium cultivars are classified in to **three** groups. 1. **Hawaiian** 2. **Holland** 3. **Others**. Upto 1970's Hawaiians stands No. 1 in the world in anthurium production. But due to **Blight disease** the quality of produce are reduced and the Netherlands stands No. 1 position in recent days. Anthuriums are available in Red, orange, pink and white colours. The bicolour anthuriums are called as **Obekes**.

1. **Red :**
   Hawaiian cultivars – Ozaki and Kaumana
   Holland cultivars – Cancan and Fla Red
2. **Orange :**
   Hawaiian cultivars – Nitta, Sun burst
   Holland cultivars – Fla Orange
3. **White :**
   Hawaiian cultivars – Trinidad, Jamica
   Holland cultivars – Uranus, Cube
4. **Pink :**
   Hawaiian cultivars – Blush, candy stripe
   Holland cultivars – Sarina

Environment : It is a typical tropical plant requires 20-30˚ C with plenty of light. Its cultivation is possible in polyhouses as well as shade net houses (75 % shade net). If prefers a CO_2 concentration of 1000-1500 ppm and a liht of 8000 Lux or 1500-3000 foot candles. Increasing temperatures results in **Blueing of flowers** and these flowers are not preferred for the international market.

Propagation :

1. **Seed Propagation :** Seeds taken from half ripen and ripe berries gave 100 % germination.
   Storage of seeds for 5 days reduces germination.
2. **Vegetative propagation :**
   (a) Division : Propagation by divisions of **Off shoots** with aerial roots is easy. Sucker production largely depends on health of plant and environment.
   (b) Cuttings : Terminal cuttings are best, **Intermittent mist** accelerating rootingof cuttings.
3. **Micropropagation :** Commercial purpose

Growing media :

- Good water holding capacity
- High porosity
- Low salt concentration interms of Ca^{+2}, Cl^{-}, Na^{+2}
- Optimum pH is 5-7, E.C. – 0.6 mm hos/cm^2
- Good structure and texture

Mixtures : Saw dust or tree bark, peat or wood shavings, ground nut shells, brick gravel and rock wool. Media required for anthurium is **Epiphytic media**.

Cultivation : Do it in

1. **Pots :** flower production of exotic types
2. **Beds :** flower and foliage production

For flower production of exotic types anthurium is grown in pots. For the foliage as well as for flower it is grown on the epiphytic media which are formed in to beds under the shade net or polyhouses.

Planting : Avoid planting during heavy rainfall period. Make sure that the medium is evenly mixed and provide initial fertilizer requirement rich in K and Ca. Dip the roots in 0.1 %. Bavistin before planting in rows in crosswise direction. Plants are planted at 15 cm depth with out pruning the leaves.

Spacing : 30 x 30 cm – 7-9 plants/m^2

45 x 45 cm – 5-6 plants/m^2

Exotic varieties where the foliage has value are planted at 45 x 45 cm

Fertilization and Fertigation :

Fertigation schedule for Anthurium :

Macro nutrient	**Quantity (ppm)**	**Micro nutrient**	**Quantity (ppm)**
Nitrate	91	Iron	0.8
Phosphate	31	Boron	0.22
Potash	14	Manganese	0.16
Sulphate	48	Zinc	0.8
Magnesium	60	Copper	0.03
		Molybdenum	0.05

This nutrition is supplemented thrice in a weak through drip irrigation. 5 g complex fertilizer dissolved in 500 ml water could be given in the medium once in 2 months. Foliar sprays of 0.5-1.0 % of 17 : 17 : 17 complex could also be given to the plants, at biweekly interval. Plants should be watered shortly after application of the fertilizers. The N, K and Ca are the important elements required in anthurium nutrition. A deficiency of **Ca** can cause fading of the spathe colour. Apply Ca (5g/plant/month) to recover Ca deficiency.

Reduce the dose of N when plants switch over from vegetative to flowering phase. An over dose of fertilizer, applied shortly before the harvest of spikes, is surely going to reduce the vase-life of flowers.

Irrigation Schedule for Anthurium : The plants should be watered at least twice daily during summer. Mist or sprinkler irrigation is the best for anthurium. The last watering in a day should be timed in such a way as to leave sufficient time for the water to evaporate so that the plants are not damp during night hours. The quality of water is also important. It should be preferably free from dissolved salts. The optimum pH is between 5.5 and 6.0. If pH of water above 6.5. Nitric or Phosphoric acids are added to maintain pH. Water requirement is 2 L of water/m^2/day.

Yield : The yield starts 18 months after planting

Year	Flowers/plant/year	Flowers/M^2	Flowers/ 1000M^2
2nd year	6	48	48000
3rd year	8	64	64000
4th year	10	80	80000

Harvesting : Harvesting is done based on

1. Firmness of the panicle.
2. Colour of spadix
3. Size of the spathe

Grading :

- Based on size of spathe (LXB) and on stalk length graded in to super, large, medium and small
- Absolutely fresh
- Free form residues of pesticides
- Straight stalks and sufficiently strong to carry the flowers
- Green petal margins are permitted if they are graded separately

Packing : They are packed in CFB boxes of 100 x 17.5 x 9 cm^3 are used for Hawaiian types where as for Netherlands types 100 x 20 x 10 cm^3

The flowers in bunches of 12 denomination are bundled the whole flower or the spathe is put in to the plastic sleeves to avoid the damage. The flower stalks cut ends are wrapped with the swab of cotton or florist brick pieces and for long distance travel the cut ends are placed in vials containing holding solution and they are properly corked. This keeps the flowers in fresh conditions for a longer time. For better storage the cold chain of 2-8˚ C in precooling chamber for 4-5 hours and 6-8˚ C during the transit period.

Rating scale for exportable blooms based on spadix and spathe condition :

Scale	Spadix condition
I	No blemishes
II	Spadix tip showing slight discolouration/browning
III	Spadix tip showing definite browning, slight separation of florets
IV	Tip definitely browning and drying out, less than 10 % of total length affected
V	Tip necrotic and dried out greater than 10 % the total length

Rating scale for spathe blueing (discolouration) :

Scale	Spathe discolouration
None	Fresh cut appearance and no blueing
Slight	<5 % blueing
Moderate	5-10 % blueing
Severe	>10 % blueing

Chapter 21

Greenhouse cultivation of Lillium

Introduction : Lilies are very beautiful ornamental plants with splendid appearance and attractive shades. They are excellent as cut flowers and occupy 4th in the world cut flower trade. The big advantage of a greenhouse that the grower can control the environment; lilies can be provided with warmth and moisture and observe weather conditions can't hamper the plant growth.

Types of Lilies Grown Under Greenhouse : Lilies, especially Asiatic and Oriental types are in great demand in the international floriculture trade.

S. No.	Asiatic type	Oriental type
1	Early bloomers	Late bloomers
2	Usually non fragnant	They are heavily scented
3	Rapidly multiply	Slow multiplication
4	Greater color range	Large flowers
5	More variance in flower shape and bloomliness	Many oriental lilies have raised pupillae in the petal nectaries
6	Varieties : Connecticut king, Gran paradise, Elite, Prato, Solemio, Pollyana	Varieties : White star gazer, Macro Polo, Casablanca

Easter lily (Lilium longiflorium) var. Osant (white) is also grown under polyhouses. Producing lilies in greenhouse requires accurate control of temperature, air circulation, ventilation and light. A standard height of 4 to 4.5 metre is customary. This will provide sufficient room for installing the screening, irrigation and lighting system. The greenhouse should have a plenty of natural light which is important during the dark winter period. Asiatic hybrids require minimum greenhouse temperature of 8-14˚ C. Optimum level of Relative Humidity inside the greenhouse should be 80 to 85 %. It is important to avoid large fluctuation in humidity levels which will cause stress and leaf scorch in susceptible varieties.

Forcing : Forcing lily flower for normal durations, the bulbs require cold treatment at 2-4˚ C for 6 weeks in case of Asiatic hybrids and 8 weeks for the Oriental ones. It is possible to use "frozen-in" bulbs which are kept at 1˚ C after pre-cooling treatment for off-season flowering. A night temperature of 16˚ C with a day temperature below 21˚ C inside the greenhouse is recommended for forcing.

Bedding Media : The soil used for cultivation of lilies, has good structure particularly the top layers and is also kept well drained during the entire growing period. Maintaining the correct pH of the soil plays a major role in the root development and uptake of nutrients. It is advisable to maintain a pH of 6 to 7 for the Asiatic and longiflorum hybrids groups and a pH of 5.5 to 6.5 for the oriental hybrids. The Chlorine in the soil should not exceed 1.5 mmol/lit.

Bed Composition : Red soil – 60 %, FYM – 30 %, Sand – 10 %, Rice husk – As per requirement

Planting Depth : Lillium bulbs should initially be planted at a depth of 6 inches. After planting and irrigation the soil will decline about an inch. Height of the bulb is approximately one inch, which leaves four inches of soil on the top of the bulb. This is sufficient soil in which the stem roots can develop. Shallow planting will result in poor stem, root development and hence one compromise on the quality of the flower. Planting depth varies according to the size of the bulb. Generally bulb should be planted to the depth of three times more than the diameter of the bulb.

Planting Density :

Bulb Size (cm)	Bulb/m²	Planting Distance (cm)
8-10	49	15 X 15
10-12	42	16 X 15
12-14	36	16 X 18
14-16	36	16 X 18

Irrigation : Water requirement in summer – 6 to 8 lit/m²/day and in other season : 4 to 5 lit/m²/day. First two weeks irrigation only by using water can or shower. Third week onwards it is recommended to use drip for irrigation.

Fertigation : Since lilium is a bulbous crop, most of its nutrient are already present in the bulb itself. Lilium is a very salt sensitive crop and therefore one should take care with applying fertilizers. Especially in the first three weeks when the rooting takes place, no additional fertilizers are required. Good root development is important at this stage. It is however advisable to apply 12:61:00 @ 2 kg/100 m² at least one week before plantation. Three weeks after plantation :- Calcium Nitrate @ 1 kg/100m²

Six week after plantation :- Potassium nitrate @ 1kg/100 m². If plants are not strong enough during growing period due to Nitrogen deficiency then a top dressing of Ammonium Nitrate @ 1kg/100 m² can be applied up to three weeks before harvesting.

Harvesting :

1. Always harvest the lilies at the cutting stage, i.e. 8 to 10 cm above the ground when lower first bud shows the colour of flower.
2. Prevent the stems drying out during and after harvesting.
3. After harvesting, stems are graded according to number of flower buds per stem, length and firmness of stem.
4. During bunching, remove 10 cm of foliage from the end of the stems and subsequently sleeve the flowers.
5. Immediately after bunching, the cut flowers should be placed in cold water in cold storage room at 2˚ C to 3˚ C. Add 2 % sucrose and 100 ppm GA_3 as a preservative agent to water to improve vase life of flower.
6. Cut lilies could efficiently be started both dry (sealed in plastic bags) or wet (1/10 portion in 25 ppm silver nitrate) at 10˚ C cold storage temperature up to 4-6 weeks provided they are pulsed with 0.2 mM STS + 10 % sucrose for 24 hr.
7. When dispatching lily flowers use only perforated boxes to maintain a proper temperature during transport.

Diseases and Their Management :

Bulb and Scale Rot : To avoid the disease, bulbs should be planted in pre-sterilized soils. Bulbs should be dipped for one hour in 0.2 % Capton + 0.2 % Benlate to minimize the disease infection.

Foot Rot : Dithane M-45 may be applied @ 200 g per 100 m² as soil drench.

Chapter 22

Greenhouse cultivation of Tulip

Tulipa gaserianama belonging to family **Lilliaceae**. Genus Tulip consists of 100-500 species, it ranks first among bulbous. Tulips are excellent for cut flowers, beds, pots and are grown in open as well as under protected conditions. The largest area under a true bulb crop in the world is that of tulip. Holland is the largest producer of tulip flowers and bulbs and it has become the back boon of flowering industry in the Netherland. In India, tulips thrive well in temperate regions of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and similar hilly regions. They do not thrive in the open in tropical climates as they require a cold-water season to grow successfully. However precooled bulbs are being made to flowers during winter in plains.

Pre-Requisites for the cultivation of Tulip flowers inside the greenhouse:

a) Treat the tulip bulbs the correct amount of chilling by either allowing them to place in an unheated greenhouse, or by placing them in a cooler. They must not be exposed to light during the chilling time, or they may sprout. The length of chilling required for most tulip varieties is 14 to 16 weeks, depending on the variety. The temperature must stay between 2 – 9˚ C during this time. Do not allow tulip bulbs to freeze during the chilling period. The amount of time from chilling to bloom time will take about 21 weeks, depending on the tulip variety.
b) Plant the bulbs in the ground inside the greenhouse, or planting trays filled with potting soil inside the greenhouse, after the chilling period is finished. It takes four to six weeks for the tulips to bloom after planting in the ground or trays inside the greenhouse once they are exposed to the correct temperatures and light levels. When planting the bulb directly in the ground or in planting trays, plant as close as 2 inches apart and 1 inch below the surface of the soil.
c) Expose the planting area for growing your tulips to a steady temperature of 17 to 20˚ C for optimal flower production. Temperatures that are below the required level will slow down tulip growth and cause the stems to be short. Temperatures that are too warm will cause the bulbs to bloom quickly on long, rangy stems.
d) Allow unobstructed sunlight levels through the top and side of the greenhouse to reach the area the tulip bulbs are planted. No artificial light is necessary once the chilled bulbs are planted and exposed to the right temperatures and normal greenhouse light levels.

Climate : Tulips require hot dry summers followed by cold and wet winters for their optimum growth and development. Among the various environmental factors, temperature is the most important factor affecting growth physiology of tulip. There is an obligatory temperature requirement for tulip growth. It requires warm (17-20˚ C), cold (2-9˚ C) and warm (17-20˚ C) temperature in sequence.

Propagation : Daughter bulb offsets from vegetative axillary buds in the axils of the tunicated scales. Two to three new bulblets are produced annually. It takes 2 to 3 years to produce a commercial size bulb capable of flowering. Bulb circumference or weight is the primary flowering control factor. Common bulb size for potted flowering plants is 4.75 – 5.5 inch (12 – 14 cm)

Planting : Media – do not overfill the pots. Arrest drench within 24 hours of being moved to greenhouse. Plant 6-7 bulbs in a 6 inch pot. Space pot to pot in the cooler and greenhouse.

Potted flowering tulip culture : Light – 1000-2500 fc (low). Shade or light exclusion are sometimes used for etiolation to increase stem length on early corps. Water – medium should always be kept evenly moist (in rooting room and greenhouse). CO_2 is not used.

Nutrition : low requirement, but $CaNO_3$ can be used to prevent stem topple. **Diseases :** Fusarium – white to tan mold growing on outer tunic of bulb and results soft bulbs and light weight bulbs.

Physiological Disorders :

Stem topple : Stem collapses a few centimeters below the base of the flower and is due to Ca deficiency or excessive cooling or high forcing temperatures.

Chapter 23

Greenhouse cultivation of Tomato, Soil, Climate, Varieties, Propagation and Intercultural operations.

Tomato occupies No. 1 place in vegetables under polyhouse cultivation. In the world it was grown in polyhouse and shade net houses.

Basically 3 types of tomatoes are grown in polyhouses

1. **Truss types :** Trust and Match 2. **Red fruited :** Vendor, Dombi and Carus
3.Pink fruited : CR-6, KR-12 and KR-15

Environment :

Germination of seeds : It requires 24˚ C and for hardening of seedlings at 20˚ C with 1000 ppm of CO_2 and 1000 Foot candles of light preferably long days.

Vegetative Phase : It requires 22˚ C night temperature 25˚ C of day temperature with 3000 ppm of CO_2 and 1000 foot candles of light, preferably long days.

Reproductive Phase : It require 23˚ C of night temperature 26˚ C of day temperature, 1000-1500 ppm of CO_2 with 3000 Lux of light and 65 % of RH.

Low temperature <15˚ C at the time of harvest reduces the flavour of the fruit.

Soil : The tomato crop can be raised in a wide variety of soil ranging from light textured sandy or sandy loam to heavy clay soils. The soil should be rich in nutrients and organic matter. The ideal soil pH is 6.00 to 7.00 for its growth. High organic matter content in soil is highly essential for higher production and quality.

Varieties/ Cultivars : Tomato hybrids with indeterminate growth habit are best suited for greenhouse cultivation, as the hybrids grow to a height of 15 feet and above which utilizes greenhouse space, both horizontal and vertical.

The varieties which are preferred for cultivation under polyhouse are –

a. Tomato – By Syngenta – Him Sona, Him Shekha, Insona, 34774, etc.
b. Cherry tomato – By Monsento – Ollch, Raisay, etc.

Raising of seedlings : Seed rate of 120 g/Ha (1 g contain 300 seeds). The seeds are sown in trays placed in playhouse and they are exposed to 24 C. After germination seedlings will be ready for planting in 3-4 weeks i.e. 10 cm height seedlings are selected.

Preparation of beds : In preparation of beds 80-90 cm width beds, 30 cm height with soil media and organic matter are prepared. Plants are – planted at a spacing of 35-45 cm in 2 rows.

Irrigation and Fertigation : N, P_2O_5 and K_2O is applied @ 50 : 50 : 50 kg/ha, to the growing beds before formaldehyde fumigation. Neem cake and Trichoderma formulation (100:1) (200 kg/ha + 2 kg/ha) has to be applied just before planting but soon after formaldehyde fumes are exhausted completely. Neem Cake + Trichoderma application has to be repeated 3 times at a monthly intervals. Fertigation is carried out using water soluble fertilizers (19:19:19 : WSF) @250 : 250 : 250 $N:P_2O_5:K_2O$ kg/ha for a six month duration crop from 3rd week after transplanting. Fertigation is carried out twice a week for 18 weeks. Use 19:19:19 WSF at the rate of 3.65 g/m^2 for every fertigation. Based on the requirement and crop growth NPK nutrients and micronutrients are supplemented by checking the E.C. and pH. The acidity and alkalinity are checked by adding acid or alkali. Tomato respond well to foliar application of nutrients. Micronutrients can be supplemented through foliar spray.

Growth phases of Tomato : There are 5 growth phases are there

1. **Seedling phase :** After germination seedlings will be ready for planting in 3-4 weeks i.e. 10 cm height seedlings are selected. During this phase the seedling growth is slow.
2. **Vegetative phase :** This phase starts from the day of transplanting till the flowers appear on the plant. During this period plant grows luxuriantly and supplement high doses of NPK. To keep the plant growing vertically, the vertically growing shoots is connected with clips on a vine and tied up to the wire fixed over the beds. As the plant grows in height the clips are adjusted. The sucker roots arise from the stem portion are periodically removed to encourage vertical growth.
3. **Early fruiting phase :** The operations like adjustment of clips, removal of suckers are attended. This phase starts from the day of first flower bud appearance. Apart from above works the other horticultural operations which has to be attended during this phase are leaf pruning, leaning and lowering and pollination.
4. **Matured fruiting stage :** During this phase all the horizontal operations attended during early fruiting stage has to be attended along with harvesting twice or thrice in a week.
5. **Post growing point removal phase :** This is the last phase of plant growth in polyhouses. To get the maximum returns 3-4 weeks before uprooting the plant, the terminal bud is removed. By this removal of terminal bud lower shoots are encourages to bear the flowers and fruits. The total growing period of tomato in polyhouse is around 8-9 months from the day of transplanting.

Cultural Practices :

Different cultural practices followed in tomatoes are as follows.

1. **Suckering :** Side shoots (suckers) will develop between each compound leaf and the stem. These suckers are removed as they develop, leaving only the main stem as a growing point. For this reason, side roots are usually not pruned until they are a few cm long, and at which time they are easier to distinguish form the main stem.
2. **Crop Support :** After transplanting as soon as possible, plant stems should be secured to nylon/plastic (high density) twine, quality of twine should be ensured. Twines are hung from horizontal wires at least 3 m about the ground. Horizontal wires must be sturdy enough to support the weight of all plants in the row.
3. **Training (Tying) :** Plants should be trained as single (main) stem. The plants can be supported with the help of plastic twine loosely anchored around the base of the plants (non-slip loop) at one end. The same plastic twine is tied to overhead support wires (12 to 16 guage) running along the length of the row. Overhead wires should be at least 3 m above the surface of beds and should be firmly anchored to support structures. Tie the plant with the help of plastic twine in inclined position to the overhead support wires. Twine should be wrapped clockwise around the plant as it develops, with complete swirl every three leaves. Plastic twine should not be wrapped around fruit clusters. When plants reach the overhead supporting wires, unite the twine and lower the vines and twines at least three feet (once in two weeks). After lowering, vines should lean in one direction in one row, vines in adjacent row should lean in opposite direction. Be sure to leave at least 4-5 meters of extra twine for this purpose when initially tying wines.
4. **Mulching :** Straw mulch is most common, if Straw mulches are used, apply to soil when tomatoes are about two feet high. The mulch reduces evaporation of water from the soil and prevents compaction of the surface. White (reflective) plastic mulches are recommended to control weeds, conserve moisture, reduce humidity and improve light conditions also to avoid contact to soil and prevent diseases.
5. **Leaning :** Due to close or high density plantation all plants may not be exposed to sunlight. Deficiency of light may result in poor development of fruits due to lack of photosynthetic supply. To overcome this problem the wires are leaned towards the path creating in a wider space between the rows and exposing them to light.
6. **Lowering :** Lowering is practiced whenever the productivity of plant reduces or whenever it reaches the terminal height. At this stage the wires are loosened to

facilitate the plant to lean and sit on the bed. This facilitates to the light, leaf pruning and removal of sucker shoots, which encourage more flower production.

7. **Topping :** Six weeks before the anticipated crop termination date, the growing point and small fruit clusters at the top of the plant are removed this operation is called Topping. Topping is carried out for fast fruit development and increase size of already-set fruit in the lower part of the plant. Some shoots at the top are left to grow as it helps to avoid risk of sunburn.
8. **Pollination :** Tomatoes are self-pollinating under open field conditions. Pollen shed and fertilization occur as a function of normal air movement leading to agitation of the plants and flowers. Under greenhouse conditions, flowers need to be agitated mechanically. For pollination hand pollination method is used, in this method gently brush your hand on flower clusters. Timing is important in hand pollination for set fruit i.e. when humidity conditions are most favourable (50-70 %). Pollination is done at least twice a week, inadequate pollination will lead to misshapen and lower yields.
9. **De-leafing :** When vines are lowered, leaves touching the ground are removed to prevent disease development. The amount of de-leafing that occurs higher up the plant varies between growers. The purpose of de-leafing higher up the plant stem is to increase light penetration and air circulation. Typically, all leaves are removed below the lowest fruit cluster which has not been harvested. De-leafing also helps to make more carbohydrates available to the fruit trusses, thereby increasing yield. This operation is carried out in all types of tomatoes.
10. **Fruit Pruning :** Small, undersized fruit at the end of a cluster (distal fruit) are always removed, as these will generally not grow to marketable size and are thought to reduce the size of the other fruit on the cluster.

Chapter 24

Tomato, Harvesting, Post-Harvest Management, Pest and Diseases

Harvesting: 60-70 days after planting the first harvest can be made. Whenever the fruits change their colour from green to yellowish they are harvested. The total crop period for tomatoes is 8-9 month after planting. The harvesting is done daily or alternate day depending on market distance and customer choice. For long distance marketing, the fruits are picked at matured green or breaker stage. For processing the fully matured red ripe fruits are harvested in order to optimize the quality parameters.

Post-Harvest Handling : Harvest has to be made in the morning hours. The harvested fruits are washed thoroughly to remove the residues of fungicides and pesticides.

Grading : Fruits are graded according to the size, colour development and free from blemishes.

Packing : Fruits are packed in CFB boxes in 2 layers and each layers and fruit is separated by a tissue paper. All the fruits are packed keeping the stem ends down. Fruits are of 5 kg, 7.5 kg, 15 kg and 20 kg denominations are packed. After packing fruits are stored at 13-15° C or they made available to consumer at the earliest. Longtime storage at low temperature fruits losses their aroma.

Yield :

45 kg/m^2 – Truss variety

31 kg/m^2 – Pink or Cherry types or 10 kg/plant

Individual fruit weight varies form 100 g/fruit during initial harvests to 60 g/fruit during last harvests.

PLANT PROTECTION

Major Insect Pest

1. Tomato fruit worm
2. Leaf miner
3. Aphids

Major Diseases

1. Bacterial diseases
2. Fungal diseases
3. Fungal diseases
4. Viral diseases
5. Physiological diseases

Successful crop production requires that crop pests and diseases be managed so that their effects on the plants are minimized. The management of crop diseases is directed at preventing the establishment of diseases and minimizing the development and spread of any diseases that become established in the crop. Managing pest problems is directed at preventing pest populations from becoming too large and uncontrollable. The presence of pests and diseases are a fact of crop production and growers must use all available options and strategies to avoid serious pest and disease problems. Integrated pest management (IPM) where cultural, biological, and chemical controls are included in a holistic approach of pest and disease control may be adopted. Key components of effective pest and disease control programs include : sanitations, crop monitoring, cultural control, resistant cultivars, biological control ad chemical control.

Chapter 25

Greenhouse cultivation of Bell pepper

Capsicum (*Capsicum annum*) belongs to the family **Solanaceae**. Also called as Sweet Pepper, green pepper, bell pepper, Simla mirchi

Media : Sandy loan soil-Soil; whereas rock wool for soil less media.

Environment : Capsicum grown under polyhouse require following climatic conditions to get good quality and better yield round the year.

Higher temperature is detrimental to fruit set. High temperature and low relative humidity at the time of flowering increase the transpiration pull resulting in abscission of buds, flowers and small fruits. Moreover, higher night temperatures are found to be responsible for the higher capsicum (pungency) content in green pepper. Seeds are sown in containers maintained a temperature below 25-26˚ C with RH 90 % and 700- 800 ppm CO_2. After germination we have to maintain 23˚ C temperature.

Soil : Although sweet pepper can be grown in almost all types of soils, well drained clay loam soil is considered ideal for its cultivation. It can withstand acidity to a certain extent. Levelled and raised beds have been found more suitable than sunken beds for its cultivation. On sandy loam soils, the crop can be successfully grown provided the manuring is done heavily and the crop is irrigated properly and timely. The most suitable pH range of soil for green pepper is 6.

Bed preparation : A raised bed is always preferred for planting of capsicum. Bed should be highly porous, well drained, providing adequate aeration for root development. The raised bed for capsicum plantation should have following dimensions.

Top width – 70 cm

Path width – 40 cm

Height – 30 cm

Planting distance :

Plant to Plant distance : 30-45 cm

Row to Row distance : 30-45 cm and planting density is 6-9 plants/m^2.

Planting Material : The planting material should be healthy, resistant to diseases and pest. Age of the seedling should be 35 to 40 days old. Height of the seedling should be 16-20 cm. Plant should possess good rooting system. Seedling should have at least 4-6 leaves on the stem at the time of transplanting.

Varieties/Cultivars :

Green and violet varieties are having strong flavour, Yellow, red, orange are mild and sweeter and white and purple in Europe are very vigorous plants grow 9-19 ft under greenhouse. Europe varieties highly rated compared to Israel peppers but Israel varieties suitable for India.

Red coloured capsicum – Hazurka, Torkel, Parker, Bombi

Yellow coloured capsicum – Oraville, Feista

Green coloured capsicum – Indra

Israel varieties – HA 195, 1038, 988, 1931

There are number of varieties of green pepper cultivated in India. The important ones are as under California Wonder, Chinese Giant, World Beater, Yolo Wonder, Bharat. There are some other varieties of capsicum such as Early Giant, Bullnose, King of North, Ruby King, Indra, Bombay, Orobelle, etc. which are grown in India under polyhouse.

Fertilizers :

About 4 to 5 tonnes of farmyard manure, 30 to 55 kg of nitrogen in the form of ammonium sulphate or urea, 50 to 110 kg of phosphorus in the form of super phosphate and 75 to 100 kg of potash per hectare should be given depending upon the fertility status of the soil. The complete dose of farmyard manure should be applied in the soil at the time of soil preparation. Potassium and phosphate fertilizers should be mixed in the plant rows just before transplanting. The nitrogenous fertilizers is given two and half a month after transplanting.

Cultural Practices :

Some varieties are very vigorous and plant can become as tall as 3.5 m and they produce about 4-5 kg fruits on one plant in their life cycle. As stems are weak, they need support system. Plant stem after transplantation is tied by a high density plastic or nylon string. Twines are vertical ropes that are tied to horizontal wires on the ceiling at one end to the crop at another end. Twines of good quality are used to hang from horizontal wires at least 3 m above the ground. Horizontal wire used should not have thickness less than 12 gauge, as it supports the weight of all plants in the row. If the wire is weak it will break and lead to losses. Three rows of overhead horizontal wires are required for one bed and for each single plant four numbers of twines are required.

Topping :

The growing point at the top of the plant is removed. This operation is called topping. This technique is adopted for producing more branches. This is practiced after one month period from transplantation. After topping two or four main leaders are kept whereas the lateral shoots is pinched first leaf (internodes) or second leaf (internodes). One or two fruits per side shoot are maintained.

Training :

Generally two system of training are practised in capsicum cultivation.

i. **Two-leader system of training :** In this system of training two main shoots are maintained as two leaders after topping. Side shoots are pinched after one or two pairs of leaves; generally one fruit is kept per side shoot.
ii. **Four-leader system :** In this system of training four main shoots are maintained as four leaders after topping. Side shoots are pinched after one or two pairs of leaves; generally one fruit is kept per side shoot.

Fruit thinning :

When there are too many fruits on the plant, it is necessary to remove some fruits, to promote the development of remaining fruits. This operation is called as fruit thinning. Fruit thinning is done when the fruit is of pea size. This practice is normally followed to increase the size of fruit thus by increasing the quality of production.

Pollination :

Capsicum is self-pollinating but there is high degree of cross pollination because of honey bees, thrips and other insects who transfer pollen from blossom. Pollination is not improved by using an “electric bees” or by spraying plant harmones but pollination is clearly better when honey bees or bumble bees fly in the greenhouse. Bees increase the number of seeds in capsicum fruits.

Fruit set : Fruits are not occurred until 3rd or 4th axils develop above bracts 4-6 fruits are ideal/ stem.

Harvesting : Harvesting starts after 60 to 75 days after the transplanting and should be done with the help of sharp knife. Harvesting at the proper stage of maturity, careful and minimal handling of the produce will help in maintaining better fruit quality and reduce storage losses. Harvesting is generally done during morning and evening hours. Avoid harvesting immediately after fogging to check the disease and pest under control and to maintain better keeping quality of fruit. Generally, Harvesting of capsicum is done by skilled worker in greenhouse and kept in plastic containers an send to the packing hall.

Yield : Average yield of capsicum is 6 to 18 kg/plant. Average weight of coloured four lobbed fruit is 180-220 g.

Post Harvest Management :

i. **Cleaning Grading :** All damaged, malformed and bruised capsicums should be removed. Those with dirt adhering to their surface can be cleaned by wiping the surface with a moist soft cloth. The capsicum should be graded into same size and colour lots according to market requirements. Sorting is done on the basis of shape and weight of capsicum.

ii. **Packing :** Capsicum is packed in cartons and should hold about 10 kg or 12 kg of capsicum. Mostly farmers use apple boxes (used ones) for packing capsicum for local market. An ideal corrugated box carries following information.
   - On top side of the lid "Fresh Vegetables" is printed.
   - On width wise side of the lid Variety, number of capsicum, gross and net weight of box, box number is written on both sides.
   - On length wise side of the lid "Fresh vegetable and handle with care is written on both sides."
   - Senders and buyers address with phone number.

iii. **Storage :** Capsicum can be stored in a cool room at a temperature of 7-10˚ C for upto 3 weeks if required.

Chapter 26

Greenhouse cultivation of Cucumber

Cucumber : Cucumber (cucumis sativus L.) known as Kihra in Hindi is an important summer vegetable in India. Cucumber stands 2nd position among the salad vegetables grown in polyhouses in European countries. It is a semitropical plant grown round the clock as the demand for this crop.

Selection of varieties :

Best cultivar

1. Overall productivity
2. Plant growth
3. Fruit quality
4. Shelf life
5. Disease resistance

Greenhouse varieties are mostly European and are three types

- 1. Gynoecious – only female flowers
- 2. Predominantly gynoecoius – bear some male flowers
- 3. Monoecious – produce male and female flowers
- 1 & 2 – parthenocarpically i.e. bear no seeds i.e. seed less cucumbers and best suited for the slice making are grown in polyhouse.
- 3 require pollination set seeds
- Predominantly female types used because less vigorous, require limited pruning, early production more and can grow at low temperature.
- Europe varieties Hasan, Sarig, Muhas, Dinar, Mustang, and Bronco, Kian, Alamir, and and Nun 9729
- Monoecious can be grown but requires pollination-honey bees are necessary.
- Important parthenocarpic varieties in India are Satis, Alamir, Nun 9729, Nun 3019, Carona, Discover and Milligon and Kian.
- Monoecious varieties are Japanese long green, Pusa Sanyog, Priya and Poinsettia.

Environment : For germination and seedling growth require 24˚ C and 20˚ C for hardening with 760 ppm of CO_2 and 5000-6000 Lux of light. Vegetative and reproductive phase require a night temperature of 18-22˚ C and day temperature of 24-28˚ C. Warmer temperatures are essential for vegetative and reproductive phase. But temperature above 30˚ C is detrimental. Lowering of the temperatures when the plants are growing and fruit development takes place upto 18˚ C during night hours.

Media : Well drained sandy loam soils are best. Heavier soil should be avoided. Tolerate acidic soil but best results in 5.5 to 6.8. In European countries the rock wool, perlite, pumice as substrate media.

Seedling production : Nursery raised on soil less media in plastic trays and cocopeat, vermiculilte, and Perlite in 3:1:1 as media and seed rate is 600 g seed for one ha. Seedlings of 25 cm height of 3-4 weeks old are preferred. Being a vine crop the plant put up 25 cm growth which need staking. Later on its helps in training in main field cultivation.

Planting and planting density : Beds of 90 cm width, 30 cm height and 50 cm path are prepared by using soil based media.

Planting distance : 75 cm between rows and 45 cm between plants.

Nutrition : After transplanting NPK at 100-140 ppm, Mg-60 ppm, Ca-90 ppm are supplemented throughout its growing period.

Training : The basic principle of training the plants is to uniformly distribute the foliage through entire greenhouse so that maximum light can be interpreted by the leaves. The choice of the training system is depends upon the grower preference, greenhouse facilities, or the crop is grown on soil or substrate media. Widely used systems of training are V system or Y cardon or Umbrella system. Among these three 'V cardon system of training is popular.

'V' cardon system :

a. In this system two wires are placed 2.5-3 m above the ground over the bed and row of plants.
b. Train the plant to the over head wire and remove the growing point after the first leaf is above the wire.
c. Tie a small rope or string to avoid slipping of the wine from the wire.
d. Remove all side shoots at very early stage except the two near the top of the plant.
e. The 2 laterals trained are allowed to trail down over the wines till they touch the ground and top from the base.
f. Do not allow the fruit to develop on the main stem upto 1 m height from ground level.

Leaf Pruning : The damaged leaves or the excess leaves that are developed are periodically removed to facilitate uniform spread of the light to all the plants grown in polyhouses. Extensive leaf growth should be discouraged for proper colouring.

Reasons for pruning :

1. To help recovery from injury to roots.
2. To remove dead or injured growth
3. Restrict unwanted growth
4. Train growth where it is desires.
5. To rejuvenate old plants.
6. To promote flower bud production.
7. Light penetration for efficient light use.
8. To expose fruits to light.

Pollination : Gynoecious flowers, they set the fruit on stimulation received from the pollen but finally the fruits mature and develop parthenocarpically. So to encourage the better fruit set and to transfer the stimulus the flowers are dusted in morning hours. Monoecious varieties depend on pollination by honey bees.

Fruit thinning : Fruit thinning to avoid malformed fruits. Multiple fruits in axils thinned to one and weak and unproductive laterals should be removed.

Harvesting : When the fruit reaches the 30 cm length, 4 cm diameters are harvested i.e. 35 to 40 days is gynoecious and 45-50days in monoecious generally. 10-14 days after flowering opening. These fruits will not be bitter, as it is free from cucurbitacin. Peel will be very thin with crispy pulp. Delay in harvesting results in maturation of the fruit and they are unfit for marketing. To overcome this problem fruits are harvested thrice in a week.

Storage : Seedless cucumber can be stored for several days without serious loss of quality when stored at 13° C. These cucumbers should not be stored along with other fresh stock like tomatoes, bananas; apples, which release ethylene gas and spoils the crop. Shrink-wrapping with polypaper extends the shelf life of fruits to even to few months.

Yield : Gynoecious lines – 40-45 q/1000 m^2

Insect and Diseases :

Cucumber is attacked by number of diseases and pests. The most important diseases are

1. Bacterial wilt

2. Anthracnose
3. Downy and Powdery Mildew
4. Angular Leaf Spot
5. Cucumber Mosaic

Major insect pests of the cucumber are

1. Red Pumpkin Beetles
2. Aphid
3. Cut worm
4. Fruit Fly

Chapter 27
Greenhouse cultivation of Strawberry

S.N. : *Fragaria zananssa*.   Family : Rosaceae

One of the most important soft fruits and low volume high value fruit crop grown under protected and open condition. It gives quickest return in shortest time than any other fruit.

Environment : Strawberry grows well under temperate climate. The main challenge in cultivating strawberries in temperature control and by means of a cooling system, the temperature in the greenhouse is never allowed to exceed 30 degrees Celcius. Some cultivars can be grown in sub-tropical climate. Maximum growth rate observed at 22-25˚ C day and 7-13˚ C night temperature. Photoperiod is effective for vegetative growth, plant morphology and yield. Daylight period of 12 hrs. or less and moderate temperature are important for flower-bud formation. Each cultivar has a different day length and temperature requirement.

Media : Sandy loam to loamy soil with pH 5.7-6.5 is ideal for cultivation. Soil fumigation with a mixture of methyl bromide and chloropicrin helps to increase root system, reduce fertilizer requirement and control the weeds. Soil : Sand : FYM in the ratio of 1:1:2 is considered as best potting media.

Varieties Cultivated :

Important strawberry varieties cultivated in India are Chandler, Tioga, Torrey, Selva, Belrubi, Fern and Pajaro. Other varieties include Premier, Red cost, Local Jeolikot, Dilpasand, Bangalore, Florida 90, Katrain Sweet, Pusa Early Dwarf and Blakemore. But Japanese strawberries are sweeter than the local variety and fetch a much higher price at Rs. 500 per kg.

Planting Material : Strawberry is commercially propagated by runner plants. Runners are uprooted from nursery, made into bundles and planted in the field. These can be kept in cold storage before transplanting. It can also be propagated through crowns (3-5 plants/crown), but division of crown of older plants is too tedious and expensive for cultivars producing runner plants readily. For large scale propagation of virus free plants, tissue culture is widely used because under favourable conditions, one strawberry meristem can be multiplied to yield more than one million plants in a year.

Planting Season : The ideal time of planting runners or crowns September-October. If the planting is done to early, plants hack vigour and result in low yield and quality of fruits. If planted very late, runners develop in March and crops are light.

Spacing : Hill row system either in single or double rows on 15-20 cm raised beds with plant to plant and row to row distance of 30 x 30-45 cm and 90-120 cm is kept between twin rows.

Nutrition : A fertilizer dose of 25-50 tonnes farmyard manure, 75-100 kg N, 40-120 kg P_2O_5, 40-80 kg K_2O/ha. May be applied according to soil type an variety planted.

Irrigation :

Strawberry being a shallow-rooted plant requires more frequent but less amount of water in each irrigation. Excessive irrigation results in growth of leaves and stolons at the expense of fruits and flowers and also increases the incidence of Botrytis rot. Trickle and sprinkler irrigation systems are becoming popular nowadays. In case of trickle irrigation, 30 % water and energy are saved.

Cultural Operations : Mulching, Training, Bud and Shoot thinning/ Deshooting/ Debudding.

Mulching : Mulching in Strawberry minimizes the freezing injury, suppresses weed growth and more importantly reduces the chances of softening of fruits. The commonly used mulching materials include clean, black and double coloured polythene. Mulching with black or double colour polythene material gives good weed control, advances early cropping and increases total yield.

Training :

Four different types of training systems viz. matterd row, spaced row, hill and plastic mulch are used to train the strawberry plants. Usually matted row system is followed in India.

Bud and Shoot thinning : Removal of 1-2 buds/plant improves fruit yield and quality.

Deblossoming : Removal of the flower truss to prevent fruiting and increased the yield of early saleable runner.

Control of Runner : Runners should be allowed to be allowed to root along the rows until sufficient crown are formed. Excess runners are not required and should be removed from the rows.

Use of Growth Regulators :

Application of GA_3 (50 ppm.) sprayed four days after flowering and maleic hydrazide (0.1-0.3 %) sprayed after flowering increases the yield by 31-41 %. Morphactin (@ 50 ppm.) improves the fruit size.

Harvesting : Maturity index-when half to three quarter of the skin develops colour. For distant market harvested at berries are green/white and still hard. Picking on alternate days and pick the berries by nipping off stalk and not holding the fruit.

Yield : 500 g/plant 22 tons/15000 plants

Plant Protection Measures :

Insect Pests :

White grubs, cutworms and hairy caterpillars attack the crop. Areas where strawberries are to be planted should be free from white grubs and cutworms. Application of malathion (0.05%) on appearance of caterpillars has been found to be effective in most cases.

Diseases : Albinism (lack of fruit colour during ripening) is a physiological disorder in strawberry. It is probably caused by certain climatic conditions and extremes in nutrition. Fruits remains irregularly pink or even totally white and sometimes swollen. They have acid taste and become less firm. Albino fruits are often damaged during harvesting and are susceptible to Botrytis infection and decay during storage.

Chapter 28

Greenhouse cultivation of Pot plants and containers

Container planting goes exceptionally well with certain plants and many of these plants do exceptionally well in greenhouses.

Pot plants and containers are plants cultivated in greenhouse pots and that are not placed directly into the ground, or row-cropped as in a vegetable farm or backyard garden. Rather, they are grown in a soil medium within a container or pot of some sort large or small and for a number of benefits only containers provide, and which supports plants in a different way.

Importance of Pot plants and containers :

1. If we plants for selling whole plants as retail, pots or containers of course come in the most convenient, ready-to-transport form for customers.
2. Root systems are allowed to grow and develop unimpeded in greenhouse pot, and without any nutrient competition with other plant nearly.
3. Varieties with highly rigorous, expansive root systems – or sensitivity to water logging might not thrive on the other hand, or need more care to do so. For more sensitive plants, however, containers are an elegant, ideal solution.
4. This is especially true if plants need to move crops easily throughout various parts of greenhouse for certain benefits, such as more shade, light exposure, or other elements.
5. Containers can help make all this easier while preventing disease in the meantime. When grown on growing benches, flower maintenance is also made a simpler task. More often, however, containers allow easy transport of flowering annuals inside and outside of greenhouses from season to season, as the vast majority of them die back in the winter.
6. For year round annual blooms and especially retail potted annual flowers with showy blooms sold to customers for their own gardens, growing in containers is best.

Pots and container growing plants :

1. **Seedlings and Transplants :**
   In both the annual and perennial plants, seedlings and eventual transplants of any sort are very well-suited to grow in containers. This especially applies to plants that need slow exposure to high temperatures or frost in order to adapt.
2. **Flowers :**
   Some perennial flowers succeed exceptionally well in other mediums besides containers, even in direct plantings underneath a greenhouse cover. This include common blooms like gladioli, or tulips. Containers allow direct watering to the roots, pH and nutrient control, and even reduced competition of nutrients for individual crops. For those wanting to sell retail flowers as potted plants, greenhouse pot are clearly the best way to go. Ex. Orchids.
3. **Succulents :**
   A popular type of houseplant nowadays, greenhouse growers can propagate succulents in containers for successful retail sale. This includes jade plants, cactuses, aloe, etc.
4. **Shrubs :**
   For obvious reasons, shrubs and containers are made for each other in a greenhouse. Shrubs tend to have specific pH requirements that are only well replicated in controlled soil mediums, such as in containers. Growing greenhouse shrubs roses and hibiscus and more require containers to be successful.
5. **Strawberries :**
   They can be lifted off the ground to avoid the interest of slugs and soil-borne diseases. Plants can be moved under cover in winter to force an extra-early crop. With some plants left outside and others housed under cover of a greenhouse or polytunnel it is possible to get a much longer harvest from exactly the same variety of strawberry.

Chapter 29

Off-season production of flowers

Flower forcing is an operation or treatment to the plant, after it reaches the ripeness to flower stage, in order to stimulate it to flower at a specific date (e.g. on New Year's day), or during off-season period. The flowering date/period may be earlier or later than the normal date/period of flowering.

The goals of flower forcing are off-season production and specific-date production.

Cut flowers which are available during the normal season are plentiful, thus fetching a low price. Sometimes the farmers have to sell their produce even at a loss. In some cases, flowers which could not be sold are either left on the plants or are spoiled after being harvested. Thus, it would be beneficial for farmers to produce cut flowers during the off-season period to obtain higher price, although the inputs may be higher. Similarly, the demand for cut flowers is generally very high during certain occasions such as New Year, Christmas, Valentine Day, etc. Thus, it will be to the farmers advantage if they can produce cut flowers to be available on these specific dates.

The objectives of forcing plants to flower during off-season or at certain specific dates are :

- To avoid surpluses of in-season cut flowers.
- To avoid wastages or spoilage of surplus cut flowers.
- To avoid danger of epidemics.
- To distribute employment throughout the year.
- To increase farmers income.
- To reduce imports and trade deficit.
- To satisfy customers at the time of their needs.

Factors affecting flowering are **photoperiod, temperature and humidity.** Flowering behaviour of plants is controlled by seasonal changes. There are two types of flowers with respect to the seasonal effect on flowering :

a) **Little influence of seasonal changes :** e.g. Roses, marigold, chrysanthemum, heliconia, etc.
b) **Great seasonal influence :** e.g. jasmine, dendrobium orchids, etc.

Seasonal factors can be of various types viz.

1) **Photoperiodic influence :** This includes short day plants, which are temperature and humidity influenced; also long day plants, which are also temperature and humidity influenced.
2) **Temperature influence :** This include low temperature requiring plants, which are photoperiodic and humidity influenced; as also, high temperature requiring plants which are also photoperiodic and humidity influenced.
3) **Humidity influence :** Including low and high humidity requiring plants.

Off-season production flowers :

1. **Tulip :**
   Seasonal flowers are produced during rainy season (June to August), requiring long day condition. No flower develops after September when short day condition commences. Above ground parts wither and die down, and rhizome enters dormancy period until next rainy season. Providing additional light breaks dormancy. Most effective is 3 hours of light in the middle of the night. Should be started soon after day length is shortened (21 September). In this way, plants will continue to produce flowers all the way up to the New Year day, provided enough humidity and nutrients are given.
2. **Chrysanthemum :**

It is a short day plant, with critical value of 14.4 hours. Thus, it will bloom all the year round under Thai conditions, having maximum day length of 13.3 hours in June.

Day length can be extended by giving artificial light after sunset for about 3 hour during the early stage of growth to keep seedlings in vegetative stage until one month prior of the planned harvest date. For example, if the planned harvest date is New Year, cutting should be made in September and transplanted to the growing plot for rooting to occur. Seedling is kept under light regime of more than 14.5 hours by providing artificial light (100 w incandescent bulb) until 1 December (seedlings should be at least 30 cm high). These will bloom on 1 January.

However, as chrysanthemum blooms profusely during the period of low temperature which commences in December, it fetches a low price in the market even during the time of Christmas or New Year. Thus, some farmers avoid producing flowers during such period but shift it to the summer. The problem is that the temperature during summer is quite high and not optimum for chrysanthemum growth. The same principle of flower forcing is applied, but in this case the day length may be lower than the critical value for certain varieties. Black cloth is used to completely cover the plant house from 16.00 to 08.00 hrs. for 30 days after the cuttings have been exposed to long day conditions (supplemental with artificial light).

3. **Gladiolus :**

Flowers can be available all the year round, provided the weather is optimum (requires cool climate). Blooms 90-100 days after planting. In cool climate prehat corms before planting for 2 weeks at 27-32˚ C. This will force such corms to flower early. In warm climate soak in GA_3 solution (10-25 ppm) before planting. This will accelerate flower by hastening differentiation of floral primordia.

Chapter 30

Off-season production of Vegetables

Vegetable growers can substantially increase their income by protected cultivation of vegetables in off-season as the vegetables produced during their normal season generally do not fetch good returns due to large availability of these vegetable in these markets.

Production of fresh vegetable after or before their normal season is called off-season vegetable production. The objective is to produce and supply vegetables to the market during their lean period of supply.

Advantages :

1. The farmers can learn specific techniques of vegetable production.
2. The farmers can develop confidence and make vegetable production as their main profession.
3. The farmers can get higher profits from off-season production.
4. The consumers can get fresh vegetables during off-season.
5. Sometimes it is possible to export fresh vegetables and earn foreign currency.
6. It creates employment for farm laborers all the year round.

Disadvantages :

1. It requires highly specialized techniques of vegetable production.
2. Sometimes it becomes a risky operation due to possibility of incidence of diseases and pests.
3. It needs very regular supervision and follows up from the government agencies concerned.
4. It is possible on a commercial scale only in areas where marketing is not a problem.
5. It may be a source of pollution.

Off-season cultivation of cucurbits under low plastic tunnels is one of the most profitable technologies under northern plains of India. Walk-in tunnels are also suitable and effective to raise off-season nursery and off-season vegetable cultivation due to their low initial cost.

Insect proof net houses can be used for virus-free cultivation of tomato, chilli, sweet pepper and other vegetables mainly during the rainy season.

These low cost structures are also suitable for growing pesticide-free green vegetables.

Low cost greenhouses can be used for high quality vegetable cultivation for long duration (6-10 months) mainly in peri-urban areas of the country to fetch commensurate price of producers. Polytrenches have proved extremely useful for growing vegetables under cold desert conditions in upper reaches of Himalayas in the country.

Off-season production requires the same management practices as ordinary vegetables production, with extra attention paid to the following factors : temperature and moisture.

Temperature :

Temperature is important for seed germination and plant growth. Different vegetables require different temperatures for germination. Beet, cabbage, cauliflower, celery, parsley, pea, radish, swiss chard, turnip require a min. of 4˚ C and an optimum of 27-29˚ C. Bean, cucumber, brinjal, okra, pumplin, pepper, squash, tomato, need a minimum 16˚ C and optimum range of 24-35˚ C.

Techniques for winter season :

Seed germination in the cold can be improved by germinating seed in compost piles or plastic tunnels.

A) Seed germination in compost pit :

1. Place seeds on a piece of cloth roll the cloth and moisten it.
2. Keep the roll in a compost pit.
3. Plant the newly germinated seed.

B) Germinating Seeds and Growing Seedlings Under Plastic Tunnel :

A tunnel of half of bamboo set in the ground/nursery and covered with plastic sheet in cold weather helps to keep the soil warm and promotes germination. Close the ends at night and open them during the day for ventilation.

C) Seedling Production in Plastic House :

For those areas where a ready market is nearby (such as in the vicinity of urban centres/along trekking trails) large-scale production of off-season vegetables might be both feasible and profitable. The large number of seedlings needed can be produced in a plastic house. High value vegetables can be produced during the off-season in that house.

- Seedlings are produced in the plastic house during the cold season and even during the peak of the rainy season.
- During rainy season high value crops like sweet pepper and tomato and, during winter, cucumber may be produced by forcing culture.

Practices of off-season vegetable production :

Netting : The use of net to protect from insect pests. The net reduces the temperatures and break the rain drops into small particles.

Plastics : The use of plastics as roofing materials in the tropics is to protect the crop from excessive rain. If the plastic is coated with white wash, partial shade can be achieved during hot summer days. The main problem from the use of plastics is building up heat. To prevent the raising of temperature in the plastic house, we can practice to build roof from the plastics and the sides are made of the net to reduce the building up of heat in the plastic house.

Misting : It is practiced to reduce the temperature in the plastic house or glass house. Generally, the misting is done with cold water.

Chapter 31

Polyhouse cultivation of economically important medicinal plants like stevia, etc

Stevia rebudiana

Stevia is a five year plantation crop. The crop is newly introduced in India. It gives regular earning. The first cutting of the green leaves is done after four month of the plantation and later on there will be regular cutting after every 3-4 months as per climatic condition. The crop is only source of natural sweetener. The stevia is the first choice of the sugar free industry. The sweetener of stevia is widely used in the world. The crop is planted for five years. After the fifth year the marginal return start to decline so it is best to uproot crop and replant it. Stevia cultivation in India is having bright future.

Soil :

Stevia grows well in sandy loam soils with an ample supply of water, stevia prefers acidic to neutral soil with a pH range of 6.5-7.5 for its best growth. Saline soils should be avoided as stevia plant is susceptible to water logged conditions.

Climate :

Stevia is a semi-humid, subtropical plant and can grow in the temperature ranges between 04-48˚ C. An annual average temperature of 31˚ C and 60-85 % RH. It shows good seed germination when subjected to light and warm conditions. Hence, a long growing season, minimal frost, high light intensities and warm temperature favors higher leaf production. Stevia is a short day plant, but the concentration of stevioside in the leaves increases when the plants are grown under long day conditions.

Propagation :

Stevia plants can be propagated from cuttings or seeds or by tissue culture. As the seed germination is very poor and seedlings are very slow to establish, it is generally propagated clonally through cuttings. For vegetative propagation, stem cuttings of 15 cm length taken from leaf axils of the current year's growth have been given better results. Treatment with Paclobutrazol @ 100 ppm has been found to induce the root initiation in short time and IBA @500 ppm is also found to be effective. The best months for propagation are February-March. The cuttings will be ready for transplanting after 25-30 days of rooting.

Transplants :

Transplants from cuttings would be superior; however, cost makes it prohibitive. Stevia must be propagated from seed in plug trays placed in a greenhouse for a period of 7 to 8 weeks.

Planting :

Depending on different climatic conditions, Stevia is cultivable throughout the year in greenhouse. Stevia plug plants are planted on 75 cm bed with row spacing of 45 cm at 45 cm height with total plant density in the order of 30,000 plants per Acre.

Fertilization :

The stevia plant appears to have low nutrient requirements; however a soil test should be conducted. Good organic manure must be applied time to time.

Pests :

Insect pest pressures other than cutworm are minimal. Septoria disease can cause considerable damage to the Stevia crop. Application on neem based product will manage the disease and pests.

Harvesting :

Time of harvesting depends on land variety and growing season. Generally, it can be scheduled when plants are 40-60 centimeters in height. Shorter days induce flowering. Optimum yield (biomass) and stevioside quality and quantity is best just prior to flowering. The plant will tolerate very low temperatures.

Drying :

Drying of the woody stems plus the soft green leaf material is completed immediately after harvesting, utilizing a drying wagon or a kiln. Depending on weather conditions and density of loading, it generally takes 24 to 48 hours to dry Stevia at 40˚ C to 50˚ C. An estimated 2500 kg/acre dry green leaves are obtained from three-four cutting of every year. It is cultivated up to 5 years after a one time plantation.

Threshing :

Immediately following drying, a specially designed thresher/separator is necessary to separate dry Stevia leaves from its stem.

Chapter 32

Polyhouse cultivation of economically important aromatic plants like Davanam Etc

Davanam – *Artemesia pallens*

The essential oil of davanam is widely used in food flavouring and perfumery industries. Davanam twigs are used to add an element of freshness and sweet fragrance to garlands, bouquets, etc., India is the only producer and exporter of Davana oil.

Environment : The crop is cultivated in South Indian states only. Davanam is an annual, winter season aromatic herb growing to a height of 30-60 cm.

Media : Well-drained light to medium textured soils of neutral pH.

Nursery :

Davana is propagated through seeds by raising nursery. About 1.5 kg freshly collected, viable seeds are required for one hectare. The seeds are mixed with Captan or Thiram at 3 g/kg and stand in 1:10 proportion, moistened, bundled and kept in a cloth or gunny bag for 2-3 days with periodical moistening with water. The pre-germinated seeds are sown in nursery beds in the month of October and watered regularly. 0.2 percent urea solution is sprayed on the seedlings four weeks after seedling for vigorous growth of seedlings.

The seedlings are ready for planting in 6-8 weeks after sowing.

Planting :

The seedlings taken old from the nursery are planted in the beds a spacing of 15 or 30 cm between the rows and 15 cm or 7.5 cm between the plants (444444 plants/hectare).

Irrigation :

The crop is irrigated on alternate days until plants establish, thereafter the crop is irrigated at 5-7 days intervals.

Fertilizers :

Davanam crop is fertilized thrice with 80 kg urea per hectare each time. First at the time of transplanting, then one and two months after transplanting. 80 kg urea is applied after the first harvest, for the ratoon crop, 25-50 kg zinc sulphate per hectare is applied in zinc deficient soils. Micronutrients and growth regulators are sprayed for every harvest.

Harvesting :

Flowering herb is harvested 8-10 cm above ground level 90-100 days after transplanting and the crop is left for ratooning. Ratoon crop harvest is obtained 60-80 days after first harvest. The two harvests yield 10-12 kg oil and Rs. 50000 – 70000 net profit per hectare with an oil price of Rs. 10000 per kg.

Distillation :

The oil is distilled from the flowering herb by a distillation process. Two or three days shade dried herb is used for the distillation. The recovery of oil from the shade dried herb is 0.2 percent. It takes about 8-10 hours of distillation for complete recovery of oil.

Plant protection :

Major Insects : Ants and aphids

Major disease : Damping off

Management :

1. Ant menace can be minimized by mixing about 10 kg of 6 % Heptachlor per hectare into the soil.
2. To control aphids spray Rogor at the rate of 1 ml per litre.
3. Seed treatment with Captan at the rate of 5 g per kg of seed.

DISCLAIMER:

The information on this website does not warrant or assume any legal liability or responsibility for the accuracy, completeness or usefulness of the courseware contents.

The contents are provided free for noncommercial purpose such as teaching, training, research, extension and self learning.