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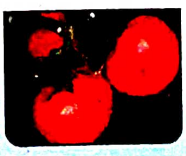



Chapter 1

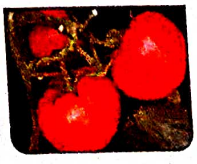
Introduction

Globally, about 40 countries are involved in protected cultivation of vegetable and flower crops. New production centers are being added constantly, mostly from developing nations. Today, majority of the production is from developing countries like Zimbabwe, Morocco, Kenya, Equador, Costa Rica, Mexico, Singapore, Malaysia and India. In developed world, USA has an area of about 6000 ha under green house mostly used for floriculture whereas in Spain around 28000 ha and 20000 ha in Italy are used mostly for growing vegetables. The Netherlands, the traditional exporter of green house grown flowers and vegetables all over the world, has about 1,00,000 ha under cover. Israel, the largest exporter of cut flowers, has wide range of crops under green houses. In India green house cultivation is still in infant stage, about two decades old.

The advent of modern protected cultivation in India is a result of liberalized policy for import of seed and planting materials and economic reforms initiated in early 1990's. Though, commercial cultivation of vegetables and flowers in open field conditions is the main stay of Indian Horticulture, the protected cultivation of vegetables and flowers indeed opens up new avenues for producing good quality flowers and vegetables for domestic markets and also for exporting to international markets to earn valuable foreign exchange. The Government of India has recognized horticulture as a major thrust area with several support programmes to promote the growth of protected cultivation as an upcoming industry. Due to this many enterprising growers, corporate houses plunged into hi-tech industry which registered a phenomenal growth over the last two decades. The cost of construction of protected structures also vary from Rs.350 to Rs.1600 per square meter depending on the type of structures. Presently, the country has about 25000 ha of protected structures including polyhouses and net-houses most of which have spread across the different states namely Karnataka, Tamil Nadu, Maharashtra, Gujarat, Himachal Pradesh, Uttarakhand, Chhattisgarh, Haryana, Punjab, Telangana and others.

Polyhouse grown Capsicum fruits ready for harvest

Vegetables being rich and good source of vitamins, minerals and food fibre, occupy an important place in the food basket of Indian consumers, from nutritional security angle. With rising per capita income, especially of those dwelling in urban areas, there is a rapid growth in consumption of vegetables which calls for supply of good quality produce, round the year. Hence, cultivation of vegetables


under cover is useful as it makes the availability of vegetables round the year and it is one of the potential sources of enhancing income.

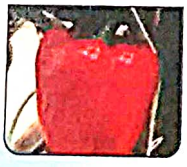
In India, with the increase in population, there is a decrease in per capita cultivable area and productivity of land has become stable in most of the crops. Now we need a technology which gives more production per unit area. Additionally, we have to get quality produce for niche domestic markets, as well as for global markets with highest input use efficiency, residue free good quality produce with minimum or no damage to the environment. All these are possible with green house technologies.

Polyhouse grown Tomato fruits

There are many advantages of growing vegetables under protected environment, of which following are the important ones.

- There is a substantial increase in yield (2 to 3 times higher) and better quality produce.
- We can go for year-round / off-season production of crops, to utilize the natural climatic conditions of different places across the country.
- Some high value crops cannot be grown in open, since they need most congenial climatic factors under protected environment for their growth and production
- Protected cultivation also serves a means of saving both the farm and external resources like irrigation water, chemicals (pesticides and fungicides) and fertilizers.
- Produce of protected cultivation will have superior quality, which fetches better price and demand in the market.
- Quality seedlings, planting material and hybrid seed production is possible in protected cultivation.
- Protected structures help in protecting crops or mitigating the abiotic stresses such as high temperature, low humidity, erratic rainfall, excess sunlight and many biotic stresses such as insect pests, diseases and weeds. Hence, it is an eco-friendly production system to minimize the use of chemical pesticides.
- Holistically, protected cultivation is safe for soil, crops, humans and environment and it is economical and profitable production system for all categories of farmers.

Capsicum crop in soilless grow bags





Chapter 2

Why vegetable cultivation under greenhouse?

Vegetable cultivation under cover is gaining popularity for reasons such as high productivity and better quality produce production round the year with enhanced input use efficiency. At ICAR-Indian Institute of Horticultural Research, Bengaluru, research on green house vegetable production is in progress since the year 2000, resulting in the development of many technologies which has made possible to realize higher yield levels in selected vegetable crops like tomato, capsicum and cucurbits. Tomato and bell pepper yields have touched 300 tonnes and 200 tonnes per/ha/year respectively and those of cucurbits 100 to 125 tonnes/ ha/ crop.

High yield with better quality capsicum grown in polyhouse

Increase in yield (tonnes/ ha/crop) of few vegetable crops under green house

Crops	Open Field	Greenhouse
Bell Pepper	20-40	125-150
Beans	15-20	30-40
Tomato	75-125	160-180
Brinjal	75-100	125-150
Cucumber	40-50	100-125

Protected cultivation has been found beneficial to produce hybrid seeds and seedlings of vegetable and flower crops, off season cultivation of vegetables in tropical plains and breaking the seasonality barrier in vegetables in temperate Himalayas, export oriented production of superior quality vegetables and flowers, combating biotic and abiotic stresses in vegetable production, organic production of vegetables, propagation of saplings of fruits, planting material of ornamentals, aromatic, spices and medicinal crops.

Healthy English Cucumber crop in polyhouse

Chapter 3

Greenhouse Structure

Green house is a structure wherein a congenial atmosphere/ micro-climatic environment is created inside the protected condition in which only desired level of sun light is allowed to enter. It has mainly two parts. 1) A frame or basic structure and 2) the cladding or covering material (U.V. film). Frame can be made of G.I. pipes, bamboos, woods, while the cover can be of glass or plastic films. In our country many types of green houses are being built depending on various factors such as climatic requirement, season, cost, crops to be cultivated, etc. Among these following few types are commonly built and used. Generally, the green house is designed depending on the prevailing local climatic conditions.

In India varying structures are used for green house production of vegetables under divergent climates. Following are the important ones, normally used in different areas.

For High altitudes long cold winter area

Long Cold Winters: Polyhouse, Poly trench, example as in Leh and Ladakh

Off-season vegetable cultivation under walk-in tunnels: Northern Plain: Mostly cucurbits are grown for early markets in summer

Plastic low tunnel technology: Northern Plains: winter months: Used for production of cucurbits under row covers for early market.

Floating row covers: Here, no mechanical support, only spun bonded/non-woven fabric is used, porous lighter films for protection against insects, which are transmitting virus.

Shade house and Net-house cultivation: Suitable for crop production in less rainfall area. Among the protected structure, this is a better suited structure for hot climate also.

For lower region

Rain Shelter, Double bed A type rain shelters are ideal structures.

Naturally ventilated polyhouse: Generally adopted in milder climate, throughout the year. Whereas in the hotter climate, it is used in all seasons, excluding summer.

Fan and pad polyhouse: Evaporative cooling polyhouse for hot and dry climate.

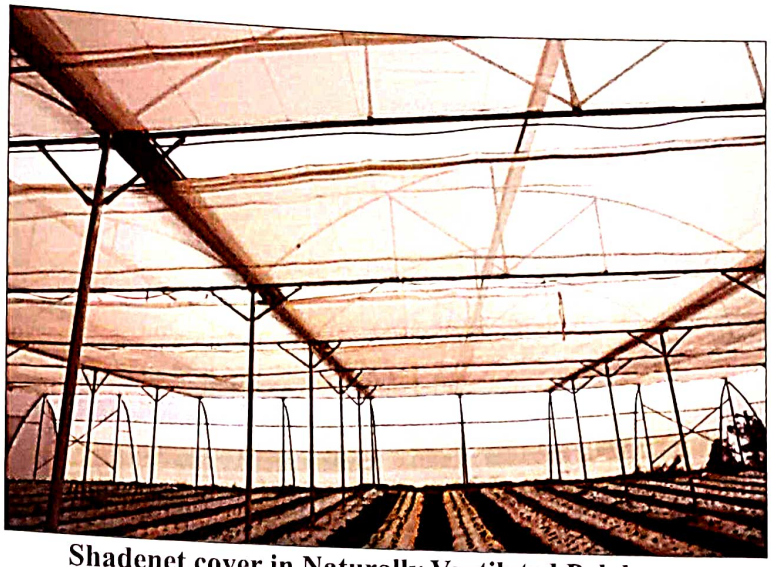
All these types of structures are adopted in different seasons/ situations indicate the large-scale opportunity to use protected cultivation round the year in different parts of the country. However, there are many factors in deciding the use of a particular type of structure. But one of the main factors is the cost-effective maintenance of inside temperature and humidity. This can be achieved by cooling the green houses.

Naturally Ventilated Polyhouses

Greenhouse Cooling can be done mainly by two methods. 1) Natural Ventilation with

the help of Vents, Shades and Misting and 2) Evaporative cooling using Fan and Pad system or high-pressure fog cooling.

In hot and dry climate, evaporative cooling is the most practical way (Fan and pad, fogging) to reduce the temperature in green houses. The theoretical limit of evaporative cooling is wet bulb temperature for that place and time. So, under high humidity ambient condition this is a serious constraint. Another way to provide cooling effect is Ventilation through Nylon nets.



Shadenet cover in Naturally Ventilated Polyhouses

Green house Cooling through Shading: In summer the level of radiation entering a green house can be reduced using shade nets. Shading is necessary for many green house crops because direct radiation at noon increases the plant temperature by 5-6^0 C. Some green house glazing materials are available with tints that can reduce heat-gain and light transmission.

Use of Shade nets in green house: Shade nets are movable panels of fabric used to cover or uncover the space above the plants and are used for heat retention, cooling effect and day length control or blackouts. Interior curtain systems are widely used to reduce indoor light intensity and help control temperature during the day. There are four colors of shade cloths such as green, black, white or aluminized. The aluminized strips reflect light out through the roof of greenhouse. This reduces the cooling load under the shade considerably. In naturally ventilated cost-effective greenhouses, HDPE woven fabric of 35-50% light cut are commonly used. Generally, the life of shade net is about 5 years. Exterior curtain is most ideal since it cuts off the radiation from entering the greenhouse.

Designing and Construction of Polyhouse: In India cost effective poly house and net house structures are most commonly used to grow vegetables. Polyhouse gives better protection compared to net house due to total avoidance of rain water entry into polyhouse. Hence, better control of diseases of leaves and roots is possible.

Generally, GI pipes are used to construct poly house. Transparent UV stabilized polyethylene film of 200-micron thickness is used for covering the polyhouse roof. Polyfilm generally lasts for 5 years if it is kept clean of dusts and algal growth. Below the polyfilm a secondary layer of shade net with movable arrangements is provided to cut down the excess sunlight and also to reduce the temperature inside the polyhouse during midday and in summer months. The sides of the polyhouse are covered with

Framework of Polyhouse structure

Well constructed polyhouse facilitates good crop

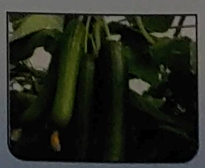
200-micron thick polyethylene film to a height of 3 feet from the ground level, to have better protection from rain splash. Remaining height of side wall is covered with 40 mesh white coloured insect proof net from all four sides which restrict the entry of insects. The disadvantage of insect screens is that it restricts air flow inside the polyhouse resulting in buildup of temperature. The life of these nets is about 5 to 10 years, depending on the quality. A 40-mesh insect net will prevent the entry of bigger insects but can also restrict the entry of small insects -thrips, aphids, leaf miners and whiteflies. A 40-mesh nylon net means 40 strands in a linear inch, which means the strands are placed at a distance of 635 microns. Strand thickness is 192 microns; therefore, pore size is 445 microns. Since average abdomen size of thrips is 340 microns, aphids 340 microns, and whiteflies is 462 microns, with good airflow these small insects can make entry through 40-mesh nets. Since leaf miners average abdomen size is 640 microns, they will be effectively screened. In 50-mesh nylon net, the pore size is 316 microns and it is more helpful to seclude these small insects, but restricted airflow resulting higher temperature is the concern to use 50 mesh nets.

Construction of naturally ventilated polyhouse costs about Rs.800 per square meter area. The structure is provided with an entry room (ante chamber) with double door systems to avoid the entry of insects while opening the door. Care should be taken not to open both the doors simultaneously to avoid the entry of pests into the protected structures. A small concrete trough of 2 feet length, 1 feet breadth and 3-inch depth should be prepared between the two doors of antechamber for facilitating washing of feet in the disinfectant solution like potassium permanganate.

Important points to be considered while constructing naturally ventilated polyhouse (NVPH)

1) **Direction**: Top vent should not face the windward direction. In a gutter connected polyhouse North South direction of gutter has advantage of uniform light distribution.
2) **Height of polyhouse**: Minimum 4m side height; Central height: Minimum 5.5m.
3) **Span**: 8m, grid size: 8m x 4m is mostly followed. 9.6 m design is also followed in some places
4) **Type of steel used**: Galvanized mild steel (called as Galvanized iron; GI)
5) **Pipe wall thickness**: Minimum 2 mm, which is found to sustain the wind speed of about 110 KMPH
6) **Gutter length**: Maximum 50 m with unidirectional slope of 1-2%.

These NVPH structures are suitable for both vegetable seedling production in hi-tech nursery as well as for crop production in different climatic conditions of the country.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Chapter 4

Hi-Tech Vegetable Nursery Production

It is common practice now by the farmers to get the seedlings from commercial vegetable nursery rather than producing own seedlings due to following advantages.

1.1. Advantages of protray grown seedlings in protected environment

- Use of right media helps in good germination of the seeds. It saves cost by reducing the loss of expensive seeds
- Each seedling will get equal area, which facilitates uniform growth
- Saving of water, nutrient and labour in the nursery; no or very less seedling mortality, with better establishment after transplanting with excellent crop stand in the main field

Well grown cucumber seedlings in protrays

- Use of uniformly grown seedlings helps in uniform and early maturity of the crop
- Viral disease damage in the main field can be drastically reduced, due to zero infection in the nursery and no transmission through the seedlings

Majority of the vegetable farmers are using the seedlings grown under protected structures (Polyhouse and Net-house). Hi-tech vegetable nurseries are useful in multiple ways such as

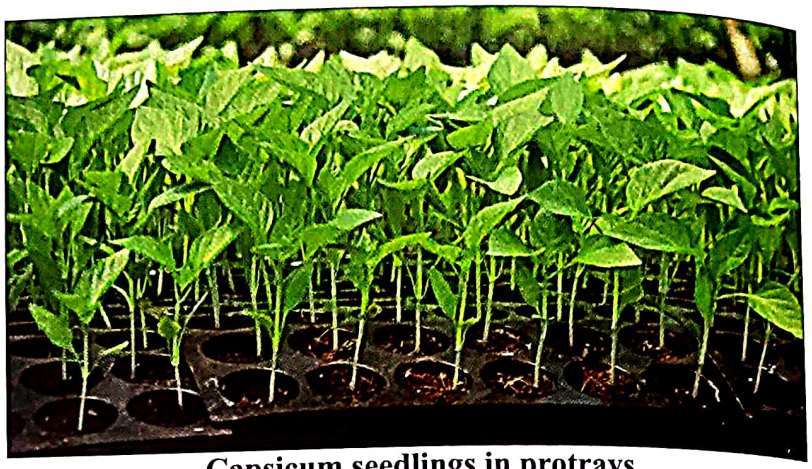
1) Development of entrepreneurship in rural areas
2) Development of related small-scale input industries
3) Sustainable employment generation especially for rural women
4) Waste utilization - Coconut coir industry byproduct is utilized as media
5) Mechanization is possible, hence reduction in drudgery of farm workers
6) Large number of good quality seedlings are produced safely in a shortest possible time
7) Seedling produced will establish easily in the main field, due to low mortality (<2%), thus there will be cost saving on the additional seedlings required for replacement.

Vegetable seedlings are produced in the Hi-tech nurseries by a large number of nurserymen, who can also act as techno agent in spreading the information on latest technologies like improved varieties/hybrids of different crops, production/enrichment and application of bio-inoculants and in selection of suitable varieties for different seasons, etc. The following steps are very useful in following hi-tech seedling production of different vegetables.



1.2. Nursery raising

- Select good quality seeds of suitable varieties for production of good quality seedlings
- Raise the seedlings in pro-trays of 98 cells or cavities or 70 cells for crop like capsicum, as its nursery period is quite longer (35 to 45 days, after protray sowing)
- Cocopeat is the most commonly used media. Cocopeat is prepared using coir pith after proper composting/fermentation. Cocopeat is extensively used as media due to its excellent water holding capacity, provides good aeration and light weight. However, vermicompost can also be used as media for seedling production, if cocopeat is not available easily.



Capsicum seedlings in protrays

- Using technology developed by ICAR- IIHR, time required for cocopeat decomposition can be reduced to a short period of 45 days, as compared to normal process of 90 days for decomposition and sterilization.
- Produce the required quantity of seedlings, depending upon the crops and season. For example, for coloured capsicum about 12,000 to 13,500 seedlings are required to plant one acre for which 130-140 gm of seeds is required. Since the seeds are counted in numbers now, as they are very expensive, each seed should be used very carefully.
- Treat the seed with talc-based bio-pesticide formulations, *Pseudomonas fluorescens* and *Trichoderma harzianum* or *T. viride* @ 10g/kg seed.
- Treating the seedling production media (cocopeat / vermicompost) with -*Trichoderma harzianum or T. viride* and *Pseudomonas fluorescens* @ 1kg/ton each + neem cake @ 50kg/ton is very useful, before filling the media in the seedling production trays (Pro-trays).
- Fill the pro-trays with the properly prepared, moist cocopeat (not too dry or not too wet) and sow one seed per cell at a depth of ½ cm and cover with the same media
- Stake about 10 seed filled trays one above the other and cover with plastic sheets till the seeds germinate. Seeds germinate in about 5 to 8 days after sowing, depending on season.
- Check daily for germination 5 days after sowing. When white radical is seen just emerging out of seed coat, shift the trays to net house/

Seedlings raised under protected environment

polyhouse and water them lightly with rose cans. No irrigation is needed when kept in packed condition.

- Drench the trays with mono ammonium phosphate (12:61:0) (2g/lit) 12 days after sowing and 19:19:19 (3g/l) solution 22 days after sowing. Drench the seedling trays with copper oxy chloride @ 3g/l before transplanting. The seedlings will be ready for transplanting in 10-13 days in cucumber and melons, 22-25 days in tomato and 30-35 days in capsicum.
- Good hygiene coupled with application of bio-agents will avoid any disease or pest incidence in the nursery. However drench copperoxychloride @ 2g/litre at 12 days after sowing to avoid damping off. Spray systemic insecticides like imidacloprid @ 0.3ml/l at 15 days after sowing to control the vectors transmitting viral diseases. Need based fungicides and insecticides need to be applied if pests and diseases are observed on the seedlings.
- Spray imidacloprid @ 0.3 ml/l and chlorothalonil @ 2gm/l separately before transplanting of seedlings. Always add about 0.3 ml/l of wetting agent per litre of water with each spray of pesticide.

Good quality seedlings of capsicum produced under polyhouse, ready for planting



Chapter 5

Site Selection, Land and Crop bed preparation

5.1. Site selection

Several factors should be considered in selecting a suitable site. 1) As far as possible, the production site should be level or nearly levelled land. Sloped sites are not completely out of the question, but they increase the construction costs considerably because, the site must be levelled or terraced to accommodate the new structure. 2) The site should be near the power source and should have a ready supply of usable water. Typically, water from a borewell is better than surface water because there is less likelihood of disease spread, particularly algae/ bacterial contamination from surface water sources. Water should have low EC, preferably less than 0.5m.mhos/cm. 3) Availability of labour is very important. Although much of the work in crop production is repetitive and tedious, we should have trained /skilled labour for better performance. Normally conscientious and skilled labour, or at least trainable ones, even though relatively expensive, more reliable in the long run and 4) Site should have better access to good roads and proximity to highways, which facilitates easy and safe transportation of the produce to the expected markets, with least damage.

5.2. Land preparation

The land should be thoroughly ploughed and soil should be brought to fine tilth. Well decomposed organic manure at minimum 5 kg per sq. meter is mixed with soil. We can also grow velvet bean (Mucuna) as a green manure crop and incorporate in the soil, which also helps in reducing nematode load in the soil. The bed size should be 80cm wide and 30cm height. Between the beds walking space of 80cm need to be provided. There will be 5 beds in a bay of 8 meters. This pattern is suitable for double row planting of tomato, capsicum and cucumbers. However, it is advisable to cultivate only two crops consecutively among tomato/ cucumber and capsicum in the same field and then grow leguminous or other suitable non host crops for nematode and wilt diseases as rotation crops.

Clean plot with raised beds ready for planting

5.3. Fumigation

When the soil borne pathogens load is high, causes higher economic damage to the crops, it is advisable to go for soil fumigation in protected cultivation. Soil analysis needs to done to test the seriousness of the problem of soil borne pathogens and nematode, before planting the crop. If the pathogen problem is serious, then beds are drenched using 4 per cent formaldehyde@4 litre/m^2 of bed and covered with black polyethylene mulch sheet. While treating with formalin, care should be taken to wear mask, gloves and apron. Four days after formalin treatment, the polyethylene cover is removed; the beds are raked repeatedly every day for three to four days. Formalin treatment can be repeated after 3 crop cycles or whenever absolutely necessary. Fumigation with formaldehyde helps to minimize the soil borne diseases. Basamid can also be used for soil sterilization with proper procedure. But it is expensive and farmers are



required to learn the proper skills for its application. After ensuring the complete removal of residual fumes of formaldehyde, neem cake enriched with bio-pesticides are applied on crop beds. Solarization combined with fumigation is highly beneficial in bringing down the load of soil borne pathogens and in reducing the cost of crop management. Bio intensive management with bio pesticide, which is explained later in this bulletin is the better alternative to formaldehyde fumigation.

5.4. Application of bio-pesticides

Bio-pesticides like *Pseudomonas fluorescens* 1% W.P., *Paecilomyces lilacinus* 1% W.P and *Trichoderma harzianum* 1% W.P can be directly applied to soil along with farmyard manure at the rate of 25g/m^2 of bed area four days before transplanting. This corresponds to 50kg/acre each of bioagents. Instead of direct application, bio pesticides can be enriched with FYM, neem cake, Jeevamrutha and Neem cake suspension as explained in the Annexure 1. (Page Nos. 87 to 90)

Application of neem cake enriched with biopesticides on crop beds

5.5. Fertilizer application

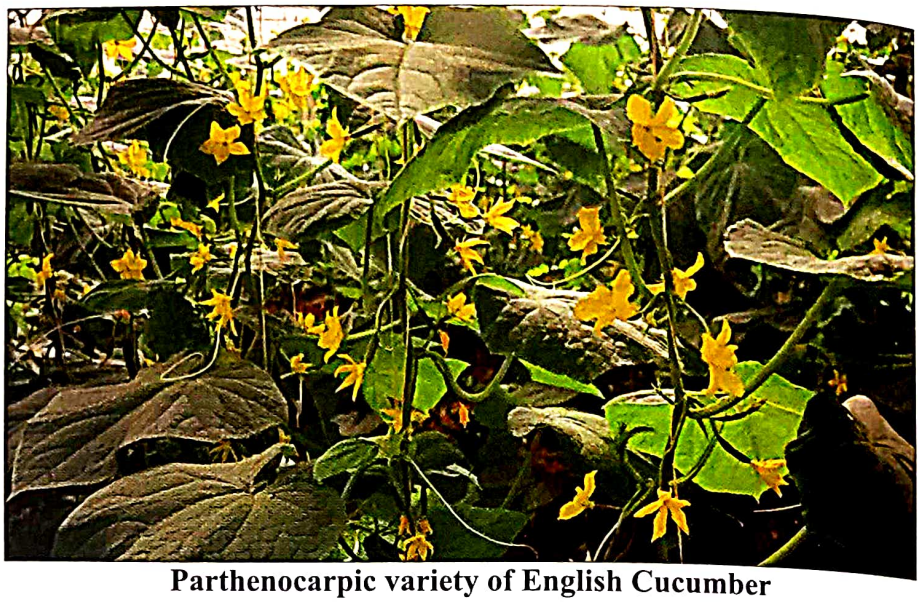
Upto 25 per cent of recommended fertilizer dose can be applied as basal dose, before planting, to reduce the cost on water soluble fertilizers, which are used in fertigation. We can also apply small quantity of micro-nutrient containing fertilizers depending on the availability of these nutrients in the soil, based on the soil test results. Approximate quantity of these micro-nutrients required per acre includes Zinc Sulphate (5 Kg.), Borax (3 kg.), Magnesium Sulphate (4 to 5 kg.), Iron Sulphate (2 to 3 kg.), Copper Sulphate (0.3 to 0.5 Kg.) per crop period. Details of fertilizer application and nutrient requirement of each crop is given separately under each crop schedule.



Chapter 6

Selection of crop, varieties, seedling preparation for planting

6.1. Selection of cultivars: Cultivars suitable for open field condition are generally not suitable for polyhouse cultivation, as relatively long duration, with shorter internodes, and high-yielding hybrids are ideal for green house cultivation. The selection of cultivars and hybrids depend on plant type and their growth habit. Tomato hybrids should be indeterminate type. The plants are grown upright as a single stem in tomato and cucumber and two stems in capsicum rather than bush type. The cucumber cultivars should be unique. They should have only female flowering habit, with dark green parthenocarpic (seedless) fruits and free of bitterness.



Parthenocarpic variety of English Cucumber

6.2. Grafting: Grafting is an emerging technique and is becoming popular throughout the world, especially for the green house cultivation of vegetable crops. It is used mainly in Solanaceous and Cucurbitaceous crops from the point of resistance against the soil borne pathogens including the root knot nematode *Meloidogyne* spp. It is also successful in cucurbits like melons for resistance against diseases in addition to better yield and quality. Grafting involves the union of suitable varieties of greenhouse crops used as scions over the resistant root stocks, which are usually from the same family. The grafted seedlings are conditioned in the dark and cool shade nets, before planting in seedling trays and finally they are transplanted in the green houses.

Vegetable grafting was first adopted to enhance ability to cope up with biotic stresses. Later, this technique is also used as a means to enhance vegetable tolerance to abiotic soil stresses, like low soil temperature, drought, salinity and flooding. However, the main objective of grafting is to avoid important soil-borne diseases such as Fusarium wilt in Cucurbitaceae, Bacterial wilt in Solanaceae and also to overcome abiotic stress in crop production. Other option to avoid the problem of soil borne diseases is to grow vegetables in soilless culture, which helps in better maintenance of water regime, root zone aeration, good control of soil borne pathogens. Soilless culture is a good option, but it is relatively expensive, as it requires preparation of new sterilized and disease-free media completely. Therefore, as long as the grafting is feasible and economical, grafted seedlings can be grown in soil-based media for soil borne disease management.

Common Species and varieties used for grafting in vegetable crops in India

a) **Inter-generic grafting:** Cucumber grafted on pumpkin (*Cucurbita* spp.), Watermelon on bottle gourd and Melon on wax gourd (*Benicasa hispida* Cogn.).

Tomato Grafting

Brinjal Rootstock

Tomato Scion

Tomato Grafts on Brinjal Rootstock

b) **Inter-specific grafting:** Eggplant on *Solanum integrifolium* Poir. and *S. torvum* Swartz, root stock.

A large number of varieties for rootstock have been bred and released for use by growers in Japan and Korea. ICAR-IIHR and other institutes and SAU's have also identified many compatible varieties of root stocks for grafting in tomato, brinjal and melons. However, we need to test them in real field conditions for the commercial feasibility i.e., cost-effective large-scale cultivation.

There are few disadvantages of grafting in vegetable crops such as

1) Grafting is laborious and require expertise/skill
2) Quality of grafts is crucial i.e., poor quality grafts may be resulted from grafting incompatibility
3) Break of resistance, if stock-scion incompatibility is present and
4) It requires improved cultivation method for better management of grafted plants.

Chapter 7

Main field preparation

7.1. Laying of drip line

For row crops in green house, inline drip laterals are used, where in drippers are welded inside at regular intervals at the time of manufacturing. Size of laterals, dripper discharges and dripper spacing varies with soil type, spacing of crop, season and crop stage. Generally, two 16 mm inline drip laterals are placed in the bed having emitting points at every 30 or 40 cm interval with discharge rate of 2 l/hr. If mulched, one lateral at the centre of the bed is also sufficient, as mulching will significantly reduce the water loss from soil. Run the drip system to check each emitting point for uniform discharge before covering the beds with polythene mulch. As a thumb rule replenishment of water is taken care in polyhouse @ 50 % evaporation loss and in net-house @ 60% of evaporation losses.

7.2. Mulching and Spacing

Irrespective of the type of growing media, the cropped area should be mulched to control weeds, retain soil moisture, reduce infestation of pests and diseases, prevent soil compaction. Mulching also results in higher yield and good quality produce. Black (bottom) and white (top) poly-ethylene, virgin or non-recycled mulch film of 30-40 micron thick, 1.2 m wide, is used to cover the planting beds. Holes of 7.5 cm diameter are made on the polyethylene film as per the recommended spacing. The planting beds are covered with the film by securing the edges of the sheet firmly in the soil.

Transplanting of healthy seedlings

7.3. Transplanting

The planting beds are watered to field capacity before transplanting. Right stage seedlings of good quality with uniform size, age and growth are used for transplanting. For example, 10-13 days old European cucumber, 25 to 28 days tomato and 30 to 35 days old capsicum are ideal for planting. Care should be taken to avoid damage to the roots and also to see that the ball of

Capsicum seedlings transplanted on raised beds

Good quality capsicum seedlings transplanted on raised bed

media is intact with the roots, while taking out the seedlings from individual cells of protray. Seedlings are transplanted into holes made in polyethylene mulch film at a depth of 5 cm. After transplanting, seedlings are drenched with copper oxy chloride 3 g/litre or captan 2 g/litre or copper hydroxide 2 g/litre solution to the base of seedlings at the rate of 25-30 ml per plant. Watering the mulched beds daily during afternoon by using hose pipe for a week continuously is essential to avoid mortality of the seedlings due to heat trapped by mulch sheet. For transplanting use only quality seedlings raised in protray and grown under proper net house in order to ensure that they are free from any pests and disease infection, especially virus infection.



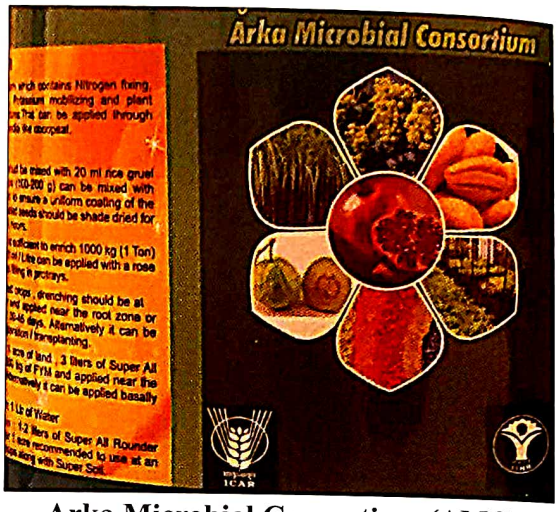
Chapter 8

Integrated Nutrient Management

8.1. Application of basal fertilizer (2 to 3 days before transplanting)

Generally, upto 25 per cent of nutrient requirement of the crop is applied as basal fertilizer to the soil, two to three days before transplanting. Apply Carbofuron at the rate of 5 g per sq. mt (20kg/acre), along with the fertilizers on the crop rows. This will reduce the initial incidence of soil borne insects, particularly root grubs and nematodes.

8.2. Application of AMC: Arka Microbial Consortium (AMC) is a very useful combination of beneficial microbes composed of N fixing, P and Zn solubilizing plant growth promoting bacterial strains (*Pseudomonas* spp. and *Bacillus* spp.) in a single carrier. This will bring down the load of soil borne pathogens, particularly wilt causing organisms. It contains N fixing, P & Zn solubilizing microbes, and plant growth promoting microbes, which triggers internal and natural production of plant hormones and other growth substances, which is likely to enhance flowering and fruiting. Apply the AMC powder/ suspension@ 5kg/acre either directly on the crop beds or through enrichment with organic manures/FYM. Later AMC liquid solution@ 5 ml / litre is prepared and drenched @20ml solution/plant, 10-12 days after transplanting.



Arka Microbial Consortium (AMC)

8.3. Fertigation:

After realizing the importance of micro-irrigation system, the next most essential input to boost the productivity and quality is the fertigation. Fertigation generally means the application of solid or liquid fertilizers via pressurized irrigation system; thus, forming nutrient containing irrigation water as per the crop need with desired concentration.

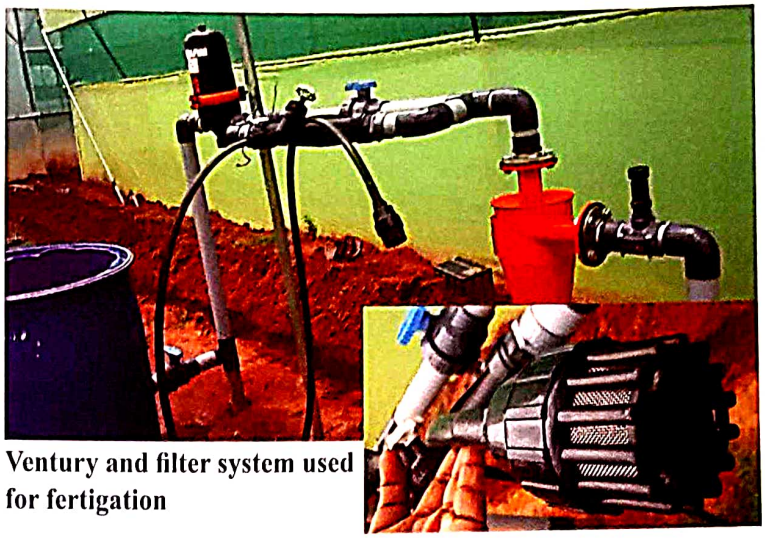
Automated Fertigation System

Soil fertility should be determined and managed with soil testing. As with any field, the soil pH should be adjusted to 6.0 to 6.5. Build-up of soluble salts can be particularly severe with the soil system. To minimize this problem, use fertilizers that do not contribute to accumulation of excess soluble salts. This would include calcium nitrate, potassium nitrate, triple superphosphate, diammonium phosphate, potassium sulphate and sulphate of potash-magnesia.



Water and fertilizers are normally applied in a targeted fashion through drip irrigation system. Generally, fertigation of the crop is done using Ventury, Fertilizer Tanks or Dosatron.

It is better to use water soluble solid fertilizers for fertigation. But, from economic point of view normal fertilizers such as urea can be used and with caution and care muriate of potash can also be used as a source of nitrogen and potash. If phosphorous has to be supplied through irrigation water, one has to use water soluble fertilizer such as Mono-Ammonium Phosphates or Urea Phosphates or Phosphoric acid. Single Super Phosphate cannot be used as it results in clogging of drip systems since it is not completely water soluble.



Ventury and filter system used for fertigation

Features of 100% water soluble fertilizers

- No chloride, no sodium and no salt build up.
- Completely soluble in water.
- Most of the fertilizers are acidic and hence special acidification treatment for dripper clogging may not be necessary.
- Blended with micronutrients.

8.3.1. Fertigation scheduling: While deciding the fertigation schedule following points need to be taken into consideration.

- Total nutrient requirement of crops to produce target quality yields.
- Part of the nutrient supplied in the form of organic manure.
- Savings in the nutrient doses due to the higher efficiency of added fertilizer through fertigation.
- Relative requirement of nutrient varies at different stages of crop growth.

8.4. Types of Fertilizers- Mainly there are two types of fertilizers namely Liquid fertilizers and Solid water-soluble fertilizers; later being used more commonly now a days. Some of the examples of different fertilizers used in protected cultivation are given below.

1. Straight Fertilizers: Urea Phosphate (17:44:0), Mono Ammonium Phosphate (12:61:0), Mono Potassium Phosphate (0:52:34), Potassium Nitrate (13:0:46), Sulphate of Potash (0:0:50 + 18% S), Calcium Nitrate (15% Nitrogen), Magnesium Nitrate.

2. NPK Formulations: 18:18:18, 19:19:19; 19:19:19 +Trace Elements

3. Chelated Micronutrients: Fe EDTA (13% Fe), Zn EDTA (15% Zn), Fe EDDH-A (6%), Chelated combination of micronutrients, Kombi, etc.

Since requirement of nutrients varies with stage to stage of crop growth, it is essential to know the nutrient requirement of the crop based on the growth stages. High level of nitrogen is required during the vegetative

growth stages to facilitate the accumulation of dry matter in different plant parts. Its requirement is comparatively low during reproductive stage. The requirement of P is more during reproductive phase as it induces flowering, fruit set and seed development. Potash requirement is high during crop maturity stage.

Arka Vegetable Special

8.5. Foliar Nutrition: All the major nutrients (NPK) and Secondary Nutrients (Ca, Mg & S) along with micronutrients (Boron, Copper, Iron, Manganese and Zinc) should be applied @ 0.3 -0.5 % at 15-20 days interval. For example, capsicum crop is sprayed with water soluble fertilizers like potassium nitrate and calcium nitrate at every 3-week interval after 1.5 months of transplanting @ 3-5g/l as foliar application. Apart from these sprays, Arka vegetable special (a mixture of micronutrients) developed by ICAR-IIHR, Bengaluru for foliar spray which contains Zn:3%, B:0.5%, Mn:1%, Fe:2%, Cu: 0.1%) is sprayed @ 5gm/l at 15 days interval. 19:19:19 formulations containing micronutrients are also to be sprayed at regular interval.

8.6 Crop Rotation: It is advisable to cultivate only two crops consecutively in the same field and then grow leguminous or other suitable crops like marigold as rotation crop. We can also grow mucuna as green manure crop and incorporate in the soil, which also helps in reducing nematode load in the soil, in addition to enhancement of soil nitrogen.


Marigold in polyhouse as crop rotation



Chapter 9

Integrated Pest and Disease Management

Integrated pest management (IPM) and Integrated Disease Management (IDM) is a holistic approach in which we use a combination of compatible components like cultural, biological and need based chemical control methods with constant pest and disease monitoring to maximize the effectiveness of different methods with the objective of minimizing the use of chemicals and to produce safe and quality vegetables. Reduced use of effective pesticides with proper time schedules not only brings down the adverse effects of these chemicals on the crop, environment and people, but also reduces the chance of pests developing resistance. Normally as an IPM package neem cake @ 0.2 kg/ meter square of growing area (800 Kg/ acre) and bio-pesticides like *Trichoderma, Pseudomonas, Pochonia* or *Paecilomyces* enriched organic manure @ 2 kg for every one ton of FYM added is recommended.

Few important prophylactic measures to be adopted in Pest and Disease Management

- Using clean and healthy seeds and seedlings free from pest, disease and virus, which are raised in plastic protrays under polyhouse / insect proof nylon net cover.
- Removal of all debris of the previous crops and weeds in the crop fields and in the surrounding places.
- Sterilize all surfaces at regular interval, including equipment and machineries, which are likely to contaminate the crop/ polyhouse with pests and diseases.

Well grown healthy cucumber crop free of pest and diseases

- Practice growing of pest and disease resistant varieties and adopt crop rotation using diverse crop species.
- Adopt bio-intensive rationale for pesticide application, in an integrated approach.

9.1. Insect Pest and Nematode Management

Most of the crops including capsicum and tomato being relatively long duration (8-10 months) crops in polyhouse, the plant parts (vegetative, floral & fruit) are more exposed to pests and diseases which adversely affect the yield, quality and market value of the produce. Hence, their identification and management at right stage of the crop should be given more importance. Major pests and diseases, typical symptoms and their management in various crops are mentioned. The major focus has been given on adoption of integrated approach in managing pests and diseases, which help to reduce the pesticide load, cost of chemicals and avoid the resurgence of pests and diseases.

9.2. Integrated Disease management

Integrated Disease Management (IDM) is also a holistic method in which we use a combination of compatible methods like cultural and biological control and the disease monitoring to maximize the



effectiveness of control methods with the objective of minimizing the use of chemicals and to produce safe and quality vegetables.

9.2.1. Application of Bio-pesticide in disease management

Wilt diseases of vegetables are caused by fungi, bacteria and nematodes, which are soil borne in nature. These pathogens are known to survive in soil for long duration due to continuous vegetables cultivation in the same soil year after year. Soil borne inoculums of these diseases can be reduced by application of bio-pesticides. ICAR-Indian Institute of Horticultural Research, Bengaluru has developed simple methods to use bio-pesticides such as *Pseudomonas fluorescens* 1% W.P., *Paecilomyces lilacinus* 1% W.P, *Trichoderma harzianum* 1% W.P, Arka Microbial consortium (AMC) and Seed pro, which are found to have good impact on reducing the incidence of diseases in vegetable crops.

9.2.2. Seeds and seedling treatment procedure

Seed pro- a seed coating formulation developed at ICAR-IIHR- is recommended for seed treatment. This product contains two bio-agents *Bacillus subtilis* and *Trichoderma harzianum.* It inhibits growth of seed and soil borne pathogens, promotes root and shoot growth, leaf area with higher seedling vigour index. Vegetable seeds should be treated with Seed Pro at 10g per kg of seed as seed coating. Spread seeds on floor and sprinkle water on seeds, or coat the seeds with equal volume of cold rice glue, then sprinkle bio-agent on the seeds and mix them well. Dry the treated seeds under shade before sowing. Alternatively, seed treatment can be done with Arka Microbial Consortium (AMC) @10-20g/100g seed by following the method explained above. AMC is a carrier based microbial product that contains N fixing, P & Zn solubilizing and plant growth promoting microbes in single carrier.

Seedlings in nursery/protrays can be drenched with bio-agents like Arka Microbial Consortium, or Seed pro @ 20g per litre, one week before transplanting. Alternatively, seedlings can be dipped in liquid formulation of bio-agents before transplanting.

Note: In India there are no insecticides or fungicides with label claim for use on Capsicum. The fungicides mentioned are based on field research and label claim products available for use in chilli. The use of captan, ziram, mancozeb, thiophanate methyl, acephate, carbofuran, or dimethoate and chlorothalonil is prohibited in draft order on "Banning of insecticides 2020" by government of India under The Insecticides Act, 1968. If any one of these is banned, they should not be used. Wherever available, only Central Insecticides Board (CIBRC) registered pesticides having label claim has to be utilized in spraying crops. For further information regarding dosage and registered pesticides refer to http://ppqs.gov.in/divisions/cib-rc/major-uses-of-pesticides.

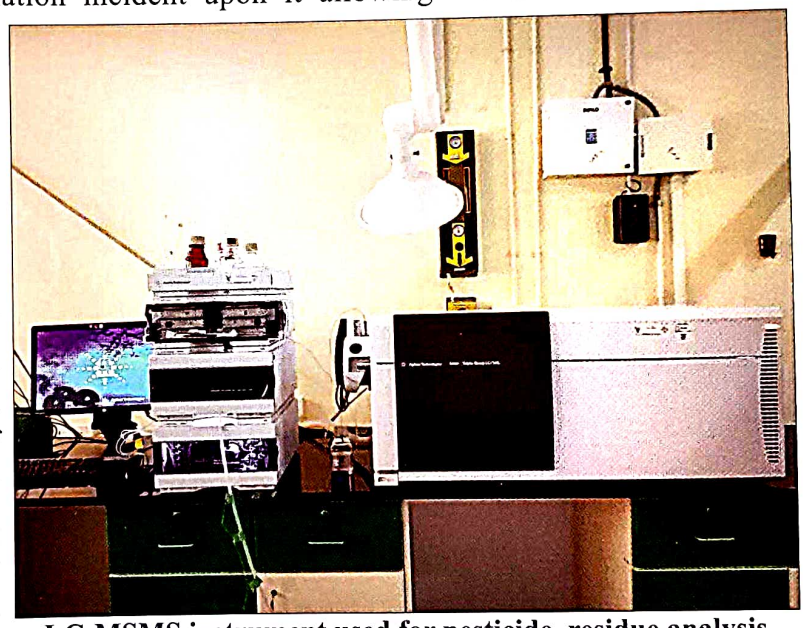


Chapter 10

Pesticide residues in greenhouse production of vegetable crops

In poly house cultivation of capsicum, high plant density, monocropping of susceptible genotypes and increased labour activities make plants more prone to pests and diseases like mites, thrips, whiteflies, powdery mildew and nematodes. Thus, chemical control of pests becomes necessary and often several sprays of insecticides / fungicides are given even at near harvest stages of the crop. In polyhouse the volatilization and wind drift losses of pesticides are lesser which may result in higher initial deposits of pesticide residues on the plant and soil, while degradation of pesticide residues may be higher due to higher average temperatures. Also, a polyhouse generally reflects back 40 – 45% of the net solar radiation incident upon it allowing the transmittance of the "photosynthetically active solar radiation" in the range of 400-700 nm wave length. Thus, there will be lesser UV radiation incident upon the crop in a greenhouse than in open field in the same area, especially when shade net is also used. Since most pesticides are UV-degradable, there is a likelihood that pesticides will persist for a longer time in polyhouse and net-house. It is thus important to evaluate the persistence of pesticide residues in these crops under polyhouse conditions, so that safe waiting period for important pesticides used in polyhouse cultivation may be established. It is established through research at ICAR-IIHR that pesticides tend to persist for a longer time in crops grown in polyhouse when compared to crops grown in open field in the same season. Also the initial deposit of pesticides on crops following their application is higher in polyhouse than in open field. Thus, it is important that waiting period of pesticides be established specifically for crops grown under polyhouse conditions and accordingly recommendation of pesticides and their stage of application may be revised for chemical control of pests in polyhouse cultivation so that the produce is safe for human consumption at harvest.

Chemical residue on capsicum fruit



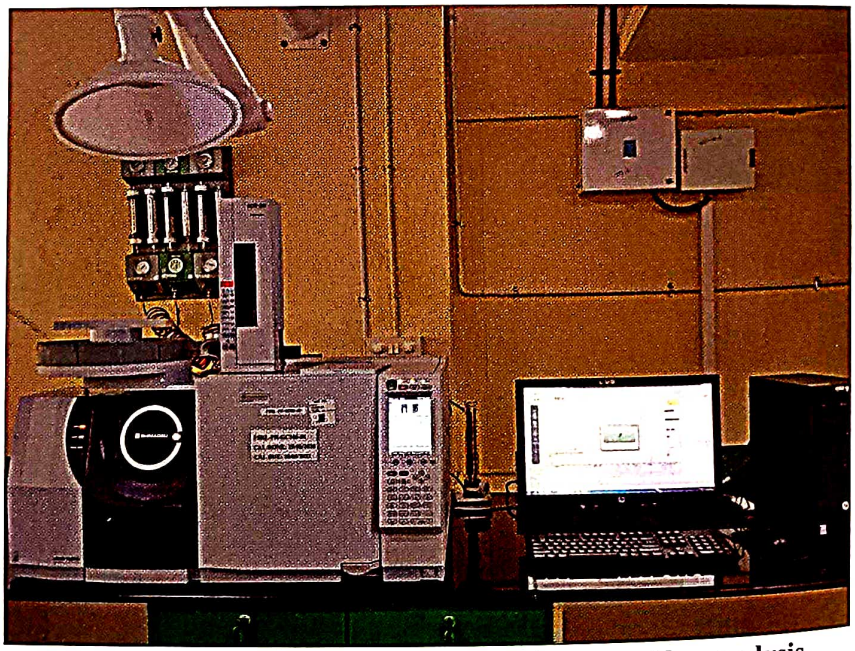
LC-MSMS instrument used for pesticide residue analysis

ICAR-IIHR conducted research programmes to determine the persistence pattern of pesticides and their waiting periods in polyhouse grown vegetables, viz. capsicum, zucchini, red cabbage, English cucumber,

broccoli and lettuce. Based on the studies carried out under the project, given below is a list of safe waiting period of some pesticides for capsicum, tomato and English cucumber grown in polyhouse.

Crop	Pesticide	Target Pest/ Disease	Safe waiting period (days)	MRL (EU) ppm
Capsicum	Abamectin	Mites	3	0.01
	Acephate	Thrips	16	0.02
	Chlorothalonil	Leaf spot	6	2.0
	Dimethoate	Thrips	10	0.02
	Ethion	Mites	15	0.01
	Imidacloprid	Aphids	7	0.5
	Dimethomorph	Downy mildew	1	1.0
	Tebuconazole	Powdery mildew	14	0.6
	Trifloxystrobin	Powdery mildew, Alternaria leaf spot	18	0.3
Tomato	Iprodione	Early blight	16	0.01
	Chlorothalonil	Leaf spots and Early and Late Blights	5	6.0
English Cucumber	Dimethomorph Metiram	Downey mildew Early Blight of Tomato	2 2	0.5 2.0

However, there are a lot of other insecticides viz. thiamethoxam, cynaxypyr, indoxacarb, ecomite, dicofol, fipronil, propargite etc. and fungicides viz. mancozeb, metalaxyl, hexaconazole, carbendazim, difenaconazole, azoxystrobin, which are used in these crops or are recommended for use. It was also seen that the varietal effect of colour capsicum varieties on rate of dissipation of pesticide residues was insignificant.



GC-MSMS instrument used for pesticide residue analysis

In another experiment conducted with an application of 50g/m^2 basal treatment of carbofuran in soil, capsicum harvested at first, second and third picking at 55, 61 and 69 days after transplanting did not contain any residues of carbofuran or its major toxic metabolite carbofuran-3- hydroxy. However, in case



the interval between the application and harvest is reduced, there may be residues of carbofuran in capsicum at harvest.

A study conducted at ICAR-IIHR showed that almost all samples of capsicum collected from different markets in Bangalore contained acephate residues above permissible levels. It was also established that acephate residues dissipated to below detectable limits (0.01 mg kg-1) within 21 days in open field (OF) grown capsicum and within 25 days in capsicum grown under polyhouse (PH). Residues of methamidophos, atoxic metabolite of acephate was found to be present in very low amounts, viz. 0.01–0.05 mg kg^{-1} in capsicum harvested between 2nd and 5th day from open field. In PH, however, methamidophos residues were found in all samples except in the 21st day sample, in the range of 0.01 to 0.03 mg kg^{-1}. The pre-harvest interval for acephate residues in open field grown capsicum was determined to be 12 days considering the European Union maximum residue limit of 0.02 mg kg^{-1}, while that in polyhouse grown capsicum was 16 days. Thus, in spite of higher residue dilution due to faster rate of growth, residues persisted for a longer time in polyhouse. Therefore, frequency of acephate application may be reduced at near harvest stages in polyhouse.

Sample preparation for residue analysis

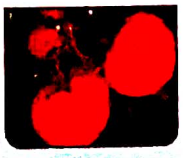
Since poly house cultivation of capsicum has gained a lot of importance, there is an urgent need to generate residue dissipation data for these pesticides, and thereby establish safe waiting periods required for harvest.

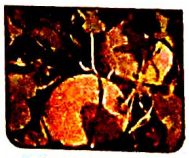
Use of safety kit during spraying of pesticides

Steps to be followed for safe use of pesticides and insecticides

- Pesticide residues in produce sent for marketing should not cross the safety level / maximum residue level (MRL) of the respective pesticides.
- Always follow safe waiting period schedule recommended for different pesticides, different crops and seasons.
- Always cover your body with masks, gloves and apron while spraying the chemicals to avoid health hazards.
- Go for crop rotation (in net/polyhouse after successive cultivation of coloured capsicum crop) with marigold, field/ pole beans, cabbage, cauliflower, sweet corn and also with

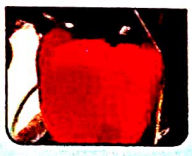
Good bearing of Capsicum fruits





any other profitable crops including sweet cucumber or green peas as per market value. It reduces pest and disease load in the polyhouse, particularly in the soil.

- Provide double door system, compulsorily. The doors of polyhouse/ net-house should always be kept closed to protect from pests, diseases and foreign materials.. Keep the doors on the sides of polyhouse / net-house and avoid keeping the entry door of the protected structures directly exposed to the road, to prevent entry of insect pests.
- Minimum number of entry or exit of the essential working staff and others only need to be entertained.
- Avoid entry of people and animals to polyhouse at least 8 to 10 hours after spray.
- When there are more number of green houses, avoid movement of people / workers from pest and disease infested polyhouse / open fields to the healthy polyhouse/ net-house.
- Mix only the known and compatible chemicals. Use mask and gloves and wooden sticks for rotating or turning, while mixing chemicals.
- Use of single chemical (insecticide/ fungicide) is preferred for spraying. Whenever a combination of pesticide/ fungicide is used, compatibility of different formulations of pesticides needs be ensured before mixing them. As far as possible, while mixing, first powder formulation, then liquid formulation followed by organic soaps like neem and pongamia soap should be done. First each formulation should be separately diluted, then the diluted mixture is mixed in a separate container (preferably in a plastic drum) to prepare the final mixture of spray solution.





Chapter 11

Production techniques for green house cultivation of capsicum

Capsicum (bell or sweet pepper) is the most popular high value vegetable grown in green house. It is rich in vitamin A, C, and minerals. Green, yellow and red sweet pepper cultivation is gaining popularity in peri-urban production systems because of easy access to urban markets and high-quality capsicums grown in a green house fetch better price in markets. Bell Pepper yields in open field cultivation range between 20 - 40 t/ha, whereas in green houses the yields obtained are 100 to 120 t/ha. In addition to quantum jump in yield, the superior quality and substantial reduction in use of pesticides and round the year production makes it an economic and eco-friendly proposition to grow capsicum in naturally ventilated green houses.

Good quality capsicum fruits grown in polyhouse

1. Climate and soil requirements

Capsicum is a cool season crop and day temperatures less than 30°C is favourable for growth and yield. Higher temperature results in rapid plant growth and affects fruit set. Lower night temperatures (20°C) favours flowering and fruit set. Shading and misting is required during summer to avoid temperature build up in green houses. Moderately high RH (50 - 60%) is preferred, which can be managed by judicious vent management coupled with misting or fogging. Sweet pepper grows best in a loamy or silt-loamy soil with good water-holding capacity. But they can grow on many soil types, as long as the soil is well drained. Soil pH should be slightly acidic between 5.5 and 6.0.

2. Selection of cultivars

Growing hybrid color capsicum in green house is useful to obtain the continuous and regular flower and fruit setting, relatively for a long period of 8 to 10 months. Most of the capsicum hybrids produce green fruits that mature to red, orange or yellow depending on the hybrid. The fruits should have uniform size and shape preferably four lobes fruit weight of >150g, uniform coloring after attaining complete maturity, with a better shelf life of more than 5 days under ambient conditions. Selected hybrid should be high yielding, with potential yield of more than 40 t/ acre. Hybrids should have shorter internodal lengths (7 to 10 cm), attaining maximum height of 10 feet in a crop period of 10 months. Popularly grown commercial hybrids of colored capsicum in India include Inspiration, Bungi, Triple star, Natasha, Pasarella (Red); Sunnyez, Bachata, Swarna (Yellow). Several commercial hybrids are available in the county and hybrids with high yield potential (>100 t/ha) and having uniform size and shape, good shelf life of >5 days and bright colour fruits needs to be selected. Among green capsicum popularly grown hybrids include Indra, Pasarella, Nemalite etc.

3. Specific care of seedlings before planting

Select good quality seeds and raise the seedlings in protrays kept in good net-house or polyhouse. While planting during hot climatic conditions, it is advised to use small, sturdy and young plants (28-35 days old) grown in sowing tray/ protrays. Small plants adapt much easier to hot conditions as the balance in root /



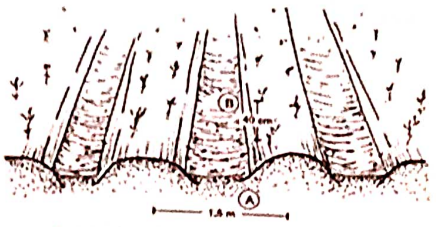
leaf mass is better. These plants will not lose too much water and will start rooting immediately into the soil and establishes quickly with faster vegetative growth. With increasing incidence of viral leaf curl diseases, it is better to grow the seedlings in 50-mesh insect nets.

4. Planting Density

The recommended plant density is 3 plants/ m^2 with 2 or 3 stem training system, with an average of 6-9 stems /m^2. Seedlings are planted in paired rows in 80 cm wide beds with row-to-row spacing of 50 cm and plant-to-pant spacing of 45 cm. This will accommodate about 11000 plants/ acre.

Double rows

A commonly used planting arrangement for double rows is shown in



A commonly used planting arrangement for double rows

5. Bed Preparation and Planting

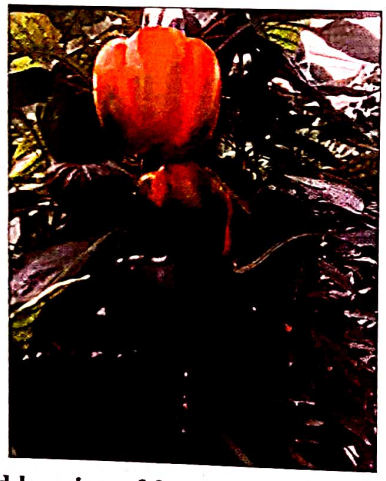
The common planting system is double row, with a bed width of 80 cm and path of 80 cm, the plant to plant spacing is 0.45 m. which will accommodate about 11,000 plants per acre with this system.

6. Training and pruning in the two-stem training system

6.1. **Pruning:** Capsicum plants are pruned to retain two to three stems. The tip of the plants split into two at 5th or 6th node and are left to grow. These two branches again split into two, giving rise to four branches. At every node the tip splits into two giving rises to one strong branch and one-week branch. Only two or three (in green fruits) should be maintained. The pruning is done after 30 days of transplanting at an interval of 8 to 10 days thus resulting in bigger fruits with better quality and high productivity. The colour capsicum plants should be pruned to two stems and same level of yield can be maintained.

Right stage of capsicum fruits for harvesting

6.2. **Training:** The main stem of plant is tied with plastic twine to train along and tied to GI wire grid provided on the top of the plants. This is practiced after 4 weeks of transplanting. The new branches and plants are trained along the plastic twines.



Good bearing of fruits in two-stem system

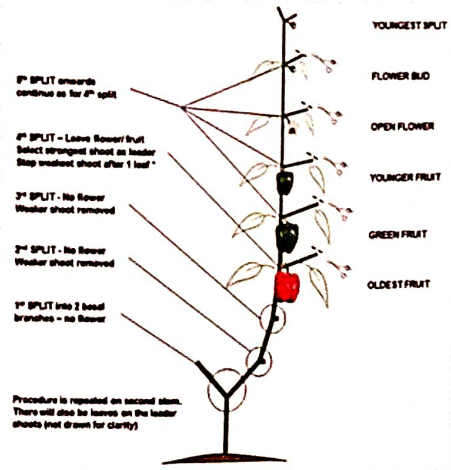
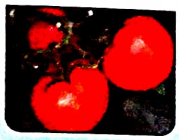


Diagram representation of two-stem training and pruning system



7. Fertilizer application

7.1. Application of Basal fertilizer: A basal fertilizer dose of 20:20:20 kg NPK/acre required and is applied to the beds uniformly before transplanting in the form of 100 kg ammonium sulphate, 125kg Single super phosphate and 30 kg murate of potash. Remaining fertilizers are applied through drip irrigation starting from 21 days of transplanting till 280 days after transplanting at an interval of twice a week for a 10-month crop. We can also apply small quantity of micro-nutrient containing fertilizers depending on the availability of these nutrients in the soil. Approximate quantity of these micro-nutrients required per acre includes Zink Sulphate (5 kg.), Borax (3 kg.), Magnesium Sulphate (4 to 5 kg.), Iron Sulphate (2 to 3 kg.), Copper Sulphate (0.3 to 0.5 kg.) and others.

7.2. Drip irrigation: Drip irrigation is given daily to supply about 6000-12000 liters of water per acre per day depending on the season in a plastic mulched crop. This corresponds to running of the drip system, as per the earlier description of drip set up, only to a period of 12 to 24 minutes depending on the season.

7.3. Fertigation: Total fertilizer requirement is 80:60:90 kg NPK/acre for a 10-month crop. A basal fertilizer dose of 20:20:20 kg NPK/acre is to be given before transplanting. Remaining is given through water soluble fertilizers with drip irrigation (fertigation) for entire crop growth period, starting from 21 days after transplanting to 280 days after transplanting. Fertigation can be given as per following schedule:

Days after transplanting	Number of fertigations (applied twice-a-week)	Quantity of fertilizers (kg/fertigation)	Day of the week
21-42	6 bi-weekly fertigations	1.5kg 19all+1.0kg KNO_3	Mondays & Fridays
43-63	6 bi-weekly fertigations	2.0kg 19all+1.0kg KNO_3	
64-280	62 bi-weekly fertigations	2.5kg 19all+1.5kg KNO_3	
43-280	34 weekly fertigations	3kg $CaNO_3$	Wednesdays
64-280	31 weekly fertigations	3kg $MgSO_4$	Saturdays

Micronutrient requirement of the crop can be met through foliar nutrition and sufficient application of FYM before planting. However, if the requirement is seen high, based on soil test value, following fertigation schedule may be adopted 64 days after transplanting.

Weekly once along with 19 All & KNO_3 (Monday)	**g/acre**
Fe-EDDHA/EDTA/DTPA	200
Zinc Sulphate ($ZnSO_4$)	500
Manganese Sulphate ($MnSO_4$)	100
Copper Sulphate ($CuSO_4$)	50
Weekly once along with 19 All & KNO_3 (Friday)	
Ammonium Molybdate / Sodium Molybdate	50
Solubor	300



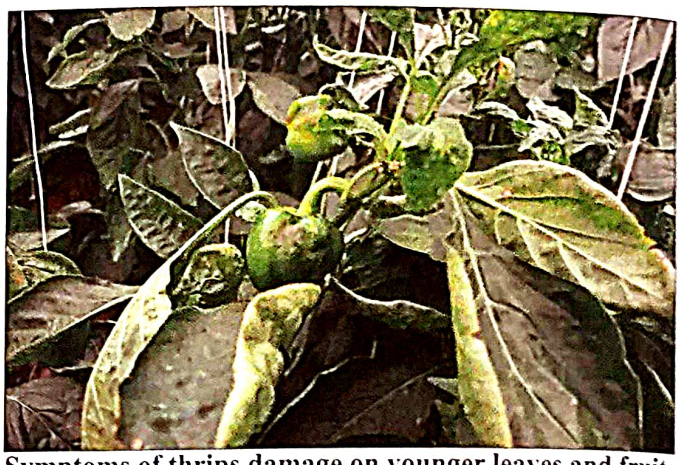
8. Integrated pest management in capsicum

8.1 Important pests of Capsicum

Thrips, Mites, Borers, Aphids and Red spider mites are the important insect pests on capsicum. Red spider mites, yellow and white mites and nematodes particularly root knot nematodes, noticed in tomato production under protected structures. Integrated management of these insect pests and nematodes is given in this chapter.

1. Thrips, *Scirtothrips dorsalis*

Identification Symptoms: Thrips cause upward curling of leaves, sucks sap and reduces the leaf growth, plant growth, yield and market value of produce. It also reduces the leaf area and hinders the absorption of nutrients and water by the plants. Increased infestation leads to blackening and drying of leaves, scraping of green area on fruits, irregular fruit shape and bearing and fruit surface turn into ash colour because of their scrapping.



Symptoms of thrips damage on younger leaves and fruits

Management: Remove affected plant parts including leaves, flowers and fruits. Keep the plots neat and clean by removing all the dropped plant parts. Spray Pongamia Oil (5-8 ml/l) or Neem Seed Kernel Extract (NSKE 4%) or Pongamia Soap/ Neem Soap developed by ICAR-IIHR (5-7gm/l) or Fipronil 5 SC (1.5 ml/l) or Chloropyriphos 20 EC (2 ml/l) or Imidacloprid 17.8 SC (0.5ml/l). Drenching of soil using Chloropyriphos 20 EC (2.5ml/l) or Imidacloprid (0.5ml/l) will reduce resting stages of thrips pupation i.e., pupal stage, thereby prevents multiplication of pest.

Typical symptom of thrips damaged fruits

Some of the new chemicals used in thrips management by the farmers include Tolfenpyrad and Thiamethoxam in capsicum crop. However, when these chemicals are used, farmers should strictly adhere to the dosage, timing and stage of spray, in addition to following all the instructions given for usage of these pesticides.

Downword curling of leaves damaged by mites

2. White or yellow mite, *Polyphagotarsonemus latus*

Identification Symptoms: Nymphs and adults of these mites are very minute and cannot be seen by naked eyes. Damage is more in hot and humid conditions. Adults and nymphs scrape terminal leaves and auxiliary shoots. As a result, leaves become narrow, twisted with elongated petiole. The damage is characterized by downward curling of leaves and stunted growth of plants and dropping of flowers.

Management: Remove the pest damaged plant parts including leaves, flowers, fruits and spray Pongamia Oil (5-7 ml/l) or Pongamia Soap / Neem Soap (5-7 g/l) or Spiromesifen Fenazaquine 10 EC or Abamectin 1.9 EC or Ecomite or Propargite or Chlorophenapyr as per the dosage suggested in the table given below.

3. Red spider mites, *Tetranychus urticae*

Identification Symptoms: Red spider mites are highly polyphagous. They can cause serious damage by their fast multiplication rate in a very short time. They thrive under high temperature and dry weather. They are generally found on the lower surface of older leaves. However, when the infestation is very high, they attack all parts of the plant and are observed in colonies covered by white-silky webs. Adults and nymphs lacerate the leaves causing yellowing and discoloration. Drying and dropping of attacked leaves is also observed when the infestation is severe.

Infestation of red spider mite in capsicum

Management:

- Remove the mite infested leaves and destroy them before spraying.
- Spray need based application of acaricides like Spiromesifen 240 SC, abamectin 1.9 EC or dicofol 18.5 EC or fenazaquin 10 EC in rotation with plant products like pongamia oil or neem oil (8-10 ml/l) or neem soap (7 g/l).

It is essential to follow the integrated management practices for mite pests to reduce the development of resistance to acaricides and to reduce the pesticide residues, by including the latest, safe and effective chemicals in the IPM package. Some of new Acaricide molecules available in the market are given below.

Sl. No.	Chemical name with ai of formulation	Trade name (s)	Dose (ml or g/l)
1	Abamectin1.9 EC	Abacin	0.5 ml
2	Propargite 57 EC	Omite	2.0 ml
3	Milbemectin 1 EC	Milbeknock	0.5 ml
4	Fenazaquin 10EC	Magister	1.5 ml
5	Fenpyroximate 5 EC	Sedna, Mitigate	1.0 ml
6	Diafenthiuron 50WP	Polo, Pegasus	0.6 g
7	Bufrofezin 25 SC	Applaud	1.0 ml
8	Bifenthrin 10 EC	Talstar	1.0
9	Clofentezine 42 SC	Apollo	0.75 ml
10	Flufenzine 20 SC	Flumite	1.0 ml
11	Spiromesifen 240 SC	Oberon	1.0 ml
12	Chlorfenapyr 10 SC	Intrepid	1.5 ml
13	Ethion 50 EC	Promite	2.0 ml



4. Aphids, *Aphis gossypii*

Identification Symptoms: Nymphs and adult aphids suck sap from leaf veins and younger leaves resulting in reduced plant growth and decrease in fruit size and yield. Its infestation not only causes curling of leaves but also spreads viral diseases.

Management:

- Keep a close watch on the plants at a regular interval for aphids infestation. Spray pongamia / neem soap (5-7 g/l) or imidacloprid 17.8 SL (0.5ml/l) or thiomethoxam 25 WG (0.5g/l) or dimethoate 30 EC (2ml/l).
- Clip and destroy infested shoots and plant parts of the plant
- Thoroughly spray neem or pongamia soap (1%) or pulverized neem seed powder extract (NSPE) - 4% solution
- During pre-flowering period, spray a systemic insecticide like dimethoate 30 EC (2 ml/l) or acetamiprid WP 1g/l.

5. Borer pests: Tomato fruit borer, *Helicoverpa armigera* and tobacco caterpillar *Spodoptera litura*

Identification Symptoms: Tomato fruit borer, *H. armigera* and Tobacco caterpillar, *Spodoptera litura*are also serious pests in chilli and capsicum. These affect the marketable value of the capsicum crop to a great extent, if proper care is not taken. *Spodoptera* adults lay eggs in groups on leaves and the emerged young larvae feed on leaves causing heavy destruction of crops and also feed on fruits affecting the quality of the produce. Infestation is increased whenever the night temperature is low, coupled with cool and high humidity. Since the eggs are laid in group, early instars larva feeds gregariously on the same leaf, which can be easily identified from a distance and to be destroyed by physically. Female *H. armigera* lays eggs singly on young leaves and reproductive parts of the plant. The larva bore into fruits, makes them unmarketable.

Feeding of fruit borer in Capsicum

Severely damaged capsicum crop by leaf eating caterpillar

Management:

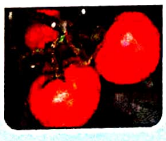
- Collect and destroy the *S. litura* egg masses and early instar larvae, which are feeding gregariously.

- Spray species specific NPV of the borer species (*Ha* NPV and *Sl* NPV)
- Collect and destroy egg masses and immature larvae of *S. litura*.
- Use poison baiting (10 Kg rice flour + 2 kg of jaggery + 250 g of methomyl 40 SP) for *S. litura* (for details refer page number 89)
- With an interval of 10 to 15 days repeat the baiting 2-3 times, if necessary.
- If required spray indoxocarb 14.5 SC @ 0.75ml/l or spinosad 45 SC @ 0.25 ml/l or thiodicarb 75 WP (0.75 g/l)

Note: 1) Botanicals have very short residual toxicity, particularly when the temperature is high. In addition, these may cause phytotoxicity. Hence, sprays with botanicals should be done with caution and sprays should to be given in the evening hours when the weather is cool and the temperature is low. 2) The insecticides used for spraying should always be mixed with spreader or sticker before spraying. While spraying, all parts of the plants from top to bottom should come in contact with spray for better result. 3) For effective prevention of multiplication and control of thrips, spray solution should cover the growing tips completely. 4) Care should be taken by the person spraying the chemicals to compulsorily cover the entire body with full clothes, mask, gloves and aprons, while spraying.

8.2. Flow Chart for Insect Pest Management in Capsicum

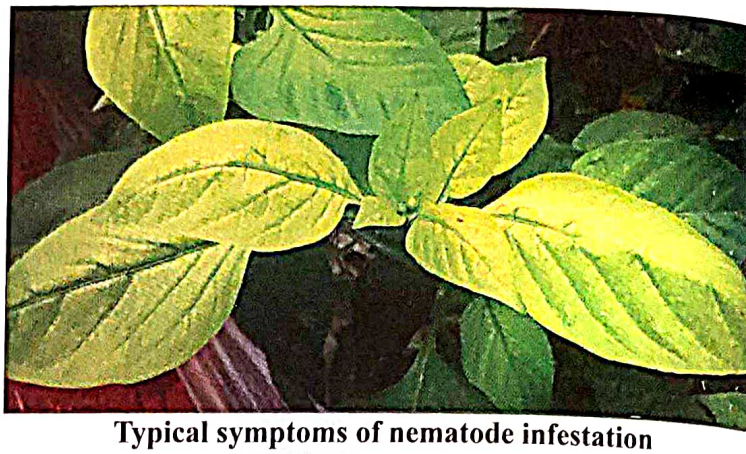
Raise seedlings in Protrays in polyhouse	
↓	
At Transplanting	Apply neem cake 250 kg /ha (First dose)
↓	
15 DAP	Spray Fipronil (1.5 ml/l) for thrips
↓	
30 DAP	Apply neem cake 250 kg /ha (second dose)
↓	
Post Flowering and fruiting stage	Monitor for pests like fruit borer, tobacco caterpillar, thrips and yellow mite Spray *Ha*NPV for *H. armigera* and *Sl*NPV for *S. litura* Spray spinosad/ lambda cyhalothrin/ethofenprox / fipronil + pongamia oil in rotation for thrips control Spray synthetic acaricide/botanical in rotation to control yellow mite


8.3 Integrated nematode management

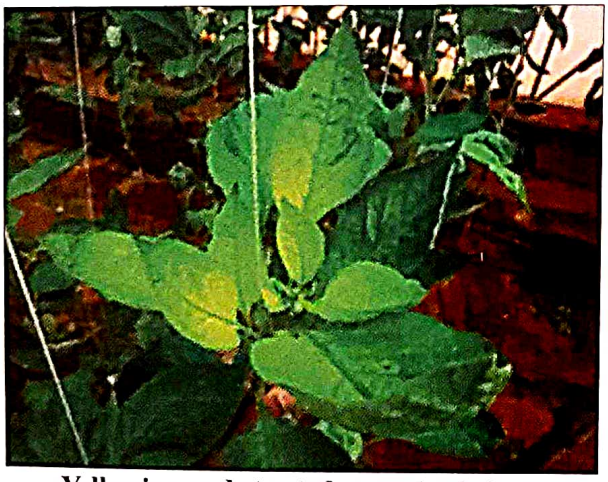
8.3.1. Root Knot Nematode, *Meloidogyne incognita*

Identification Symptoms and diagnosis: Nematodes are commonly seen damaging more in solanaceous and cucurbitaceous crops, when they are grown 3-4 times continuously in the same field. Initially yellowing of young leaves can be observed followed by reduction in leaf size, count and drastic reduction in fruit size. With increase in nematode population, all leaves become yellow and start drying. When infected plant is uprooted and observed, small and big sized galls filled with large number of nematodes can be observed on roots depending on the level of infestation. Nematode damage also predisposes the roots to easy entry of other soil borne-disease causing fungi and bacteria inside the plants. This creates a much complex situation and crop exhibits more yield loss.

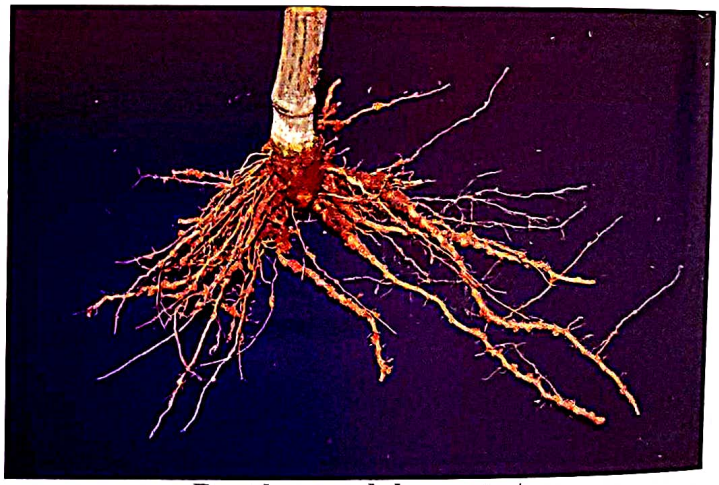


Typical symptoms of nematode infestation

Severe nematode damaged capsicum at early crop stage



Yellowing and stunted growth of plants



Root knot nodules on roots

8.3.2. Integrated Management:

1. Go for crop rotation with non-solanaceous crops like marigold, sweet corn and cabbage to avoid nematode.
2. Mucuna (*Mucuna pruriens*), when grown upto flowering stage (about 45 days) and incorporated into the soil, found very effective to reduce the nematode population.
3. Apply FYM enriched with bio-pesticides (refer page number 87 for procedure of enrichment).



4. Apply 800 kg neem cake per acre enriched with bio-pesticides like *Trichoderma harzianum* or *Trichoderma viride, Pseudomonas fluorescens, Pochonia clamadosporia, Paecilomyces lillacinus, Bacillus subtillis* (for procedure, please refer page number 87) 5 days before transplanting on the beds.
5. Apply Carbofuran granules (furadon @ 20kg /acre) at the time of planting.
6. Apply Jeevamrutha prepared with bio-pesticides once in a month to reduce the nematode population during cropping period (refer page number 89)
7. Drench enriched neem cake suspension mixed with bioagents once in a month (please refer to the procedure in page number 89)
8. Keep a close watch at the nematode infestation of the plants, particularly in 2nd and 3rd crop.
9. Get the soil tested for nematode count, before planting of all the susceptible solanaceous crops. If the population count is more, then avoid growing such crops.

8.4. Advantages of enrichment of bio-pesticides over chemicals:

- All these bio-agents (*Paecilomyces lilacinus*, *Pseudomonas fluorescens* and *Trichoderma harzianum*) multiply innumerably to billions of propagules in one ton of neem cake. Thus, neem cake becomes a medium for mass production of bioagents and few kg of bio-pesticides is converted to one ton of enriched neem cake. This is economical for the farmers as they can easily multiply in their own farm with minimum labour.

FYM enriched with biopesticides

- Regular application of enriched bio-pesticides substantially reduces the cost incurred on chemical nematicides and fungicides by 40 to 60%.
- Many popular chemical pesticides are withdrawn from the market owing to their high toxicity to human health and environment. Bio-pesticides are environmentally safe and can help in the sustainable management of nematodes and disease-causing bacteria and fungi.
- Application of bio-pesticides also promotes plant growth and boosts the crop yield by 15 to 20%.



8.5. Impact of applying bio-pesticides:

Impact of applying bio-pesticides on nematode population and yield in Capsicum under protected cultivation

Treatment	Yield (tons per acre)	Per cent increase in yield over control	Root knot-nematode (*M. incognita*) Gall index on 1-5 scale	Nematode population per 250 cc soil	Per cent decrease in nematode population in soil	Cost benefit ratio
Application of biopesticides (TV+PF+PL+NC*)	61.8	21.4	1.62	95.3	70.6	1:2.1
Chemical (Carbofuran)	57.3	12.6	2.04	105.2	67.5	1:1.7
Untreated control	50.9	-	4.95	323.8	-	-
C.D-5%	3.16		0.39	9.32		

*Tv-*Trichoderma viride*; PF-*Pseudomonas fluorescens*; PL-*Paecilomyces lilacinus*; NC-Neemcake

8.6. Supplementing bio-pesticides with Jeevamrutha application:

Biopesticide can also be supplemented with Jeevamrutha which provide a congenial environment for multiplication of microbes. This can be diluted in water and given as soil drenching or spraying to crop at fortnightly intervals. (Method of preparation and application procedure is given in page number 89).

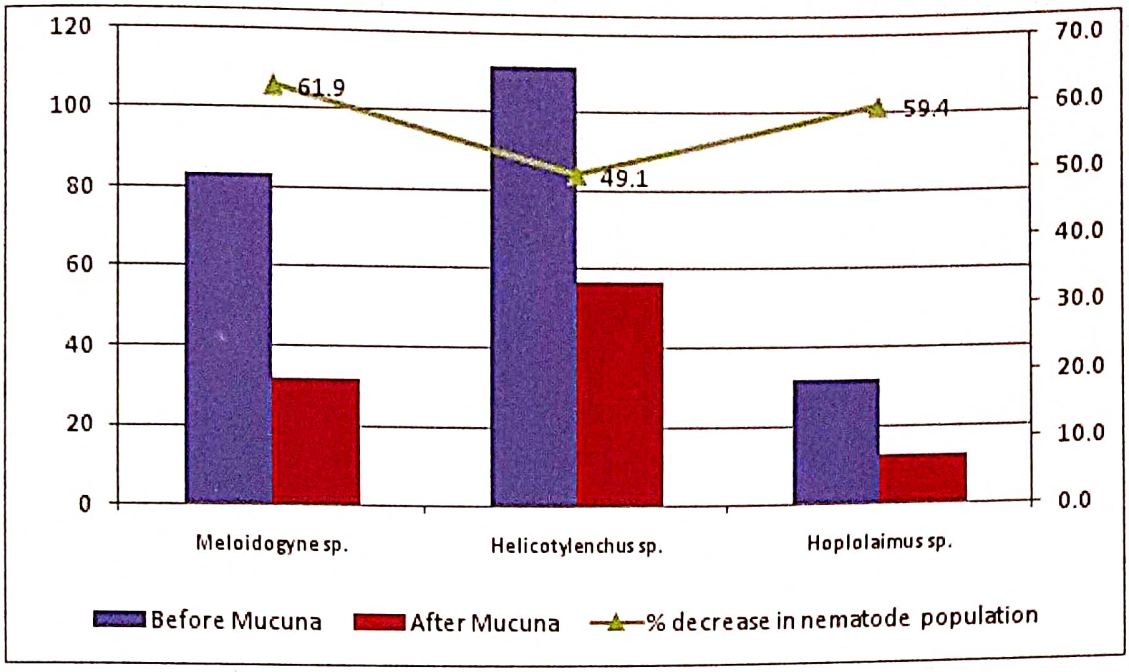
8.7. Effect of *Mucuna* on reduction of nematode population

Growing velvet bean (*Mucuna pruriens* var. *utilis*) in polyhouse and incorporation of its residues at 45 DAS significantly reduced the plant parasitic nematode population in soil to the extent of 49.1 to 61.9%. Since velvet bean is well known for its pharmacological benefits and as a green manure crop, it can be an economically feasible option for use in polyhouses as a rotational crop for suppressing nematode population in soil. This has a great scope as a promising component in integrated nematode management in polyhouses to bring down the initial population of nematodes for the succeeding crop. In addition, it is low cost and eco-friendly as it adds nitrogen and biomass to the soil. It is also an effective alternative to chemical nematicides and could reduce the chemical usage in the initial stages by 25 to 40%.

Mucuna crop in polyhouse to reduce nematode population



Growing of velvet bean as rotational crop in polyhouse brings down nematode inoculum in soil.



Effect of incorporating Mucuna residues on nematode population dynamics in soil

Soilless cultivation or Polybag cultivation using sterilized media is also a good alternative to reduce the infestation of many soil borne problems, including nematodes. However, the economics needs to be worked out for large scale promotion of this technology in India. Application of Bio-pesticides/ beneficial microbes like *Trichoderma harzianum, Trichoderma viride, Pseudomonas fluorescens, Pochonia chlamydosporia, Bacillus subtilis* and others at a regular interval (fortnightly to monthly application) through drenching or directly to the root zone or through Jeevamrutha (liquid solution enriched with bio-pesticides) will bring down the multiplication of nematode population significantly, in addition to reducing the population of other soil borne pathogens.

9. Integrated Disease management in CAPSICUM

Integrated Disease Management (IDM) is a holistic approach in which we use a combination of compatible components like cultural, biological and need based chemical control methods with constant disease monitoring to maximize the effectiveness of control methods with an objective of minimizing the use of chemicals and to produce safe and quality vegetables.

Collar rot of capsicum seedlings

1. Damping-off and root rot of seedlings (*Pythium*, *Phytophthora* and *Rhizoctonia* spp.)

Symptoms: Infected seeds do not germinate. They decompose in the nursery medium. On infected young seedlings, initial symptoms appear as brown water-soaked lesions on stem at soil line. The lesions constrict stem, leading to the collapse of seedlings. The disease spreads through infected planting material, contaminated soil and water.



Management

1. Seed treatment with Seed pro@ 10g/kg seed or *Trichoderma harzianum* or *Pseudomonas fluorescens* @ 6-10g/kg seed.
2. Sowing in nursery beds with enriched medium/FYM/Neem cake using bio agents; Arka - *Pseudomonas fluorescens* 1% W.P., Arka – *Paecilomyces lilacinus* 1% W.P, Arka -*Trichoderma harzianum* 1% W.P
3. Soil drenching with captan 75% WP (2.5g/L) or copper oxychloride 50% WP(3g/L)

2. Powdery mildew (*Leveillula taurica)*

Symptoms: The disease first appears as white powdery growth on under surface of the leaves. Yellowish spots appear on the corresponding infected portions on the upper surface of the leaves. Infected leaves drop off prematurely. The disease spreads through airborne spores.

Powdery mildew in capsicum

Management

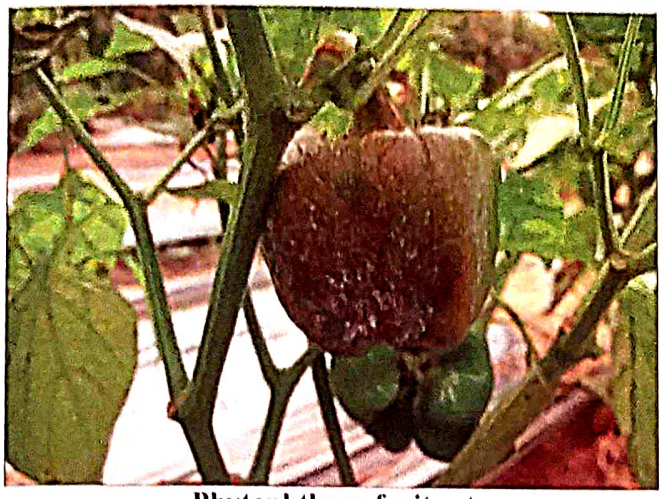
1) Preventive spray of Sulphur 80% WP (3 g/l). Care should be taken to spray in evening hours, when temperature is low. Spraying at high temperature causes phytotoxicity.
2) Need based curative spray of Azoxystrobin 23% SC (1 ml/L) or Flusilazole 40% EC (100-150 ml/500 litre of water) or Tebuconazole 25% WG (0.5 ml/L) or Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC (1ml/L) or Azoxystrobin 8.3% + Mancozeb 66.7% WG 3g/L) or Azoxystrobin 11% + Tebuconazole-18.3% SC W/W (1ml/L), 2-3 sprays in rotation at 10 -12 days intervals.

Powdery growth on lower surface of capsicum leaves

3. Phytopthora blight (*Phytophthora capsici)*

Symptoms: Initial symptoms are water-soaked small dark green spots that enlarge and become bleached, as though scalded. Infected fruits initially develop dark, water-soaked patches that become coated with

white mold and spores of the fungus. Fruits wither but remain attached to the plant. Collar infection causes root rot and wilting of affected plant.



Phytophthora fruit rot

Phytophthora infected capsicum leaves

Management

1. Practice crop rotation with crops other than tomato, eggplant and cucurbits
2. Avoid soils with poor drainage for growing these crops. Plant the crop on raised beds with silver or white and black polythene mulching to provide better soil drainage.
3. Avoid frequent irrigation which builds up high soil moisture, which is congenial for spread of this disease.
4. Enrichment of FYM/Neem cake/ Vermicompost with bioagents *Pseudomonas fluorescens* 1% W.P., *Paecilomyces lilacinus* 1% W.P and *Trichoderma harzianum* 1% W.P before their application in nursery and main field, is very useful in preventing this disease.
5. Seed priming with seed pro @ 10g/kg seed.
6. Protective foliar application of chlorothalonil 75% WP @ 2g/L followed by curative spray of Dimethomorph 50% WP (1g/L). Drenching of the same against wilt.

4. Cercospora leaf spot *(Cercospora capsici)*

Symptoms: Oval or oblong spots with light grey centers on leaves, stalks and stem. Infected leaves drop off pre maturely. The disease is seed borne and spreads through airborne spores.

Management

1. Remove and destroy low lying, old infected leaves.
2. Seed treatment with Captan or Carbendazim @ 2g/kg seed as dry powder.
3. Protective foliar spray of Copper oxy chloride 50% WP (2.5 to 3 g/L) or Zineb75%WP (2g/L) at 15 days interval. Need based curative spray of Carbendazim12%+ Mancozeb63%WP (1.5g/L).

Cercospora leaf spots in capsicum

5. Bacterial wilt (*Ralstonia solanacearum*)

Symptoms: Initial symptoms are sudden drooping of leaves and wilting of plants in the afternoon. The wilted plants recover during evening. This is followed by complete wilting of plants with green leaves intact. Wilting and death is accompanied by dark brown internal discoloration of the vascular elements. Bacterial wilt pathogen, *Ralstonia solanacearum* is soil borne in nature and spreads through irrigation water and is aggravated by nematode infestation. Bacterial wilt occurs/ appears after earthing up at flowering stage.

Management:

1. Seed treatment and seedling root dip with *Pseudomonas fluorescens.*
2. Green manuring with *Mucuna pruriens.*
3. Crop rotation with green peas/coriander/french beans in polyhouse.
4. Soil drenching with copper oxy chloride 50% WP (3 g/L of water).

6. Virus diseases (Chilli Leaf Curl and Tospo virus)

Leaf curl symptoms: Leaf curl symptoms are upward and downward curling of leaves, leaf margins develop pale green to yellow color, which extends into the interveinal areas. The nodes and internodes are significantly reduced in size. The infected plants assume bushy appearance with severe stunted growth look pale and produce more lateral branches giving a bushy appearance. The fruits from infected plants are small and deformed. Leaf curl virus is transmitted from plant to plant by whitefly.

Chilli Leaf curl Virus

Tospo symptoms: The characteristic symptoms like chlorotic concentric ring spot, necrotic concentric ring spot are observed on infected leaves and fruits. The ring spots become conspicuous when fruit turns into color. This disease affects marketability of fruits, particularly in color capsicum. Infected leaves are distorted. In severe infection, plants growth is stunted. Virus is transmitted from plant to plant through several species of thrips.

Tospo virus symptoms on fruits

Management

1. Raising nursery under 50 mesh nylon net cover
2. Early rouge out of virus infected plants and weeds.
3. Use of UV aluminum surfaced reflective agri-mulch for repelling insect vectors.
4. Installing yellow and blue sticky traps @ 12 traps per acre.
5. Foliar spray of micronutrient formulation "Arka vegetable special" @ 5g/L three times from 30

days after transplanting at 15 days interval, which enhances yield and tolerance to viral diseases. Avoid excess application of nitrogenous fertilizer.

6. Foliar spray of sea weeds extract @ 2ml per litre. Spray application of bio-stimulants derived from organic sources enhances tolerance to diseases. Ex: Sagarika is an organic bio-stimulant derived from red and brown seaweeds Red Seaweed *(Kappaphycus alvarezii)*, which enhances crop productivity and provides resistance against stress. It can be sprayed @ 250 ml /acre or 1-2 ml per litre of water as per crop stage; 1st spray at plant establishment stage/ tillering stage, 2nd spray at pre - flowering stage, 3rd spray at post flowering stage.
7. Spray with neem soap/pongamia soap @ 5g/L in initial stages at weekly intervals to control insect vectors. They can also be sprayed in rotation with insecticides.
8. Spray Insecticides such as Fipronil 5% SC(1.0 ml/L), or Imidacloprid 17.8% SL (0.35ml/L) in combination with neem oil (2 ml/L) at 7 to 10 days interval in rotation.

10 Nutritional disorders:

1) **Cat facing** of capsicum fruit is an abnormal development occurs due to cold conditions during flowering and fruit set. This symptom is normally observed when calcium deficiency is severe.

Cat face in capsicum due to calcium deficiency

2) **Blossom End Rot (BER)** of fruits is seen when Nh_4 based fertilizers are largely used which are antagonistic to Calcium uptake as they reduce soil pH also. It occurs during the period of maximum fruit expansion- couple of weeks after pollination. Common inducing factor is excess or deficit moisture. Under high humidity conditions, transpiration reduces and Ca uptake reduces. Most of the time salinity also restricts Ca uptake, resulting in the expression of symptom. It was observed that fresh fruit with 0.12% Ca do not show BER. This is not pathogenic disease but a nutritional disorder. This is mainly due to calcium deficiency. Fruits mainly exhibit sunken dark brown to black areas at the distal end. This disorder is common in soils with excess salinity and due to poor root growth.

Blossom end rot

Management:

1. Application of lime and calcium fertilizers before planting and spray of calcium nitrate (5g/l) to reduce the deficiency.
2. Apply nitrogen in the form of Calcium Ammonium Nitrate to manage this disorder.

Severe calcium deficiency on capsicum fruits

3. We can also spray the mixture of Curd (2-3 ml/lit) + fine lime powder (0.3 to 0.4 g/lit). Solution of these should be prepared separately and mixed in a single container with proper blending of the dilated formulations. This is found to be effective in quickly reducing the calcium deficiency in capsicum. However use of calcium nitrate in drip, as well as through spray will minimize the incidence of Blossom End Rot.

11 Pesticide residues in capsicum grown in poly house:

Details are given in general topics on PCV in Chapter no. 10 page nos. 21 to 24.

12 Harvesting and yield

Harvesting of capsicum fruit using secateur

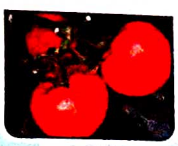
Early morning hours are best suited for capsicum harvest. Green capsicum can be harvested at 55 to 60 days after transplanting, yellow capsicum at 75-80 days, whereas red capsicum at 80-85 days. Fruits with 3 to 4 lobes weighing > 150 g can be harvested once in 3 to 4 days. Yellow and red fruits can be harvested when they have gained 50-80 per cent of the colour development. After harvest, fruits should be kept in cool place and avoid direct exposure to sunlight. The fruits should be handled carefully by adopting clip harvest technique, using good quality secateur and scuffing should be minimized. In capsicum, the average yield of 35-40 tons per acre can be obtained. At ICAR-IIHR, Bengaluru a very high productivity of 252 t/ha (Hybrid Indra) was achieved from two crops of green capsicum grown in the period of 14 months (October 2002 to December 2003) in a naturally ventilated polyhouse. Hence, it is possible to grow capsicum in a naturally ventilated polyhouse round the year. The average fruit size was 128g and on an average 26 fruits/plant was harvested per crop of 10 months.

Capsicum yields obtained at ICAR-IIHR, Bengaluru in a naturally ventilated polyhouse

Period	Duration	Yield (t/ha)
October to April	6 ½ months	109
May to December	7 ½ months	143
Total yield for a period of 14 months		252

Special tips to achieve higher and quality yield from polyhouse capsicum cultivation

- The organic manure/compost applied to the soil should be enriched with bio-pesticides like *Pseudomonas fluorescens, Paecilomyces lillacinus, Trichoderma harzianum, Pochonia clamydosporia,* etc. and bio-fertilizers like, PSB, *Azospirillum, Azotobacter;* etc. to enhance soil health status.


- Any damage of net or polythene sheet, in the structure, should be immediately repaired to prevent entry of pests and diseases and to avoid wind and rain damage.
- The polyhouse/ net-house should have double door system, which is the safest way to prevent the entry of pests and diseases. The doors should be constructed preferably away from roadside.
- Seedlings raised in protrays have to be transplanted within 30-35 days after sowing on the main raised planting beds (¾ to 1 ft above the ground level).
- Regular pruning has to be followed to retain two to three healthy branches and retain one fruit with good shape and size in each branch and remove deformed fruits, if any, at a very early stage.

Grading and packing of capsicum fruits

- Branches are properly tied with plastic twine and other end tied to the supporting GI grid to give strong support and to avoid breakage of branches/ fruits.
- Drip irrigation and fertigation schedules should be followed regularly.
- Avoid pests and disease incidence by adopting prophylactic measures. Use proper and recommended quantity and dosage of pesticides and insecticides for effective management of the pest and diseases.
- Maintain hygiene condition in green house and dispose the rotten, fallen and infected plant debris/ fruits daily during evening hours, after completing all the operations of the day. Use clean plastic bags to collect and carry these materials to the place of disposal, to avoid the spread of infection.
- Care should be taken not to pinch the apical bud and protect it from the mite infestation.

Grading of capsicum fruits for export

- Botanical, bio-pesticides, biological agents and bio-fertilizers should be used regularly as an integrated pest, disease and nutrient management practice.
- Yield should constitute 85-90 percent of A grade fruits (3-4 lobes weighing 150-180 gm per fruit). Deformed and irregular shaped fruits are pinched out at early stage and fruits with 70-80 per cent colour should be harvested, graded and packed properly.

Chapter 12

Green house production of tomato

1. Introduction

Tomato is the most popular vegetable crop grown under greenhouses throughout the world. It is consumed either as salad, cooked or as processed food. Growing tomatoes in green houses can increase the yield and will have superior quality. Fluctuation in the price of tomato is a regular feature. Through greenhouses, production of tomato can be achieved round the year. In addition to the quantum jump in yield and superior quality, substantial reduction in use of pesticides makes it an eco-friendly proposition to grow tomato in naturally ventilated green houses. However, season has to be chosen depending on the market price for tomato, otherwise tomato production in greenhouse may not be economically viable.

Good bearing of fruits in polyhouse grown tomato

2. Climate and soil requirements

Tomatoes grow best in the temperature range of 20–27°C. Fruit setting is poor when average temperature exceeds 30°C or fall below 10°C. Tomatoes prefer well drained soil because they are sensitive to water logging. Optimum soil pH is 6.0–7.0. Tomatoes benefit from crop rotation. Growing tomato after rotation with cereal crop reduces the incidence of diseases and nematodes. Avoid repeated / successive planting of tomato and also after pepper, eggplant, or other solanaceous crops. These crops are affected by similar disease problems.

Good quality tomato fruits grown in polyhouse

3. Choosing a variety

Selecting the best variety is critical for successful crop production. Consider the following factors while selecting the varieties:

Fruit type. Tomato varieties are grouped into one of three market classes:

(1) **Fresh market**-fruits are usually red but vary in color, shape, and size;

(2) **Cherry**-a small-fruited (less than 30 g) fresh market type borne on long clusters.

Good quality ready to harvest cherry tomato fruits

Variety/Hybrids:

a) **Indeterminate hybrids:** GS-600, PTH 1 & 2, Palam tomato hybrid, SH7710, Valouro (Beef steak group about 200g), Nowara: (Plum Oval type, square round fruits: 100g).

b) **Determinate hybrids:** In polyhouse, determinate hybrids like Arka Rakshak, Abhinava and other popular fresh market hybrids can also be grown to reduce the cost on pruning and training. These hybrids can also be grown for 7 months and in green house growing height of about 3m can be achieved. Hybrids with resistance to bacterial wilt like Arka Rakshak are preferable in greenhouse.

4. Seedling raising:

Select good quality seeds and raise the seedlings in protrays kept in good net-house or polyhouse. While planting during hot climatic conditions, it is advised to use small, sturdy and young plants (22 to 25 days old) grown in sowing tray/ protrays. Harden the seedlings by slightly reducing water and exposing them directly to sunlight for about 5 days before transplanting. A good seedling is in the four or five-leaf stage vigorous and stocky.

Well grown healthy tomato seedlings

5. Land and Bed Preparation

Prepare the land with ploughing, cultivation, harrowing/rotovating to bring the soil into fine tilth. Well decomposed FYM can be applied before final rotovating @ 20t/acre. Then prepare the raised bed of 80cm width separated by the walking space of 80cm. In a polyhouse bay of 8m, 5 beds can be easily accommodated. Nine-inch bed height can be achieved by this way.

Raised beds with drip lines ready for planting

5.1. Fumigation: Formaldehyde fumigation is optional. It may be required, if the soil is heavily infected with soil borne pathogens. It can be done once in 3 crop cycles. Regular application of bioagents like *Trichoderma, Pseudomonas, Pochonia* and *Paecilomyces* is a better alternative to formaldehyde fumigation. In fumigation, crop beds are drenched using 4 per cent formaldehyde (@ 4 l/m^2 of bed) and covered with black

polyethylene mulch sheet. To prepare 4% formaldehyde solution, one litre of formalin is added to 9 litres of water. While treating with formalin, care should be taken to wear mask, gloves and apron. Four days after formalin treatment, the polyethylene cover is removed; beds are irrigated and are raked repeatedly every day for 3-4 days to remove the trapped formalin fumes completely, prior to transplanting.

5.2. **Basal Fertilizer application:** A basal fertilizer dose of 20:20:10 kg NPK/acre required and is applied to the beds uniformly before transplanting in the form of 100 kg Ammonium Sulphate, 125kg Single super phosphate and 20kg murate of potash. Remaining fertilizers are applied through drip irrigation starting from 15 days of transplanting till 240 days after transplanting at the interval of twice a week for a 9-month crop.

5.3 **Application of neem cake and bio-pesticides:** Apply 800 Kg enriched neem cake, 3-4 days before transplanting. Follow the procedure as explained in page number 87.

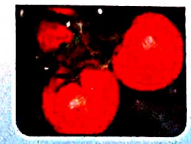
5.4 **Laying of drip line**: Place two 16mm inline drip laterals/bed at a spacing of 40cm having emitting points at every 30 cm interval with discharge rate of 2 litre/hour. Run the drip system to check each emitting point for uniform discharge, cuts and leakages, if any, before covering the beds with polythene mulch.

Well grown tomato plants with good bearing of fruits

5.5 **Mulching:** Black-silver polyethylene mulch film of 25-40 micron thick, 1.0 to 1.2 m wide, is used to cover the planting beds. Holes of 7.5 cm diameter are made on the polyethylene film as per the recommended row and plant spacing. The planting beds are covered with the film by securing the edges of the sheet firmly in the soil. Mulching practice conserves water, controls weeds, and reduces infestation of pests and diseases and results in higher yield and good quality produce. Crop can be taken even without mulching also in polyhouses.

5.6 **Spacing:** Seedlings are planted in paired rows in 80cm wide beds with row-to-row spacing of 50 cm and plant-to-plant spacing of 45 cm for indeterminate hybrids that are trained to single stem. This will accommodate about 12000 plants/acre. In case of determinate hybrids, only one row can be transplanted per bed and spacing between the seedlings will be 75cm. This will accommodate about 5500 seedlings per acre.

5.7 **Transplanting:** Planting beds are watered to their field capacity before transplanting. Seedlings of about 28 days old are used for transplanting. Seedlings are transplanted into holes made in polyethylene mulch film at a depth of 5 cm. After transplanting, seedlings are drenched with 2 g/l


Captan solution to the base of seedlings at the rate of 25 ml per plant. Watering the mulched beds daily by using hose pipe fitted with rose for a week continuously to regulate moisture in the growing beds.

5.8. **Drip irrigation:** Drip irrigation is given daily to supply about 6000-12000 liters of water per acre per day depending on the season in a plastic mulched crop. This corresponds to running of the drip system of above description only to a period of 12 to 24 minutes depending on the season.

6. Balancing:

Keep a vigilant eye on the crop to ensure the balance between the growth of the top (new leaves) and the energy going into the fruits. Ideally the stem thickness will remain same and every week 3 new leaves will be formed and 1 cluster is harvested. A well-balanced plant will have enough energy for vegetative growth (top, new leaves, roots) and generative growth (flowers & fruits).When a plant grows too generative it will use all its energy for the fruits. This will give a good harvest on the short run but production will drop soon after that. More vegetative growth will give weak plants and bad quality fruits.

Balancing of plants to get good quality fruits

7 Staking

Staking or trellising tomato plants inside the polyhouse should be done using good quality, strong nylon threads supported by tying with GI wires used for supporting shade net or separate line of GI wires of 14 gauge can be drawn on the crop line to give strong support to the crops. Staking can increase fruit yield and size, reduce fruit rot, and make spraying and harvesting easier. Both indeterminate and determinate varieties should be staked to facilitate pruning, pinching, harvesting, and other cultural practices. Many staking arrangements are possible. Plants should be fixed securely to the stake or string supports in the beginning stage, about two weeks after transplanting. Jute twine thread, plastic strips, horticultural fixing tape or other material can be used for fixing. Fixing should be done to support fruit clusters.

Staking of tomato plants with strong nylon threads

8 Pruning and training

Training of tomato plants in polybag cultivation

Pruning (selective removal of side shoots to limit plant growth) can cause fruit to mature earlier and grow to greater size and uniformity. Pruning improves air circulation within the canopy, which reduces foliar diseases and facilitates spraying and harvesting. Indeterminate varieties should always be pruned, so that they do not produce too much vegetative growth. The degree of pruning varies according to the season. Prune indeterminate plants to one stem. Pruning usually starts 20 to 30 days after transplanting. Prune the plants at weekly intervals. Train the plants along the plastic twine. Tie the branches to the plastic twines so that the branches do not break up due to the weight of the fruits. Tying of plants to the plastic twine starts from 3rd week after transplanting and tying is usually done at weekly interval along with the pruning operation. Round plastic clips need be tied at regular interval (approximately at every 1.5 feet), to provide good support to the growing stem and to strengthen the plant to support the fruits load and to avoid breakage of stems. In case of determinate variety, maintain all branches with individual twines tied to the support. Since flower clusters are borne on the terminal, we need to maintain all branches and sub branches, prune only lower branches that do not develop due to lack of sunlight, watery shoots and week branches. If the market prices are higher for larger fruit, it is possible to increase fruit size by keeping four fruits per cluster and pinching off extra flowers. Since, medium size fruits are preferred in Indian market, it is better to retain all the fruits in the cluster and increase their size by providing good nutrition.

8.1 **Whenever there is excess vegetative growth, we can observe the following symptoms.** The leaves are big and thin, growth is quick, colour of the plants will be light green, internodes become longer, the stem is very thick, flowers open far from the top of the plant and looks whitish and pale, fruit quality often poor, will not form many seeds.

Tapping of plants to facilitate better pollination in tomato

8.2 **Whenever there is more regenerative growth** then the leaves become small, thick and crispy, growth becomes slow, colour of the plant turns dark green, internodes become shorter, the stem becomes thinner, flowers open in the top of the plant and looks dark yellow, which leads to good quality fruits.

8.3 Poor quality fruits due to poor pollination

Only fruits with enough seeds will attract enough energy to become good quality and size. When it is too hot, too humid or there is not enough light, pollination can be a problem.

8.4 Improving pollination: We should help the pollination by tickling or shaking the plant manually or we can also use mechanical vibrators for assisting pollination. In some countries bumble bees are used. Optimum time for pollination is between 8AM and 3PM. During overcast or rainy days, pollen will not be dry enough to adequately pollinate the crop. Therefore, plants must be shaken during sunny, dry days.

8.5 Lowering of plants:

Lower the plants periodically so that the plants are maintained at workable heights. For this, provide extra length of plastic twine in the beginning itself so that the plants can be lowered to required length. Lower the plants at 20 to 30 days interval starting from 80 to 90 days after transplanting.

Bending and lowering of tomato plants

8.6 Removal of unproductive old leaves (Deleafing)

Deleaf the older leaves periodically starting from 70 days after transplanting. Retain leaf in stem to a length of about five feet from the growing tip at any given point of time.

Fertigation: Total fertilizer requirement is 80:60:90 kg NPK/acre for a 10-month crop. A basal fertilizer dose of 15:25:15 kg NPK/acre is to be given before transplanting. Remaining will be given through water soluble fertilizers with drip irrigation (fertigation) for entire crop growth period, starting from 21 days after transplanting to 280 days after transplanting. Fertigation can be given as per following schedule.

Micronutrient requirement of the crop can be met through foliar nutrition and sufficient application of FYM before planting. However, if the requirement is seen high based on soil test value, following fertigation schedule may be adopted 64 days after transplanting.

Old leaves removed in polyhouse 11 months old tomato crop

Days after transplanting	Number of twice-a-week fertigation	Quantity of fertilizers (kg)/fertigation	Day of the week
21-42	6 bi-weekly fertigations	1.5kg 19all+1.0kg KNO_3	Mondays & Fridays
43-63	6 bi-weekly fertigations	2.0kg 19all+1.0kg KNO_3	
64-280	62 bi-weekly fertigations	2.5kg 19all+1.5kg KNO_3	
43-280	34 weekly fertigations	3kg $CaNO_3$	Wednesdays
64-280	31 weekly fertigations	3kg $MgSO_4$	Saturdays

Weekly once along with 19 All & KNO_3 (Monday)	g/acre
Fe-EDDHA/EDTA/DTPA	200
Zinc Sulphate ($ZnSO_4$)	500
Manganese Sulphate ($MnSO_4$)	100
Copper Sulphate ($CuSO_4$)	50
Weekly once along with 19 All & KNO_3 (Friday)	
Ammonium molybdate /Sodium Molybdate	50
Solubor	300

8.7 Integrated pest management

1. South American tomato moth, *Tuta absoluta*

South American Tomato moth, *Tuta absoluta* (Meyrick) is one of the major invasive pests of tomato with a potential to incur 100 % yield losses particularly under protected conditions. The pest is rapidly spreading world over and is reported in India during 2014 and since then it has spread to different tomato growing regions of the country. Though tomato is the main host, it can also attack other solanaceous hosts like potato, eggplant, tobacco *etc.*

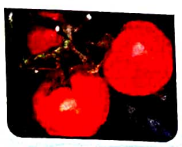
Tomato leaves infested with *Tuta absoluta*

Identification of Damage: Young larvae mine into tomato leaves, apical buds, stalks or fruits. Feeding results in conspicuous mines (blotches) which are visible from both sides and pinholes on fruits from the stalk end generally covered with the frass.

Integrated Management: The effective IPM module developed by ICAR-Indian Institute of Horticultural Research, Bengaluru under protected conditions against *Tuta* is given below.

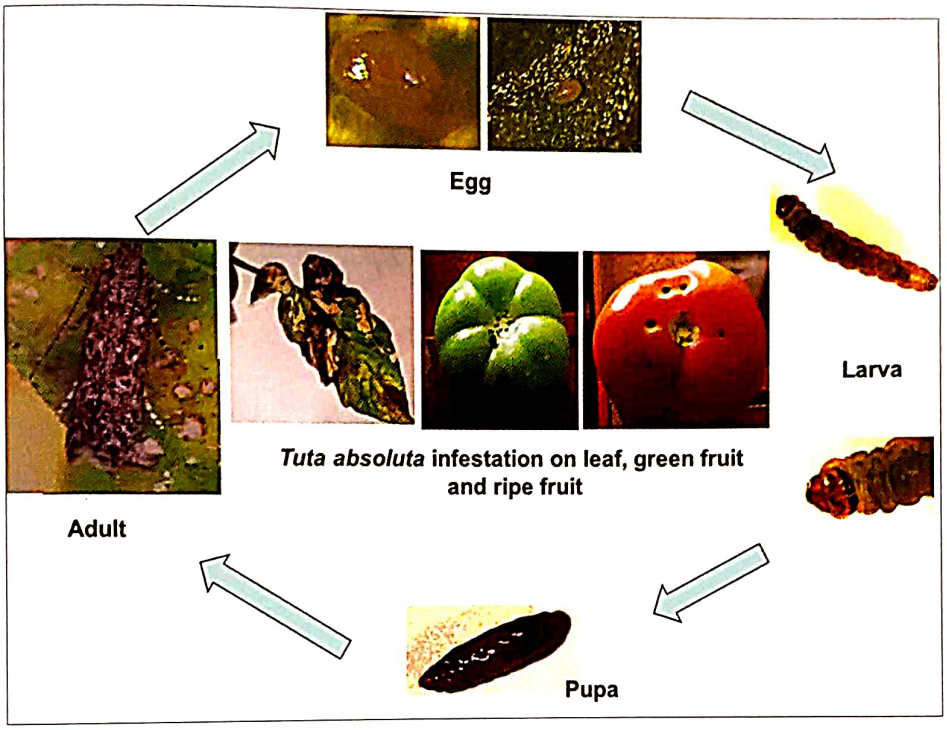
Light trap based integrated management of Tuta on tomato:

- Transplanting of pest free seedlings in the polyhouse.
- Regular monitoring of the fields for the Tuta symptoms and collection and destruction of the infested plant parts in early stage of infestation.
- Use of incandescent bulb 60 W @ one bulb/150 m^2 (water traps) or light cum suction trap @ 2 per acre, which can be rotated and placed in different spots in the polyhouse.
- *Tuta* species specific sex pheromone traps @ 10/Ac
- Need based spray of indoxacarb 14.5 SC @ 0.75 ml/l or spinosad 45 SC @ 0.25 ml/l or flubendiamide 480 SC @ 0.20 ml/l in rotation at 2-3weeks interval.
- Coinciding with the peak emergence of the *Tuta* adults, spray decamethrin 2.5 EC @ 1 ml/l for killing adults.


- **Reduction in *T. absoluta* damage due to IPM**: In polyhouses, when the IPM practices were followed, fruit damage was reduced to 6 per cent as against up to 56 per cent in control. Similarly, number of live mines/plants ranged from 6.5 in IPM plots as against 12.8 in control. Number of eggs laid by *Tuta* were also significantly lower in IPM plots (0-2 eggs/leaf) when compared to non-IPM plots (up to 30 eggs/leaf).
- Mass trapping with light traps significantly reduced the percentage of infested leaves and fruits compared with control and lead to reduced insecticide sprays.

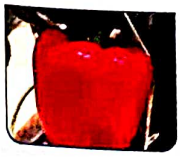
Note (other points to be kept in mind in IPM plots): Light/pheromone traps are to be installed starting from the transplanting of the crop itself for effective pest monitoring and management; remove and destroy the affected plant parts and alternate hosts *etc*.



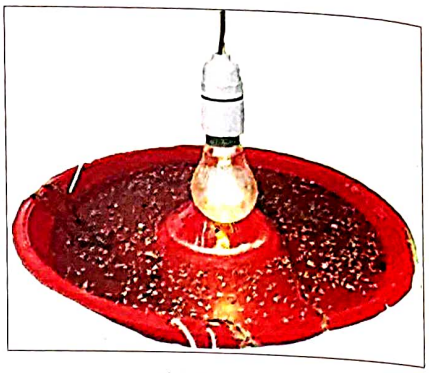
Life cycle of *Tuta absoluta* on tomato

Severely damaged polyhouse tomatocrop by *T. absoluta*

IPM followed polyhouse




Tuta adults in light trap



Light trap

2. Whitefly, *Bemisia tabaci*

Whitefly infesting vegetables under greenhouse conditions is a vector of tomato leaf curl virus. Adults and nymphs suck the sap from leaves resulting in curling of leaves. If the infestation is severe, sooty mould develops on the leaves due to excretion of honeydew by the whitefly, which reduces the photosynthetic activity of the plant and yield gets reduced drastically.

Tomato leaf curl disease

Whitefly on tomato

Integrated Management Package:

- Raise the seedlings in polyhouse using plastic seedling trays.
- Spray imidacloprid 17.8 SL (0.5ml/l) or thiomethoxam 25 WP (0.3 g/l) in nursery at 15 days after sowing.
- Drench the base of the seedlings with imidacloprid 17.8 SL (0.5 ml/l) or thiomethoxam 25 WP (0.3 g/l) before transplanting.
- Remove the leaf curl infested plants as soon as disease symptoms are expressed. This helps in reducing source of inoculum of the disease.

- After transplanting, give need-based sprays of imidacloprid 17.8 SL (0.5 ml/l) or thiomethoxam 25 WP (0.3 g/l) at 15 days after planting and do not repeat after fruiting stage as this may leave harmful residues in fruits.
- Install yellow sticky traps coated with adhesive or sticky glue at crop canopy level for monitoring adult whitefly population.
- If the traps indicate the whitefly activity, spray dimethoate 30 EC @ 2ml/l or neem seed kernel extract 4% (NSKE) or pongamia or neem oil (8-10 ml/l) or neem soap (10 g/l).

3. Red spider mite, *Tetranychus urticae*

Red spider mites are highly polyphagous. They can cause serious damage by their fast multiplication rate in a very short time. They thrive under high temperature and dry weather.

Red spider mite damage in tomato

Leaf miner damage in tomato

They are generally found on the lower surface of older leaves. However, when the infestation is very high, they attack all parts of the plant and are observed in colonies covered by white-silky webs. Adults and nymphs lacerate the leaves causing yellowing and discoloration. Drying and dropping of attacked leaves is also observed when the infestation is severe.

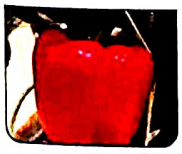
Management:

- Remove the mite infested leaves and destroy before spraying.
- Spray need based application of acaricides like abamectin 1.9 EC @ 0.5ml/l or fenazaquin 10 EC@ 1 ml/l in rotation with plant products like pongamia oil or neem oil (8-10 ml/l) or neem soap (10g/l).

Note: Botanicals have very short residual toxicity, particularly when the temperature is high. In addition, these may cause phytotoxicity. Hence, sprays with botanicals should be done with caution and sprays to be given in the evenings when the temperature is low.

4. Serpentine leaf miner, *Liriomyza trifolii*

Serpentine leaf miner is a tiny metallic fly with a characteristic yellow patch behind the compound eye. Damage starts in nursery itself. Initially the adult female punctures the developing leaf and feeds on the oozing sap. Larvae mine leaves in a serpentine manner and on pupation they drop to soil. Severe damage leads to drying and dropping of leaves.



Integrated Management:

- Remove and destroy cotyledon leaves with leaf mining at 7 days after germination
- Apply neem cake @ 250 kg/ha to beds while planting and repeat after 25 days to prevent pupal emergence from soil.
- Spray neem seed powder extract (4%) or neem soap 1%.
- Frequent spraying of synthetic pesticides should be avoided as it may cause resurgence of the pest. At the most, one spray of deltamethrin 2.8 EC @ 1ml/l or cypermethrin 25 EC @ 0.5ml/l may be given, if required.

Typical symptoms of serpentine leaf miner damage

5. Tomato Fruit borer, *Helicoverpa armigera*

This is a major problem in poorly maintained polyhouses. Eggs are laid on young leaves. Initially larvae feed on tender leaves and scrape the leaf surface, later they bore into fruits. Generally, the posterior end of the body remains outside the hole. The damaged fruits become unmarketable.

Tomato fruit borer

Dead tobacco caterpillar after poison baiting

Management:

- Spray *Ha*NPV at 250 LE/ha + 1% jaggery along with sticker (0.5 ml/litre) during evenings when the larvae are young.
- For grown up larvae spray indoxacarb 14.5 SC @ 0.5 ml/l or thiodicarb 75 WP @ 1g/l

6. Tobacco caterpillar, *Spodoptera litura*

This pest is also important in ill managed polyhouses. Eggs are laid in clusters on foliage. Young larvae feed gregariously on leaves. Mature larvae, migrate and cause extensive damage to leaves and fruits. They hide in soil and crop debris during day time.

Larvae of *Spodoptera litura*

Management:

- Collect and destroy egg masses and gregarious larvae from all affected plants
- Spray *Spodoptera* NPV 250 LE/ha + 1% jaggery along with sticker (0.5 ml/litre) during evenings.
- Use poison baiting. Mix 10 kg of rice bran or wheat bran with 2 kg jaggery by adding a little water in the morning. In the evening add 250 gm of methomyl or thiodicarb formulation and sprinkle over the bed. Caterpillars get attracted to fermenting jaggery, feed and get killed.

Flow Chart for Insect Pest Management in Tomato

Raise seedlings in Protrays in polyhouse	
↓	
15 DAP	Spray the plants with imidacloprid or thiomethoxam
↓	
One day before transplanting	Drench the base of seedlings with imidacloprid (0.3 ml/l) orthiomethoxam (0.3 g/l)
↓	
At Transplanting	Apply neem cake 250 kg /ha (2 split doses)
↓	
15 DAP	Spray the seedlings with withimidacloprid (0.3 ml/l) orthiomethoxam (0.3 g/l)
↓	
25 DAP	Apply Neem cake 250 kg /ha
↓	
Post Flowering and fruiting stage	Monitor for pests like fruit borer, tobacco caterpillar, leaf miner, whitefly and red spider mite Erect yellow sticky traps to monitor whitefly Spray NPV according to the pest Remove leaves severely infected with leaf miner/red spider mite Spray neem seed powder (4 %) or neem soap (1%) for leaf miner Spray synthetic acaricide/botanical in rotation to control red spider mite Spray systemic insecticide/botanical to control whitefly



Integrated disease management in polyhouse TOMATO

1. Damping-off and root rot of seedlings (*Pythium*, *Phytophthora* and *Rhizoctonia* spp.)

Symptoms: Infected seeds do not germinate. They decompose in the nursery medium. On infected young seedlings, initial symptoms are appearance of brown water-soaked lesions on stem at soil line. The lesions constrict stem, leading to the collapse of seedlings. The disease spreads through infected planting material, contaminated soil and water.

Damping off of tomato seedling

Management

1. Seed treatment with Seed Pro @ 10g/kg seed or *Trichoderma harzianum* or *Pseudomonas fluorescens* @ 6-10g/ kg seed.
2. Sowing in nursery beds with enriched medium/FYM/Neem cake using bio agents; IIHR-*Pseudomonas fluorescens* 1% W.P., IIHR-*Paecilomyces lilacinus* 1% W.P, IIHR-*Trichoderma harzianum* 1% W.P
3. Soil drenching with captan 75% WP (2.5g/L), or copper oxychloride 50% WP (3g/L)

2. Powdery mildew (*Leveillula taurica*)

Symptoms: On the upper surface of the leaves, a fine white powdery fungal growth is seen. The fungal growth may appear on the lower leaf surface later. The infected areas show bright yellowish spots on the other side of the leaves. As the disease advances entire leaf blades turns brown and wither. Infection is rarely seen on the fruits.

Powdery mildew on tomato leaves

Epidemiology: Warm and dry weather conditions favour the disease. The pathogen survives on alternate weed hosts.

Management

1. Good air circulation is the best way to prevent disease. In naturally ventilated polyhouses, roll up polythene sheets on all sides to provide cross ventilation.
2. Avoid close planting and use of excess nitrogen fertilizers.
3. Prophylactic sprays with wettable sulphur @ 3g/l. At onset of the disease, application of Hexaconazole (1ml/l) or Difenoconazole (1ml/l) or Tebuconazole (1ml/l) can effectively reduce the disease.

3. Early blight

Symptoms:

Early blight is a fungal disease caused by ***Alternaria solani***. The characteristic symptoms of this disease are circular or irregular leaf spots, dark to light brown in colour with distinct pattern of concentric rings and yellow halo around the spots. Depressed brown to black spots appears both on ripe as well as green fruits

Early blight on tomato leaves

Early blight symptoms on fruit

with characteristic zonation. The pathogen affects all aerial parts of the plant such as leaves, petiole, stem, calyx and fruit. The incidence and intensity of disease is high in hot humid weather conditions. Plants of 45 days old are the critical stages affected by the disease. Farmers should observe for presence of this disease in low lying old leaves. Pathogen survives in the soil on infected plant debris. The conidia are air borne in nature.

Management:

1. Seed treatment with Captan or Carbendazim @ 2g/kg seed as dry powder.
2. Use disease-free seeds and seedlings.
3. Removal of lower most old and diseased leaves in the morning at first flowering and first harvest stage of the crop.
4. Foliar application of Mancozeb 75%WP (0.2%) or Zineb75%WP (0.2%) or Iprodione 50% WP 3g/L or Metiram70%WG 3g/L or Pyraclostrobin 20% WG 1g/L or Metiram 55% + Pyraclostrobin 5% WG 3g/L/ or Tebuconazole 50% + Trifloxystrobin 25% WG 0.75g/l, Azoxystrobin 18.2% w/w+Difenoconazole 11.4% w/w SC(1ml/L) at fortnightly interval.

4. Late blight (*Phytophthora infestans*) – This disease is not severe in polyhouse, whereas under shade nets, it spreads much faster than open cultivation, since there will be falling of rain droplets for many hours, even after rain stops. Even if there are few spores of the pathogen in the rain drops, the infection spreads like wild fire and makes it very difficult to control.

Symptoms:

Late blight infected by fungus, is one of the destructive disease of tomato in India. Dark green water-soaked irregular lesions appear on leaves and later turn in to purple or brownish black necrotic regions.

Late blight infected tomato leaves

Phytophthora infected tomato fruits

Grey to white fluffy growth appears on the under surface of the affected portion of the leaves. Affected stem and petiole shows dark brown to black necrotic spots. Infected fruits turn dark brown to black and rot.

The disease is severe in *kharif*, when weather is cloudy, high humidity is built up inside naturally ventilated polyhouse. Late blight is a soil borne disease which spreads rapidly in cool humid conditions. Farmers should monitor for the presence of disease on low lying leaves touching soil line from transplanting. Pathogen survives in the soil on infected debris.

Management:

1. Seed treatment with seed pro at 10 g/kg.
2. Maintain adequate plant spacing and proper Staking to ensure good air circulation. Plastic mulching will reduce the infection drastically. Closer spacing results in build-up of humidity and change in microclimate favouring rapid multiplication of diseases.
3. After one or two harvests, remove old and infected leaves touching soil line. Collected leaves may be buried in soil. This reduces the disease inoculums level and prevents disease spread. Always remove infected dead leaves and rotted fruits before each spray.
4. Protective sprays of contact fungicides; Mancozeb75%WP or Zineb75%WP (2g/l) or Ziram 80% WP(2g/l), or Propineb70%WP (3g/L) in rotation at 10 days interval.
5. Once disease is noticed, give need based curative sprays of Famoxadone16.6%+ Cymoxanil 22.1% SC (1g/L) or Metiram 55% + Pyraclostrobin 5% WG (3g/L) as Mandipropamid 23.4% SC (0.8ml/l) or cymoxanil 8% + Mancozeb 64% WP (3g/l) in rotation at 7 days interval.

5. Bacterial wilt (*Ralstonia solanacearum*)

Symptoms: Initial symptoms are sudden drooping of leaves and wilting of plants in afternoon. The wilted plants recover during evening. This is followed by complete wilt of plants with green leaves intact. Wilting and death is accompanied by dark brown internal discoloration of the vascular elements. Bacterial wilt pathogen, *Ralstonia solanacearum* is soil borne in nature and spreads through irrigation water and is aggravated by nematode infestation. Bacterial wilt occurs appears after earthing up at flowering stage.

Bacterial wilt in tomato

Management

1. Do not cultivate tomato in polyhouse with known history of bacterial wilt and nematode problem.
2. Avoid cultivation of solanaceous crops (Capsicum, Bottle Brinjal, Chilli) after tomato; follow crop rotation with peas/coriander/beans in polyhouse.
3. Green manuring with mucuna to reduce nematode population. Nematode injury predisposes tomato crop to bacterial wilt.

4. Application of neem cake enriched with bio-pesticides of ICAR-IIHR-Arka *Pseudomonas fluorescens* 1% W.P., Arka *Paecilomyces lilacinus* 1% W.P, Arka *Trichoderma harzianum* 1% W.P.
5. Seed treatment and seedling root dip with *Pseudomonas fluorescens*. One week before transplanting, seedlings in nursery/portrays can be drenched with bioagents at 20g per litre. Alternatively, seedlings can be dipped in liquid formulation of bioagents before transplanting.
6. Reduce frequency of irrigation to prevent further spread
7. Avoid intercultural operations that lead to root injury as bacterial wilt pathogen enters through injured points.
8. Soil drenching with copper oxy chloride 50% WP (3 g/L of water).

6. Tomato leaf curl disease

This disease is one of the economically important diseases of tomato in India. The disease is caused by virus and transmitted by Whiteflies (*Bemisia tabaci*).

Tomato leaf curl disease

Symptoms:

Severe stunting of the plants with downward rolling and crinkling of the leaves characterize leaf curl disease. The newly emerging leaves in an infected plant exhibit slight yellow coloration and later show curling symptoms. Older leaves become leathery and brittle. Nodes and internodes significantly get reduced in size causing stunting of plants. The infected plants look pale and produce more lateral branches giving a bushy appearance. Leaf curl is prevalent throughout the year with peak severity in summer months. High temperature and low humidity favour disease development and build-up of vector population. Monitoring and management interventions should be done from nursery to flowering stage.

7. TOSPO virus (GBNV)

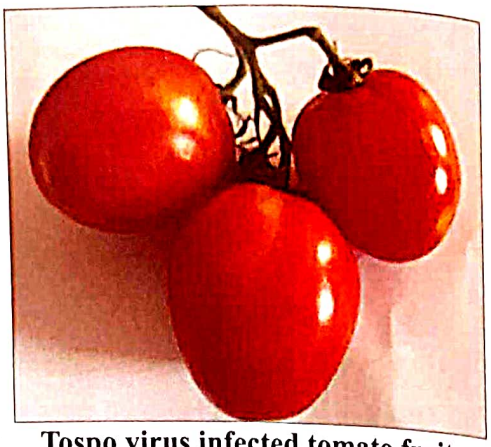
This disease is characterized by bronzing of newly formed young leaves, chlorosis followed by necrotic ring spots. Necrotic spots appear on the growing tips and the entire plant dies back. In some cases, this leads to severe stunting and cessation of growth. Early infected plants have deformed uneven fruit ripening while the fruits formed after late infection show concentric rings and discoloured fruits. This disease is a result of infection by Groundnut Bud Necrosis Virus which is transmitted by thrips.

Management of virus diseases {Tomato leaf curl disease and TOSPO virus (GBNV)}

- Enrichment of FYM with *Trichoderma* and Arka Microbial Consortium.
- Seed treatment with Seed Pro@ 10g/kg seed.



- Raising nursery under cover with 40 mesh nylon net or under polyhouse.
- Use of silver or black coloured mulches for repelling insect vectors.
- Rouging of virus infected plants.
- Foliar spray of Arka Vegetable Special @ 5g/lit, three times starting from 30 days after transplanting at 15 days interval, to make seedlings vigorous and sturdy.



Tospo virus infected tomato fruits

- Spray of organic bio stimulants like Sagarika @1-2 ml per litre of water as per crop stage; 1st spray at plant establishment stage, 2nd Spray at pre - flowering stage, 3rd Spray at post flowering stage.
- Insecticide application; Spraying Acephate 75%WP spray (1.5g/L) at 10 days after transplanting, Fipronil 5% SC spray (1.5ml/L) @ 20 days after transplanting, copper hydroxide 77% WP spray (2.0g/L) @ 25 days after transplanting, Imidachloprid 70%WG spray (2g/15L) @ 40 days after transplanting.

8. Blossom End Rot (Calcium deficiency)

This is not pathogenic disease but a nutritional disorder. This is mainly due to calcium deficiency. Fruits mainly exhibit sunken dark brown to black areas at the distal end. This disorder is common in soils with excess salinity and due to poor root growth.

Blossom end rot in tomato

Management:

1. Application of lime and calcium fertilizers before planting and spray of calcium nitrate 5 g/lit to reduce the deficiency.
2. Apply nitrogen in the form of Calcium Ammonium Nitrate to manage this disorder.

Good growth and fruit bearing in polyhouse tomato crop

9. Yield

A very high productivity of 313 t/ha was achieved from two crops of tomato (Hybrid SH 7711) grown in a year under naturally ventilated polyhouse. Therefore, it is possible to grow tomato in a naturally ventilated polyhouse round the year.

Period	Duration	Yield (t/ha)
October to April	Six months	160
May to November	Six months	153
Total yield per 12 months		313

Ripened fruits ready to harvest

Chapter 13

Production Technology of Parthenocarpic cucumber

(Sweet Cucumber / English Cucumber / European Cucumber)

1. Introduction

Parthenocarpic cucumber is also called as English Cucumber or European Cucumber, Baby Cucumber, Mini Cucumber etc. They are gynaceous in nature meaning bearing only female flowers. They are having dark green parthenocarpic (seedless) fruits, hence do not require pollination unlike other cucurbits. They are uniform in size and shape and are free from bitterness.

Healthy fruits of English cucumber

2. Varieties:

Usually Gynoecious, pathenocarpic F_1 hybrids are used for cultivation inside polyhouses. They do not require pollination. Pantnagar parthenocarpic cucumber hybrid is released from GBPUAT, Pantnagar, Uttarakhand. Other important hybrids available in India are Multi Star and Valley Star, from Rijk Zwaan seeds, I.Satis and Keon from Nunhems, Hilton of Clause seeds, Fadia from Enza Zaden, Kuk-9 & Taxi, Yuksel seeds are some of the hybrids generally cultivated in India.

Classification of different types of polyhouse cucumbers:

a) **Mini Cucumber:** Fruit Length18-19 cm, Shiny fruit, One or multiple fruit per internodes, Sweet and crispy, Broader Leaves

b) **Cocktail or snack cucumbers:** Small (8 - 12 cm) crispy cucumbers with a smooth thin skin.

c) **Parthenocarpic:** They will produce no male flowers and don't need pollination to grow. No problems with bad pollination, no seeds in the fruit, which means no bitter taste. When a parthenocarpic variety is grown close to another cucurbit that has male flowers, seeds can be formed resulting in bad shaped fruits.

Cucumber planted on raised beds with driplines

3. Climate: Cucumber loves warm climate, most of the Mini cucumbers are Parthenocarpic, can grove well when the Temperatures are around 28-32 Degree Celsius. However, they are grown throughout the year in moderate climate area.

4. Nursery raising: Seedlings are raised in the 98 cell seedling trays for costly seeds of English cucumber. Properly prepared cocopeat can be used to raise the seedlings. The seedlings will germinate within 2-3 days and stacked trays have to be spread immediately after the sprouting is seen. The seedlings will be ready for transplanting in

about 10-13 days after sowing. Direct sowing of the seeds can also be practiced as they establish well with good vigour.

Healthy cucumber seedlings ready for planting

5. Bed Preparation: Prepare the land with ploughing, cultivation, harrowing/rotovating to bring into fine tilth. Well decomposed FYM can be applied before final rotovating @ 20t/acre. Then prepare raised bed of 80 cm width separated by the walking space of 80cm. In a bay of 8m, 5 beds can be accommodated. Nine-inch bed height can be achieved by this way.

6. Fumigation: Details of procedure for fumigation of the soil is given in Chapter No. 5, page No. 10.

Cucumber planted on raised beds with driplines

7. Basal Fertilizer application: A basal fertilizer dose of 10:8:10kg NPK is required per acre and is applied to the beds uniformly before transplanting in the form of 50 kg Ammonium Sulphate, 50kg Single super phosphate and 20kg muriate of potash. Remaining fertilizers are applied through drip irrigation starting from 15 days of transplanting.

8. Application of neem cake and bio-pesticides: It should be done 3-4 days before transplanting. Please refer page 87 for the procedure.

9. Laying of drip line: Place two 16mm inline drip laterals/bed at a spacing of 40cm having emitting points at every 30 cm interval with discharge rate of 2 l/hr. Run the drip system to check each emitting point for uniform discharge, cuts and leakages if any before covering the beds with polythene mulch.

10. Mulching: Black-silver polyethylene mulch film of 25-40micron thick, 1.2 m wide, is used to cover the planting beds. Holes of 5 cm diameter are made on the polyethylene film as per the recommended spacing. The planting beds are covered with the film by securing the edges of the sheet firmly in the soil. Mulching practice conserves water, controls weeds, reduces infestation of pests and diseases and results in higher yield and good quality produce. Crop can be taken even without mulching in polyhouses.

11. Spacing: Seedlings are planted in paired rows in 80cm wide beds with row-to-row spacing of 50 cm and plant-to-pant spacing of 60 cm. This will accommodate about 8000 plants/acre. The Ideal Planting density will be about 2 plants per square meter with proper pruning and twining and maintaining single shoot per plant.

12. Transplanting: The planting beds are watered to field capacity before transplanting. Seedlings of about 10-13 days old are used for transplanting. Direct seedling also can be practiced if rat damage is not there. Care should be taken to see that no damage is occurred to roots or breakage of ball of media, while taking out the seedlings from individual cells of portray. Seedlings are transplanted into holes made in polyethylene mulch film at a depth of 5 cm. After transplanting, seedlings are drenched with 2 g/l Captan



solution to the base of seedlings at the rate of 25 ml per plant. Watering the mulched beds daily by using hose pipe fitted with rose for a week continuously is essential to avoid mortality due to heat trapped by mulch sheet.

13. Drip irrigation: Drip irrigation is given daily to supply 6000 to 12000 liters of water per acre per day depending on the season. This corresponds to running of the drip system of above description only to a period of 12 to 24 minutes depending on the season.

14. Fertigation

Total fertilizer requirement is 40:30:50 kg NPK/acre for a 4-month crop. A basal fertilizer dose of 15:15:15 kg NPK/acre is to be given before transplanting in the form of ammonium sulphate 75kg, 100kg single super phosphate and 25 kg muriate of potash. Remaining NPK will be given through water soluble fertilizers with drip irrigation (fertigation) for entire crop growth period, starting from 15 days after transplanting to 105 days after transplanting. Fertigation can be given as per following schedule.

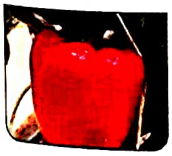
Micronutrient requirement of the crop can be met through foliar nutrition and sufficient application of FYM before planting. However, if the requirement is seen high based on soil test value, following fertigation schedule may be adopted 43 days after transplanting.

Days after transplanting	Number of fertigations	Quantity of fertilizers (kg)/fertigation	Day of the week
15-28	4 bi-weekly fertigations	2kg 19all+1.0kg KNO_3	Mondays & Fridays
29-42	4 bi-weekly fertigations	2.5kg 19all+1.0kg KNO_3	
43-105	20 bi-weekly fertigations	3kg 19all+2kg KNO_3	
43-105	10 weekly fertigations	3kg $CaNO_3$	Wednesdays
43-105	10 weekly fertigations	2kg $MgSO_4$	Saturdays

15. Foliar spray: The crop is sprayed with micronutrient formulation like Arka vegetable special (2g/L) four times at 15 days interval starting from 45 days after transplanting.

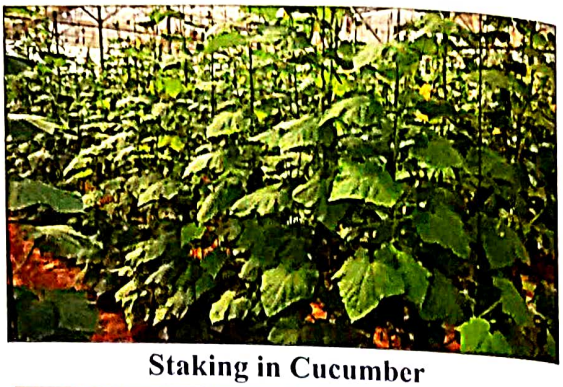
16. Pruning: Cucumber is pruned to single stems. All lateral branches appearing will be removed when they grow to the length of 5 cm.

Weekly once along with 19 All & KNO_3 (Monday)	g/acre
Fe-EDDHA/EDTA/DTPA	100
Zinc Sulphate ($ZnSO_4$)	100
Manganese Sulphate ($MnSO_4$)	50
Copper Sulphate ($CuSO_4$)	50
Weekly once along with 19 All & KNO_3 (Friday)	
Ammonium molybdate /Sodium Molybdate	50
Solubor	50





17. Training: Cucumbers are to be trained to grow vertically upwards along a polythene twine or plastic net. The plants are trained upwards so that main stem is allowed to climb to the over-head wire. Wires are fixed at about 3m from ground level and they run all along the length of the rows. As the plant grows, the main stem is loosely wound around the string for support. One week after transplanting, support strings are to be attached to the plants. Special plastic clips can also be used to attach the stem to the string just below the point where a leaf joins the main stem. This will make sure that the plant does not slide down the string as the fruit load develops. When the single branch reach the wire grid, it is allowed to trail down without damaging the vine.

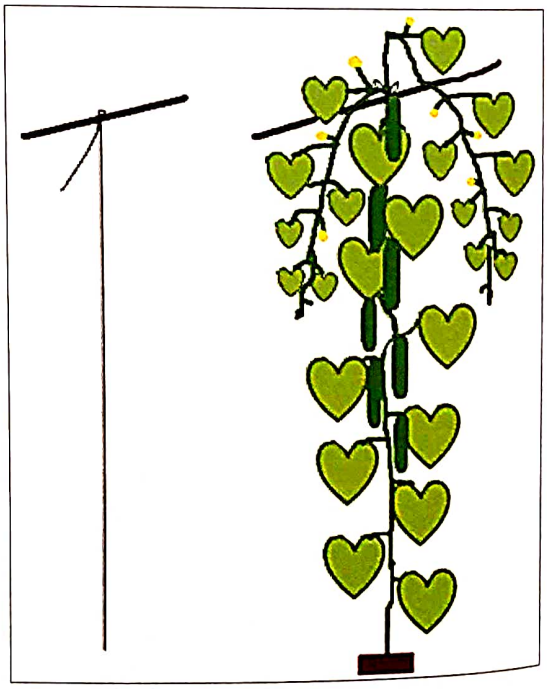


Staking in Cucumber

Training of cucumber vines with supporting threads

Some advice on roping & pruning

- Leave some extra rope near the wire to fix the plant later.
- Don't allow fruits in the first 75cm of plants, from the ground level.
- Remove all laterals
- Take out 2 - 3 leaves above the wire.
- Secure the plant with the rope.
- Older leaves can be taken off.
- When the plants are too heavily loaded more misshapen fruits can be expected hence, maintain proper fruit load.
- To prevent flowers from aborting, it sometimes helps to take off some leaves and clean the plastic.
- Take off misshaped fruits as soon as possible, to allow better quality fruits to grow well.



Schematic diagram of pruning and training

18. Integrated pest management in cucumber and muskmelon

Cucurbits are popular vegetables, particularly during summer months. Red pumpkin beetle, serpentine leaf miner, fruit fly, thrips, mites, leaf eating caterpillar are some major pests on cucurbits.

1) Red pumpkin beetle, *Aulacophora foveicollis* (Lucas) and *A. lewisii* (Baly)

The adults are small, elongate yellow or orange beetles. The adults defoliate the leaves, immediately after germination. The larvae feed on roots and plant parts. If the pest incidence is low, collect and destroy the pest manually. If the incidence is

high, spray indoxacarb 14.5 SC @ 0.5 ml/l or carbaryl 50 WP 4g/l or quinalphos 25 EC @ 2ml/l or chlorpyrifos 20 EC 2.5 ml/l.

2) Serpentine leaf miner, *Liriomyza trifolii* (Burgess):

This is an introduced pest occurring on many cucurbit vegetables. Heavy incidence is noticed in watermelon, pumpkin, cucumber *etc*. However, bitter gourd seems to be resistant.

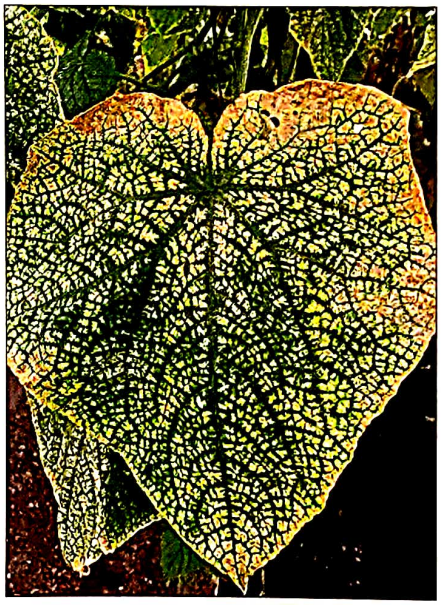
- A native larval parasitoid, *Hemiptarsenus vericornis* has been observed to be the major parasitoid on this pest.
- Soil application of neem cake @250 kg/ha immediately after germination
- Remove and destroy cotyledon leaves with leaf mining at 7 days after germination.
- Spray NSPE @ 4 % or neem soap 1% or neem formulation with 10000 ppm or more (2 ml /l) after 15 days sowing and repeat after 15 days if necessary.
- If the incidence is high first remove all severely infected leaves and destroy and spray Arka Neem Soap @ 5%. After one-week, spray Arka Neem Soap @ 1% or PNSPE or neem formulation with 10000 ppm or more (2 ml /l).
- Avoid spraying of same insecticide repeatedly, at least for two months.

3) Fruit fly, *Bactocera cucurbitae (Coquillett)*

Symptoms of damage: This is the major pest of cucurbits. The damage by maggots results in rotting of young and ripened fruits or drying and shrivelling of fruits before maturity are the symptoms of damage. Sometimes even the base of the plant gets attacked and plants start wilting. The incidence is more in wet climate.

Management:

- Soil application of neem cake @ 250 kg/ha immediately after germination and repeat at flowering followed by sprays of neem soap 1% or PNSPE 4% at 10 days interval after flowering.
- Crush pumpkin 1 kg and add 100 gm jaggery and 10 ml malathion and keep in the plot (4-6 places per acre). This will attract the adults to the fermenting pumpkin and they lay eggs and get killed. Repeat the process 2-3 times in a cropping season.
- Erect cue lure (para pheromone) trap@ 12 nos. per ac to attract and trap male fruit flies.
- Spray indoxacarb 14.5 SC @ 1.0 ml/l



Typical symptom of mite damaged cucumber leaves

4) Two-spotted spider mites (*Tetranychus urticae*):

Mites can be a serious problem on cucurbits, especially watermelons and cantaloupes, during hot, dry weather. These tiny mites feed on the contents of individual cells of the leaves. This damage appears as pale yellow and reddish-brown spots ranging in size from small specks to large areas on the upper sides of leaves. Damage can develop very quickly and the mites can kill or seriously stunt the growth of plants. Because of their small size, spider mites are hard to detect until vines

are damaged with hundreds of mites on each leaf. Certain insecticides applied at planting or as a foliar spray for insect control apparently contribute to severe outbreaks of mites on melons by killing their natural enemies.

Management:

- Spraying of neem or pongamia soap at 1 %. Spray lower surface thoroughly.
- Alternately, spray dimethoate 30 EC @ 2 ml/l or ethion 50 EC @ 2ml/l or wettable sulphur 80 WP @ 3g/l

Two-spotted spider mite (*Tetranychus urticae*)

5) Thrips, *Thrips palmi* Karny

Both nymphs and adults feed on the young shoot tips and floral parts and is suspected vector of tospo virus. They are serious during summer months.

Management:

- Soil application of neem cake (once immediately after germination and again at flowering) followed by NSPE @ 4 % and Arka neem soap 1% alternately at 10-15 days interval.
- Spray any systemic insecticides like dimethoate 30 EC @ 2 ml/l

6) Leaf eating caterpillar, *Diaphania* (*Margaronia*) *indica* Saund.

Long shining caterpillars feed on leaves and fruits. Apply neem cake to soil immediately after germination. Spray any contact insecticides like carbaryl 50 WP @ 4g/l. Arka Neem Soap or Arka Pongamia Soap @ 1 % also effectively manages this pest.

- Soil application of neem cake (once immediately after germination and again at flowering) followed by NSPE @ 4 % and Arka Neem Soap 1% alternately at 10-15 days interval.
- Spray indoxacarb 14.5 SC @ 1 ml/l or spinosad 45 SC @ 0.25 ml/l.

IPM for cucurbits:

- Soil application of neem cake @ 250 kg/ha after germination and repeat once at flowering stage
- Management of leaf miner by i) removal of cotyledon leaves infected with leaf miner one week after germination ii) followed by spraying of neem seed powder extract @ 4 % or Arka neem soap @ 1% reduces the incidence of leaf miner substantially.
- Spray neem seed power extract 4% or Arkaneem soap or Arka Pongamia Soap @ 1% after flowering at 10 days interval.
- Erect pheromone traps cuelure @ 12 traps/ac and change after 60 days.
- If the incidence of fruit fly is more, apply splashes of 10 % jaggery mixed with 4 ml of deltamethrin 2.8 EC on staking at an interval of 5 m.

3.10 IDM in European cucumber and Muskmelon

1. Damping-off and root rot of seedlings (*Pythium*, *Phytophthora* and *Rhizoctonia* spp.)



Symptoms: Infected seeds do not germinate. They decompose in the nursery medium. On infected young seedlings, initial symptoms are appearance of brown water-soaked lesions on stem at soil line. The lesions constrict stem, leading to the collapse of seedlings. The disease spreads through infected planting material, contaminated soil and water.

Damping off of cucumber seedlings

Management

1. Seed treatment with Seed pro@ 10 g/kg seed or *Trichoderma harzianum* or *Pseudomonas fluorescens* @ 6-10g/ kg seed.
2. Sowing in nursery beds with enriched medium/FYM/Neem cake using bio agents; Arka *Pseudomonas fluorescens* 1% W.P., Arka *Paecilomyces lilacinus* 1% W.P, Arka *Trichoderma harzianum* 1% W.P
3. Soil drenching with captan 75% WP (2.5g/L) or copper oxychloride 50% WP(3g/L)

2. Powdery mildew (*Erysiphae cichoracearum)*

Symptoms: White to dirty grey powdery growth on leaves, petioles and stem. Infected leaves turn yellow, die and fall off. The pathogen survives on other hosts of cucurbit family. Low humidity, cool and dry condition and shade favour the disease.

Powdery mildew on cucumber leaves

Management:

1. Maintain proper spacing to provide air circulation between plants
2. Remove piles of infected leaves and fruits before each spray
3. Stake plants properly, remove old and infected leaves touching soil line.
4. Spray Carbendazim 50%WP (0.5g/l) or Azoxystrobin 23%SC (1ml/l).

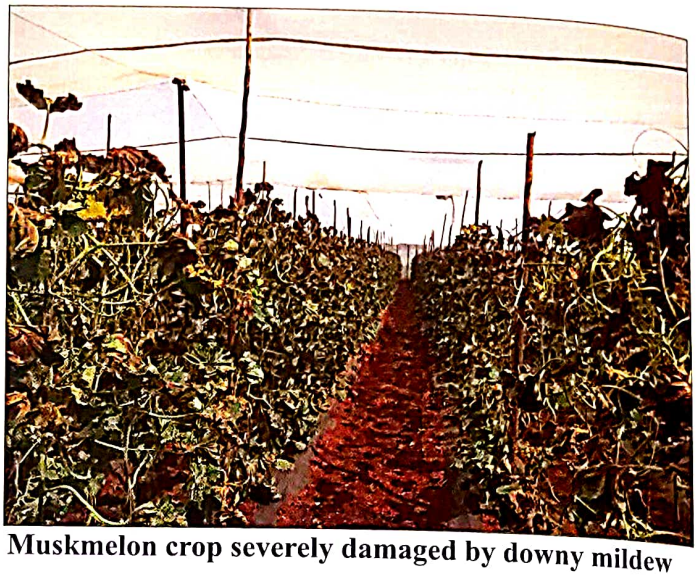
3. Downy mildew (*Pseudoperanospora cubensis*)

Symptoms: Initial symptoms are angular yellow spots on the upper leaf surface in cucumber. On muskmelon, lesions are not angular but are covered by yellow halo. The corresponding undersides of these spots are covered with grey brown to purplish black moldy growth due to sporulation of the fungi. Infected leaves turn necrotic, wither and die. The disease is soil borne and pathogen survives on other hosts of the cucurbit family. Humid cool conditions and frequent rains favour the disease.

Downy mildew in cucumber

Management:

1. Protective sprays of Zineb75%WP or Mancozeb @ 2.0g/L
2. Need based curative spray with any one of the following fungicides; or Ametoctradin + Dimethomorph 20.27% w/w SC @2g/L, Azoxystrobin 23% SC (1ml/l), Cymoxanil 8%+ Mancozeb 64%WP (3g/l), Fenamidone 10%+Mancozeb 50% WG (3g/l). Dimethomorph 12% + Pyraclostrobin 6.7%WG (3g/l).



Muskmelon crop severely damaged by downy mildew

4. Gummy stem blight

This is an emerging disease on cucurbits in India. It is caused by fungi *Stagonosporopsis spp. (Didymella spp.)*

Symptoms: The disease affects leaf, petiole, stem and fruit. Diagnostic symptoms are crown and stem cankers. Stem with whitish fungal growth around collar region with characteristic black fruiting bodies

Sporulation on stem due to Gummy stem blight

Gummy stem blight on leaves

pycnidia. Most conspicuous symptom is split stem with amber colored gummy drops exuding from infected portion. Leaf spots are round or irregular and are water soaked. In muskmelon, external and internal fruit rot is observed, whereas in English cucumber infected fruits show internal discoloration. Infected plants wilt and collapse at fruiting stage. Gummy stem blight pathogen is seed, soil and air borne in nature.

Management:

1. Use disease free seeds and seedlings.

Gummy stem blight affected stem of musk melon

2. Application of FYM enriched with *Trichoderma harzianum* and *T. viride*
3. Crop rotation: Avoid repeated cultivation of cucurbits (Pickling cucumber, squash and English cucumber) in same field.
4. Regulate irrigation, water stress (excess or low) splits stem which serve as entry point for this pathogen
5. Foliar spray of contact fungicides Chlorothalonil or Mancozeb (2g/L) at 7-10 days intervals, followed by spray with systemic fungicide Tebuconazole 1 ml/lit.

5. Fusarium wilt (*Fusarium oxysporum* f.sp. *cucumerinum* (Cucumber), *Fusarium oxysporum* f.sp. *melonis* (Muskmelon).

Symptoms: Yellowing of foliage, followed by drooping and wilting. Vascular tissue in lower stem and root show light brown streaks and discolouration. The disease is more severe at fruiting stage. The pathogen survives in infected seeds, plant debris and soil. Moderately high temperature and rainfall favour the disease. Once introduced chlamydospores of this fungus can survive in soil for 20 years.

Management

1. Use disease free seeds and transplants
2. Follow Crop rotation with non-cucurbitaceous crops
3. FYM enrichment with bio-agents
4. Foliar spray of Carbendazim 50%WP (1g/l) or Thiophanate Methyl 70% WP (1.0g/l). Spot drenching of wilting and surrounding plants with Carbendazim 50%WP or Thiophanate Methyl 70% WP (2.0g/l).

Fusarium wilt in polyhouse grown English cucumber

3.11 Harvest and Yield: It commences at 35-38 days after planting. Need to be harvested every alternate day to maintain the size of about 12[illegible]g/fruit, which is the preferred size for most of the markets. We can get a yield of 40-50 t/acre in [illegible]00-120 days.

Harvested good quality cucumber fruits

3.12 Precautions to be taken while harvesting and PHM of European Cucumber fruits

- ✓ Harvest fruits during morning hours and avoid harvesting after 12 Noon
- ✓ Avoid damage to the fruits while harvesting. If needed, harvesting secateurs may be used for safe harvesting of fruits

- ✓ Proper grading of fruits (A and B grades) should be done before packing. Keep graded fruits separately. Avoid mixing of misshaped, oversized, small, diseased and damaged fruits with graded fruits.
- ✓ Shift the harvested fruits immediately to the shaded area, in plastic crates and avoid keeping in open area, directly exposed to the sunlight, as the fruit skin may get burnt, makes it unmarketable.
- ✓ Do not pack the fruits, immediately after harvest. Avoid packing fruits in cartons without holes / aeration. Never keep the packed carton directly exposed to sunlight
- ✓ Transport the fruits in a good vehicle with good aeration, without much shaking to avoid damage to the fruits. Fruits should be marketed as early as possible and avoid keeping in the box / crates for long time, without cold storage.

Well grown healthy European Cucumber in polyhouse

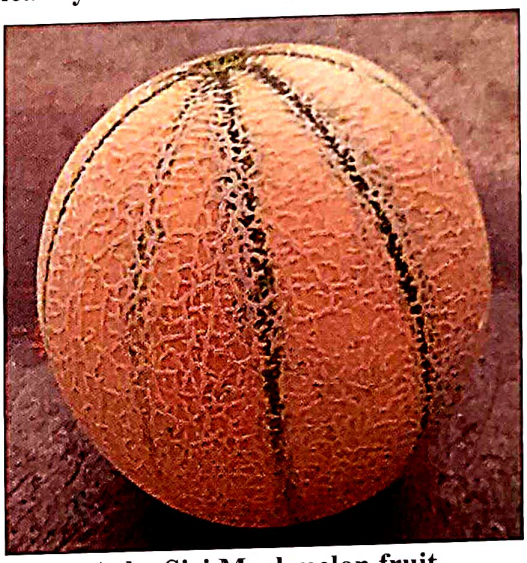


Chapter 14

Production Technology of Muskmelon

Muskmelon is a vining plant in the cucurbit family. This warm season crop is sensitive to cold temperatures. In North Indian plains, early summer harvests can be achieved by following transplanting of musk melon crop in low tunnel cultivation. To grow in peak winter, it requires heated greenhouses in northern plains. Muskmelon requires warm climate to grow well and produce high quality fruits. Experiment conducted at ICAR-IIHR, Bengaluru during winter months shown that growing of muskmelon in a naturally ventilated polyhouse has increased the yield by two folds compared to open field cultivation. General varieties meant for open field cultivation can be tried in polyhouse, as they need to be hand pollinated for the production of fruits inside the polyhouse. Recently, ICAR-IIHR has successfully demonstrated the cultivation of muskmelon variety- Arka Siri-inside the naturally ventilated polyhouse using native pollinators.

Well grown healthy Muskmelon in polyhouse



Arka Siri Muskmelon fruit

Muskmelon varieties: ICAR-IIHR released an OP variety "ARKA SIRI". It is a Tuscan type cantaloupe weighing about 1kg each, with an appealing pattern of netting, plus green sutures on orange rind on ripening, along with sweet, dark-orange flesh (TSS 12%) and a strong, musky aroma.

Kohinoor, Kanchan, Sun, NS-10 and other open field hybrids/varieties are grown inside the polyhouse during mild winter condition of the southern tropics. Some of the Holland hybrids like Caribbean Gold, Intenan and others which have excellent shelf life (10-12 days) and other quality parameters can be used for polyhouse cultivation with assisted pollination.

Yellow melon fruits ready for harvest

Nursery raising: Seedlings are raised in the 98 cell seedling trays for costly seeds of melons. Properly prepared cocopeat can be used to raise the seedlings. The seedlings will germinate within 2-3 days and stacked trays have to be spread immediately after the sprouting is seen. The seedlings will be ready for transplanting in about 10-12 days after sowing. Direct sowing of

the seeds can also be practiced as they establish well with good vigour for less costlier seeds and in areas of no rat damage.

Land and Bed Preparation: Prepare the land with ploughing, cultivation, harrowing/rotovating to bring the soil into fine tilth. Well decomposed FYM can be applied before final rotovating @ 20t/acre. Then prepare raised bed of 80 cm width separated by the walking space of 80 cm. In a polyhouse bay of 8m, 5 beds can be accommodated. Nine inch bed height can be achieved by this way.

Fumigation: Formaldehyde fumigation is optional. It can be used, if soil is heavily infested with soil borne pathogens. It can be done once in 3 crop cycles. Regular application of bioagents like *Trichoderma, Pseudomonas, Pachonia* and *Paecilomyces* is a better alternative to formaldehyde fumigation. To do fumigation, crop beds are drenched using 4 per cent formaldehyde (@ 4 l/m^2 of bed) and covered with black polyethylene mulch sheet. To prepare 4% formaldehyde solution, one litre of formalin is added to 9 litres of water. While treating with formalin, care should be taken to wear mask, gloves and apron. Four days after formalin treatment, the polyethylene cover is removed; the beds are irrigated and are raked repeatedly every day for 3-4 days, to remove the trapped formalin fumes completely, prior to transplanting.

Basal Fertilizer application: Total fertilizer recommendation is 35:30:45 kg NPK/acre. A basal fertilizer dose of 15:15:15 kg NPK is to be applied to the beds uniformly before transplanting in the form of 75 kg Ammonium Sulphate or 30kg urea, 100kg Single super phosphate and 25kg muriate of potash. Remaining fertilizers are applied through drip irrigation starting from 15 days after transplanting till 90 days after transplanting at the interval of twice a week.

Application of neem cake and bio-pesticides: Fifteen days before transplanting, neem cake has to be enriched with bio agents like *Trichoderma, Pseudomonas and Paecilomyces*. Neem cake of about 150 kg is powdered and slightly moistened. Five kg each of *Trichoderma, Pseudomonas* and *Paecilomyces* are mixed thoroughly to the 150kg neem cake separately. The mixture is covered with a wet gunny bag or dry grass and left for 8-10 days. Avoid direct exposure to sunlight and rainfall. After 10 days, this enriched mixture of neem cake and bio-agent along with 650 kg of neem cake has to be applied uniformly on the beds for an area of one acre. This is highly useful to reduce the problem of soil borne pathogens and nematodes. Azospirullum or Azactobacter, VAM and Arka Microbial Consortium can be mixed to the soil at this stage @ 5kg/acre.

Laying of drip line: Place two 16mm inline drip laterals/bed at a spacing of 40cm having emitting points at every 30 cm interval with discharge rate of 2 litre/hour. Run the drip system to check each emitting point for uniform discharge, cuts and leakages, if any, before covering the beds with polythene mulch.

Mulching: Black-silver polyethylene mulch film of 25-30 micron thick, 1.0 to 1.2 m wide, is used to cover the planting beds. Holes of 5 cm diameter are made on the polyethylene film as per the recommended spacing. The planting beds are covered with the film by securing the edges of the sheet firmly in the soil. Mulching practice conserves water, controls weeds, and reduces infestation of pests and diseases, resulting in higher yield and good quality produce. Crop can be taken even without mulching also in polyhouses.

Spacing: Seedlings are planted in paired rows in 80 cm wide beds with row-to-row spacing of 50 cm and plant-to-pant spacing of 60 cm. This will accommodate about 8000 plants/acre. The ideal planting density



will be about 2 plants per square meter with proper pruning and twining and maintaining two shoot per plant and allowing only two fruits per shoot.

Transplanting: The planting beds are watered to field capacity before transplanting. Seedlings of about 10-12 days old are used for transplanting. Direct seedling also can be practiced if rat damage is not there. Care should be taken to see that no damage is occurred to roots or breakage of ball of soils, while taking out the seedlings from individual cells of portray. Seedlings are transplanted into holes made in polyethylene mulch film at a depth of 5 cm. After transplanting, seedlings are drenched with 2 g/l Captan +1g/l Bavistin solution to the base of seedlings at the rate of 25 ml per plant. Watering the mulched beds daily using hose pipe fitted with rose for one week continuously helps in regulating moisture in the growing beds.

Drip irrigation: Drip irrigation is given daily to supply about 6000-12000 liters of water per acre per day depending on the season in a plastic mulched crop. This corresponds to running of the drip system of above description only to a period of 12 to 24 minutes depending on the season.

Well grown Muskmelon crop in polyhouse

Fertigation: Total fertilizer requirement is 40:30:50 kg NPK/acre for 100 days crop. A basal fertilizer dose of 15:15:15 kg NPK/acre is to be given before transplanting in the form of ammonium sulphate 75kg, 100kg single super phosphate and 25 kg muriate of potash. Remaining NPK will be given through water soluble fertilizers with drip irrigation (fertigation) for entire crop growth period, starting from 15 days after transplanting to 90 days after transplanting. Fertigation can be given as per following schedule.

Days after transplanting	Number of fertigations	Quantity of fertilizers (kg)/fertigation	Day of the week
15-28	4 bi-weekly fertigations	2kg 19all+1.0kg KNO_3	Mondays & Fridays
29-42	4 bi-weekly fertigations	2.5kg 19all+1.0kg KNO_3	
43-91	16 bi-weekly fertigations	3kg 19all+2kg KNO_3	
43-91	8 weekly fertigations	3kg $CaNO_3$	Wednesdays
43-91	8 weekly fertigations	2kg $MgSO_4$	Saturdays

Micronutrient requirement of the crop can be met through foliar nutrition and by applying sufficient application of FYM to the soil before planting. However if the requirement is seen high based on soil test value, following fertigation schedule may be adopted 43 days after transplanting.

Foliar spray: The crop is sprayed with micronutrient formulation like Arka vegetable special (2g/L) three to four times at 15 days interval starting from 45 days after transplanting.

Weekly once along with 19 All & KNO3 (Monday)	g/acre
Fe-EDDHA/EDTA/DTPA	100
Zinc Sulphate ($ZnSO_4$)	100
Manganese Sulphate ($MnSO_4$)	50
Copper Sulphate ($CuSO_4$)	50
Weekly once along with 19 All & KNO_3 (Friday)	
Ammonium molybdate / Sodium Molybdate	50
Solubor	50

Pruning: Crop is pruned to double stems. All lateral branches appearing will be removed when they grow to the length of 5 cm.

Training: Melons are to be trained to two stems to grow vertically upwards along a polythene twine or plastic net. The plants are trained upwards so that main stem is allowed to climb to the over-head wire. Wires are fixed at about 3m from ground level and they run all along the length of the rows. As the plant grows, the main stem is loosely wound around the string for support. One week after transplanting, support strings are to be attached to the plants. Special plastic clips can also be used to attach the stem to the string just below the point where a leaf joins the main stem. This will make sure that the plant does not slide down the string as the fruit load develops. Also a net support for hanging fruits is required to prevent the vines being pulled down by the weight of the fruit and also to prevent from slip out during maturity.

Pollination: In musk melon two fruits are allowed per branch. Hand pollination during morning hours is necessary to get fruit set which is labour intensive and time consuming. A technology has been developed at ICAR-IIHR, Bengaluru, as a substitute to hand pollination. It involves using any of two species of honey bees viz., Indian honey bee (*Apis cerana*) or stingless bee (*Tetragonula iridipennis*). The protocol is described below.

Use of Indian honey bees for pollination of muskmelon under polyhouse: Customize the Newton hive with an additional entry/exit point at the back of hive (box) so that bees can move in either of directions. Place the box (7-8 frame strength) at the border of polyhouse in such a way that half of box with main entry/exit portion is facing inside polyhouse and other half (back of box) remaining outside polyhouse. The hive has to be placed when the crops are about to flower. No. of hives (boxes) required: 3-4/acre (Desired strength: 7-8 frames).

Fruits wrapped with foam net

Use of stingless bee for pollination of muskmelon under polyhouse: Eight bee hives are required per acre. They have to be introduced at the initiation of flowering. Hives have to be hung from top such that the hives are kept at about 6ft from ground level.

Precautions to be taken for using honey bees for pollination under polyhouse:

I Remove spider webs from corners or at top of polyhouse before placing bee hives

ii. Do not spray any insecticide after introduction of bees inside polyhouse

iii. Spray insecticides, if necessary, before placing bee hives. There should be a gap of minimum one week between last insecticide spray and placement of honey bee colonies.

iv. Hives have to be removed after cessation of flowering.

v. Shade nets to be avoided above crop as they hinder bee flight and bees get entangled in the net.

Netting on Muskmelon fruits, ready for harvesting

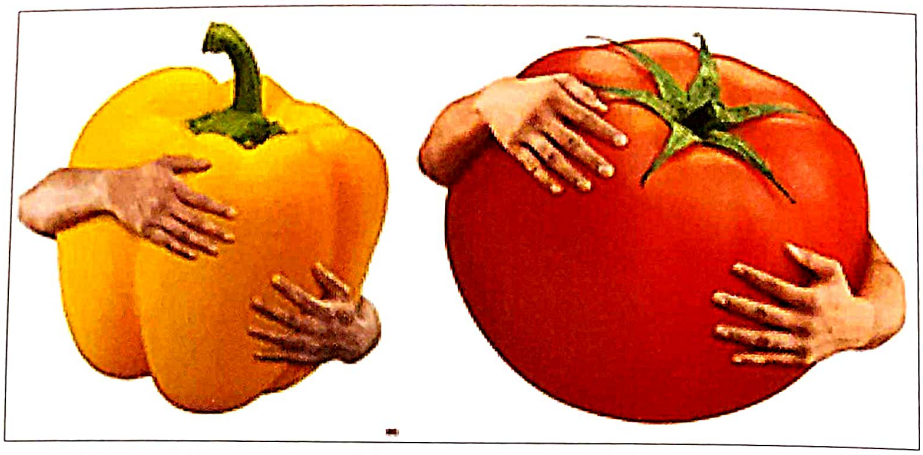
Harvesting and yield:

Harvesting can be done 75-100 days after planting depending on the variety and season. Harvest is done when they are matured at half-slip stage or full slip stage, depending upon the distance to market and variety. About 20 to 30t/acre fruit can be harvested depending on the variety and duration. TSS of the completely matured fruits is seen upto15-degree brix depending on the variety.

Ready to harvest muskmelon fruits in polybag cultivation

Chapter 15

Post Harvest Management of Capsicum, Tomato, Muskmelon and Cucumber



High quality vegetables are produced under protected cultivation and their quality has to be maintained till they reach the consumer by adopting better post-harvest management (PHM) practices. Appropriate harvest and handling techniques are to be employed for each crop which includes conscientious attention to maturity indices and grading standards, care in handling, proper packaging, timeliness and thoroughness in pre-cooling, storage at the desired temperature and relative humidity, and implementation of strict sanitation program. While planning for polyhouse production of vegetables thought must also be given to post harvest management requirements like sorting, washing, grading, packaging, storage and transport. The general post-harvest considerations for poly house grown vegetable crops *viz*., capsicum, tomato, cucumber and muskmelon are described below.

Coloured capsicum ready for harvesting

I. Harvesting

A) Maturity at harvest

Capsicum: Immature fruits are dull in colour, as they do not have the protective waxy layer on the surface and will shrivel faster if harvested at this stage. The pedicel (stalk) and calyx (stalk base) should be green and the fruits should look fresh and firm.

Tomato: The stage of harvesting depends on the purpose to which the fruits are to be used (*i.e*., fresh market or processing) and the desired length of storage life or transport. Fruits can be harvested at ***Mature green stage*** (light green surface colour with waxy gloss) meant for long distance shipment which takes longer time for full ripening. ***Breaker stage*** fruits are harvested, when less than 10% of the surface at the blossom end changes to pink or

Colour break stage in tomato

red. Similarly, tomatoes can be harvested at ***Turning stage*** (10 to 30% colour change) ***Pink stage*** (30 to 60 % colour change) ***Light red stage*** (60 to 90% colour changes) and ***Red ripe stage*** (> 90 % colour stage) depending on the marketing needs.

Muskmelon: Cantaloupes when harvested at full maturity (i.e. at full slip) are high in sugars, and have good flavour and aroma. At full-slip an abscission layer forms allowing the melon to separate from the vine, leaving no stem tissue attached to the fruit. However, unfortunately melons harvested at full slip stage have a short storage life. Hence, commercial maturity is ideally at the firm-ripe stage or "3/4 to full-slip" when a clear abscission (slip, separation) from the vine occurs with light pressure.A raised and well-rounded netting on the fruit surface is another indicator of correct commercial maturity. In order to extend shelf life, some producers prefer to clip the melons from the vine before peak ripeness. Full slip tears the stem from the fruit and leaves a scar, whereas clipping leaves a short stem.

Muskmelon fruit harvested at full slip stage

Cucumber: Cucumbers are harvested when the fruits attain uniform length, shape, and diameter and before any yellowing appears at the blossom end. The main external indices of harvest maturity are fruit size and peelcolour. The main internal indices of harvest maturity are seed development, locular jelly formation, and flesh texture. Cucumbers are generally harvested at a slightly immature stage, near full size but before seeds fully enlarge (should be at half of their size) and harden. Firmness and external glossiness are also indicators of maturity. Over mature fruits turn yellow & show carpel separation in transverse section. Harvesting three or four times per week is necessary as the fruits over matures very quickly.

Capsicum harvesting using secateur

B) Method of harvesting and handling

Proper harvesting techniques should be used to minimize the mechanical injury. Frequent sanitizing of hands/gloves and clippers will assist in reducing the disease incidence during subsequent storage and marketing. Harvesting is done either in the morning or late afternoon/evening when it is cooler.

Capsicums are generally harvested by holding the pedicel between two fingers and snap the fruit off, upwards towards the back of the curve to make a clean break. Sharp pruning scissors or knives can also be used to cut the fruits at the level of the abscission zone on the fruits peduncle. Harvested fruits with intact peduncles are more resistant to bacterial soft rot than those with torn or partial peduncles.

Tomatoes should be snapped from the plant without causing undue damage to the fruit or plants leaving a small portion of the pedicel and green calyx bracts attached to the fruit, a distinct trademark for polyhouse-grown tomatoes.

Tomato fruits ready for plucking

Melons should be harvested during cool period i.e. early in the morning or late in the evening. Warm, dry weather just prior to harvest improves fruit flavour. Avoid rough handling, as cut or bruise injuries make fruit more susceptible to disease. To reduce the risk of damage due to excessive handling, it is preferable to sort, size, grade, and pack the fruit into boxes in the field.

Cucumbers are picked by hand gently to avoid any injury to the vine with a portion of stem attached to the fruit. It is advisable to cut or clip away the fruit rather than tearing them off to avoid peeling off the skin at stalk end.

Tender cucumber fruits ready for harvest

The harvested produce should be collected into clean reusable picking containers that have smooth inner surfaces, shallow and made of an easily cleanable material, such as plastic. Care should be taken not to over fill or under fill the crates, as the produce may be damaged during transport. If necessary, line the inside of the field container with protective padding to prevent fruit scarring and abrasion. After harvest, the produce should be immediately shifted out from the green house as the temperature inside the green house is usually higher than outside atmosphere and kept under shade to protect from the direct sun light. Good quality 5 ply carton boxes can also be used for packing and transportation of European Cucumber and Muskmelon fruits. Capsicums are considerably more susceptible to water loss, sun scald and heat damage, after they are harvested. The harvested produce should be transported carefully to the packing/storage areas soon as possible. The crates / carton boxes should be stacked properly to prevent the produce from being pressed and jolted. It is advisable to transport in the cooler part of the day to avoid heat damage.

Grading and packing of cucumber

II. Pack-house operations

The pack-house should be located preferably near the polyhouse. It should be large enough to accommodate any packing line equipment necessary for sorting, washing, grading, waxing, etc. and adjoining with cooling and storage facility.

Multiple PHM activities of Capsicum - Grading, packing, etc.

A. Sorting

Sorting is essential to separate undersized, misshapen bruised/damaged, split/cracked or broken, decaying, insect infested, immature or over-ripe fruits.

B. Grading

There are two main grades for export of capsicum. Grade "A" are those fruits with highest quality and Grade "B" include those that are of reasonably good quality.

Characteristics of Grade "A"

- Shape: Three to four lobes
- Size: Minimum of 3.5 cm wide and should weigh > 150 g per fruit
- Length of pedicel: Should not be more than 3cm
- skin should be completely free from spots, bruises or decay
- pesticide residue free

'A' grade quality capsicum fruit

Grading is also done based on diameter (maximum distance across shoulders) and fruits with greater size fetch higher prices. These are extra-large (>3.3 inches); large (3 to 3.2 inches); medium (2.5 to 2.9 inches) and small (2.2 to 2.4 in).

In case of tomato, only healthy, attractive, clean and bright fruits should be selected and graded based on the required specifications in terms of ripening stage, size and weight.

Sorting of tomato fruits on grading machine

Grading of tomato fruits in grading machine

Cucumber grading is primarily based on uniform shape, firmness, weight (100-120 g per fruit) and a dark green skin colour. Additional quality indices are size, free from growth or handling defects, free from decay and absence of yellowing. Long, moderately slender, tender, straight and dark green coloured cucumbers fetch better price.

C. Washing

Washing in clean water is essential to remove dirt and spray residue marks, if any. The water may be chlorinated and the chlorine level (100 ppm) and pH (7.0) should be checked frequently. Washed fruits are rinsed in clean water and air dried to remove the adhering excess surface water.

Capsicum **should not be dipped in water** for washing since water can easily infiltrate the hollow pod and cause post-harvest decay. Overhead spray with clean water is recommended for washing and free surface water should be removed prior to packing.

D. Packaging:

The packing container is a critical component in maintaining quality during handling and transportation. It should be compatible with the intended crop and provide adequate ventilation for rapid cooling, and at the same time be durable enough to protect the produce during transportation. Ventilation holes should be present (about 5% of the exposed surface area of the carton) to ensure sufficient air circulation during storage and shipping. The package size should be fit to standard pallet size of 100 cm x 120 cm or 80 cm x 120 cm.The packages should also be clearly labeled as to crop, grade, count, weight, and shipper.

Capsicum should be packed in CFB cartons (5 ply thick) in single or in multiple layers with paper shreds as cushioning material for long distance transport. Only good quality fruits with uniform maturity, colour, shape, size, weight and free from defects should be packed.

The transport and market requirements dictate the type of containers to be used for packing tomato fruits. For local markets tomatoes should be packed in plastic crates/ smooth wooden containers. Sufficient care should be taken to ensure that bruises and other damages are not caused to the fruits during packaging. Plastic crates can be stacked conveniently with minimum damage to the fruits. For long distance transport and export purpose, tomatoes should be packed in 7 ply rating ventilated CFB boxes of 10 Kg capacity, with the dimension of 30 x 25 and 30 cm.

Tomato fruits packed for transportation in plastic crates

Muskmelon fruits should be placed in the boxes downward for large size, sideways for medium size and upward if the fruit size is small. Generally, fruits with vine attached are packed stem end facing up word. It is recommended to place heavier muskmelon fruit in the box downward for storage and distribution at ambient temperature. Never fill the carton too tight or overfill so as to avoid compression damage that makes the inside pulp soft. To minimize moisture loss, cantaloupes can be wrapped individually in polyethylene or packed in bulk in cartons lined with polyethylene.

Muskmelon packed in foam fruitnet for export

Cucumbers should be packed in strong, well-ventilated containers. Plastic crates that can be stacked without collapsing are appropriate for the domestic market. Mesh sacks are not a good container as they provide little protection to the fruit. Use of synthetic sacks filled with more than 25 kg of fruit should also be avoided. Cucumbers for export and long distance domestic markets should be packed in strong good quality and well-ventilated CFB cartons.

Muskmelon packedin foam fruitnet for domestic market

E. Pre-Cooling

The field heat of polyhouse grown vegetables will always be higher than field grown crops resulting in higher respiration and transpiration of the harvested produce. This necessitates faster cooling of the harvested produce to prevent shriveling or wilting of the harvested produce. Post-harvest life and quality of poly house grown vegetables can be significantly extended by removing the field heat within a couple of hours of harvest. Although there are several methods used for pre-cooling, forced-air cooling is one of the easiest and convenient methods. Humidity should be maintained at 85 to 90%, to minimize water loss during cooling and subsequent storage.

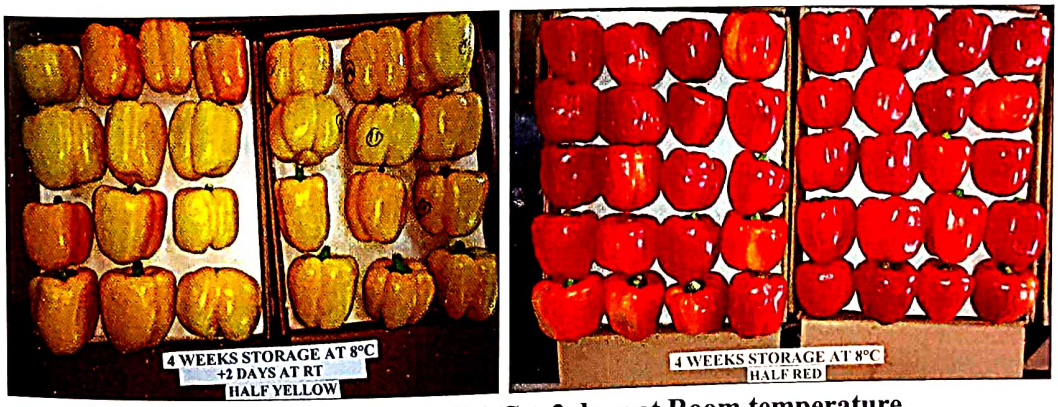
F. Cold storage

The optimum temperature of storage varies, depending upon the vegetable as certain vegetables are chilling-sensitive resulting in pitting or sunken lesions on the surface, surface discoloration, off flavour development and increased susceptibility to decay. Examples of chilling-sensitive polyhouse grown vegetables are capsicum, cucumber that should not be stored below 5 and 10°C respectively. Similarly, mature green tomatoes should not be stored below 12°C.

After 3 weeks storage at 8° C

Capsicum is more susceptible to water loss and the symptoms of shriveling may become evident with as little as 3 % weight loss. Pre-cooling and storage in a high relative humidity (90 - 95%) will minimize weight loss. The optimum temperature for storage of capsicum is 7-8°C. Capsicums are sensitive to chilling injury and storing below 5°C results in softening, pitting, and predisposition to decay. Similarly, storing at temperatures greater than 20°C accelerate ripening and colour changes. Under optimum storage conditions (7- 8°C) and high relative humidity (90 to 95 %), the shelf life is 2 to 3 weeks with minimum loss of quality.

The storage life of color capsicum can be further extended if harvesting is done at 50% coloration and stored at 8°C. Both red and yellow colour capsicum harvested at half maturity (50% coloration) could be stored for 4 weeks at 8°C without affecting the quality as compared to 3/4th and full red color maturity stages.



After 4 weeks storage at 8° C + 2 days at Room temperature




Tomato fruits harvested at breaker stage can be stored for 10 to 12 days at room temperature. The storage life can be extended to 4 to 5 weeks by storing at 12 to 13°C with 90-95 % R.H. In cold chain method, where the temperature is maintained at 12-13°C from harvest to consumption, the storage life can be extended up to 6 weeks.

Storage life of tomato harvested at different maturity stages

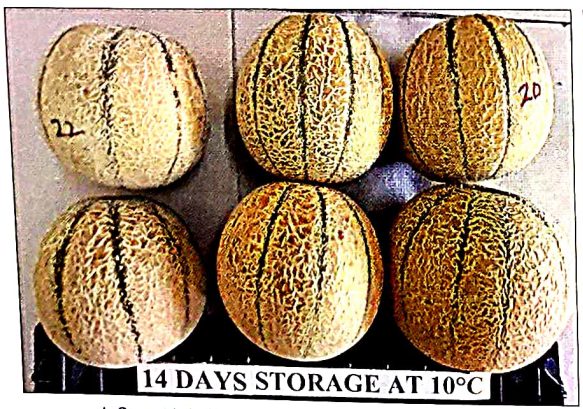
Maturity stage	Storage temperature	Storage life (days)
Mature green	12-14 °C	30-35
Breaker-turning	12-13°C	28-30
Pink-light red	10-12°C	10-14
Firm ripe	7-10°C	4-5

The storage temperature has to be raised to 20°C one week before marketing as this temperature is optimum for the development of colour (lycopene) development and ripening.

In case of cucumbers, the optimum temperature and relative humidity for storage are 10-12.5°C and 90- 95 % respectively. Storage life of cucumber is generally less than 14 days as visual and sensory quality deteriorates rapidly. Shrivelling, yellowing, and decay are likely to increase following storage beyond two weeks, especially after removal to ambient conditions. Cucumbers are chilling sensitive at temperatures below 10°C if held for more than 2 to 3 days resulting in water-soaked areas, pitting and a tendency for more rapid loss of green color and fungal decay. Cucumbers are also sensitive to ethylene gas. When cucumber fruits are exposed to ethylene, they lose chlorophyll and rapidly become yellow. Hence, it is very important that cucumbers should not be held or shipped in the same compartment with moderate to high ethylene producing fruits or vegetables.

Pre-cooling of cucumber in crates

The optimum temperature for storage of muskmelon is 10°C where they could be stored for 2 weeks with less weight loss and maintenance of colour, firmness and quality. The storage life is only 1 week at 13°C and 10 days at 10°C.



After 14 days storage at 10° C

Cut opened fruits after 14 days storage at 10° C

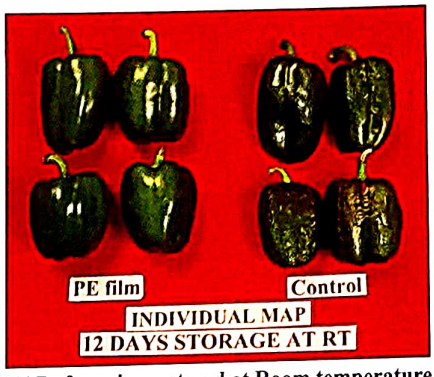
G. Sanitation

Development of decay during storage and transportation is one of the major causes of post-harvest loss. Post-harvest quality control should begin in the poly houses. Decay can be markedly reduced by a routine sanitation program that include prompt removal of trash, plant cuttings, diseased plant parts, and culls from the polyhouses, picking containers, packing shed, pre-cooler, and cold room. Packing containers, packing line components, and cold room floors and walls should be cleaned periodically with chlorine solution to reduce populations of decay organisms.

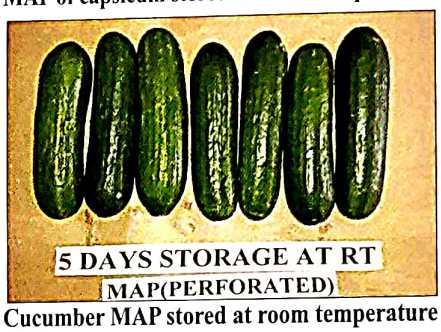
H. Methods to extend the storage life

a) Modified Atmosphere Packaging:

Modified atmosphere packaging (MAP) involves the use of polymeric films to create a modified atmosphere around the fresh produce that is high in CO_2 and low in O_2. The plastic film also acts as a barrier to minimize water loss from the packed produce. The storage life of capsicum could be extended to 21 days and 8 days at 7°C and ambient temperature (28 -32°C) respectively by MA packing in 100-gauge PE bags. At 8°C, fruits could be stored for 3 weeks packed either in polyethylene (PE) or D-955 film followed by 3 days at ambient temperature. MA packing reduces the weight loss to minimum compared to non-packed fruits at all the storage temperatures. Chilling injury (CI) develops when the fruits are stored at 5°C. However, alleviation of CI and extension of storage life of fruits to 5 weeks at 4°C can be achieved by packing the fruits individually in 100-gauge polyolefin film.



MAP of capsicum stored at Room temperature



Cucumber MAP stored at room temperature

The storage life of cucumbers could be extended to 20 days by modified atmosphere packaging with low density polyethylene film and storing at 10°C. MAP greatly reduces the weight loss and maintain the firmness during storage.

Storage life of breaker stage harvested tomato fruits can be extended to 6 weeks by MAP in Polyethylene (25 micron/ 100gauge) bags and storing at 12±1°C. Turning stage tomatoes could be stored for 21 days at RT (24 to 30°C) by the MAP. Storage life of the fruits harvested at turning stage, precooled to 12°C and stored in bulk in plastic crates (20 kg capacity) with flexible film lining can be extended to 30 days at 12±1°C.


Cucumber packed in polythene cover

Weight loss (%) of MA packed capsicum stored at different temperatures

Method	Storage period	
At 5°C	**5 weeks**	**5 weeks at LT + 2days at RT**
MA Packed	0.69	0.83
Control	9.76	13.48
At 8°C	**3 weeks**	**3weeks at LT + 3days at RT**
MA Packed	0.69	1.10
Control	19.43	23.25




Pre-cooling of tomato before storage

Pre-cooled tomatoes stored at 12°C for 1 month

b) Shrink wrapping techniques

A method for extension of storage life of capsicum by overcoming the problem of shriveling due to water loss has been standardized using Shrink Wrapping (SW) technique. It can be done as individual, unit or even box wrapping. In this technique, an individual fruit or group of capsicum or entire CFB box (in which capsicums are packed) is loosely sealed in a flexible film using an L-sealer and the packs are then passed through a heat-shrunk tunnel where they are exposed to hot blown air for a few seconds. The loosely sealed film shrinks tightly over the produce in the shrink tunnel and comes out tight-wrapped. This method prevents weight loss by reducing the transpiration rate and maintains fruit firmness as in harvest fresh condition.

At room temperature, shrink wrapped capsicum could be stored for 2 weeks with least weight loss and quality deterioration as compared to the non-wrapped fruits which are rendered unacceptable within 4 days of storage due to shriveling. At 7°C, shrink wrapped capsicum could be stored for 50 days with harvest freshness and least weight loss (< 1 %) as compared to 14 per cent weigh loss in non-wrapped fruits. About 90 per cent of the shrink-wrapped fruits are marketable with 2 days of shelf life at ambient temperature after removal from low temperature storage.

Shrink wrapping facilitates to extend the period of retail marketing by greatly reducing the weight loss and maintaining the freshness for longer periods. Good potential for this technology is envisaged based on the better consumer response for fruit quality.



Steps followed in shrink wrapping of capsicum

Shrink wrapped colored capsicum fruits

Shrink wrapped and non-wrapped capsicum fruits after storage

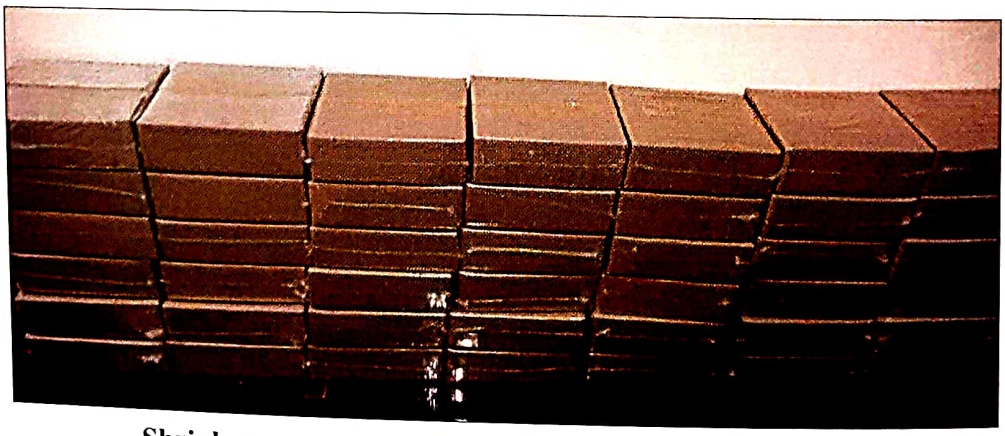
Weight loss (%) of individually shrink wrapped capsicum

Storage Method	Storage period (days)	PLW (%)	Un-marketable fruits (%)
Room temperature (22-30°C)			
Shrink wrapped	14	2.22	3.72
Non-Wrapped	14	28.97	100
Low temperature (7°C)			
Shrink wrapped	50 +2	0.98	10.69
Non-Wrapped	50 +2	14.71	100

In case of unit shrink wrapping (2, 4 and 6 fruits) of red and yellow capsicum; the shelf life could be extended for only 5 days against 10 days in case of individually wrapped fruits. Similarly, at 8°C, Unit shrink wrapped red and yellow capsicum could be stored for 5 weeks against 7 weeks in case of individually wrapped fruits.

Shrink wrapped colored capsicum after 5 weeks of storage at 8° C

Shrink wrapping technique can also be used to overwrap the entire CFB boxes in which the capsicums are packed (see below photograph). Colour capsicum (Red and yellow) packed in CFB boxes and shrink wrapped with semi permeable films could be stored for 8-11 days at ambient temperature (25.7-33.2°C)



Shrink wrapped individual boxes with capsicum fruits



and with a weight loss of only 6% as compared to 20% weight loss in non-wrapped capsicum for the same period. Similarly, at 8°C, box wrapped colour capsicum could be stored for 5 weeks without any shriveling with a weight loss of about 5%.

Box shrink wrapped capsicum fruits after 11 days of storage at room temperature

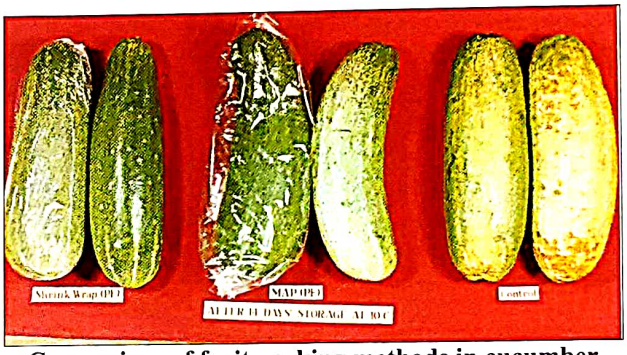
Non-wrapped capsicum fruit box after 11 days of storage at room temperature

Box shrink wrapped capsicum fruits after 5 weeks of storage at 8° C

Non-wrapped capsicum fruits after 5 weeks of storage at 8° C

Cucumber

The storage life of cucumber could be extended to 3 weeks at 10°C by MA packing in flexible films with retention of freshness and tenderness. Individual shrink-wrapping with semi-permeable films also helps to retain the green colour and maintains texture with least weight loss for 10 days at ambient temperature.



Comparison of fruit packing methods in cucumber

Shelf life and weight loss of packed cucumber

Packing and storing method	Storage life (days)	Weight Loss (%)
MA packed RT	7	0.46
Shrink-wrapped RT	10	0.54
Non-packed RT	3	7.17
MA packed 10°C	21	0.48
Shrink-wrapped 10°C	24	0.68
Non-packed 10°C	5	5.45

Similarly, English cucumbers packed in CFB boxes and over (shrink) wrapped with semi permeable films could be stored for 1 week at RT (25.0-29°C & 45-65% RH) and 3 weeks at 13°C without shriveling and with maintenance of firmness and green colour.

Box shrink wrapped cucumber fruits after 7 days storage at room temperature

Box shrink wrapped cucumber fruits after 12 days storage at 13° C

Flow chart of BetterPost-Harvest Operations

Harvesting at right Maturity

⇩

Careful harvesting and handling

⇩

Sorting to remove non-preferred fruits

⇩

Grading based on market demand to fetch better price

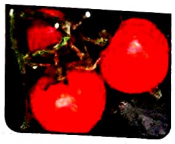
⇩

Right kind of packaging for protecting and maintaining freshness

⇩

Storage at optimum conditions for extending life and long-distance transport

Attractive and consumer friendly packaging of cantaloupes for better marketing



Annexure – I

1. Enrichment of FYM with Bio-pesticides and Bio-fertilizers

Application of Farm Yard Manure (FYM) to the main field should also be incorporated after enrichment with the following bio-agents and bio-fertilizers. 1) *Trichoderma harzianum,* 2) *Pseudomonas fluorescens,* 3) *Paecilomyces lilacinus,* 4) *Pochonia chlamydosporia, 4) Azotobacter or Azospirillum* and 5) VAM and 6) Phosphate Solubilizing bacteria (PSB) all @ 1-2 kg/ton of FYM. After application of these bio-agents and bio-fertilizers, FYM is thoroughly mixed and moistened by sprinkling water and covered wet gunny cloth and kept for incubation for 15 to 20 days under shade, in a rain protected place. This enriched FYM should be applied to the soil bed and bed should not be allowed to dry after application.

At the time of mixing, substrate should be in powder form and it should not have excess moisture, when held in hand and left, it should flow freely. After mixing bioagents, cover the enriched heap with coconut fronds or shade net or any material to provide shade and store it for 15 days. Turn enriched FYM with spade every two to three days to facilitate aeration in heaps. While turning water has to be added to maintain optimum moisture. Enrichment should be always done in shade. Care should be taken to avoid excess moisture in compost/ FYM/ Neem cake during enrichment period. Excess moisture promotes growth of undesirable organisms during enrichment.

2. Neem cake Enrichment and its application in the main field

Enrichment of neem cake with bio-pesticide is a useful practice, as it would supplement the bio-pesticides applied through enriched FYM and facilitates faster multiplication of beneficial microbes to increase their population rapidly on the crop beds. Twenty-five to thirty days before transplanting, mix the following bio agents @ 2-3 kg each to about 150 Kg of powdered and moistened neem cake. 1) *Trichoderma harzianum,* 2) *Pseudomonas fluorescens,* 3) *Paecilomyces lilacinus,*4) *Pochonia chlamydosporia* and 5) *Bacillus subtilis.* Two to three days before transplanting, this enriched neem cake is added to 650 Kg of Neem Cake to make it a total of 800 kg enriched neem cake, which should be applied to 1 acre area on the crop beds uniformly and covered with the soil. Then other inputs can be added on the beds, before transplanting. Optimum moisture should be maintained on the crop beds, till the transplanting is completed.

Mix 2 – 3 kg each of bio-pesticide *Paecilomyces lilacinus* or *Pochonia chlamydosporia* + *Pseudomonas fluorescens* + *Trichoderma harzianum* or *T. viride* in 800 kg of moistened neem cake

↓

Leave it under shade for 2 to 3 weeks and cover it with leaf mulch or soil or polythene sheet.

↓

Maintain optimum moisture of 20-25% and mix it thoroughly from top to bottom once in 3 days.

↓

After 15 to 20 days, neem cake gets enriched with billions of propagules of bio-agents and it is ready for use for one acre area.



Enrichment of neem cake with bio-pesticides

Preparation of enriched neem cake suspension

Enriched neem cake with bio-pesticides

3. Preparation of Jeevamrutha solution

Day 1:

1. Take the following materials:

   10 Kg fresh cow dung +10 litres fresh cow urine +2 kg horse gram floor 2 kg Jaggery +1 Kg native soil in the 200 litres of water
2. Mix them together in a plastic drum so as to dissolve them in 200 litres of clean water.
3. Keep it inside the polyhouse or in safe, covered shaded place. Cover with lid or clean gunny bag.
4. Open the cover and keep stirring the solution three to four times a day, by turning the solution with wooden stick. Avoid use of metal container for preparation of Jeevamrutha. Cover the drum again with gunny bag or lid.

Day 3:

1. Mix 2 Kg each of Arka *Trichoderma harzianum*, Arka *Paecilomyces lilacinus* and Arka *Pochonia chlamydosporia* in Jeevamrutha solution by stirring continuously for few minutes.

Day 5:

1) Mix Jeevamrutha solution thoroughly and take the solution in a plastic bucket and drench 50 to 100 ml solution per plant, using stainless steel or plastic mugs, directly to the root zone.
2) Before drenching of Jeevamrutha, keep the soil in moist condition by irrigating.

Jeevamrutha solution can be applied to the crops every month, starting from 1 month after planting. However, care should be taken to avoid excessive usage, as it adds higher nitrogen, leathery growth of leaves and may cause reduced availability of trace or micro-nutrients to plants.

Precautions to be taken while preparing and applying Jeevamrutha solution

1) Wash the drum, before mixing of the materials. Prepare the solution in a clean drum with clean water. This is essential to avoid any chemical or other residues in the drum.
2) Always use fresh and clean water, fresh cow urine and cow dung and other materials and good quality fresh bio-pesticides from known sources, while preparing the solution, to ensure good quality of Jeevamrutha solution.
3) Do not mix any other products and solutions with Jeevamrutha solution, so as to avoid the negative effect on the solution and to prevent toxicity or scorching on the plants.
4) Keep the solution under shade and do not expose it to direct sunlight.
5) Apply fresh Jeevamrutha solution every time and avoid storing the solution beyond 7 days.

4. Procedure for preparation of poison baiting:

Poison baiting with Methomyl is a good and safe practice to kill the borers of Spodoptera Spp and to prevent their multiplication. Since they (larva) are nocturnal in nature, poison baiting is an effective and safe method than spraying of chemical pesticide. Prepare a mixture of 10 kg rice flour with 2 kg jaggery solution and store for 8-10 hours for fermentation. Add ¼ kg Methomyl to this mixture and keep it for 1 hour. Small sized balls are made from the mixture, in hand. These balls are spread near root zone of the



plants and also around poly house/ net-house to avoid infestation of fruit borer. It should be applied during evening hours. While preparing and applying the baiting mixture, use hand glouse, goggles and face mask, for safety of the worker. After spreading of bait, domestic or pet animals should not be allowed to move in and around the net/polyhouse overnight. As Methomyl is highly poisonous, all precautions and safety measures mentioned for using Methomyl should be strictly followed.

5. Preparation and Application of Bordeaux mixture

Materials required for preparation of 1% 100 litre solution

1) 1 Kg Copper Sulphate ($CuSo_4$) + 1 Kg lime + 100 litres water + New blade/ Knife

Steps in Preparation

- Dissolve 1 Kg copper sulphate in 40 litres of water and 1 kg Lime in 40 ltr of water separately in two plastic containers. Soak it separately for overnight. Warm water can be used during winter season, as the copper sulphate dissolves slowly in cold water.
- Keep stirring the solution to ensure that the $CuSo_4$ and lime dissolves completely
- Lime solution should be passed through a strainer, for filtering the solution and get clear and completely dissolved solution.
- Make it to 100 litre solution by mixing both the solutions ($CuSo_4$ and lime) by pouring into one bigger separate plastic container with 20 litre water, simultaneously. Add copper sulphate solution to the lime solution slowly and stirring should be done constantly.
- Keep stirring the solution repeatedly during and after pouring them into one container, so as to get clear and completely mixed solutions
- Always use non-metallic vessel while mixing both the solutions together into a third container
- Once the solution (Bordeaux mixture) is ready, use it within few hours of its preparation. Therefore, prepare only the required quantity of solution and do not store it.
- Make up the volume to 100 litres after testing the neutrality.

Testing of quantity of copper in the mixture

It is essential to know whether the Bordeaux mixture solution has any excess copper. It can be easily be detected by dipping pH paper or sharpened knife or bright iron piece for about one minute. If solution has excess copper, it gets deposited on the blade / knife / iron piece, which may be neutralized by adding some more lime to the mixture. Testing the Bordeaux mixture solution should be done before its application on the crop.

Precautions to be taken while preparing and applying the solution

- ✓ Avoid use of metallic vessels for preparation of the Bordeaux mixture solution.
- ✓ Spraying and Drenching 1% Bordeaux solution should be done during cool hours. Do not spray or drench when it is raining or during noon time, when temperature is high.
- ✓ Use fresh solution for drenching and spraying and do not store the solution.
- ✓ Do not mix Bordeaux mixture with any other insecticides or herbicide.



Annexure II

General information about protected cultivation of vegetables

1. Soil based production / Ground Culture

Ground culture of greenhouse vegetable crops involves growing crops directly in the natural soil under the greenhouse cover. Plants are oriented in double rows, and irrigation is handled through the use of proportioning pumps, injection pumps, or large nutrient storage tank with sump pumps. Drip or ring emitters are placed at the base of each plant to provide water and nutrients. In-ground culture, for certified organic growers, using protected culture with permanent structures is very challenging and requires significant additions of organic amendments. In areas which have sandy soil profiles with fluctuating water tables, excessive nutrient levels could leach into local groundwater tables or accumulate in the soil surface. The high-water table could also cause periodic flooding.

Although costs of establishing the operation are extremely high, the return from the crop can be good. Profitability depends on how successfully the individual manages the operation and markets the crop. For example, coloured capsicum crop should yield about 2.5 3.0 kg of A Grade fruits per plant. At a price of Rs.50 per kg, farmers can get a gross income of Rs.15,00,000/- per acre (4000 sq.mt with 12,000 to 12,500 plants). Yields and returns on this order of magnitude have only been achieved by the most experienced growers in India. Therefore, the potential grower must be realistic in setting income goals for a greenhouse operation. It is especially critical if the operation is to be financed by a lending institution.

2. General Harvesting and Handling of vegetables grown under polyhouse:

Harvesting of tomato, pepper, melons and cucumber will be a continual process throughout the growing cycle. Tomatoes and peppers are harvested with stems attached and are packed that way to avoid bruising and damage. Care should be taken so that tomatoes are not stored or transported with other vegetables such as peppers, lettuce or cucumbers. Tomatoes produce ethylene during the ripening process that can damage other vegetables. Harvesting should be done during the cooler period of the day and vegetables should be protected from heat. Harvested material should be pre-cooled as soon as possible if this is part of the postharvest procedure. Few important tips for good post-harvest management are:

- ✓ Use clean and good quality secateurs while harvesting fruits, to avoid scratching or damage to fruits.
- ✓ Harvest completely matured fruits/produce at right stage as per the market demand. Morning hours are very ideal for harvesting and good for better PHM. Harvest all the matured fruits, ready for marketing. Avoid staggered harvesting, as it would create imbalance in further harvesting and affected plant health, if next harvest is delayed.
- ✓ Grading of fruits/ produce is essential and it should be done with utmost care and as per the market standards and requirement. Market requirements and standards are available for different crops and markets. Clean the hand at regular interval to avoid infection.
- ✓ Packing of graded fruits should be done neatly in the new 5 or 7 ply CFB cartons or in plastic crates, as per the requirement of marketer. It should be done in the shade or in covered place to avoid sun scorching or rain damage.



- ✓ Dispose off the damaged, rotten and rejected fruits, immediately after grading and packing of good fruits. Maintain cleanliness and good hygienic condition at harvest, grading and packing places. Pre-cooling of produce can be done, if facility is available.
- ✓ Handle the packed produce carefully while loading and avoid damage to the packs or carrying materials. Transport the produce during evening hours and avoid during mid-noon hours.

Follow all these good harvesting, PHM and marketing practices to get more market demand and better price for the produce and to avoid the post-harvest loss and rejection by the marketer. Details of good post-harvest management practices for vegetables grown under protected environment is given in the separate chapter 15 (Refer Page No. 74).

3. Economics of Greenhouse Vegetable Production:

Greenhouses are expensive to build and operate. The commercial greenhouse of one acre with shade nets and foggers, fertigation and ventilation systems will cost between Rs. 35 to 40 lakhs to erect and equip. On the other hand, one-acre low cost naturally ventilated simple greenhouses - like stone or wooden pole and plastic or nylon net houses can be constructed for Rs. 12 to 14 lakhs. On an average five labourers per day per acre are required for proper crop care and upkeep. In order to keep the maintenance cost as minimum as possible, areas with minimum extremities of weather conditions such as Bengaluru, Pune, Nasik and surrounding places, are ideal for year-round polyhouse production of vegetables. As the cost of cooling is quite high, regions with hot summer conditions will add to the production costs making the commercial vegetable production an economically viable proposition provided the market prices for the produce fetches higher premium price.

All the PCV farmers compulsorily keep three points in mind, to make it an economically viable proposition. 1) Total involvement in all the activities at all stages from selection of land, soil, crop, variety to construction of structure to crop management practice to harvesting to PHM and marketing, 2) Holistic management of crop, with no chance for any lenience /lapses in adoption of all recommended package at right stage and time, 3) Harvesting crop at right stage regularly and selling the produce to the right person, preferably with pre-production market tie-up and 4) Use of quality inputs with relevant and right dosage, which are blended with organic / botanical products from known sources. This will help the farmer to reduce the input cost, increase the total and good quality yield and enhance the profitability. Profitability of the protected cultivation of vegetable crops depends on multiple factors. Among these important contributing factors include 1) Total yield and grade of the produce- Focus on getting 85-90% A grade produce, 2) Price per unit (Kg)- Farmers can grow any crop, provided if he gets at least Rs.30/- per Kg in all seasons and he should get minimum 40 tons A grade yield per acre 3) EMI to be paid to the Bank / lending institution – Farmer should take lowest possible amount of loan, so that EMI will also be less and he can clear the loan as early as possible and 4) Per Annum per acre gross income should be at least Rs.15,00,000/- (Fifteen Lakhs Only). So that, he can get at least Rs. 6,00,000/- (six Lakhs Only) annual net income per acre, excluding all the expenses.

4. Minimum precautions to be taken in protected cultivation

- ✓ Apply correct amount of irrigation water (neither less nor more) and avoid pouring extra water
- ✓ Maintain proper humidity. High or low humidity enhances pollination problem
- ✓ Maintain proper temperature inside the structure. High temperature leads to dropping of flowers and thus reduces yields.

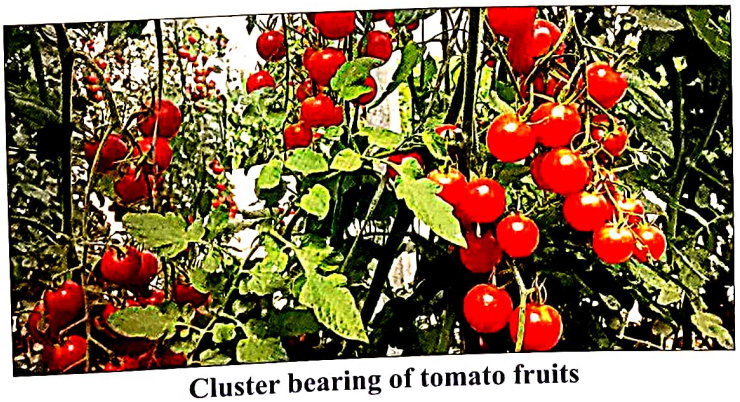


- ✓ Select disease resistant varieties in different vegetable crops, to reduce the incidence of pests and diseases and the cost of crop management
- ✓ Immediate identification of occurrence of all pest and disease in the greenhouse is essential; otherwise, it spreads very rapidly and makes control difficult and expensive.
- ✓ Use double door system in the greenhouse, compulsorily to avoid entry of pests and diseases
- ✓ Plant crops with reduced spacing (both plant to plant and row to row) in the greenhouse compared to open field. This will enhance crop yield and productivity.
- ✓ Do not enter the greenhouse without work.

5. Tips for More Income from Greenhouse

- ✓ Always plan for production of off-season crops.
- ✓ Plan your crop in such a way that your produce should reach the market when there is maximum demand for it.
- ✓ After the first harvest, take the ratoon or plant next crop with less lag time
- ✓ Reduce plant and row spacing inside the green house and get more yield.
- ✓ Maintain the complete plant population always by fully utilizing the green house space. Do not keep blank space.
- ✓ Take immediate measures for plant protection, whenever problem is traced. Greenhouse workers should be able to identify the pest and disease so that as soon as the first symptom in the house is noticed, spraying can be taken up. It spreads in a short time otherwise.
- ✓ Apply organic manures in sufficient quantity to maintain the soil health, in addition to the chemical fertilizers in order to sustain the soil fertility and crop productivity.
- ✓ Solarize the land inside the structure for about two to three weeks, after at least six months of crop period, in order to make the land free from pests, germs, etc.
- ✓ Follow proper crop rotation. Avoid mono cropping for long duration.
- ✓ Take short term training for green house cultivation before going for commercial crops in green house.

Conclusion: Although greenhouse production is an intensive enterprising activity, it can be very satisfying and rewarding. One advantage of greenhouse vegetable production is the relatively small amount of area required compared to open field production to achieve the similar targeted yield and the produce will be of superior quality. In addition, the return on investment can be good if the requisite markets can be found.

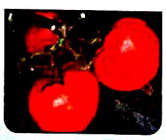


Cluster bearing of tomato fruits

Annexure - III

Important safety and precautions to be taken in protected cultivation of vegetable crops

- ✓ Use safety kits (gloves, goggle, face masks) and other safety equipments to ensure complete covering of the body, while spraying, drenching and carrying out other works in the polyhouse
- ✓ Do not mix chemicals / pesticides / fertilizers in bare hand. Always use gloves for mixing as well as during spraying/ drenching chemicals
- ✓ Do not mix and use non-compatible chemicals as well as unknown products with any chemicals or spray / drenching solutions, as it causes scorching and phytotoxicity
- ✓ Keep the main doors (double door entrance) always closed. Use the door only for essential operations/ activities and minimize the opening and closing of doors
- ✓ Do not allow weeds to grow, as they host and the source of pests and diseases in the polyhouse, as well as in the surrounding areas of polyhouse
- ✓ Prepare and use fresh solutions for spraying or drenching and avoid use of stored spray / drench solutions of chemicals or other bio or organic products
- ✓ Use movable (manually drawn or motorized) trolleys during tying of supporting wires/ threads/ clips, training and pruning, harvesting in grownup plants, etc. for safety of the labour and to prevent the physical strain
- ✓ Use of tobacco products and eating of foods or snacks / drinking of water or other drinks should be banned inside the polyhouse
- ✓ Do not allow any pet animals inside the polyhouse, particularly after spraying and drenching of chemicals
- ✓ Do not store any chemicals, fertilizers, boxes or any products and materials either near the doors or inside the polyhouse. Keep them safely in a separate store room and take out and use them, when they are required.
- ✓ Drip lines should be operated at regular and required time only. Avoid excessive irrigation and water stagnation inside the polyhouse.
- ✓ Keep the polyhouse structure, including shade net, polyethylene sheet and side nets in good condition, without any tearing or openings or holes.
- ✓ Do not mix chemical pesticides with any fertilizers, either for spray or for drenching. Take the expert advice, while mixing the fertilizer combinations for fertigation.


ರಾಷ್ಟ್ರೀಯ ತೋಟಗಾರಿಕೆ ಮಿಷನ್ (NHM)

ಕಾರ್ಯಕ್ರಮಗಳು

1. ರೈತರಿಗೆ ಉತ್ತಮ ಗುಣಮಟ್ಟದ ಕಸಿ / ಸಸಿ ಗಿಡಗಳನ್ನು (Good quality planting material) ಒದಗಿಸಲು ಸಸ್ಯಾಗಾರ ಸ್ಥಾಪನೆಗೆ ನೆರವು
2. ಹೊಸ ಅಂಗಾಂಶ ಕೃಷಿ ಘಟಕ ಸ್ಥಾಪನೆಗೆ (Establishment of New Tissue Culture unit) ನೆರವು
3. ತರಕಾರಿ ಬೀಜೋತ್ಪಾದನೆಗೆ (seed production for vegetables) ನೆರವು
4. ತೋಟಗಾರಿಕೆ ಬೆಳೆಗಳ ಬೀಜ ಸಂಸ್ಕರಣೆಗಾಗಿ ಮೂಲಭೂತ ಸೌಕರ್ಯ ಅಭಿವೃದ್ಧಿಗೆ (Seed infrastructure for processing, packing, storage etc) ನೆರವು
5. ಹೊಸ ತೋಟಗಳ ಸ್ಥಾಪನೆಗೆ (Formation of new orchard) ನೆರವು
6. ಹಳೆಯ ತೋಟಗಳ ಪುನ:ಶ್ಚೇತನಕ್ಕೆ (Rejuvenation of old orchard) ನೆರವು
7. ಅಣಬೆ ಕೃಷಿಗೆ (Mushrooms production) ನೆರವು
8. ನೀರಿನ ಮೂಲಗಳ ನಿರ್ಮಾಣಕ್ಕೆ (Creation of water resources) ನೆರವು
9. ಸಂರಕ್ಷಿತ ಬೇಸಾಯ ಕ್ರಮಕ್ಕೆ (Protected cultivation) ನೆರವು
10. ಸಮಗ್ರ ಪೋಷಕಾಂಶ, ಕೀಟ / ರೋಗಗಳ ನಿರ್ವಹಣೆಗೆ (Integrated Nutrient / Pest Management) ನೆರವು
11. ಜೇನು ಸಾಕಾಣಿಕೆ ಮೂಲಕ ಪರಾಗಸ್ಪರ್ಶ ಅಭಿವೃದ್ಧಿಗೆ (Apiculture) ನೆರವು
12. ತೋಟಗಾರಿಕೆಯಲ್ಲಿ ಯಾಂತ್ರೀಕರಣಕ್ಕೆ (Farm mechanization) ನೆರವು
13. ಮಾನವ ಸಂಪನ್ಮೂಲ ಅಭಿವೃದ್ಧಿಗೆ (HRD) ನೆರವು
14. ಕೊಯ್ಲೋತ್ತರ ನಿರ್ವಹಣೆಗೆ (Post Harvest Management) ನೆರವು
15. ಶೀಥಲ ಗೃಹ ನಿರ್ಮಾಣಕ್ಕೆ (cold storage) ನೆರವು
16. ಮಾರುಕಟ್ಟೆಗಳಲ್ಲಿ ಮೂಲಭೂತ ಸೌಕರ್ಯಗಳ ಸ್ಥಾಪನೆಗೆ (Market infrastructure) ನೆರವು

ಹೆಚ್ಚಿನ ಮಾಹಿತಿಗಾಗಿ ಸಂಪರ್ಕಿಸಿ:

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Greenhouse Production of Capsicum, Tomato, Cucumber and Muskmelon

ICAR- Indian Institute of Horticultural Research
Hesaraghatta Lake Post, Bengaluru – 560089

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MESSAGE

Globally, India is the second largest producer of vegetables. It is extensively promoting GAP's in both open and protected cultivation of large number of vegetables through effective spreading of innovations in crops, varieties, production techniques, PHM and marketing strategies. Farmers are also engaged in adoption of these innovations to produce pesticide residue free, good number of Indian and exotic vegetables round the year as well as during off-season across the states. This is triggered by use of good number of high yielding hybrids of both public and private sectors along with holistic production package in open and green house production of vegetables.

Green house production of vegetables has multiple advantages such as higher productivity, good quality with residue free produce, intensive input management for extended period of harvest (as high as 8 to 11 months), continuous production of diversified best quality vegetables round the year to cater high demanding elite urban domestic markets and also the export markets of various countries. Keeping in view the demand for GAP's in protected cultivation of vegetable crops by the farmers, the ICAR- Indian Institute of Horticultural Research, Bengaluru has developed and popularized the technology to a large number of farmers. Adopting this holistic package of the institute, greenhouse farmers are not only getting a very high yield, better quality crops and enhanced gross and net-income, but are saving cost, reducing chemical usage and helping the ecosystem services. I am happy that our multi-disciplinary team of scientists of the institute are able to prepare a very good scientific documentation of this holistic package in the form of technical bulletin on greenhouse production of four important vegetable crops such Capsicum, Tomato, Cucumber and Muskmelon, which are extensively cultivated under greenhouse condition.

I hope this publication of ICAR-IIHR will be very useful as a ready reckoner for our farming community and to all the practitioners of greenhouse cultivation of vegetables in the country. I appreciate the efforts of our scientists, researchers and other contributors in compiling all the relevant information and presenting in a simple language with brief, understandable and effective manner. It will go a long way to support the cause of our farmers and also contribute for overall development of protected cultivation industry in the country.

(M. R. DINESH)
Director, ICAR-IIHR, Bengaluru.

February 2021
Bengaluru



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Government of Karnataka
Department of Horticulture

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ನಿರ್ದೇಶಕರು

B. Fouzia Taranum, I.A.S.
Director

MESSAGE

Karnataka state is one of the leading state and exemplary in many areas of horticulture, producing a large number of crops with highest production and productivity in many horticultural crops in the country. The state is the pioneer in promoting greenhouse technology in the country, since 90's. Hence, there is lot of diversity in crops and production techniques adopted by a large number of farmers and entrepreneurs in the state, which led to achieve the higher production with the best quality produce to cater the needs of domestic as well as export markets across many states and continents. This is made possible due to various synergy programmes of the department with many institutions dealing with research, development, finance and extension with a strong inter-institutional linkages, in addition to a large number of developmental programmes and schemes like NHM, PMKSY, CHD, RKVY, Krishi Bhagya, etc. implemented by the department for the benefit of our farming community. These programmes also facilitated adoption of innovations in many crops and areas of production, including precision farming and protected cultivation.

In the area of greenhouse production or protected cultivation, institute like ICAR-IIHR, Bengaluru has developed good number of technologies, which along with many developmental programmes and schemes of the department such as RKVY, NHM and Krishi Bhagya have given our farmers a big advantage to effectively utilize both financial and technological support. So that many constraints in the field are overcome to achieve higher yields with best quality produce. Greenhouse cultivation is used for multiple purpose such as production of quality seeds, seedlings and other planting materials and many ornamental, plantation, spices, medicinal and vegetable crops by > 15,000 farmers across the state. Yet, there is lot of opportunities to expand the greenhouse production in the state, including soilless culture.

The publication on Greenhouse Production of ICAR-IIHR, Bengaluru brought out under KSHM-IPM scheme, covering all aspects of crop production, crop protection, post-harvest management and good marketing practices on four commercially important vegetable crops is a very useful and comprehensive book, which contains easy to adopt practices, which can be used for commercial production by the farmers. It is also a very useful guide for the officers of the department, field executives of corporate companies, entrepreneurs and all those interested in protected cultivation of vegetable crops. I congratulate and appreciate the efforts of Director of ICAR-IIHR, Bengaluru and his team of scientists in bringing out this useful book at right time. I hope this publication will help a large number of farmers and other stakeholders of protected cultivation industry across the country.

With Best Wishes,

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Plant a tree, plant a new life...




MESSAGE FROM AUTHORS

Greenhouse production in India has started during early 90's with commercial cultivation of Roses and diversified with various commercially viable crops. However, commercial greenhouse cultivation of vegetable crops started in many parts of the country on small scale during 2001-05, after many technologies were developed and released under NATP projects. But, area under greenhouse production (GHP) of vegetables expanded quickly from 2010-11 due to good financial support from many government funded schemes of state horticulture departments (VIUC, NHM, RKVY, Krishi Bhagya, etc.), NHB, NABARD and other institutions. Simultaneously, production techniques were also extended by ICAR institutes, SAU's under various schemes and programmes by undertaking many field-based outreach programmes and made GHP commercially viable, even for a farmer with 500 sq.mt protected structures from Kerala to Kashmir and from NEH region to Rajasthan.

Using the information available from various research experiments, trials and demonstrations, the ICAR-IIHR has published a technical bulletin on GHP of Capsicum in 2011, which is being used today by >2,50,000 farmers across the globe. Since then, there was a sustained demand for similar publication with holistic package for important vegetables grown under protected environment. Keeping in view the practical needs of farmers, field executives and officers of developmental departments and corporate companies, entrepreneurs, practitioners, startups and all other stakeholders of protected cultivation industry, this publication on greenhouse production of important vegetable crops is planned with holistic package covering all aspects of crops production, crop protection, post-harvest management and marketing practices. This publication is a good compilation of the research experiments in the institute, with compiled and scientifically analyzed data of multi-location trials and demonstrations in research stations and farmers fields and experiences of all the scientists working on protected cultivation.

This publication is a unique one because of its practical relevance of each topic presented in most scientific, understandable and brief manner. In each chapter, all the essential information, technologies, process and practices are explained very clearly. We have also made an effort to include the latest information and technologies available in each aspect covered in the publication. We hope that our long-time effort to bring out this publication will be very useful to everyone concerned with protected cultivation industry. We express our heartfelt gratitude and sincerely acknowledge all the scientists, researchers, other individuals, institutions and sources, who/which have shared their information, experience and knowledge in bringing out this good publication.

- AUTHORS



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The technical bulletin on **"Greenhouse Production of Capsicum, Tomato, Cucumber and Muskmelon"** is prepared by multi-disciplinary team of scientists of ICAR-IIHR, Bengaluru with the help, guidance, technical input and support from many individuals and institutions. We would like to acknowledge all those persons and institutions whose contributions immensely helped us in bring out this useful publication.

We express our deep sense of gratitude and sincere thanks to Mission Director and Director of Horticulture, Additional Director and Executive Directors of Karnataka State Horticulture Mission (KHSM), particularly Dr. K.B. Dhundi and Dr. K. Parashivamurthy, Department of Horticulture, Govt. of Karnataka for facilitating and extending all support and cooperation along with their officers of 16 project districts. We duly appreciate their efforts in providing both personnel, particularly services of Deputy Directors' of Horticulture of all 16 districts of Karnataka state and their field executives, and financial support to bring out this publication. Heartfelt thanks are also due to all of them for helping in implementation of KSHM-IPM project in farmers' polyhouses.

We express our sincere gratitude and thanks to Dr. M.R. Dinesh, Director, ICAR-IIHR, Bengaluru and Director of ICAR-NBAIR, Bengaluru for their open hearted help, cooperation and support in sparing the services of the scientists in making this publication possible and also in planning and implementation of various activities of KSHM-IPM project in farmers' polyhouses

Contribution of all the project team members such as Dr. V. Sridhar, Dr. D V Sudhakar Rao, Mr. Sandeep Kumar, G. M., Dr. Uma Maheshwari, Dr. Debi Sharma, Dr. A. Kandan, Dr. Richa Varshney, Dr. Anilkumar Nair and Dr. Mahesha B. is highly appreciable who have provided the required technical information and services, analysis of samples and all the data of the project, which helped in improving the quality of this technical bulletin.

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Dr. Shankara S Hebbar
Dr. B. Balakrishna



CONTENT