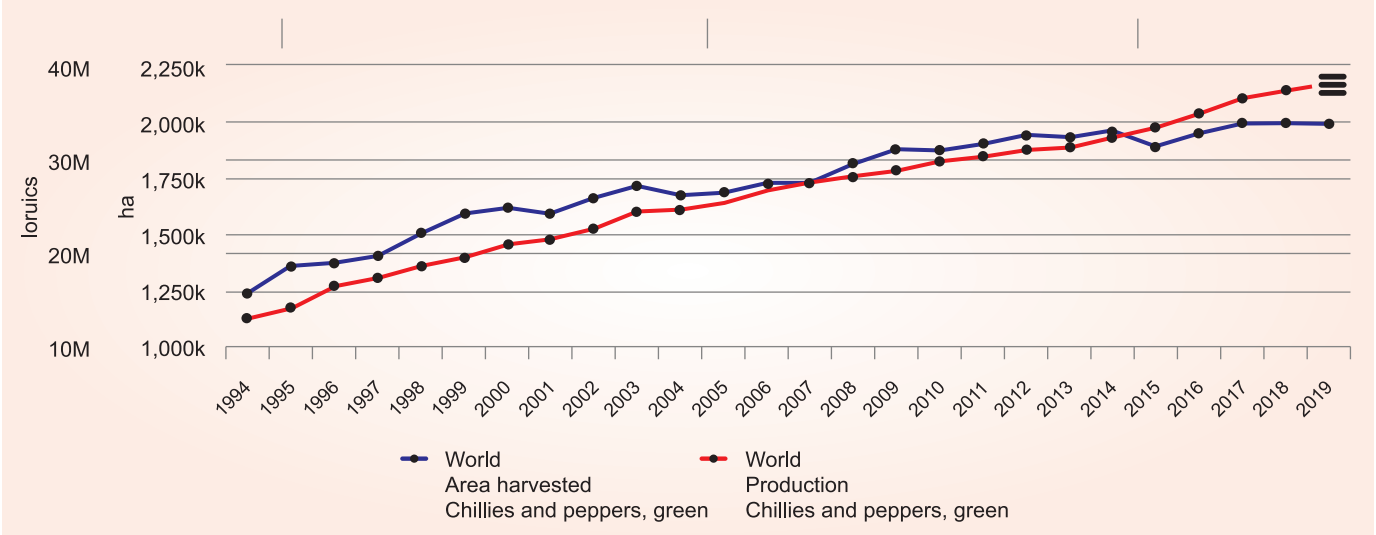
Hemlata Bharti*, M C Singh, P K Singh, K P Sahana and Indra Mani Mishra

Hi-Tech cultivation of capsicum

Capsicum (sweet pepper or bell pepper) is a high-value greenhouse crop widely cultivated in temperate zones than in the tropics. The name capsicum is derived from Greek word kapto, meaning to bite or to swallow. Despite being a single species, C. *annuum* has many forms, with a variety of names, even in the same language. The official names in American English is *sweet pepper,* any variety lacking heat, and those sweet peppers that have a blocky-shape are referred to as *bell peppers,* whereas, variety that produces *capsaicin* is known as a *hot pepper* or *chili pepper*. In *British English*, the sweet varieties are called peppers and the hot varieties as chillies, whereas in Australian English and Indian English, the name capsicum is commonly used for bell peppers exclusively and chilli is often used to encompass the hotter varieties.

CAPSICUM species are members of the Solanaceae family which includes tomato, potato, tobacco, and petunia. This genus contains about 31 species of which five are domesticated, namely *C. annuum, C. frutescens L., C. chinense Jacq., C. baccatum L.,* and *C. pubescens R.* and 25 wild species. Mexico is believed to be the centre of origin of *C. annuum*, whereas *C. frutescens* and the other cultivated species (*C. baccatum* var. *pendulum, C. chinense* and *C. pubescens*) originated in South America. By the mid-17th century Capsicum was being cultivated throughout southern and middle Europe as a spice and medicinal drug, with introduction of one species to Japan and five to India. One medium green capsicum can provide up to 8% of the recommended daily allowance of Vitamin A, 180% of vitamin C, 2% of calcium and 2% of iron.

Internationally Netherlands, Japan, France, Germany and United States are the leading countries in terms of area under protected cultivation. Fresh pepper is cultivated in 126 countries of the world in all the continents. The world's largest producer is China with over 18 million tons annually, followed by the Mexico with about 3.5 million tons. The maximum percentage of sharing for capsicum production is in Karnataka (Table 1) under protected cultivation. The Government of India has initiated a number of schemes and programmes namely Mission for Integrated Development of Horticulture (MIDH) by subsuming various schemes such as National Horticulture Mission (NHM), National Horticulture Board (NHB), Rashtriya Krishi Vikas Yojana (RKVY) and Horticulture Mission for North East and Himalayan States (HMNEH) for the promotion and development of protected cultivation.



Production share of hydroxyl by region Average (FAOSTAT 2019)

Table 1. Indian production of capsicum

State	Production ('000 Tonnes) 2017-18	
	Production	Share (%)
Karnataka	65.27	20.04
Himanchal Pradesh	57.76	17.74
Haryana	40.05	12.30
Jharkhand	33.03	10.14
Madhya Pradesh	2391	7.34
Maharashtra	22.96	7.05
Tamil Nadu	16.69	5.13
Uttarakhand	15.70	4.82
Jammu & Kashmir	13.63	4.19
Odisha	6.99	2.15
Total	**295.99**	

Source: NHB-2019

Climate

Temperature plays a key role in the flowering, fruit setting, seed setting, shape and number of fruits per plant in capsicum under protected condition. As seeds germinate best at 25-30°C where optimal temperatures for productivity should be between 18-30°C. The functioning of the female organs of flower are affected by low (14°C or less) night temperatures, and the number of viable pollen grains per flower reduce markedly which causes parthenocarpic (seedless fruit) effect and impairs germination. The fact of low night temperature effect is associated with reduced starch accumulation in pollen grains at 3 days before anthesis and a decrease of total soluble sugars in the mature pollen grains. To prevent the low night temperature affect during winter, exposing Capsicum plants to extremely high day temperatures (day/night temperatures of 36 ± 2°C), obtained by keeping the greenhouse closed during the day to exploit solar heating. Flower buds will usually abort when night temperatures reach 30°C.

Growing media

(i) *Soil system:* It can be grown from sea level to an altitude of zero meters in loam or sandy loam soil with good water holding capacity but soil pH should be 5.5 to 6.8 for successful capsicum cultivation. While preparing the field for crop, soil should be worked to a fine tilth by repeated ploughing and pulverizing. Dead roots and weeds collected, removed and burnt. Well-decomposed organic manure @4-5 kg/m^2 should be mixed thoroughly in the soil. The width of the bed should not more than 100 cm with a length of 150 cm to 200 cm. The inner bed spacing should be enough to facilitate weeding and watering without trampling the top of bed. The beds should be raised to about 1 cm above the field surface, so as to provide proper drainage of excess water. Mostly greenhouse capsicum crop is grown under drip irrigation systems. After preparation of beds, drip lines of 16:2:30 are laid on the beds and two drips lines are laid on each bed at a distance of 60-65 cm depending upon the bed size.

Thirty day old plants of capscium transplanted on soil raised beds in polyhouse

(ii) *Soilless system:* In hydroponic system, Capsicum plants are grown in various media. First, system called the nutrient film technique (NFT) in which plants are placed in a polyethylene tube that slits cut in the plastic for the roots to be inserted. Nutrient solution is pumped through this tube for dipping the roots. The solution is re-circulated and nutrients are added as depletion occurs. Other systems use rockwool, saw dust or perlite as the supporting medium, while nutrients are applied in liquid form. These production systems are very clean, with no organic material present. In addition, they give the grower complete control over the crop`s nutritional needs to maximize growth and fruit production. However, it requires a very strict and specific fertilization schedule. Mistake in calculation of quantities used for scheduling would result in immediate and visible deficiencies or toxicity in the crop than in the other methods employed.

Two-month old capsicum plant on soilless media in polyhouse

Effect of low night temperature on fruit shape

Selection of site and structures

Selection of site for taking up of protected cultivation is a critical step and this has to be done with utmost care. Places having high rainfall and humidity are not suitable for its cultivation, since this encourages many foliar diseases. Also the areas with high wind velocity are not suitable since they are likely to damage the structure and the polyethylene sheet frequently, thereby enhancing the maintenance cost of the structure. Avoid the location or

area where heavy rains accompanied with gusty winds are prevalent to avoid damage to the protected structure. Protected structures act as physical barrier and play a key role in integrated pest management by preventing spreading of insects, pests and viruses causing severe damage to the crop. The selection of protected structure should be determined by the grower`s expectations, suitable varieties (Table 2), experience, and above all its cost-effectiveness in relation to the available market for the produce.

Types of polyhouse for capsicum cultivation

(1) *Natural ventilation polyhouse:* Natural ventilation uses no specific control devices for regulating environmental parameter inside the polyhouse hence, low initial investment. It can be constructed with locally available material such as bamboo, timber etc. also, and is suitable during cold weather, especially in hilly areas. The external cool air enters the greenhouse through the lower side openings while the hot internal air exits through the roof openings due to the density difference between air masses of different temperature and resulting in the lowering of temperature in the greenhouse. In order to prevent insect intrusion and decrease insecticide use, it is common practice to position insect screens in the ventilation openings.

Table 2. Varieties available in India for protected cultivation

No.	Hybrids	No.	Varieties
1	Orobelle	1	California Wonder
2	SV 1865-PB	2	Yolo Wonder
3	Laxmi	3	Arka Gaurav
4	Indra	4	Arka Mohini
5	Asha	5	Arka Basanth
6	Hunbington	6	Arka Athyla
7	Swarna Gold		
8	Bomby		

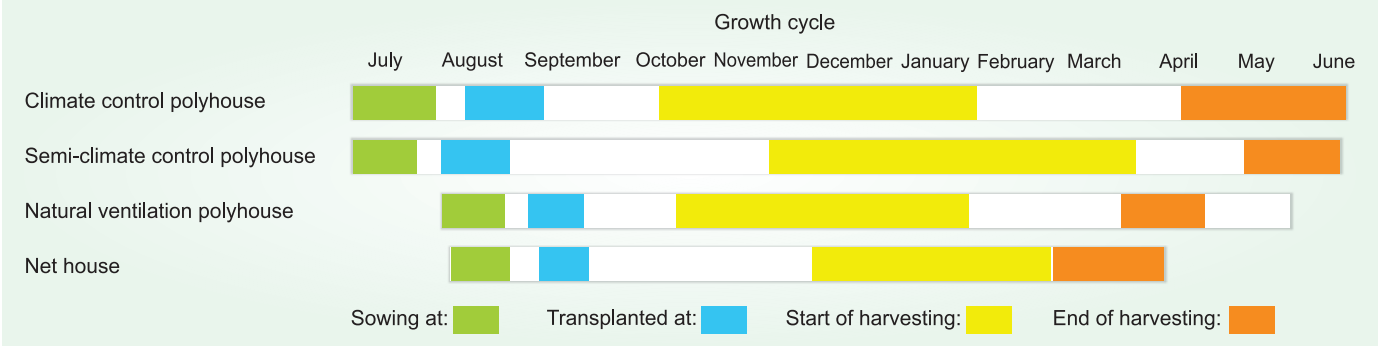
(2) *Semi-climate control polyhouse:* In this type of poluhouse, the structure frame is made up of galvanized iron pipes. Exhaust fans are used for ventilation, these are thermostatically controlled. Cooling pad is used for humidifying the air entering the polyhouse. These are suitable for cultivation during mild winter and mild summer for the low hills or plains of north western part of india.

Semi-control type polyhouse at CPCT-IARI, New Delhi

(3) *Climate control polyhouse:* The fully climate control polyhouses are completely based on sensors. Their frames are made up of iron or aluminium having designs are either dome shaped or cone shaped. These are highly durable but 5-6 times costlier. Growing medium used in these types of polyhouse are peat, perlite, vermiculite, rockwool. In India coco fibres and rice husks are used as growing media as these materials are cheaper. Fertigation and pesticide sprays are done by fogging machine. In these polyhouses, capsicum can be grown throughout the year with 3-4 harveting per year and with 90 % A grade fruit quality.

(4) *Net house:* These simple-frame structures are of two types, namely, shade nets and insect-proof nets. Shade nets are perforated plastic materials used to cut down the solar radiation and prevent scorching or wilting of leaves caused by marked temperature increases within the leaf tissue from strong sunlight. These nets are available in different shading intensities ranging from 25% to 75%.

Insect-proof nylon nets are available in different intensities of perforations, ranging from 25 mesh to 60 mesh. Nets of 40 or higher mesh are effective means to control entry of most flying insects and save crop from diseases. These structures permit early planting of capsicum without the risk of vector. Higher mesh size, however, reduces the air exchange of the structure. Now-a-days UV stabilized nets are available which have a longer life.



Given the year-round demand for capsicum, farmers can choose one of the suitable protected structure options.

Hi-tech nursery for capiscum

Growing media used in hi-tech nurseries are highly modified mixtures of organic and inorganic materials. With reference to plant propagation, growing media are defined as all those solid materials, other than soil, which alone or in mixtures can guarantee better conditions than agricultural soil (for one or more aspects). Mainly three viz, coco peat, vermiculite and perlite are being commercially used as a rooting media for raising the nursery in the high-tech nursery greenhouse. These ingredients are mixed in the volume ratio of 3:1:1 before filling in the trays.

Coco peat (Coir pith): It is produced by partial decomposition of plant material under low-oxygen conditions and a by-product of the coconut industry, used widely as a substrate due to its low cost, aeration, drainage and long life. It is usually marketed in compressed bricks form to which water is added. The bricks weigh about 4–5 kg and can expand to 4–5 times of their volume once water is added after loosening them. It is advisable to use coco peat after treatment with steam or other means of disinfestation. It has a pH of about 5.0 making and contains low levels of micronutrients, but higher levels of phosphorus and potassium.

Vermiculite: Vermiculite is produced by heat treatment of mica at 700 to 1000°C temperature. It is porous and light and has a water-holding capacity of three to four times of its weight. Media containing vermiculite should be mixed dry. When mixed wet, the desirable physical properties deteriorate because particles tend to collapse flat. Furthermore, vermiculite can hold positive-charged nutrients such as K, Mg and Ca.

Perlite: Perlite is a natural mineral of volcanic origin which is light in weight. The pH is usually neutral to slightly alkaline. Its high porosity helps to control the water-holding capacity and aeration of the substrate. Perlite can be used alone or mixed

Pro-tray or seedling trays

There are two kinds of plastic trays used for raising seedlings. One tray 187 cavities of 3.75 cm (1.5``) size, whereas the other tray is having 345 cavities of 2.5 (1.0``) size. These trays help in proper germination, provide independent area for each seed to germinate, eliminate the mortality rate, maintain uniform and healthy growth of the seedlings, are easy in handling and storing, reliable and economical in transportation. These trays are fixed in thermocol trays having the same number and size of cavities before filling the media. Thermocol base provides a good insulation to help in minimizing fluctuation in root temperature.

Seed sowing and application of nutrients and water

The best time for seed sowing is August-September in nursery with the optimal temperature at 25-30°C at the depth of 0.5 inch in the nursery tray. First filled the tray with the mixture of root media and then the seeds are sown in the cavities (one seed in each cavities). If the seeds are of good viable capacity and not old than will take 6-10 days for germination elsewhere germination range from 15-21 days depends on the quality and genetic constituent

Raising the capsicum seedling in the Hi-tech nursery

of the seeds. Usually healthy seeds germinate without pre-soaking in normal water but in case germination hampered by internal dormancy or seed coat then 24-36 hr pre-soaking help in the uniform germination of seeds. The seedlings are ready within 25-30 days after sowing. For healthy and vigorous growth, fertigation will be promising by applying NPK 19:19:19 @ 1g per litre water once in a week at 3-4 stage of leaf through fine sprinkler.

Transplanting

Seedling are transplanted on a planting distance of 60 × 30 cm around 4,200-4,300 seedlings are required for planting in 1,000 m^2 area of greenhouse. Mostly transplanting is done in the evening and the nursery must be sprayed with systematic insecticides like confidor or metasystox @1/2 ml/litre of water before taking it out from the nursery greenhouse for protecting the plants from post transplanting infestation of leaf curl virus or mites.

Pruning and training

In greenhouse conditions, to ensure good growth and fructification, plants are cultivated with one, two or three branches. Fewer ramifications on the plant result in improved air circulation, increased lighting and reduced pests. Perform pruning at 10–14-day intervals as new shoots appear. Remove the base leaves, shoots and some flowers to stimulate plant growth and development. Pruning the plants to a single stem, two stems or four stems facilitate better management, permit closer planting, early maturity of fruits, higher yield of larger sized fruits as well as uniform light penetration in the plant canopy. Due to the heavy vegetative growth and fruit load on the coloured pepper plants, shoot pruning proves to be one of the important factors in proper utilization of production area. Capsicum plants are pruned after 30 days of transplanting at an interval of 8 to 10 days which resulted in bigger fruits with better quality and high productivity. Each capsicum plant is trained to retain only 2 or 4 stems. Shorten the lateral shoots, leaving 2–3 fruits on secondary shoots. There should be a maximum of 2–4 branches: the lowest at 15–20 cm from the ground or mat, the next at 20–25 cm. Prune secondary shoots or

branches to leave only the ramifications of the main stem. This practise of pruning is usually done under protected or polyhouse structure cultivation with the only purpose to get maximum and continuous production by making indeterminate type of plant.

The plants are trained along the plastic twines tied to the main stem after 6-7 weeks of transplanting. A grid is prepared over the plants with a GI wire for this purpose. The main stem grows to a height of 3.5–4.0 m and must be trained to remain vertical. Use threads or plastic or metal rings to trellis each fructification stem of the pepper so it can bear the weight of the fruits. Trellising is necessary only for the main branches, not for secondary ramifications.

Two leader system of pruning in capsicum

Fertigation

Fertigation is applicable after three weeks of transplanting when plant is established completely. During the initial vegetation phase, N: P: K:: 19: 19: 19 @ 300 g in 100 litre water should be applied at fortnightly interval for better leaves. The doses of fertilizers should be increased with the growth of plants, apply 50 kg nitrogen in form of neem coated urea, 10 kg DAP, and 10 kg MOP in 1,000 m^2 area of polyhouse at 30 days of interval along with micronutrient. Avoid overuse and inadequate or imbalanced use of fertilizers. Capsicum has a superficial root system and is very susceptible to water stress, for this reason, it is recommended to irrigate frequently with small amounts of water. Water scarcity causes abortion of flowers resulting in fruits of poor quality. The requirement of water is higher during flowering and fructification than during the remaining vegetation period. Always use fresh water (do not store water for 4 to 5 days) and pour from afternoon when the relative humidity of air should not be more than 90–92% because it is inclined to disturb the fruit.

Weeding and hoeing

Usually weeding and hoeing are done once in a month manually if mulching is not being used on transplanting beds. But mulching of beds especially of yellow colour plastics protect the capsicum from weeds as well as against leaf curl virus, which is spread by an insect white fly. Yellow plastic mulch is black from the other side, which helps in weed control and soil moisture conservation. The yellow plastic mulch has reflective properties, which interfere with the movement of white flies.

Harvesting

In greenhouse production of capsicum, fruits are harvested when they reach full colour and are still firm on the plant itself for marketing them to up market and getting very high price of the produce. When fruits are harvested a week after the harvestable green stage the fruits will turn gradually into colour, which is not desired. Green capsicum requires about 40-42 days developing from pollination to mature green fruit, a further 14-21 days are required to fully i.e. from green to red or yellow etc., depending upon the temperature. Best colour develops between 18 to 24°C whether the fruits are on the plants or in storage. Capsicum fruits must be harvested with a very sharp knife or scissors to get a smooth stem end appearance and so to minimize damage to other fruits. It is better to start harvesting of fruits early in the morning and to finish before the hottest hours of the day. It is most important that harvesting, handling and packaging should be done with greatest care because capsicum fruits are very prone to handling damage. Fruits will mature in flushes, certainly in beginning of the production. In peak periods frequent harvesting is needed coloured fruits once or twice a week and green fruits once per fortnight.

Yield

On an average capsicum varieties can produce 60-70 tonnes of coloured fruits and 100 to 120 tonnes of green fruits per hectare under greenhouse conditions. Although, yield directly depends upon the suitable variety, climate conditions and crop management for protected cultivation. Average weight of quality coloured fruits is 160 to 190 g/ fruit with mostly four lobes.

Grading of fruits

Capsicum fruits are graded according to colour of the fruit, size and shape of the fruit. A^+ grade fruits are mostly four lobed, firm and bright in colour and their average

Table 3. Optimal range of leaf macronutrient concentrations for capsicum under protected cultivation

Macronutrient	% in dry weight	Micronutrient	(ppm or mg/ kg dry weight)
Nitrogen (N)	3.0–4.5	Iron (Fe)	60–300
Phosphorus (P)	0.30–0.60	Manganese (Mn)	30–150
Potassium (K)	3.0–7.5	Zinc (Zn)	20–100
Calcium (Ca)	1.0–2.5	Copper (Cu)	6–25
Magnesium (Mg)	0.35–0.90	Boron (B)	25–80

fruit weight is 180-190 g. The next grade fruits may have 3-4 lobes with average fruit weight of 150-160 g followed by 'B' grade with 2-3 lobes fruit with average fruit weight of 120-50 g. Grade 'C' fruits are with conical fruit shapes or 1-2 lobes and small in size with average fruit weight of 90-100 g per fruit. A^+ and A grade fruits after proper packing and proper clearing sold to high market and 'B' and 'C' grade fruits are sold to the local markets.

Physiological disorders

Conditions of high relative humidity (e.g. 85%) in a greenhouse can lead to disorders, such as poor or incomplete pollination, sunburn, fruit cracking and red fruit.

Disease and management

The major pests and diseases, their symptoms and their management in capsicum are given below.

Thrips

Symptoms: Thrips cause upward curling of leaves, sucks sap and reduce leaf growth, plant growth, yield and market value of produce. It also reduces leaf area and hinders absorption of nutrients and water by the plants. Increased infestation leads to blackening and drying of leaves and irregular fruit bearing.

Management: Remove affected plant parts including leaves, flowers and fruits. Keep the plots clean by removing all the dropped plant parts. Spray acephate (1.5 g/L) or Imidacloprid (0.5 ml/L).

Mites

Symptoms: Young larvae and adults feed on leaves, bud and fruits, suck sap from plant parts which in turn causes downward curling of leaves. The size of leaf, fruit and plants gets reduced, affecting the market value of the produce. This pest infestation increases with increased temperature coupled with high humidity.

Mites infected leaves of capsicum

Management: Remove the pest damaged plant parts including leaves, flowers and fruits and spray dicofol (2 ml/L) or wettable sulphur (2 ml/L) or abamectin (0.5 ml/L) or ecomite or chlorophenapyr (1 ml/L).

Aphids

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

Management: Keep a close watch on the plants at regular intervals for aphids' infestation. Spray imidacloprid (0.5ml/L) or thiomethoxam (0.5g/L) or dimethoate (2ml/L). Use reflective mulches and apply weed control.

Fruit borer

Symptoms: Fruit borers are very active during night. The adults lay eggs on fruits, flowers and leaves in large number and the nymphs that come out of eggs, feed on fruits and leaves causing heavy destruction of crops and severely affects the quality of the produce. Whenever night temperature is low, coupled with cool and high humidity the infestation is increased. Since eggs are laid in group, the larva also feeds gregariously on leaves at one place, which can be easily identified and destroyed.

Management: Pick and destroy nymphs and adult insects. Generally eggs are laid and hatch in groups, which is easy to identify from a distance. Hence they should be identified and destroyed immediately. Spray thiodicarb (1 ml/L) or carbaryl (3 g/L) or indoxcarb (1 ml/L) fipronil (1 ml/L).

Nematodes

Symptoms: Nematodes are commonly seen in solanaceous crops when grown 3-4 times continuously in the same field. Initially yellowing of leaves can be observed followed by reduction in leaf size, count and drastic reduction in size of fruits. When infected plant is uprooted and observed, small and big nodes filled with large number of nematodes nodules can be observed on roots depending on the level of infestation.

Management: Cotation with non-solanaceous crops like marigold, sweet corn and cabbage may be followed to avoid nematode. Bio-pesticides enriched neem cake (as explained earlier) is to be applied @ 800 kg/ acre 4-5 days before transplanting to the beds. Apply carbofuran (furadan) granules @ 20 kg/acre at the time of planting. Keep a close watch on nematode infestation of the plants, particularly in 2^{nd} and 3^{rd} crop. The insecticides should always be mixed with spreader or sticker while spraying. The plants from top to bottom should come in contact with spray for better result and adopt integrated approach for better plant growth, use root-knot nematode-resistant varieties, fumigate infested soil.

Damping off

Symptoms : Infection takes place at the base of the young seedlings just above the ground level which leads to wilting and later death of seedlings. Any damage caused to seedlings while transplanting can also lead to damping off or seedling wilt besides fresh infection in main field or infection that is carried from nursery.

Management: Drench carbendazim (1 g/L) or metalaxyl MZ (2 g/L) or copper oxychloride (3 g/L) or captan (3 g/L) drenched to the base of the plant at about 25-50 ml/plant.

Powdery mildew

Symptoms: The disease initially appears as tiny yellow spots on surface of leaf and powder like material on the lower surface leading to a powdery growth covering the entire lower surface of leaf which leads to drying and dropping of leaves at later stages. The disease reduces growth of leaves and fruits leading to low quality and quantity of the produce.

Management: Spray wettable sulphur (2 g/L) or penconazole (0.5 ml/L) or flusilazole (0.5 ml/L).

Cercospora leaf spot

Symptoms: Cercospora appears initially as tiny yellow spot on leaf surface leading to increased dark grey spots which spreads on entire leaf resulting in dropping of leaf.

Management: Spray chlorothalonil (2.5 g/L) or mancozeb (2.5 g/L) or carbendazim (1 g/L).

Phytophthora

Symptoms: This disease appears during fruiting and flowering stage resulting in tiny oil like spot on leaf surface resulting in rottening and blackening of plants. Later plant weakens and dies in 2-3 days. Heavy and continuous rainfalls coupled with high humidity favour disease appearance and its quick spread. *Phytophthora* disease is relatively more severe in net houses which may lead to 40-80% crop damage.

Management: Spray copper ydroxyl chloride (3 g/L) or Ridomil (2 g/L) or azoxystrobin (0.5 ml/L). Severely infected plant parts should be destroyed. It is better to avoid capsicum cultivation in severely affected net-houses.

Viral diseases

Symptoms: Viral diseases are transmitted through aphids and thrips leading to upward and downward curling of leaves with yellow spot in the middle of leaf and sometimes on fruit also. Heavy infestation leads to dropping of leaves, stunted plant growth and reduces quality and quantity of fruits. Virus affected fruits are unmarketable.

Management: Grow nursery beds under nylon cover (50 mesh), proper management of aphids, mites and thrips which act as disease transmitting vectors and disposal of diseased/infected plants, control infestations of viral diseases.

Leaf curl virus disease in capsicum

Challenges in capsicum cultivation under polyhouse.

High capital investment: Capsicum cultivation under polyhouse requires high initial investment for creating structures, therefore, there is a need for developing low cost poly house designs suitable for various agro climatic zones. There is also a growing need for credit for meeting working capital and post-harvest facilities as well as banks need to channelize credit facilities for promotion of polyhouse cultivation.

High cost of planting material: The cost of imported seeds and planting materials of capsicum for polyhouse conditions is very high. Though, government provides 50% subsidy for initial year for purchasing planting materials and cultivation of capsicum under polyhouse which is not sufficient for sustainability. Thus, the subsidy scheme for planting materials may be continued every year and also there is a need for developing domestic varieties for higher productivity and quality.

Lack of proper marketing facilities: There is a need for formation of farmer's producer's organization and linking farmers with super markets for assured and sustainable income.

Incidence of pest and diseases: There is a need to educate the farmers about the management of pests and diseases for polyhouse cultivation through the department of horticulture and other line departments for providing technical guidance to the farmers.

Advantages of capsicum cultivation under polyhouse

- Higher productivity and profitability
- Better quality of produce
- Efficient use of water and fertilizers
- Better management of pests and diseases
- Off-season production
- Additional employment generation

For further interaction, please write to:
Hemlata Bharti (Scientist), Centre for Protected Cultivation Technology ICAR-Indian Agricultural Research Institute, New Delhi 110 012. Corresponding author *e-mail:* hemlatafloriculture@gmail.com