Technical Bulletin No. 69

Prospects of Protected Cultivation in Hot Arid Region

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ICAR-CENTRAL INSTITUTE FOR ARID HORTICULTURE

BIKANER–334 006, RAJASTHAN, INDIA

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Publication
Prospects of Protected Cultivation in Hot Arid Region (2018)
Technical Bulletin No. 69

Published by
Director
ICAR-Central Institute for Arid Horticulture (CIAH)
Bikaner-334 006 (Rajasthan)

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Laser typeset & Printed at:
M/s Royal Offset Printers, A89/1, Naraina Industrial Area, Phase-I, New Delhi-110 028
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FORWARD

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The productivity of vegetables is very less in hot arid region of India on account of vagaries of harsh climatic conditions. Climate change and resource constraints are posing serious constraints on the profitability and sustainability of horticultural crops. Efficient technologies for horticultural production in terms of space, labour, water, stresses (biotic & abiotic) and other inputs are emerging in a big way to increase productivity and improve quality of produce.

Protected cultivation of horticultural crops is reasoned to be the next logical step to open field agriculture because one million hectares of area under protected cultivation is efficient to increase the production of vegetables alone by about 60-70 million tonnes. This can also create about one million additional jobs in the rural sector where unemployment problem is more acute. The north Indian plains pose problems of cold winters and hot summers where the requirement is to moderate the winter and summer conditions. Besides, availability of suitable water in these areas is often highly inadequate. Under such climatic conditions a bit of protection from weather aberrations and biotic stresses greatly improves horticultural crop productivity.

Protected cultivation in the form of naturally ventilated greenhouse, shade net house, insect proof net house, walk-in tunnels and low tunnels with value chain is drawing the attention of educated youths for more profitable and dignified agriculture. Low cost protected cultivation of vegetables particularly cucurbits is gaining popularity among the farmers of hot arid region.

The present Technical Bulletin 'Prospects of Protected Cultivation in Hot Arid Region' written by Dr. B.R. Choudhary and Dr. A.K. Verma is an excellent material being made available at appropriate time when state government is promoting protected cultivation. I congratulate the authors and Director of ICAR-CIAH, Bikaner to make this bulletin available for stakeholders.

(Balraj Singh)

PREFACE

In India, hot arid zone is spread over 31.7 million ha area and the maximum in western Rajasthan (19.62 million ha). The prevalent harsh climatic conditions reduced the productivity and quality of vegetables under open field conditions particularly during summer season. Therefore, the protected cultivation of vegetables is one of the emerging areas which offer several advantages like quality, productivity and favourable market price to the growers. The growers can substantially increase their income through protected cultivation of vegetables during off-season. Protected cultivation of vegetables not only provides high water and nutrient use efficiency but it can easily increase the productivity by 5-10 folds under varied agro climatic conditions.

Off-season cultivation of cucurbits under low plastic tunnels is one of the low cost and most profitable technologies under hot arid region. Walk-in tunnels can also be used to raise off-season nursery and cultivation of high value crops. Insect proof net houses can be used for virus-free cultivation of tomato, chilli, *Capsicum, etc*. Shade net houses can be used to grow leafy vegetables like green coriander and beet leaf. Low cost greenhouses particularly naturally ventilated greenhouse can be used for cultivation of high value crops like cucumber, tomato, *Capsicum* in peri-urban areas to fetch commensurate price of the produce.

Protected cultivation technology has very good potential but requires proper knowledge, sound planning, selection of site, selection of right structure, choice of varieties which are able to produce high economical yield of high quality, *etc*. Since the protected cultivation is highly mechanized and promotion of suck kind of technologies will certainly help in creation of huge self-employment for unemployed educated youths. We sincerely acknowledge the contributions of authors whose publications have been used while compiling this technical bulletin.

Bikaner **(Authors)**

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1. IMPORTANCE AND SCOPE

Indian arid zone is one of the largest subtropical deserts of the world of which 20% is arid and rest is semi-arid. Hot arid zone is spread over 31.7 million hectare area and mainly confined in the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab and Haryana. The major part of hot arid region of the country lies in western Rajasthan (19.62 million ha) followed by North-western Gujarat (2.16 million ha). It is characterized by high aridity index, extremes of temperature, low and variable precipitation, very high wind velocity and dust storm, high soil pH, high infiltration rate, very limited availability of groundwater and saline ground irrigation water (More, 2010). Under such harsh climatic conditions cultivation of vegetable crops in open condition results in very low and poor-quality yield which fetches less return per unit area. By creating the suitable micro-climate for plant growth round the year cultivation of vegetables can be done under adverse climatic conditions. It is possible through protected cultivation which has tremendous scope in peri-urban areas of the country (Singh and Sirohi, 2006). It is the best way to increase the productivity and quality of vegetables, especially cucurbits. India is the second largest producer of vegetables in the world next only to China. Presently India has 166.61 million tonnes of total vegetable production, but the productivity and quality of most of the vegetable crops is very poor (17.41 t/ ha) due to several biotic and abiotic stresses under open field cultivation. In Rajasthan, the total production of vegetables is very less *i.e.* only 0.51 million tonnes from an area of 1.15 m ha with a productivity of 7.84 t/ ha.

Table 1: Area under greenhouse vegetable production in different countries of the world

Country	ha ('000)	Country	ha ('000)
China	81.0	Chile	2.1
Spain	70.4	Jordan	2.0
South Korea	47.0	Belgium	1.6
Japan	36.0	Portugal	1.5
Turkey	33.5	Russia	1.4
Italy	25.0	Germany	1.4
Morocco	16.5	Australia	1.3
France	10.0	Tunisia	1.3
Poland	5.2	Romania	1.3
Hungary	5.4	Egypt	1.2
Algeria	5.0	Canada	1.2
Greece	5.0	Bulgaria	1.1
Netherlands	4.6	Libya	1.0

Country	ha ('000)	Country	ha ('000)
Columbia	1.2	Serbia	1.0
Mexico	4.3	Lebanon	1.0
Israel	4.0	Brazil	1.0
Iran	4.0	United Arab Emir.	0.8
Palestine	3.3	India	0.7
Syria	3.1	New Zeeland	0.7
Ukraine	2.7	UK	0.7
Ecuador	2.7	USA	0.7
Argentina	2.2	Moldova	0.5

Source: Hickman, 2011

Area under protected cultivation in India is about 70000 hectares only. State wise crops grown under protected cultivation in India is presented in Table 2. Maharashtra is leading state in India in protected cultivation followed by Karnataka and Himachal Pradesh. Other states which have area under protected cultivation are Punjab, Uttarakhand, Haryana, U.P., Gujarat, Rajasthan, Jharkhand, J&K, Delhi, West Bengal, Orissa, Bihar, M.P., *etc*. Farmers are growing generally roses, gerbera, carnation under flowers and *Capsicum*, tomato, cucumber under vegetables crops.

Table 2: Leading states with major crops grown under protected structures

S.No.	State	Crops
1.	Maharashtra	Carnation, gerbera, rose, *Capsicum*
2.	Karnataka	Roses, gerbera, carnation, vegetable seed production and nursery raising of vegetables
3.	Himachal Pradesh	*Capsicum*, carnation, gerbera, tuberose
4.	Punjab	Vegetable crops
5.	Uttarakhand	Gerbera, *Capsicum*
6.	Tamil Nadu	Floricultural crops
7.	North-Eastern States	Floricultural and vegetable crops
8.	Other States: Haryana, UP, Gujarat, Rajasthan, Jharkhand, J&K, Delhi, West Bengal, Orissa, Bihar, MP.	

Source: Anonymous (2014)

Production of vegetables in India is mainly restricted to open field cultivation and most of the varieties grown are open pollinated in nature and are mainly grown in two seasons, as a summer and rainy season crop in northern plains of the country. The crops grown under open condition are always affected by several diseases and pests, resulting in low productivity and poor-quality produce. On the other hand, vegetable markets are flooded with these vegetables during their main season and sometimes the vegetable growers are even not able to recover the cost of cultivation spent on these vegetables. But the same vegetables are sold at very high prices during off season in several parts of the country. The demand of off-season vegetables is increasing rapidly in several big cities of the country because of continuous increase in availability and continuous changing choice of consumers towards off season and high quality produce. There are different types of protected structures based on the cost and technical feasibility such as high cost (fully automated), medium cost (semi-controlled) and low cost (naturally ventilated, tunnels). Thus, high cost (fully automated), medium cost (semi-controlled) structures requires high input costs and good management practices compared to low cost structures, which have direct bearing on the economic viability of the production system. Before going for protected cultivation, knowledge about the techno-economic suitability of the protected structure or protected cultivation technology for the particular region is necessary for the growers. Therefore, it becomes important to adopt low cost protected structures to ensure maximum benefit against per unit of area and cost invested. Protected cultivation technologies can provide specific advantage over open field practices which includes protection against both biotic as well as abiotic stress factors.

Protected cultivation of horticultural crops is reasoned to be the next logical step to open field agriculture because one million hectares of area under protected cultivation is efficient to increase the production of vegetables alone by about 60-70 million tonnes. This can also create about one million additional jobs in the rural sector where unemployment problem is more acute. The north Indian plains pose problems of cold winters and hot summers where the requirement is to moderate the winter and summer conditions. Besides, availability of suitable water in these areas is often highly inadequate. Under such climatic conditions a bit of protection from weather aberrations and biotic stresses greatly improves horticultural crop productivity (Chandra, 2001).

Looking to the increasing population, climate change, decreasing land holdings, increasing pressure on natural resources *i.e.* land & water and high demand of quality horticultural fresh produce we are forced to shift towards modern technologies of crop production like protected cultivation. Presently area under protected cultivation of horticultural crops is only around 70,000 ha and out of which large portion mostly in northern parts of India is not successfully being utilized for protected cultivation (Singh, 2014). Plastic tunnels had registered a significant growth of 60.5% for the years 2007 to 2012. The area protected by the plastic tunnels was 4.3% of the total area under the protected cultivation in 2012. Although promotion of protected cultivation will certainly help in creation of huge self-employments for unemployed educated youths and will also raise the national economy by sale of high quality produce in domestic and international markets. Production of vegetables under protected conditions not only provides high water and nutrient use efficiency but it can easily increase the productivity by 5-10 folds over open field cultivation under varied agro-climatic conditions of the country. This technology has very good potential especially in urban and peri-urban areas adjoining to the major cities which is a fast growing market for fresh produce of the country. Vegetable farming in agri-entrepreneurial models targeting various niche markets of the big cities of the country is regularly inviting attention of the vegetable growers for diversification from traditional ways of crop cultivation to such modern methods.

Despite the several constraints, the hot arid region of India offers very good opportunity for cultivation of cucurbits like, watermelon, muskmelon, longmelon, bottle gourd, ridge gourd, *tinda*, summer squash, cucumber, *etc*. because it has warm sunny days and cool nights which is favorable for cucurbits. The sowing of cucurbits is generally done in second fortnight of February for summer season crop. The flowering stage of February sown crop coincides with the prevailing high temperature and hot wind (*Loo*). These climatic conditions lead to high transpiration which results in wilting of plants. Desert soil being sandy in texture gets warm soon which cause burning of pistillate flowers touching the ground. The population of pollinators (honey bee) is decreased considerably during summer season which affect yield. High temperature favours to induce more number of male flowers and less pistillate flowers. Cultivation of cucurbits under such conditions leads to low yield of poor quality. The existing low productivity of cucurbits in hot arid regions can be increased by adopting innovative approaches like drip irrigation and fertigation, low tunnel technology, spray of micronutrients and integrated crop management (ICM).

Still the vegetables are traditionally grown with little technological inputs, therefore, new technology like tunnel cultivation is to be brought to increase production, productivity and quality of cucurbits. Low tunnel technology can be used to raise off-season crop of cucurbits making cultivation more profitable. The use of low cost protected structures particularly low tunnels with some modification may become a viable option for successful cultivation of cucurbits in arid regions (Choudhary *et al.*, 2015).

2. PROTECTED CULTIVATION

Protected or greenhouse cultivation is defined as an improved technology of growing crops under controlled environment. The crops are protected from abiotic (temperature, rain, wind, humidity, *etc*.) and biotic (diseases and insect-pests) stresses. Greenhouse cultivation of vegetables offers distinct advantages of quality, productivity and favourable market prices to the growers. Vegetable growers can substantially increase their income by greenhouse cultivation of vegetables in off season as the vegetables produced in the normal season generally do not fetch good returns due to large availability of these vegetables in the market. Greenhouse technology is popular in various countries *viz.,* U.S., Canada and Europe. It allows precision farming and overcomes limitations of space and disadvantages of climate change. Production of vegetables under protected conditions is increasing worldwide. In these systems various factors of the environment such as air, temperature, humidity, atmospheric gas composition, *etc*. are controlled. Protected cultivation in the form of greenhouses, net houses, low tunnels, mulches, *etc*. offers several advantages to grow crops of high quality and yield, thus using the land and other resources more efficiently.

Advantages of greenhouse

- The yield may be 5-10 times higher than that of out door cultivation depending upon the type of greenhouse, type of crop, environmental control facilities, *etc*.
- Reliability of crop increases under greenhouse cultivation.
- Off-season/ round the year production of vegetable and flowers is possible.
- Disease-free and genetically superior transplants can be produced continuously.
- Efficient utilization of fertilizers, insecticides and pesticides.
- Water requirement of crops is very limited and easy to control.
- Hardening of tissue cultured plants.
- Production of quality produce free of blemishes.
- Useful in monitoring and controlling the instability of various ecological systems.
- Modern techniques of hydroponic, aeroponics and nutrient film techniques are possible only under greenhouse cultivation.

Important aspects to be kept in mind before undertaking protected cultivation:

- Climate of the place.
- The crop to be grown.
- Resources to undertake protected cultivation.
- Knowledge of government support schemes of protected cultivation.
- Market for selling of quality produce.

Selection of vegetables

The choice of vegetable crop to be raised in greenhouse is made on the basis of the size of the structure, the economics of the crop production and income generated (profit). It may be possible to raise any crop at any time in a high cost greenhouse, selection of crops is more critical in case of ordinary low cost greenhouse. The high value vegetable crops *viz.,* tomato, *Capsicum*, cucumber, brinjal and chilli have been more popular for cultivation in greenhouse. The labour and other input requirement per unit area in greenhouse is more than that of open field conditions. There is always a large and sustained demand of fresh vegetables round the year in big cities. Among vegetables tomato is the first crop grown in greenhouses worldwide. Tomato is relatively easy to grow under protected conditions.

Type of protected structures

i) Climate controlled greenhouse

Greenhouses are framed or inflated structures covered with transparent or translucent material large enough to grow crops under fully controlled environmental conditions to get optimum growth and productivity. These are ideally suited for high value crops like vegetables and flowers for round the year cultivation. During summer, cooling pads and exhaust fans are provided in the greenhouse to lower the temperature. During winter heaters are provided to raise temperature. Night temperature is not allowed to go down 12-13^{0}C. Such greenhouses are expensive both in construction and maintenance. Greenhouse vegetable production is a highly intensive enterprise requiring substantial labour and strong commitment, which restrict the adoption of this technology.

ii) Zero energy naturally ventilated greenhouse

Naturally ventilated greenhouses are the protected structures where no heating or cooling devices are provided for climate control. It is naturally ventilated through insect proof netting mainly at the top and sides also. They are simple and medium cost greenhouses having a manually operated natural ventilation system. Such greenhouses can be used successfully and efficiently for year round growing of cucumber, tomato and *Capsicum* for 8-9 months duration.

The basic prerequisite of implementing the technology depends upon selection of appropriate design based on the climatic conditions, availability of market and the type of vegetable crop. Under arid and semi arid conditions maximum ventilation up to 40-50% is required to make the structure efficient and successful to raise vegetable crops. Under extreme hot periods (May-July) rooftops of the greenhouses should be covered with shade nets (preferably with black colour) allowing a space between the shade net and roof surface for air movement. Such greenhouses can be equipped with low-pressure drip irrigation system to make them energy efficient and eco-friendly model.

Advantages

- Energy is not required to regulate temperature inside the greenhouse.
- Being less costly such greenhouses are liked by farmers.

iii) Shade net house

Shade nets are perforated plastic materials used to reduce the solar radiation and prevent scorching or wilting of leaves caused by increased temperature. The basic objective of shade net is to reduce radiation and temperature up to some extent during critical summer months (May-Sept.). Shade nets are available in different shading intensities ranging from 25-75%. Shade net houses are suitable for the places where night temperature does not go below 15-18^{0}C and generally temperature during day time is 28-30^{0}C.

Black color shade nets are most efficient in reduction of temperature compared to other colours like green, white or silver, *etc*. as the black colour is the maximum absorbent of heat. Mostly leafy vegetables like beet leaf and green coriander are preferred to be grown under shade nets. Shade net houses are also suitable for growing early cauliflower and radish during June to September months.

iv) Insect-proof net house

It is a cheap and can be made as temporary or permanent structure. The structure is cladded with 40-50 mesh UV stabilized insect proof nylon or rust proof metal net. The main purpose of the structure is to provide barrier for the entry of harmful insect-pest and vectors of diseases. Insect proof net house vegetable cultivation minimizes the use of pesticides in fresh vegetable cultivation. This technology can be used for raising crops like tomato, chilli, sweet pepper, *etc*. but for growing these crops under insect proof net houses, it is prerequisite to raise virus free healthy seedlings of the crop either in the greenhouse or by covering the nursery beds with insect proof net. These structures can be fabricated with 40-50 mesh insect proof nylon net during critical summer months (April-June) and with transparent plastic covering during critical winter months (December-February) under arid and semiarid climatic conditions.

Advantages

- Pests and other vector population can be checked effectively.
- Reduce the cost of insecticides.
- Virus free seed production is possible.

v) Walk-in-tunnel

Walk-in-tunnels are temporary structures made from GI pipes or plastic pipes or bamboo bended semi spherically and transparent UV stabilized (150-200 micron) polyethylene as cladding. The central height is kept 6 to 6.5 feet and width 4.0 to 4.5 feet. Length of the structure can vary according to requirement. Use of prefabricated structures makes the walk-in-tunnels easy to assemble and dissemble. The complete structure is assembled with nut-bolts and no welding is required. Walk-in-tunnel structures are designed to bear trellising load of 15-25 kg/ m^2.

The basic objective and utility of walk in tunnels is to fetch high price of the complete off season produce to earn more profit per unit area. Generally walk-in-tunnels are used to give favourable controlled environment like temperature, humidity, light intensity, ventilation, soil media, disease control, irrigation, fertigation and other practices throughout the season irrespective of the natural conditions outside. Walk-in-tunnel technology is a simple and profitable technology for off-season cultivation of cucurbits during the winter season in northern plains of India. Crops like summer squash can be grown as a complete off-season crop, whereas other cucurbits like muskmelon, round melon, bottle gourd, cucumber, bitter gourd, watermelon are mainly grown during off-season.

Advantages

- Cost of the structure is less than other protected structures like greenhouse.
- Easy to operate, maintain and control.
- Less chances of disease attack thus reduction in disease control cost.
- High yield with uniform and better quality of produce.
- Higher efficiency of water and fertilizer use.
- Cultivation in problematic topography, soils and climatic conditions is possible.

vi) Low tunnels

Low tunnels are flexible transparent coverings over hoops of GI wires. Transparent plastic of 25-50 micron thick and 2 m width is covered/ stretched over the hoops and the sides are secured by placing in soil. Low tunnels are temporary and usually no higher than 1.0 m. Just after sowing, the flexible galvanized iron hoops (4-6 mm thick) are fixed manually at a distance of 3-4 m on trenches. The width of two ends of hoop should be kept 1.0 m. Length of row is variable depending upon the requirement.

Single or multiple rows of vegetables are covered with polythene to enhance the plant growth by warming the air around the plants in the open field during winter season when the temperature is below 8^{0}C. This technology is highly suitable and profitable for north India plains. Cucurbits can be grown successfully by using the plastic low tunnel technology.

3. GREENHOUSE CULTIVATION OF TOMATO

Tomato is one of the important vegetable crops. It is grown throughout the world. In India the major tomato producing states are Andhra Pradesh, Karnataka, Odisha, Maharashtra, West Bengal, Bihar, Gujarat, Chhattisgarh and Madhya Pradesh. Its average productivity in India under open field conditions is 213.3 q/ ha (2014-15) which gets multiplied by five to ten times under protected cultivation.

Climate

Tomato does not tolerate water logging and frost. Temperature below 15^0C and above 27^0C is not suitable for its growth and development. At very high temperature, fruit set is very poor and flower drop is common. Critical factor in setting fruits of the tomato is the night temperature, the optimum range being 16^0C to 22^0C. Under greenhouse conditions tomato crop can be grown for long duration (10-12 months) by cooling the greenhouses during summer months (April to July) and by heating the greenhouses during peak winter (December and January) months.

Suitable varieties

Selection of the most suitable cultivar is a prerequisite for successful tomato cultivation in greenhouse. Important considerations are size, shape and colour (red or pink). Important characteristics related to cultivars include high yields, freedom from cracking, disease resistance, high per cent of fruit setting, freedom from green shoulder, good shelf life and TSS. Some of indeterminate elite varieties/ hybrids which have performed exceedingly under low cost greenhouses are Pusa Divya, Naveen, Him Shikhar, Abiman, NDT-5, NDT-120, Meenakshi, Lakshmi, Soberano, Scissor, Dev, *etc*. The fruit of these varieties weighs about 110 to 120 g. The fruits of these varieties have good blend of acid and sugar making them tasty. Indeterminate cherry tomato varieties grow very well under greenhouse. The individual fruit weighs 12-15 g. Each cluster has 35-55 fruits. Suitable varieties of cherry tomato are VR-124, Pusa Cherry Tomato, Ole, Sairan, NS Cherry-1 and Paireso.

Soil and its preparation

Loam and sandy loam soils are suitable for tomato production. Soil should have good water absorbing and holding property with pH of 6 to 6.8. For preparing the field 5 to 6 ploughings/ harrowing can be done which helps in reducing chances of weeds. At the time of last ploughing vermicompost @ 4 kg per m^2 of land should be mixed to get better crop.

Soil solarization

Soil solarization is essential for greenhouse cultivation. By continuous cultivation of the same crop, several soil borne fungus and root knot nematode developed, which can be easily controlled by solarization technique. Soil solarization should be done by applying the formaldehyde (37%) at one month before transplanting of the crop. It should be done after mixing vermicompost and then soil is covered with 30 micron polyethylene sheet for 15 days. Irrigate alternate day with drip irrigation. After removal of plastic the soil should be ploughed to completely remove the fumes of gas. Solarization is done for about six weeks during May and June months when temperature is very high. Solarization helps in destruction of seeds of weeds, insect eggs and larvae, nematodes and soil borne plant pathogens.

Nursery raising

After selection of suitable variety, healthy and disease free seedlings are raised in plastic trays under protected structures using soilless media *i.e.* coco peat, perlite and vermiculite in the ratio of 3:1:1 to produce disease and virus free seedlings. The seedlings become ready for transplanting within 28-30 days after sowing under soilless media.

Bed preparation

15-20 cm raised beds are prepared at a distance of 2 m from the centre to centre of adjacent bed. The base of bed is kept 1.0 cm and top 80 cm. On the top of the bed two lines at 60 cm distance are made, where planting is done at a spacing of 45 cm on both the lines.

Arrangement of drips and mulching

Drip lines are laid at a spacing of 60 cm on both side of bed. Drippers are arranged in each lateral at a spacing of 45 cm. It is ensured that, flow of water from each emitter is perfectly normal. After this operation complete bed is covered with 40-50 micron polythene sheet of yellow/ black/ white or silver colour. The polythene sheet is thoroughly pressed by soil at all four side of the bed. Mulching helps in saving water up to 40-50% and control weed population by almost 90%. Holes in mulch should be prepared with a PVC pipe of 8-12 cm diameter at 45 cm distance in a zigzag fashion.

Transplanting

Optimum time of planting tomato in greenhouse is from first week of August to second week of September in northern India. August or September planted crop is continued upto June or July under climate controlled greenhouse conditions. If the greenhouse is naturally ventilated then the crop can be grown up to April or May months. Transplanting is always done in the evening hours and immediately after transplanting a light irrigation is essential.

Training, pruning and trellising

Greenhouse grown tomatoes needs regular training, pruning and trellising of plants. Single stem (main) should be retained by removing all side shoots or suckers that develop between leaf petioles and the stems. The height of the plant is not allowed more than 8-9 feet and it is managed with the help of supporting rope. Usually in early stage shoots are removed by snapping them off, not cutting them by knife, blade or scissors, as diseases mainly the virus (TMV) can be transmitted from one plant to other. Pinching off older leaves below the fruits provide air circulation, which helps to reduce the incidence of the diseases and opens vines up for spraying and harvesting. Removal of excess fruits will also result in larger tomatoes at harvest that can fetch good price.

Plants are supported by plastic or binder twine, loosely anchored on the base of plants with the help of plastic clips or directly by non-slip loop and to overhead support wires (11 to 12 gauge) running to the length of the row of the bed. Overhead wires are fixed normally 8 to 9 feet above the surface of the bed and are anchored firmly to the support structure. Twine should be wrapped clockwise around the vine as it develops with one complete swirl every three leaves. The vine should be supported by the twine under the leaves, not the stems of the flower truss or fruit clusters. Twine is not wrapped around the growing tip otherwise the tip may break. When the plants reached overhead supporting wires, untie the twine (or take down the twine) from the twine roll after unlocking it to take down the vines at least 2 to 3 feet in every 15-20 days gap. Vines with twines are moved in one direction with twine roll in one row on the overhead wires and in opposite direction in the adjacent row. The plants must be pruned and trellised on regular basis for 8-9 months life cycle and as a result plants attain 30-35 feet length. The operation of trellising is started after 20-25 days of planting and continued till the end of the crop. These ropes are arranged in parallel direction to the bed. Trellising should be practiced very carefully without damaging flower clusters and growing leaves.

Pollination

Although tomato is highly self pollinated crop but under greenhouse the aided pollination is generally needed due to limited air movement and high humidity. This can be done by an electric or battery operated vibrators which vibrate the flowers cluster above the area where they originate from the stem. The vibration will release sufficient pollens necessary for pollination. This practice is done twice a day (10:00 am to 11.00 am and 2.0 pm to 3.0 pm). This operation is done till the end of April and May. If tobacco mosaic virus (TMV) has been a problem the vibrator should be wiped after each use with a clean cloth.

Fertigation

In greenhouse grown tomato, all nutrients are supplied in the form of water soluble fertilizers through fertigation. The details of fertilizers for 4000 m^2 area are as follows.

Stage of plant/ crop	N:P:K	Application rate (g)
Transplanting to emergence of first flower bunch	19:19:19	2000.0
First flowering bunch to first harvesting	19:19:19 46:0:0 0:0:50	850.0 1400.0 2200.0
Fruit harvesting to topping stage	19:19:19 46:0:0 0:0:50	850.0 2000.0 2200.0
After topping up to last harvesting	19:19:19 46:0:0 0:0:50	450.0 2000.0 1100.0
i. Requirement of water depends on temperature, humidity and types of soil ii. Application of above stated fertilizers with mentioned quantity is practiced two times a week		

Topping

This is an essential operation in greenhouse tomato where top of each plant is removed by a sharp secateurs or pruner by the end of April or up to mid of May. This operation will help in the development of smaller fruits in big size and add to higher production per plant.

Cooling and heating of the greenhouse

Heating and cooling of the greenhouses are required during growing of tomato for a period of 10-12 months. In northern plains, cooling is done from September to October and from April to June months. Evaporative cooling system is quite effective when the relative humidity in the atmosphere is below 40%. Heating of the greenhouses can be done from 15th December to end of January so that the temperature can not fall below 14^{0}C during night.

Harvesting and yield

Generally most of the varieties are ready for first picking 75 to 85 days after transplanting. Big size tomato (slicing tomato) fruits are harvested singly with attached calyx, and are graded and packed according to grades. During the summer months harvesting should be done in the early morning or late evening to avoid post harvest losses. Under greenhouse conditions tomato can yield 100 tonnes/ ha.

Plant protection

Mostly greenhouses are designed to minimize or eliminate insects and diseases problems so that plants can be grown pesticide free. Generally all four sides of greenhouses are covered with insect proof nylon net of 40 to 50 mesh size to prevent insects, including white fly, thrips, aphid, *etc*. Preventing insects from entering the protected structures is the best way of controlling virus and insect problems. However, if required, one or two sprays of insecticides can be done on need base. One spray of Imidacloprid @ 0.3-0.5 ml per litre of water should be done at 10 days after transplanting. If there is severe problem of mite, spray of Propargite @ 2.0 ml/ litre of water is recommended. Sometimes white fly or thrips entered in greenhouses, yellow and blue trappers are used for trapping of such insects.

Regular inspection of the crop is required and at early stage plant showing symptoms of virus infection are removed with roots, packed in polybag and buried in the soil. The field worker who helps in various intercultural operations in greenhouse should have clean dress and all implements used should be sterilized before use in the solution of 1% sodium hydrochloride. No one should smoke inside greenhouse.

Physiological disorders

Disorder	Cause	Control measures
Blossom end rot: Rotting or blackening of fruit at flower end.	Irregular water supply. Higher nitrogen content to soil. Poor availability of calcium in plant system.	Regular irrigation. Optimum nitrogen application. Spraying of $CaCl_2$ @ 0.5% solution on the fruit and flowers when fruit size is like a pea grain.
Fruit cracking	It may be hereditary. Irrigation at irregular interval. Excess irrigation after a dry spell. Boron deficiency.	Regular irrigation should be practiced. Two spray of borax @ 0.4%. First at the time of flowering and second after 15 days of first spray.
Spongy fruits	It may be hereditary. Irrigation at irregular interval. Excess irrigation after a dry spell. Boron deficiency.	
Fruit and flower drop	This is because of high temperature condition (more than 32^{0}C during day time and more than 20^{0}C in the night).	Spray 50 ppm PCPA (Parachloro phenoxy acetic acid) at the time of flowering.

4. GREENHOUSE CULTIVATION OF *CAPSICUM*

Capsicum can be grown under shade net houses and greenhouses to get good quality and better yield round the year.

Climatic requirement

Capsicum requires 21-28^{0}C day temperature and 18-20^{0}C night temperature with 60-65% RH for successful cultivation. The light intensity should be 50000-60000 Lux.

Varieties

The most commonly grown varieties of *Capsicum* in India are Bomby (red), Orobelle (yellow) and Indra (green). 20 g seed is sufficient for 1008 m^2 area. Seedling can also be purchased from the recognized nurseries.

Selection of planting material

- The planting material should be healthy, resistant to diseases and pests.
- Age of the seedling should be 35 to 40 days old.
- Height of the seedling should be 16-20 cm.
- Plants should possess good rooting system.
- Seedling should have at least 4-6 leaves at the time of plantation.

Other characteristics like fruit shape, fruit colour, production, fruit quality and vigour should also be considered while selecting plant material of good variety of *Capsicum*.



Bed preparation

A raised bed is always preferred which should be free from pebbles, clods, *etc*. It should be highly porous and well drained to provide adequate aeration for root development. Beds should be covered with plastic mulch in order to save water and check the growth of weeds.

Transplanting

The bed should be irrigated with water and kept wet at the time of transplanting. Seedlings should be transplanted in two rows on the raised beds by making holes in a zigzag method. The seedlings should be dipped in Carbendazim (0.2%) solution at the time of transplanting. Transplanting should be avoided during the hottest period of the day/ year and should normally be done during morning hours or late in the evening. In northern Indian plains, the optimum time of transplanting is from first week of August to second week of September.

Area of greenhouse (m^2)	Planting density	Total plants required	Spacing
560	2.5- 3.5 plants/ m^2	1400-1960	Row to row=50 cm
1008	2.5-3.5 plants/ m^2	2520-3528	Plant to plant=40 cm

Care after transplanting

After transplanting, the soil around the plants must be kept humid but not soaking wet. Irrigate the plant with hose pipe immediately after planting. During periods with strong sunshine or high temperature, the young plants must frequently be given an over head spray of water to assist establishment and reduce post planting losses. For first three weeks the irrigation should be done only by using hose sprayer and later on irrigation should be done by drip system. The following schedule of fungicides should be followed to raise the healthy crop. Quantity of water 50 ml/ plants should to be used while drenching.

S. No.	Fungicide	Dose (g per litre water)	Time of drenching
1.	Carbendazim	1.0	Immediately after transplanting
2.	Indofil M-45	1.0	3 days after transplanting
3.	Carbendazim	1.5	7 days after transplanting
4.	Indofil M-45	1.5	10 days after transplanting
5.	Carbendazim	2.0	14 days after transplanting
6.	Indofil M-45	2.0	17 days after transplanting

Fertigation

The quantity of water required for pepper irrigation completely depends upon the crop growth stage and climatic conditions. The irrigation should be given at weekly interval during September and October. However, this interval is increased to 10-12 days during winter season which may continue till first or second week of March. Thereafter this interval is reduced to a week upto April and then twice a week irrigation is done during May and June. Optimum supply of nutrients is essential for high production of peppers. Among the fertilizers, N:P:K solution in the ratio of 5:3:6 is prepared for application. For drip fertigation ammonium nitrate, potassium nitrate and phosphoric acid are used as source of nitrogen, potash and phosphorus, respectively. Calcium deficiency may cause a problem of blossom-end rot in *Capsicum*, therefore, calcium fertilizer in the form of calcium nitrate should be applied with other fertilizers. The deficiency of magnesium, zinc and iron can be corrected by application of magnesium sulfate, zinc sulfate and chilated iron, respectively. General fertigation schedule at different stages is given as under:

Water/ fertilizer	Fruit setting	Fruit set to harvest	After first harvest and each harvest
Irrigation (m^3 /1000 m^2 /day)	2.0-2.5 m^3	2.5-3.0 m^3	2.0-2.5 m^3
Nitrogen (ppm/ m^3 of water)	80-100 ppm	120-150 ppm	100-120 ppm
Phosphorus (ppm/ m^3 of water)	50-60 ppm	75-100 ppm	50-60 ppm
Potash (ppm/ m^3 of water)	100-120 ppm	120-150 ppm	100-120 ppm

Crop support

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

Topping

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

Training

Generally two system of training are practiced in *Capsicum* cultivation which are as follows.

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

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

Two-leader system

Fruit thinning

If plants bear too many fruits on the plants, it is necessary to remove some fruits for proper development of remaining fruits. Fruit thinning is done when fruits attain pea size. It is generally adopted to increase the size of fruits which ultimately improve the quality of produce.

Pollination

Capsicum is self pollinating crop but there is high degree of cross pollination because of honey bees, thrips and other insects who transfer pollen from blossom to blossom. Pollination is not improved by using an "electric bees" or by spraying plant hormones but pollination is clearly better when honey bees or bumble bees fly in the greenhouse.

Maturity indices

Harvesting of *Capsicum* is done at green, breaker and coloured (red/ yellow) stage. It depends upon the purpose for which it is grown and distance for the ultimate market. In India fruits are harvested at breaker stage for long distant markets. For local market, it is better to harvest at coloured stage. Breaker stage is the one when 10% of the fruit surface is coloured. When more than 90% of the fruit surface is coloured it is considered as coloured stage.

Harvesting

Capsicum is a nine months to one year crop and production starts after 60 to 75 days from the date of transplanting. Harvesting should be done with the help of sharp knife. Harvesting at the proper stage of maturity, careful and minimal handling of the produce will help in maintaining better fruit quality and reduce storage losses. Harvesting is generally done during morning and evening hours. Avoid harvesting immediately after fogging to check the disease and pest under control and to maintain better keeping quality of fruit. Generally, the yield of *Capsicum* is 8 to 10 kg/ m^2. Harvesting should be done by skilled worker in greenhouse and kept in plastic containers.

Cleaning, grading and sorting

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

Packing

Capsicum is packed in cartons and should hold about 10-12 kg fruits. Mostly farmers use apple boxes (used ones) for packaging *Capsicum* for local market. An ideal corrugated box carries the following information.

- On top side of the lid "Fresh vegetables" is printed.
- On width wise side of the lid "Variety, number of *Capsicum*, gross and net weight of box, box number" is written on both sides.
- On length wise side of the lid "Fresh vegetable and handle with care" is written on both sides.

Senders and buyers address with phone number.

Storage

Capsicum can be stored in a cool room at a temperature of 7-10^{0}C for up to 3 weeks if required.

5. GREENHOUSE CULTIVATION OF CUCUMBER

Cucumber (*Khira*) is an important summer vegetable crop. The tender fruits are usually eaten as salad. Greenhouse cucumbers are parthenocarpic (produce fruit without fertilization of ovules) and the fruits are usually seedless which do not require peeling.

Climate

Cucumber thrives best in warmer season or summer time. It requires a moderate warm temperature and grows best at a temperature between 25^{0}C and 30^{0}C. Optimum temperature for seed germination is 20-25^{0}C. Cucumber plant needs a light level of about 45,000 to 50,000 Lux. It is recommended to maintain the temperature above 15^{0}C during winter. Temperature over 40^{0}C or less than 14^{0}C is not favourable for cucumber production in greenhouse.

Soil and field preparation

Cucumber prefers light textured soils that are well drained, high in organic matter and have pH of 6.0-6.8. Excess sodium and fluoride may affect proper plant growth. Ideally, the land should be gentle sloping to facilitate drainage. Land is ploughed 4-5 times to a fine filth. Well rotten farm yard manure @ 20-25 tones/ ha should be incorporated at the time of final ploughing. After application of FYM or compost soil solarization with formaldehyde (37%) is essential for effective control of soil borne fungus and nematodes.

If soil is infested with nematodes, white ants or red ants, then Carbofuran @ 25 kg/ ha should be applied. Application of 2 kg each of *Azospirulum* and Phosphobacteria, 2.5 kg *Pseudomonas* along with 50 kg FYM and 100 kg neem cake per hectare before last ploughing is also recommended. Bio-control agent *i.e. Trichoderma viridae* @ 2 kg/ ha along with 100 kg FYM should be applied to planting beds.

Varieties

Parthenocarpic (seedless) varieties are best suited to greenhouse cultivation which produces fruits without pollination. The important varieties grown in India are Pusa Seedless Cucumber-6, Pant Parthenocarpic Cucumber-2, Pant Parthenocarpic Cucumber-3, Hilton, Kian, Papino, Terminator, Sun Star, Multi Star, *etc*.

Seed requirement and nursery raising

The amount of seed is determined by the spacing. A plant density of 1.5-2.5 plants/ m^2 is recommended. Seeds are sown in a porous medium at a depth of 0.5 to 1 inch in sterilized plastic cell trays. Ensure to cover the seeds with 8 to 10 mm of perlite. The soil temperature should not drop below 15^0C during germination. Soil temperatures should be between 20^0 and 24^0C during the day and at least 18^0C at night. Cover the seeded trays with plastic to reduce heat loss and to prevent drying. Remove the cover as soon as the seeds have germinated and emerged. Keep seedlings moist and provide a minimum 14 hours of light each day.

Transplanting

The seedlings need about 20 days during summer and 25-28 days during winter for transplanting. Cucumber seedlings may be transplanted at 3 to 4 leaf stage. Transplanting is best done in the evening when the weather is cool. Transplant the seedlings directly into already prepared holes on raised beds. Spacing ranges from 60 x 45 cm or 60 x 30 cm depending on soil condition. Very closely planting results in poor yield and can build up diseases due to insufficient light. Optimum plant population for 1000 m^2 area is 2200-2300 plants.

Though the cucumber can be grown in greenhouse throughout the year, the best cropping periods are from August to November and April to May. If there is extreme temperature in summer then summer cropping will be difficult.

Fertigation

Maximum yield and fruit quality will be realized only if the plant receives adequate and timely moisture when fruit begins setting and maturing. A continuous supply of nitrogen and other essential nutrients through fertigation support the growth and development of cucumber. As the plants grow and increase in size, a larger amount of water and fertilizer is needed. Therefore, the concentration rate of the nutrient solution should start out low and increase as the plants grow. The greatest demand for nutrients is during the peak fruit production period.

Nitrogen and potassium are required in the greatest amounts. Any micro-nutrient deficiencies in the soil, indicated by soil test or plant analysis, should be supplemented by incorporating into the soil before planting.

During summer season fertigation should be done twice a week. Fertigation during mild winter and peak winter should be done at an interval of 7-8 days and 10-12 days, respectively.

Table 1. Fertigation schedule in cucumber

	At vegetative stage	After start of picking
Irrigation (m^3/1000m^3/ day)		
During winter	2.0-2.5	2.5-3.0
During summer	3.0-4.0	3.5-4.0
Fertilizers (ppm/m^3 of water)		
Nitrogen	80-100	100-150
Phosphorus	60-70	80-100
Potash	100-120	120-150

Training, pruning and trellising

The basic principle in developing a training system is to uniformly maximize the leaf interception of sunlight throughout the house. The selection of a training system will largely depend on the greenhouse facility, the production system and grower preference.

The most common training system is vertical cordon also known as umbrella system. In this system, all lateral branches are pruned out as they appear until the main stem reaches the overhead wire. The growing point of the main stem is removed when one or two leaves have developed above the wire. Two lateral branches near the top of the plant are allowed to grow and are trained over the overhead wire resulting in these two branches growing downward. The growing point of each lateral is removed when near to the ground. Continue to remove all lateral vines on the main stem throughout the life of the crop. The fruits on the base 30 inches of the main stem should be pruned off as soon as they appear. This allows the plant to vigorously produce early vegetative growth that is essential for maximum fruit production. Fruits are developed at the node of each leaf. Fruits above the basal 24-30 inches of the main stem are then allowed to develop. The productivity of the lateral branches is generally less than the main stem.

Tendrils must be removed, if these wrap around the cucumber fruits. Old and diseased leaves should be removed to allow better light and aeration into the plant center.

Harvesting and yield

Cucumbers are harvested as immature fruit at 4 to 6 weeks after planting in summer and 10 to 11 weeks in winter. At suitable harvest maturity, a jelly like material is started to form in the seed cavity. Cucumber production will be reduced if the fruits are left on the plant for too long. Cucumbers are hand harvested, normally 3 times per week, depending on the weather and growth stage of the plant. Harvesting should be done with the help of sharp knife or a sickle. Cut the cucumbers by leaving 1 to 2 cm of stalk at the end of the fruit. It is recommended to harvest the fruits in early morning. Cucumbers should be picked carefully without any damage or marks.

Usually 3 crops of cucumber per year can be taken from greenhouse. Yield of cucumber crop depends on variety, disease control, fertilizer inputs, soil quality, irrigation and other greenhouse management practices. On an average, 120-150 q yield can be obtained from 1000 m^2 greenhouse in one season.

Post harvest handling

Cucumber loses moisture quickly and has the tendency to soften during storage. Marketable cucumbers should be sorted according to size and quality and individually wrapped in clear plastic. The optimum storage temperature and relative humidity is 10-12.5^{0}C and 95%, respectively. Storage or transit temperature below 10-12.5^{0}C should be avoided to prevent from chilling injury.

Physiological disorder

Crooking: A serious physiological disorder results in decreased yield and reduces quality of greenhouse cucumbers. Curvature in fruit begins at an early stage often when the ovary is less than ½ inch long-and remains throughout maturity. Slight curvature (up to 1 inch per 12 inches of fruit length) is tolerable in first-grade fruit, but excessive curving or crooking reduces market value.

Insects-pests

Greenhouses are subjected to infestation by aphid, flea beetle, white fly, mite, leaf miner, melon fruit fly, *etc*. Insect pests may transmit viruses from other host plants. Several viruses can infect cucumbers, such as cucumber mosaic, watermelon mosaic and squash mosaic viruses. There are no methods for controlling viruses in an infected plant. Managing pests that are known to transmit viruses, such as aphid and white fly, is therefore essential.

Aphid: Small, soft-bodied, pear-shaped insects with a pair of cornicles (tailpipe-like projections) protruding from the rear end. They may be red, black or green. They may be winged or wingless and feed in colonies on terminals and leaves. Infested leaves often curl and become distorted. Aphid transmits viral diseases.

Leaf miner: They tunnel the leaves between the upper and lower surfaces. This damage results in long, white and zig-zag tunnels under the surface of the leaves. If there are many larvae feeding on a single leaf, their tunnels may join and give the appearance of large blemishes or spots.

Spider mite: Outbreaks of spider mite occur occasionally, especially during hot, dry weather. Spider mite feed on plant sap and prefers to live on the leaf underside. Their feeding causes stippling of white areas on the leaves. Heavily infested leaves may turn yellow and drop off prematurely.

White fly: They are small insects with broad wings covered with fine, snow-white waxy powder. Both adults and nymphs may feed on foliage by sucking juices from the underside of the leaf. They produce honey dew which may result in a blackening of the leaf. White fly transmit leaf curl virus, which greatly damage the crop.

Melon fruit fly: Damage of melon fruit fly occurs when adult female flies lay eggs into fruit. An indentation often occurs at the site of oviposition and the fruit may or may not become curved. Attack is severe on young developing fruit, especially under high humidity conditions.

Thrips: Thrips are small (15 mm) slender insects. They tend to live and feed on the leaves. Leaf edges tend to curl downward after heavy thrip feeding. Population pressure is especially high during hot and dry conditions.

Nematode: It is likely to be found in greenhouses where continuous production is taken. Plants become stunted and the roots develop galls or knots. Plants start to wilt rapidly during periods of moisture stress. Leaves turn yellow and may appear to have a nutrient deficiency.

Control measures

Insecticide	Quantity	Effective against
Thiamethoxam	0.5 ml/ litre	Sucking pests like thrips, white fly, aphid.
Imidacloprid	0.5 ml/ litre	Sucking pests like thrips, white fly, aphid.
Thiodicarb	2 g/ litre	Fruit borer
Spinosad	0.5 ml/ litre	Thrips and caterpillar.
Abamectin	0.5 ml/ litre	Leaf miner and red spider mite.

Diseases

Cucumber grown in soil culture is subjected to *Fusarium* wilt, *Verticillium* wilt, gray mold, viruses and nematodes. These can occur as a single problem or a combination of two or more at a time. Marketable yield can be reduced by 10-80%, depending on the severity of one or a combination of diseases.

Downy mildew: Initially lesions irregular to angular and pale green spots appear on the upper side of leaves near the plant crown. The lesions then turn into yellow angular spots. The underside of leaves later develops a downy white to gray mold, which may turn gray to purple during wet weather.

Powdery mildew: Symptoms develop primarily in 2-3 week old leaves and on stems. The disease is characterized by white powdery-like growth, especially on the upper side of leaves and on stems.

***Fusarium* wilt:** Typical symptoms include a yellowing and wilting of the foliage. Stem tissue near the ground line is likely to show brown streaks.

Gray mold: It is usually recognized by a fuzzy and gray growth on the stems or flower pedicels. The leaves turn brown beginning at the tip and progress backward. It becomes a major problem when the greenhouse is not ventilated and the humidity is continuously kept at high level.

***Verticillium* wilt:** The foliage turn yellow and wilt. It forms V-shaped lesions on the leaves. Internal tissues near the base of the plant usually show brown discoloration.

Bacterial angular leaf spot: First symptoms are small and water-soaked angular lesions on the leaf underside. Lesions restricted between the small cucumber leaf veins, turn yellow, develop yellow hollows and finally disintegrate. Under wet conditions particularly during early in the morning, the bacteria ooze from the lesions which later dry into a white crust.

Gummy stem blight: In older plants lesions produce characteristic red or brown exudates at the crown of the plant and along the vines. Black spores may be seen around the infected tissue. Initial leaf symptoms are irregular circular dark spots which may be surrounded by a yellow spot and later dry up and crack.

Mosaic viruses: Initially mottling with raised dark green areas and some distortion of younger leaves occur. At severe infection the leaves turn downward at the margins, become rough, crinkled or corrugated. Plants may become stunted.

Control measures

Fungicide	Quantity	Effective against
Dimethomorph	1.5 g/ litre	Downy mildew, anthracnose, *Altenaria* leaf spot and blights.
Azoxystrobin	0.5 ml/ litre	Blight, downy mildew and powdery mildew
Carbendazim	2 g/ litre	Wilt, root rot, collar rot and leaf spot.
Copper oxychloride	2-2.5 g/ litre	Bacterial leaf spot, Damping off, root rot and collor rot.
Indofil M-45	2 g/ litre	*Alternaria* leaf spot, *Phytophthora* leaf blight and other foliar diseases.
Metalaxyl	1.5 g/ litre	Damping-off and downy mildew.
Chlorothalonil	2 g/ litre	Leaf spots, late blight and early blight.

General management aspects of pest and diseases

Pests and diseases remain the greatest challenge in greenhouse cucumber production. Appropriate and timely management makes all the difference between good production, poor production or total crop failure. Proper identification of the pest and disease is critical in a control strategy. The general principles in pests and disease management are as follows.

- **Crop rotation:** Follow a minimum of 2 year rotation programme.
- **Quality seed/ resistant varieties**: Use certified disease free seed treated with an approved fungicide to control seed rot and post emergence damping off.
- **Field hygiene**: Old crop, weeds and crop debris should be removed from the greenhouse since these are source of pests and diseases. Staking and pruning also helps in reduction of disease incidence.
- **Proper crop production practices**: Provide the right growing conditions to plants (sufficient water and balanced fertilization), particularly when they are young. Remove lower leaves to increase the airflow around the plants. Maintain optimum relative humidity (80%) in greenhouse. Avoid over application of nitrogenous fertilizers. Do not over ventilate the planting area as this can reduce the relative humidity and can result in lower yields and fruit can have gummy ends. Always use healthy plants which are more likely to withstand pests and diseases.
- **Irrigation management:** Poor irrigation timing and scheduling may lead to disease. Overhead irrigation in the evenings can encourage early blight.
- **Regular crop monitoring:** Ensure regular crop scouting for pests, diseases, weeds and nutrient deficiencies. Proper pest and disease identification is the first and critical step in their management. This helps to detect problems early and take control measures on time.

6. LOW TUNNEL TECHNOLOGY

Need of low tunnels

Presently, river bed cultivation is in practice for production of cucurbitaceous vegetables in off-season in northern parts of India, although area under river bed cultivation is very limited, which cannot be extended further. Besides, glut in the market and low quality produce causes poor economic returns to the farmers. But with the use of protective structures such as row covers or low tunnels vegetable crops like muskmelon, watermelon, longmelon, roundmelon, bitter gourd, bottle gourd, summer squash, *etc*. can be grown very early in the spring or summer season so that the produce to the market can be sent early in the season. It also extends the growing season for selected vegetable crops when large quantities of the crop produce are not available results in higher prices from their off-season produce. For example, crops like longmelon, roundmelon, bottle gourd, bitter gourd, muskmelon, summer squash, *etc*. if grown early in spring or early summer often command a greater price on the market to the growers. It is an eco-friendly and sustainable technology for off season vegetable production.

Low tunnels are flexible transparent covering that are installed over the rows or individual beds to enhance plant growth by warming the air around the plants using heat from the sun especially during winter season. Plastic tunnels are transparent which provides required sunshine to the plants, and the plastic also plays a barrier against the cool air in winter.

Normally the economics of protected cultivation directly depends upon the initial cost of fabrication of the protected structure, its running cost and the available market for high quality

Cracking

Mosaic

Drying of ovary

Wilting

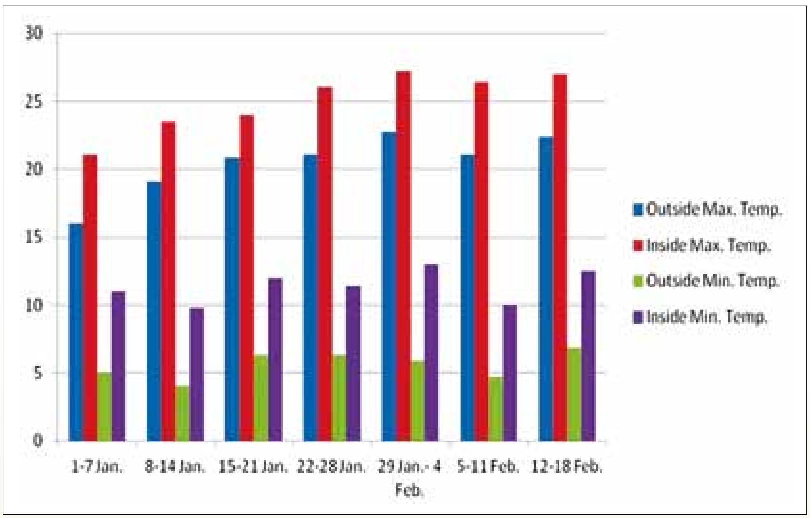
Sun scorching

produce. Therefore, low cost protected structures such as low tunnels, which can generally be fabricated with low cost and the running cost of such structures is also very low. These are highly suitable for off-season cultivation of cucurbits and are also highly economical for peri-urban areas of northern plains of India (Singh, 2014).

Problems associated with cultivation of cucurbitaceous crops under open field conditions during summer season in hot arid conditions are depicted as under.

Table: 5 Meteorological data of winter spring seasons of 2015-16 and 2016-17 at Bikaner

S. No.	Month	Temp.		RH %		Rainfall (mm)	Wind speed (km/ hr)	Sunshine hours	Evaporation (mm)
		Max.	Min.	Max.	Min.				
1.	November, 2015	29.32	12.34	62.93	33.70	0.0	1.74	8.54	3.10
2.	December, 2015	24.60	7.40	65.90	28.50	0.0	1.10	7.71	1.40
3.	January, 2016	23.80	6.20	60.20	57.90	0.0	1.00	4.20	1.10
4.	February, 2016	27.40	0.60	70.20	49.20	4.9	4.80	8.00	1.70
5.	March, 2016	33.70	15.90	72.10	44.50	21.0	5.00	9.20	3.60
6.	November, 2016	24.51	9.42	73.17	40.07	0.0	1.14	8.29	5.67
7.	December, 2016	22.75	5.67	70.39	36.29	0.0	1.19	7.57	3.88
8.	January, 2017	21.40	6.60	91.30	56.20	2.2	4.10	5.40	2.10
9.	February, 2017	28.30	9.30	74.40	24.60	0.0	4.70	9.40	5.00
10.	March, 2017	33.70	15.60	60.30	21.00	0.8	5.60	8.30	7.20



Average temperature of 3 years outside and inside low tunnels

What is low tunnel?

Low tunnels also known as row covers are low cost miniature structures producing greenhouse like effect. A flexible transparent covering of plastic sheet or non-woven cloth is installed over the rows or individual beds of direct seeded/ transplanted vegetables. It enhances plant growth by warming the air around the plants during winter season and the photosynthetic activities of the plant by increasing the concentration of carbon dioxide inside the tunnels. When the night temperature during winter season goes below 8^0C for a period of 30-45 days it warms the soil and protect the plants from hails, cold wind, injury which stimulates germination, early growth and improves the quality of crop. Thus, the plants can be grown successfully during winter or off-season and by this way the crop can be advanced the by 30 to 45 days than the normal season. All together help to increase yield per unit of area and cost invested. Besides being inexpensive, these structures are easy to construct and dismantle.

Plastic low tunnels are miniature form of greenhouses used to protect the plants from rains, winds, low temperature, frost and other vagaries of weather. The low tunnels are very simple structures requiring very limited skills to maintain and easy to constructs and offer multiple advantages. For construction of low tunnels, film of 25-50 micron would be sufficient.

Principle of low tunnels

In our surrounding atmosphere CO_2 concentration is 0.03% means 300 ppm. Plants use this CO_2 for photosynthesis. In poly tunnels, during night time there is no photosynthesis but CO_2 is given out through respiration. This CO_2 remain accumulated around plants hence the CO_2 concentration is higher inside the poly tunnels as compared to outside and this CO_2 is again used by plants growing in ploy tunnels for rapid photosynthesis.

Advantages of low tunnels

- Early and off-season production of cucurbits can be done to get better return.
- Provides crop diversification opportunities and supports production of high quality and clean products.
- Makes cultivation of vegetables possible in areas where it can't grow in open conditions *viz*., high altitudes and hot arid regions.
- It creates optimum microclimate for plant growth thus, increases photosynthetic activities of the plants and thereby yield.
- Used for raising healthy and early nursery.
- Maintains optimum temperature for plant growth.
- Enhances nutrients uptake by the plants.
- Increases photosynthetic activities of the plants.
- Used for cultivation during winter.
- Provide protection against unfavourable environment like high rainfall, hail, low temperature, frost, wind, insect-pests, *etc*.

- Inexpensive, as these structures are easy to construct and dismantle.
- It generates better revenue even though total yield may be the same or lower because market prices are higher.

Components of tunnels

Structural

GI wires (2.0 m long with 4-6 mm diameter) or *phlasa* sticks or bamboo sticks.

GI wires

Phlasa sticks

Covering material

- Transparent and biodegradable polyethylene film of 25-50 microns having 2 meter width.
- White coloured non-wooven cloth.

Important points for cultivation under low tunnels

- Prior to start off-season vegetable cultivation in tunnels, the farmer must have practical knowledge about vegetable cultivation.
- Soil and water quality should be tested before starting the cultivation.
- Recommended package and practices should be followed.
- Farmer must have the updated market information to earn high profit.

Table 1. Improved varieties and seed rate of cucurbits

S. No.	Crop	Varieties	Seed rate (kg/ ha)
1.	Bottle gourd	Thar Samridhi, Pusa Naveen, Pusa Summer Prolific Long, Pusa Summer Prolific Round, Pusa Sandesh, Pusa Santushti.	2.5-3.0
2.	Longmelon	Thar Sheetal, Punjab Longmelon-1	1.0-1.2
3.	Muskmelon	Durgapura Madhu, Hara Madhu, Pusa Madhuras, Pusa Madhurima, Punjab Sunheri.	2.0-2.5
4.	Ridge gourd	Thar Karni, Pusa Nasdar, Pusa Nutan.	2.0-2.5
5.	Summer squash	Pusa Alankar, Early Yellow Prolific, Australian Green, Pusa Pasand, Punjab Chappan Kadddu-1.	3.0-3.5
6.	*Tinda*	Pusa Raunak, S-48.	2.5-3.0
7.	Watermelon	Thar Manak, Sugar Baby, Durgapura Lal.	2.0-2.5

Field preparations and sowing

The land should be prepared to a fine tilth before construction of low tunnels. Application of manures and fertilizers depends upon the crop, variety and soil status. Well decomposed FYM should be to be applied @ 150-200 q/ ha, phosphorus @ 60-80 kg/ ha and potash @ 50-60 kg/ ha at the time of final land preparation. Nitrogen should be applied @ 60-80 kg/ ha in three split doses. One-third of N should be applied basally, about 8-10 cm away from the seeds. Remaining dose of nitrogen should be given at the time of earthing up and initiation of flowering as topdressing. 45-60 cm deep and 45-60 cm wide trenches should be made at a distance of 2.0-2.5 m in east-west direction in December end. Recommended doses of fertilizers (NPK) should be applied in trenches and mixed thoroughly. The excess dose of nitrogenous fertilizers should be avoided as it results in more vegetative growth and less pistillate flowers. For irrigation one lateral (12-16 mm size) in each trench having drippers of 4 litre/ hour discharge spaced at 60 cm distance should be placed.

Before sowing, the seeds should be allowed to soak in water for 3-4 hours (muskmelon, longmelon, cucumber), 6-8 hours (bottle gourd), 10-12 hours (*tinda*, watermelon, ridge gourd) and 24-36 hours (bitter gourd) for quick germination. After soaking, seeds should be treated with Captan or Thiram @ 2 g/ kg, wrapped in gunny bag and kept at warm place (straw) for 2-3 days to facilitate early germination. Daily monitoring of seed in gunny bag should be done to avoid any damage. Sowing of pre-germinated seeds should be done from third week of December to first week of January. Two seeds near each dripper should be done to maintain optimum plant density. The trenches should be irrigated with drip irrigation prior to sowing.

How to construct low tunnels?

Low tunnels are constructed with bamboo or iron rods to form semicircular frames, which are then covered with transparent plastic sheet or white coloured non-wooven cloth. Such structures are temporary and usually no higher than 1.0 m. Just after sowing, the flexible galvanized iron hoops (4-6 mm thick) are fixed manually at a distance of 3-4 m on trenches. The width of two ends of hoop and height from ground level should be kept 1.0 m. The erected iron hoops should be covered with transparent 25-50 micron biodegradable plastic sheet of 2.0 m width on the day of sowing. Both the perpendicular ends of plastic sheet should be buried in the soil to make low tunnel. It is done manually however; tractor driven machines are also available in advanced countries for this purpose. The prepared tunnel reflects infra-red radiation and keep inside temperature 8-10^{0}C higher than outside. Locally available material such as *phalsa* twigs can also be used instead of GI wire to reduce the cost.

The increase in temperature inside low tunnel facilitates early germination of seed and crop growth. The plastic sheet serves two purposes: first it traps heat and reduces water loss and second it protects plants from adverse climatic conditions. Good cross ventilation and potential stresses caused by heavy wind, hail or heavy rains must be considered while constructing the structure.

Erection of wires

Poly tunnels

Profuse growth of cucurbits under low tunnels

Mulching with *Saccharum (sarkanda)*

Crops ready for harvesting

Generally biodegradable plastic film of 25-50 micron thickness is used. However, plastic film of 25 micron performed best under arid region. This biodegradable plastic is available according to the requirement of the duration one want to cover the crop or use as mulch in the crop. After that period, the plastic after receiving sufficient sunlight, it becomes brittle. The film eventually breaks down into small flakes and finally completely composted in the soil. The plastic is having vented or silted during the growing season as the temperature increase within the tunnels during peak day time. Vents also help bees to enter inside tunnels for pollination. Generally, 3-4 cm size vents can be made on eastern side of the tunnels just below the top on a distance of 2.5 to 3.0 m. Now a day's non-woven cloth is also being used as covering material instead of plastic which is cheaper than plastic.

Fertigation, irrigation and inter-culture

It is very difficult to obtain full benefit from low tunnels without micro-irrigation and fertigation. Drip irrigation combined with fertigation is essential for growing plants inside the tunnels. It not only applies water in the root zone but also keeps the humidity low leading to less pest and disease problems. Fertilizers are applied through drip irrigation. The water and fertilizer requirement of crops is usually depends upon the crop, variety and soil conditions. Solid water-soluble fertilizers should be used for fertigation as they are 100% water soluble and generally contain two or more major nutrients as well as micro-nutrients. They completely dissolve in water leaving no precipitate therefore; there is no chance of clogging of emitters due to fertigation. Fertigation with water soluble NPK (19:19:19) @ 8-10 kg/ ha should be done at vine development and flowering stages. Spray of 25 ppm boric acid along with 1% urea as the adjuvant 3 times from 8-leaf stage to 45 days after sowing was found beneficial which increase number of pistillate flowers, fruit setting and improve quality of fruits in all cucurbits. Addition of urea as an adjuvant @ 1% to the spray solution improved the absorption of boron by leaves. Optimum soil moisture should be maintained by operating drip system at 5-6 days interval during December to February) and at an interval of 2-3 days during March-April months for 1-1.5 hour.

Weeding and hoeing should be done along and between the rows. It should be done at the time of topdressing of nitrogenous fertilizer which is generally done before emergence of tendrils. Once the foliage has covered the soil, it is better to stop hoeing since it may damage the roots. Normally two to three hoeing and weedings are required to keep the crop weed free.

Pollination under low tunnels

Poor pollination is a major problem at high temperature. Inadequate pollination cause drying of ovary, misshapen and undersize fruit. Pollination is an important factor in cucurbits to be taken care of for good fruit setting thereby increasing total yield. The sex form in most of the cucurbits is monoecious or andromonoecious, hence effective pollination is needed. It can be performed by honeybees (*Apis melifera*) which can work in tunnels easily through the vents, made on the plastic. Optimally, one beehive having 30000-50000 workers is sufficient for one-acre area for effective pollination in crops like muskmelon, summer squash, *etc*. It is recommended to keep the beehive box on the north-west side of the field for effective working of the bees. Plastic can also be removed during day time when plants start to produce pistillate flowers to facilitate pollination of the crop by visit of bees. It is very important to ensure pollination when there is complete flowering in the plants inside the tunnels because the yield would be reduced if there is poor pollination.

Hardening of plants

When plants start to produce pistillate flowers, the plastic should be removed partially during day time and covered during night hours. In second or third week of February when outside temperature rises, the plastic is completely removed from the plants. While removing the plastic care should be taken that it should not be removed suddenly. Hardening of plants is essential to prevent death of plants. Always remove the plastic during morning hours and cover in evening hours. Repeat this process for 2-3 days to harden the plants and avoid shock.

Care of crop during summer

With the onset of summer season in hot arid regions the wind velocity increases which increase the soil temperature, collect the vines in rows leading to poor pollination and flower drop. To avoid this situation, *Saccharum* (*sarkanda*) should be put in the space left between rows to facilitate proper vine spread and to avoid the direct contact of vines with warm soil. Proper direction to the growing vines should be given manually so that each and every pistillate flower gets pollinated which ultimately resulted in increased yield.

Management of insect-pests and diseases

Monitoring of the crop inside low tunnels should be done to protect the crop from insect-pests and diseases. Hadda beetle, leaf eating caterpillar, leaf miner, white fly, aphid and fruit fly are the main insects of cucurbits in hot arid region of Rajasthan. Among the insects fruit fly is one of the most devastating insect of cucurbits. Spray of either Imidacloprid 17.8SL or Thiamethoxam 70WS @ 0.3-0.5 ml/ litre water control the aphid, white fly and leaf miner. Hadda beetle, leaf eating caterpillar and fruit fly can be controlled by spraying Dimethoate 30EC or Spinosad 45SC @ 0.5-0.7 ml/ litre water. Spray should always be done after harvesting of fruits. It is better to adopt integrated pest management (IPM) practices to reduce load of insecticides. Expose the soil to sun by deep ploughing during summer to kill hibernating pupa of insects. Install commercially available Cue-lure traps 7-8 in one hectare area to manage fruit fly. Add 4-5 ml Malathion 50EC and 250 g jaggery (*gur*) in one litre water. Fill the prepared solution in small 8-10 pots and place them in one hectare field to control fruit fly.


Cue-lure to manage fruit fly

Fungal diseases (downy mildew, *Alternaria* leaf blight, *Fusarium* wilt) and viral diseases (cucumber mosaic virus, bud necrosis) adversely affect the yield of cucurbits. Treat the seed with Captan or Thiram or Carbendazim @ 2.0 g/ kg seed prior to sowing to protect the crop from fungal diseases. Spraying of Indofil M-45 @ 2.0 g/ litre water is helpful to control downy mildew and *Alternaria* leaf blight. Drenching of crop with Carbendazim @ 2.0 g/ litre water should be made as and when symptoms of wilt appear. The insect vectors (aphid, white fly) of viral diseases can be effectively controlled by spraying the crop with Imidacloprid 17.8SL @ 0.3-0.5 ml/ litre water.

Harvesting and crop advancement

Different cucurbits sown during December (third to fourth week) advanced the crop by 30-50 days over their normal season of cultivation. If the longmelon crop sown in third week of December, can be harvested in last week of February or first week of March. Similarly, other cucurbitaceous crops such as muskmelon, watermelon, bottle gourd, roundmelon, summer squash and ridge gourd can be advanced 40-50 days early than the normal season under low tunnels.

Table 2. Sowing time, harvesting time and crop advancement of cucurbits in arid region under low tunnels

S. No.	Crop	Sowing time	Harvesting time	Advancement in harvesting (days)
1.	Bottle gourd	Third to fourth week of December	Second to third week of March	40-50
2.	Longmelon	Third week of December to first week of January	Last week of February or first week of March	30-50
3.	Muskmelon	Third week of December to first week of January	Second week of April to last week of April	30-40
4.	Ridge gourd	Third to fourth week of December	Second to third week of March	40-50
5.	Summer squash	Third week of December to first week of January	Last week of February	40-50
6.	*Tinda*	Third to fourth week of December	Last week of February	40-50
7.	Watermelon	Third week of December to first week of January	Second week of April to last week of April	30-40

Off season cucurbits produced under low tunnels can fetch very high price in the market. On an average the cost benefit ratio of 2.0-2.75 can be obtained under hot arid conditions.

Table 3. Yield and expected B:C ratio of different cucurbits under low tunnels in arid region

Crop	Cost of cultivation/ ha (Rs.)	Production (q/ ha)	Rate (Rs./ kg)	Gross income (Rs.)	Net income (Rs.)	B: C ratio
Longmelon	90000	180	15	270000	180000	2.00
Muskmelon	80000	150	20	300000	220000	2.75
Watermelon	80000	240	10	240000	160000	2.00

Future scope and research need

There are number of opportunities in various agro-climatic zones in India for low cost protected structure *viz.,* low tunnels. They are highly suitable for growing vegetables in the peri-urban areas of the northern plains of India with location specific modifications (Singh and Sirohi, 2006). The plastic low tunnel technology has great potential for early and off-season cultivation of arid cucurbits during winter. It is highly profitable and can give good economic returns to the farmers. The package of practices including fertigation, need to be worked out for different agro-climatic situations. Use of biodegradable plastics or polymers should be encouraged to combat environment pollution. The further refinement in existing technology will definitely go a long way to harness the full potential of low cost poly tunnels in vegetable production in hot arid zone and may be used on a commercial scale by the farmers. Sometimes due to uncertainty of market prices of vegetable produce the expected profit is less. Low tunnel technology is emerging as future horticulture production technology because of its potential to overcome emerging problems of climate variations in arid regions.

The technology has wide scope in arid regions to produce quality yield of cucurbitaceous crops. It is gaining popularity among the farmers however; more research is required on the following points to reduce cost of cultivation.

- Identification and development of low tunnel responsive varieties.
- Technology for raising complete off season crop under tunnels.
- Standardization of tunnel technology for cabbage, cauliflower, coriander, tomato, brinjal, *etc*.
- Use of non-wooven cloth for tunnel preparation.
- Research on proper disposal of waste material, especially plastic film.

7. INSECT-PESTS OF CUCURBITS AND THEIR MANAGEMENT

The main pests of cucurbitaceous crops are red pumpkin beetle, leaf eating caterpillar, leaf miner, white fly, Hadda beetle, aphid, mite and fruit fly. The melon fruit fly has been the most prominent pest over the last several decades in India. Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100%. The nature of damage and management practices of different insect-pests of cucurbits is as follows.

Red pumpkin beetle

Both grub and adult attack the crop at seedling stage and make holes in the cotyledonary leaves. When the attack is severe, the crop is totally destroyed. However, it is not observed under hot arid conditions.

Management

- Spray the crop with Spinosad 45SC (0.5-0.7 ml/ litre water) or Dimethoate 30EC (2 ml/ litre water) or Malathion 50 EC (1.5-2 ml/ litre water).

Hadda beetle

The grubs and adults scrape the leaves in a characteristic manner and feed. They feed on the epidermal layers of leaves which get skeletonized and gradually dry away. They affect the crop in all the stages. Incidence of this pest is observed in summer as well as rainy season. The peak period of infestation varies with the region; however, the peak is April-June during summer and September-November during rainy season.

Management

- Plough the fields just after harvesting to destroy the adults.
- At initial stage collect and destroy the affected leaves along with the eggs, grubs and adults.
- Spray either Imidacloprid 17.8SL or Thiamethoxam 70WS @ 0.3-0.5 ml/ litre water.

Leaf eating caterpillar

Caterpillars roll the leaves with silken threads and eat the leaves between the veins. They also attack the flowers and reduce the number of fruits set. Young fruits are also attacked by this pest. The caterpillars damage the skin and cause the fruits to rot. Incidence is recorded in both summer as well as rainy seasons.

Management

- Foliar spray of either Malathion 50 EC or Dimethoate 30EC @ 2 ml/ litre of water should be done at periodic interval.

Melon aphid

It infest the tender shoots and the under surface of leaves in very large numbers and suck the sap. Severe infestation results in curling of leaves, stunted growth and gradual drying and death of young plants. Black sooty mould develops on the honey dew of the aphid which falls on the lower leaves affecting photosynthetic activity. Incidence can be observed from last week of February to first week of April.

Management

- Infested crops should be destroyed immediately after harvest to prevent excessive dispersal.
- Spray of Imidacloprid 17.8SL @ 0.3-0.5 ml/ litre water control the aphid.

White fly

The nymphs are found in large numbers on the under surface of leaves and suck the sap. Severe infestation results in premature defoliation and development of sooty mould on honey dew excreted.

Management

- Foliar application of either Imidacloprid 17.8SL or Thiamethoxam 70WS @ 0.3-0.5 ml/ litre should be done.

Mite

Both nymphs and adults suck the sap from young foliage and growing tips. Downward curling and crinkling of leaves giving an inverted boat shaped appearance, stunted growth and elongation of petiole are the characteristic symptoms.

Management

- Spray the crop with Propargite @ 2-3 ml/ litre water.

Melon fruit fly

The female flies puncture the soft and tender fruits with their stout and hard ovipositor and lay eggs below the epidermis. On hatching the maggots feed inside on the pulp of fruits and the infested fruits can be identified by the presence of brown resinous juice which oozes out of the punctures made by the flies for oviposition. These punctures also serve as an entry for various bacteria and fungi; as a result, the infested fruits start rotting, get distorted and malformed in shape and fall off from the plants pre-maturely.

It remains active throughout the year on one or the other host. During the severe winter months, they hide and huddle together under dried leaves of bushes and trees. During the hot and dry season, the flies take shelter under humid and shady places and feed on honeydew of aphid infesting the fruit trees. It actively breeds when the temperature falls below 32^{0}C and the relative humidity ranges between 60 to 70%.

Management

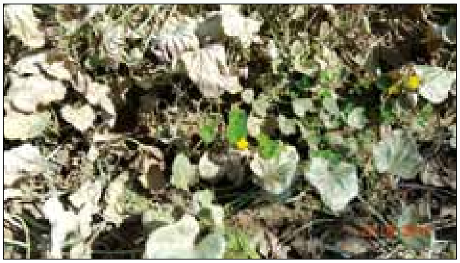
- Expose the soil to sun by deep ploughing during summer to kill hibernating pupa.
- Destruct all infested and unmarketable fruits and the dispose off completely burying them deep into the soil.
- Install commercially available Cue-lure traps 7-8 in one hectare area.
- Application of either Dimethoate 30EC @ 2 ml/ litre water or Spinosad 45SC @ 0.5-0.7 ml/ litre water is helpful in reducing the damage.



8. DISEASES OF CUCURBITS AND THEIR MANAGEMENT

A large number of diseases occurred on cucurbitaceous crops and adversely affect the crops at different stages which are as follows:

Powdery mildew



Tiny white to dirty grey spots on the foliage, leaves and green stem appears. Later theses spots become powdery and enlarge into patches. Under severe infection the fruits may also be covered with powdery mass. The humid weather is favourable for the spread of this disease.

Management

- Grow resistant varieties.
- Spray the crop with Karathane @ 0.1% at 2-3 times at an interval of 10-15 days just after the appearance of disease.

Downy mildew

Angular yellow coloured spots often restricted by the veins appear on upper surface of leaves giving purplish growth on the lower surface. The affected leaves die quickly.

Management

- Give hot water treatment to seeds before sowing (55^{0}C for 15 minutes).
- Follow prophylatic spray of Indofil M-45 @ 0.2% at 15 days interval.

Anthracnose

Reddish brown spots are formed on the affected leaves and become angular or round when many spots collapse. It results in shriveling of leaves which later die.

Management

- Treat the seeds with Agrosan GN or Carbendazim @ 2 g/ kg seed.
- Spray the crop with Indofil M-45 @ 0.2% or Carbendazim @ 0.1% or Copper Oxychloride @ 0.2% and repeat at 7-10 days interval if necessary.

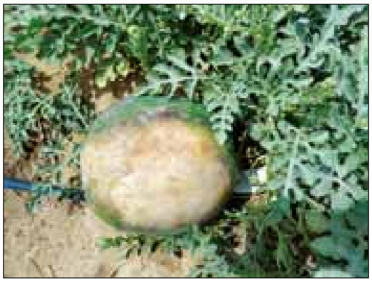
Alternaria leaf blight

Symptoms first appear on the upper leaf surface as small, circular, tan spots with white centers. These spots enlarge, turn light brown and form a slight depression. Severely infected leaves turn brown, curl upward, wither and die.

Management

- Three sprays of Indofil M-45 (0.25%) at 10 days interval was effective for reducing this disease.
- Combined treatment of Carbendazim @ 0.1% (seed treatment)+Indofil M-45 @ 0.25% (foliar spray)+*Pseudomonas fluorescens* @ 5% (foliar spray)+Neem leaf extract @ 5% (foliar spray) gave the most effective control.

Fruit rot



Water soaked lesions girdle the stem, later extending upwards and downwards. The rotting of affected tissues occur and even grown up plants collapse. The fungus causes rotting of fruits which have direct contact with soil.

Management

- Avoid flood irrigation and raise the crop on drip system.
- Treat the seeds with Thiram or Carbendazim @ 2 g/ kg seed.
- Apply *Trichoderma* @ 5 kg/ ha in soil before sowing. Spray the crop with Carbendazim @ 0.1% or Copper Oxychloride @ 0.2% and repeat the spray if necessary.

Fusarium wilt

The fungus is seed-borne as well as a persistent soil inhabitant. Seedling injury is high at 20-30^{0}C temperature. Wilt development is also favoured by temperature of about 27^{0}C. No infection occurs at temperature below 15^{0}C and above 35^{0}C. The plants are prone to attack at all stages of growth. Germinating seeds may also rot in the soil. The affected plants turn yellow, show wilting, and later, the whole plant die. It causes damping off disease of seedlings. Small leaves lose their green colour and wilt.

Management

- Dip the seeds in hot water (55^{0}C) for 15 minutes to kill the seed-borne infection.
- Treat the seeds with Captan or Thiram or Carbendazim @ 2 g/ kg seed before sowing.
- Drench the soil around roots with Captan or Carbendazim @ 0.2% solution.

Mosaic virus

The young leaves develop small greenish-yellow areas and they become more translucent than those in remaining parts of the leaf. Yellow mottling is seen on leaves and fruits. Leaf distortion and stunting of infected plants occur. The virus is transmitted through sap, seed and aphid.

Management

- Use the seed collected from virus free plants.
- Rough out the infected plants from the field as soon as they are noticed.
- Eliminate the weed hosts from the field.
- Spray Imidacloprid 17.8SL @ 0.5-0.6 ml/ litre water to control the vectors.

Bud necrosis

It is a serious disease of watermelon and caused by Tospovirus. The infected plants have small internodes, erect shoots and finally the apical portion of the infected vines die. It is transmitted through thrips.

Management

- Uproot and destroy alternate hosts.
- Treat the seeds with Imidacloprid (5 g/ kg seed) prior to sowing.
- Use silver coloured ultra-violet reflective plastic mulch.
- Spray the crop with Imidacloprid 17.8SL (0.5-0.6 ml/ litre water) and Thiamethoxam 70WS (0.5-0.6 ml/ litre water) alternatively at 15 days interval.

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