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# DISEASE MANAGEMENT IN ARID HORTICULTURAL CROPS

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# PREFACE

India is endowed with diverse agro-climatic conditions, which is one of the biggest assets of Indian agriculture and offers unique opportunity to grow wide range of plant species including fruits and vegetables. Arid Horticulture denotes cultivation of fruits and vegetables under dry and arid regions. Arid region in India is stretched over 39.54 million ha (31.71 million ha is under hot arid region and 7.38 million ha under cold arid region) comprising about 12.02% of the total area of the country. In India, Rajasthan is the largest state covering maximum area under hot arid zone. The tracts of hot arid region are found in the states of Rajasthan, followed by Gujarat, Andhra Pradesh, Haryana, Karnataka, Maharashtra and Punjab. Hot arid region of Rajasthan receives very low rainfall, extremes of temperature (1–48°C), drought, high wind velocity, low soil fertility and sandy soils which lead to poor crop growth. Apart from these limitations, plant diseases are major bottleneck in the production in hot arid ecosystem, which cause heavy losses to the crops frequently.

Arid horticultural crops like ber, bael, aonla, date palm, pomegranate, karonda, mulberry, watermelon (*mateera*), kachri, muskmelon, bottle gourd, ridge gourd and snap melon, which are mostly grown in Central and Western India are affected by various plant diseases caused by fungi, bacteria, viruses, phytoplasmas and nematodes which in turn cause substantial yield losses every year to the growers of arid regions. Fairly good numbers of management practices have been suggested by various workers to check theses diseases; however, such information are scattered and frequently not accessible. Earnest efforts have been made to bring up a technical bulletin on disease management entitled **"Disease management in arid horticultural crops"** in its present form, which includes the work done at ICAR-CIAH and elsewhere. This technical bulletin contains good coloured photographs depicting symptoms, epidemiology and salient disease management strategies of major diseases of arid horticultural crops to protect yield loss of the crop as well as quality of produce for easy comprehension and update the knowledge of growers, extension workers and Ph.D. Scholars, alike. I hope the reader would be benefitted from this publication.

June, 2018
Bikaner

**(Authors)**

# INTRODUCTION

Arid Horticulture denotes cultivation of fruits and vegetables under dry and arid regions. Arid region in India is stretched over 39.54 million ha (31.71 million ha is under hot arid region and 7.38 million ha under cold arid region) comprising about 12.02% of the total area of the country. The hot arid region constitutes a major part of north-western India; however, it occupies small pockets in southern India. In India, Rajasthan is the largest state covering maximum area under hot arid zone. The tracts of hot arid region are found in the states of Rajasthan (19.6m ha), followed by Gujarat (6.2m ha) and other states such as Andhra Pradesh, Haryana, Karnataka, Maharashtra and Punjab of India. Out of total geographical area of Rajasthan, 79.08% lying in arid and semi–arid climate, spread over 21 districts of the state. The twelve districts of north-western Rajasthan (Barmer, Bikaner, Churu, Sri Ganganagar, Hanumangarh, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Pali and Sikar) accounts for 63.4% of the hot arid region of the country. Hot arid region receives very low rainfall, varies from 100 mm per annum in north-western district of Jaisalmer to 450 mm per annum in the eastern boundaries of arid districts of Rajasthan. In Gujarat, it varies from 300-500 mm and in Punjab and Haryana from 200-400 mm per annum. Most of the precipitation in north-western arid region takes place from July to September. Occasional frost has also been a grave issue for horticultural crops, especially, aonla and moringa (Dhandar and Saroj, 2004). The region is exemplified by low and erratic rainfall with extremes of temperature (1–48°C), high wind velocity and sandy soils (Bhandari *et al.* 2014).

Growing of annual crops restricted only a particular season of the year is the only source of livelihood for the inhabitants. However, these crops often experience abiotic stresses such as drought, hot and desiccating winds during their growth period resulting into poor crop productivity. These regions have remarkable potential for cultivation of perennial fruit trees. With biotic pressures, the majority of the arid and semi-arid regions are threatened with the challenges of producing more crops per unit land with unsure and deteriorating water resources. Selected crops can be raised under such challenging environment by utilizing water available through rainfall or to some extent by making use of deep underground water. This traditional knowledge of raising hardy crops, their specific cultivation practices and exploitation of land races has been traditionally passed on to next generations to the extent that 'Thar desert' is considered as most thickly populated desert of the world because of time tested water harvesting structures providing livelihood security (Bhandari *et al.*, 2014).

Horticultural crops have a great importance at present due to their potential in terms of nutritive values and reservoirs of vital genes against various stresses. Development of suitable varieties/hybrids/technologies in horticultural crops through research and their wide spread

dissemination among the farmers and developmental policies of the government culminated in unprecedented increase in area (23.4 million ha) and production (283.5 million tonnes) in India. Presently, India is the second largest producer of fruits and vegetables in the world (Anonymous, 2016a).

The success or failure of crop production depends, primarily, on interaction among varieties/genotypes, inputs used, environment and various management factors. Plant diseases caused by fungi, bacteria, viruses, phytoplasmas and nematodes reduce crop yields. Arid horticultural crops like ber, bael, aonla, date palm, pomegranate, karonda, watermelon (*mateera*), *kachri*, snapmelon, muskmelon, bottle gourd, chilli, longmelon and ridge gourd are mostly grown in Central and Western India. These crops can be infected by *Alternaria* leaf blight, *Cercospora* leaf spot, downy mildew, *Fusarium* wilt, mosaic disease, sucker rot, *Alternaria* fruit rot and post harvest diseases, etc. These diseases are major challenges in the cultivation of horticultural crops, which cause heavy losses to the crops frequently. Disease incidence in a crop is governed with the seed materials used and environment encompassing seed/plant. Therefore, before proposing the symptoms and etiology of any disease, a thorough knowledge of various disease management strategies are essential. Some efforts have been made in few diseases of arid horticultural crops. However, a detailed information has not been available at one place and therefore, this technical bulletin envisages almost all aspects of disease management of arid horticultural crops. So, it will be very useful and informative for the research workers, extension personals and growers.

## 2. A) Disease management in arid fruit crops

### A-1) A*onla* (*Emblica officinalis* Gaertn.)

Aonla or Indian gooseberry is an indigenous fruit of India, which has high medicinal value. Area under cultivation is increasing rapidly not only in tropical and subtropical areas of India but also under arid region. Area and production of aonla in India is 0.91 lakh ha and 1.025 million tonnes, respectively during 2016-17 (Anonymous, 2017a). The edible aonla fruit tissue has 3 times the protein concentration. It is rich in polyphenols, tannins, minerals and is regarded as richest source of vitamin C.

Rust disease, anthracnose and post harvest diseases are major constraints in aonla crop production in some parts of Rajasthan and Uttar Pradesh states. In other countries like China, the brown spot, false anthracnose and powdery mildew were reported. The disease caused considerable losses in major aonla growing areas of Uttar Pradesh. The disease was prevalent in growing areas in all popular and local cultivars in Jobner (Jaipur), Ajmer, Jodhpur, Jhunjhunu and Nagaur districts as well as Bawal and Mandi (Anonymous, 2010).

#### i) Rust disease

##### Symptoms

Reddish spots are formed on plant leaves from the beginning of August month. Conspicuous brown rust pustules develop on the leaves and fruits and later these pustules become dark brown

to black. Under severe condition, many pustules coalesce together and cover a large fruit area. Severely infected fruits may lead to premature fruit drop. The reddish brown uredo pustules can be seen on both surfaces of the leaflets. In susceptible leaves, pinkish brown pustules develop.

**Casual organism**- *Revenelia emblicae*

**Taxonomic position**

- Division- Eumycota
- Subdivision- Basidiomycotina
- Class- Teliomycetes
- Order- Pucciniales
- Family- Reveneliaceae
- Genus- *Revenelia*
- Species- *emblicae*

Rust pustules on aonla fruits

## Disease Cycle

Uredia of this pathogen are typically sub-epidermal erumpent bearing smooth walled uredospores produced singly on pedicel. The uredosori rupture the epidermis and uredospores are exposed. Growth stages of uredospores and the reactions host tissue and fungal colony can be observed. Telia are sub-epidermal in origin, erumpent bearing pedicellate teleospores. The uredospores are easily blown away by air which infect the new leaflets and fruits during growing season.

## Epidemiology

Under Rajasthan conditions, disease development was more when relative humidity increases, while temperature decreases. At Faizabad, the rust symptoms on fruits were observed in 2$^{nd}$ week of October (40$^{th}$ meteorological week) and reached on peak in the month of December (52$^{nd}$ meteorological week). Temperature showed highly significant negative correlation whereas RH (morning) and sunshine hrs/day showed significant positive correlation with per cent disease intensity (Anonymous, 2015).

## Disease management

### Cultural control

a) Orchard should be clean for growing of aonla plantation.
b) Proper pruning after harvest should be done in orchard for reducing humidity.
c) Use of disease free planting material
d) The orchards should be free from weeds.

### Host resistance

Cultivar Francis and NA-6 has been found PDI with 5.50% and 15.50%, respectively against this disease under Faizabad conditions (Anonymous, 2015).

### Chemical control

The use of fungicides is imperative to save crop losses and also increasing the productivity.

a) Three sprays with indofil Z -78 (0.2%) at monthly interval during the months of July to September proves effective against this disease.

b) This disease can also be controlled by wettable sulphur (0.25%) during July- September.

## ii) Anthracnose

It is a serious disease in aonla growing areas. This disease results heavy loss in fruit yield up to 15-35% in susceptible cultivars.

### Symptoms

This disease appears on leaflets and fruits in August-September. At the beginning, symptoms are minute, circular, brown to grey spots with yellowish margin in leaflets. Leaves dried up at advance stages. In fruits, pin lead like spots appear with dark brown to pink, while on fruits, depressed lesions develop which later turn dark. In severe cases, many spots coalesce with each other to form bigger lesions. The central areas of spots remain grayish raised with dot like fruiting bodies- the acervuli arranged in rings. Under severe condition, plenty spots result the fruits become shrivel and rot.

**Causal organism**- *Colletotrichum gloeosporioides*

**Taxonomic position**

- Division-Eumycota
- Subdivision-Deuteromycotina
- Class-Coelomycetes
- Order-Melanconiales
- Family- Melanconiaceae
- Genus- *Colletotrichum*
- Species- *gloeosporioides*

Anthracnose of aonla

### Disease Cycle

The fungus perpetuates in infected crop debris and in the soil. Spores are released from last year's diseased tissue. Conidia germinate by germ tube which form appressorium after coming in contact with surface of the host. The infection peg arises from the appressorium and penetrates the host. The spores are carried out by rain splash or wind and cause secondary infection to soft and succulent tissues. The fungus obtains nutrients from plant cells and these cells are killed by leaf lesion. The lesion expands as the fungus spreads.

### Epidemiology

Temperature and moisture are one of the most important factors which influence the disease development. The disease is favoured under hot and humid weather. This disease respond positively to increase in the temperature along with cloudy weather.

### Disease management

#### Cultural control

(a) Discard affected fruits and leaves at initial stage from the orchard.
(b) Proper pruning should be done in orchard for air circulation.
(c) Plant trees on a wide spacing and keep the surrounding area clear of vegetation.

#### Chemical control

a) Spraying of carbendazim (0.1%) can reduce the disease.
b) Copper based fungicide (blitox-50 @0.25%) is also effective against this disease.

### iii) *Alternaria* fruit rot

*Alternaria alternata* was found with dropped fruits of aonla. It is also a serious problem in aonla growing areas. This disease results heavy loss in fruit yield under humid region.

#### Symptoms

Initial disease symptoms appear as small brownish to black spherical necrotic spots on fruits and increase in circular fashion with the development of the disease. In advance stage, the spots become dark brown to black and neighboring spots coalesce. The middle part of this infected tissues become soft and pulpy.

**Causal organism**- *Alternaria alternata*

**Taxonomic position**

- Sub –Division-Deuteromycotina
- Class-Hyphomycetes
- Subclass- Sporomycetidae
- Order-Moniliales
- Family- Dematiaceae
- Genus- *Alternaria*
- Species- *alternata*

#### Disease cycle

The fungus perpetuates as mycelium or spores in infected debris of plant parts. Conidia can remain viable up to few months at room temperature. The infection starts from the fruits, where a large number of conidia are formed. These are spread by wind, water, rain splash and cause

secondary disease. The conidia germinate in the presence of moisture at temperature nearly 25-30$^0$C giving rise to germ tubes, which enter the host tissue.

### Epidemiology

Presence of high moisture, followed by warm and dry weather conditions is the most favourable for disease development. Very high temperatures along with continued dry spells check this disease. Dew and frequent rains accompanied with moderate to high temperature results in disease development.

### Disease management

#### Cultural control

a) Use of disease free planting material

b) Removal of infected plant debris from the aonla orchard.

c) Harvesting should be done very carefully to avoid any injury to the fruits.

#### Chemical control

a) Mancozeb (0.25%) spray at 10 days interval to reduce this disease.

b) One spray of carbendazim (0.1%) should be done 15 days prior to fruit harvest.

c) Treatment of fruits with borax (0.5%) or sodium chloride (1%) checks the rot.

In addition to above control, full sanitary measures should be adopted during storage and transit.

## A-2) Ber (*Ziziphus mauritiana* Lamk.)

Ber (*Ziziphus mauritiana* Lamk.) is one of the most important fruit crops grown in arid and semi-arid regions of India (Pareek, 2001) and worldwide. Mostly, ber cultivation is common in water deficient and low rainfall areas of Rajasthan, Gujarat, Maharashtra, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh and Andhra Pradesh. Area and production of ber in India is 0.5 lakh ha and 0.526 million tonnes respectively during 2016-17 (Anonymous, 2017a). Ber fruits are natural antioxidants for people in arid regions. The fruits are quite nutritious, rich in vitamin C, second only to aonla and guava and much higher than citrus and apple. The ripe fruits are rich in nutritive value, having 13-24 per cent total soluble solids and up to 160 mg/100g vitamin C. The dehydrated fruits are kept for a long time and are consumed in the off season.

However, the avoidable loss is more due to diseases. In ber diseases like powdery mildew, leaf spots and fruit rots in arid and semi-arid region and post harvest diseases in marketing locations are economically important.

## i) Powdery mildew

It is a major disease causing up to 40% loss in production and quality of ber fruits in semi-arid and sub-tropical region but it is not serious in Bikaner and nearby regions from last few years. This disease was first reported from Allahabad. Occurrence of this disease of ber, maximum disease incidence (38- 60%) was observed in local cultivars 'Kali' and 'Bagwari'. Complete loss of ber fruits due to havoc nature of powdery mildew is being experienced in semi-arid and humid regions. It affects productivity and quality of fruits. Being an obligate parasite, recurrent incidence results in heavy loss up to 80% in susceptible cultivars round in humid region every year.

### Symptoms

Initial symptoms appear as white floury patches on young fruits at pea size and later cover the entire fruits. The infected fruits become misshapen, corky and finally are dropping. In severe incidence, floral parts, whole fruits, tender branches and leaves would appear with fungal conidia and less number of fruit setting and malformed fruits. Ber orchards are devastated completely when the powdery mildew occurs in severe form at flowering and fruit setting stages.

Powdery mildew of ber

**Causal organism:** *Oidium erysiphoides f.* sp. *ziziphi*

### Epidemiology

The cloudy, humid with moderate temperature favour its occurrence in ber orchards. In North India, infection appeared from October and reaching peak by December. Maximum severity could occur at max. temperature of 21.9° C, 59- 88 % relative humidity and 9.6 hours sunshine per day.

## Disease management

### Cultural control

a) Removal and destruction of infected leaves, twigs and collateral hosts from orchard.

b) Ber orchards should be free from wild species of ber (*Ziziphus nummularia*).

### Biological control

a) *Psendomonas fluorescens* CIAH- 196 (1%) was also moderately effective against this disease (Nallathambi *et al.* 2006).

b) Spraying of *Trichoderma viride* (CIAH- 240) @ 5% also reduced the disease.

### Host resistance

a) Resistant/tolerant varieties such as Sanaur-2, Chinese, Jogia and Vikas must be grown.

b) Resistance types (Chinese, Jogia and Vikas) identified by AICRP on Arid Zone Fruits may be the potential source of resistance for varietal improvement.

### Chemical control

a) Maximum disease control has been found by combined application of *Psendomonas fluorescens* (1%) and Karathane @ 0.05% (Nallathambi *et al.*, 2003).

b) Three sprays of karathane (0.1%) followed by difenoconazole (0.05%) at 15 days interval proved 51.0% and 40.3% disease control against the disease of ber (Anonymous, 2016b).

c) The disease can be controlled by three sprays of karathane (0.05%) or wettable sulphur (0.25%) starting from the flowering time in September followed by a spray in mid October, November (Singh, 2009).

## ii) Black leaf spot

It is common in Southern and Northern part of the country. Disease incidence was noted during survey program of Rajasthan and Uttar Pradesh from 01- 8.0 per cent and 4.75 to 38.75 per cent, respectively (Anonymous, 2010). It can cause heavy damage on leaves and thereby the yield is reduced up to 10-25%.

### Symptoms

The disease is characterized by sooty tuft like circular to irregular black spots on lower surface of leaves. Leaves and twigs are dried rapidly under severe infection.

Black leaf spot of ber

**Causal organism**- *Isariopsis indica* var. *ziziphi*

### Epidemiology

Cloudy weather with moderate temperature in October- November is favourable for disease development.

## Disease management

### Cultural practices

a) Removal and destruction of infected leaves, weeds and twigs from orchard.

b) Pruning should be done properly in the orchard.

### Host resistance

Use of resistant varieties such as ZG-3, Seb, Bahadurgarh and Safeda Rohtak.

### Chemical control

a) Sprays of mancozeb or copper oxychloride @ 0.2% at 15 days interval were effective.

b) Two sprays of propiconazole (tilt), followed by difenoconazole (score) @ 0.1% was found to be effective against this disease and also increased fruit yield (Anonymous, 2016 c).

### iii) Fruit rot

Fruit rot was recorded in ber fruits during December- January. Disease was observed in immature as well as mature fruits. Disease severity in ber germplasm/varieties was observed 2.4-11.8% under hot arid climate of Bikaner, Rajasthan.

### Symptoms

Symptoms started from pedicel and in bottom portion of fruits. Small, irregular, light brown to dark brown spots appeared on fruit surface. Many spots coalesce to form large patches on fruit and these fruits later drop. Under severe conditions, mature infected fruits caused brown blotching.

Fruit rot in ber

**Causal organism**- *Alternaria alternata*

### Disease management

a) Removal and destruction of infected leaves, weeds and twigs from orchard.

b) This disease is reduced by spray of 0.2% indofil Z- 78.

c) *Pseudomonas fluorescens* (CIAH-196) inhibited the maximum mycelia growth (Nallathambi *et al*. 2006)

## A-3) Date palm (*Phoenix dactylifera* L.)

Date palm (*Phoenix dactylifera* L., Family-Palmaceae) is one of the most important fruit trees for semi-arid and hot arid regions of the country. It is drought hardy plant and tolerates salinity and aridity. It is an important fruit crop of the subtropics grown, especially, in western part of Rajasthan, Punjab, Haryana and Kachchh region of Gujarat. The districts of Rajasthan such as Jaisalmer, Barmer, Bikaner, Jodhpur are extremely dry and suitable for date palm cultivation. In addition to this, parts of Sri Ganganagar, Churu, Nagaur and Hanumangarh are also suitable for date palm production. It is of economic importance and represents a source of income to many farmers in large parts of Iraq, Iran, Arabian Peninsula and countries in North Africa and represents a good cash crop for many farmers. Its fruits are consumed as hard ripe at doka or khalal, soft dates (pind khajoor) and dry dates (*Chhuhara*). Every part of the date palm plant is useful since its history of cultivation and utilization. Dried fruit pulp is used for flavouring

the bakery products. Date palm leaves are used for making handicraft items (broom, hand-fan, mat, rope, etc). Date is nutritious fruit having high calorific value in the form of sugar, mineral (iron, potassium, calcium, copper, magnesium, sulphur, phosphorus) and vitamins (Singh and Dhandar, 2007). It has high market potential since the production of soft dates and dry dates in our country is very less.

Palm diseases (*Alternaria* leaf spot, *Graphiola* leaf spot and wilt) are among the major factors that affect the production. Fungi are known as the most causal pathogens on date palm trees. At Bikaner, survey of date palm diseases was carried out at farmers field orchards like Bikaner, Bajju (under marshy land), Raiser, Khajuwala, Dantour, Nokha, Birmana (Sriganganagar under marshy land), Lakhuwali (Hanumangarh marshy land) and Fatehpur (Anonymous, 2010). Some diseases were also recorded from Saudi Arabia and Iraq. Several trees showed symptoms of wilt and dieback disease in Saudia Arabia and in particular in Al Qassim and Medina Al Monawara regions. In recent days, date palm offshoots are severely affected by soil borne pathogens i.e. *Fusarium* under dry conditions.

### i) *Alternaria* leaf spot

It has been observed in severe form at Date Palm Research Centre, SKRAU, Bikaner and disease incidence was recorded from 14.16 to 72.50% depending upon cultivars as well as climatic conditions.

#### Symptoms

The spots are most common on the lower leaves (pinnae) of the plants, whereas, on upper leaves the spots are few and small size. The disease cause heavy losses to the date industries in both quality and quantity of production (Pal *et al.* 2006).

**Causal organism**- *Alternaria alternata*

#### Epidemiology

It requires hot and humid weather conditions for disease initiation. Disease development is favoured between 20 to 30° C.

### Disease management

#### Cultural control

a) Removal and destruction of infected leaves, twigs and weeds from orchard.
b) Pruning should done.
c) To disinfect all tools in pruning, etc. and cut surfaces.

#### Host resistant

a) Use of resistant varieties such as Medjool, Nagal Hilali and Medini (Pal *et al.* 2006).

### Chemical control

a) Fungicidal sprays (mancozeb @ 0.2%) at 15 days interval can be given to minimize the disease.

b) Copper oxychloride (0.2%) is also useful for retarding the fungal growth.

### ii) *Graphiola* leaf spot

The disease is also called false smut on date palm. It is the most widely spread disease and occurs wherever the date palm is cultivated under humid conditions and hyper-arid partially irrigated western plains of Bikaner, Jaisalmer, Barmer and Jodhpur. This disease was not observed at Date Palm Research Farm, SKRAU, Bikaner and demonstration field of farmers (Anonymous, 2010). This disease was also found in Egypt.

### Symptoms

Symptoms of the disease appear as sub-epidermal spots on both sides of the pinnae (leaf flat) and on the rachis with small black sori (fruiting bodies) developing in abundance on old fronds. Fruiting structures emerge as small-yellow/brown to black sori. These sori are abundant on three year-old leaves. The sori are 1-3 mm in diameter.

*Graphiola* leaf spot of date palm

**Causal organism**- *Graphiola phoenicis* (Moug.)Poit

### Epidemiology

The disease is widely spread and occurs whenever the date palm is cultivated under humid conditions but absent in less humid regions.

## Disease management

### Cultural control

a) Removal and destruction of infected leaves, twigs and weeds from orchard.

b) Pruning should be done in orchard.

c) Disinfection all tools in pruning, etc. and cut surfaces.

d) Use of disease free planting material

### Host resistant

a) Grow genetically tolerant varieties (Barhee, Adbad, Rahman, Gizaz, Iteema, Khastawy and Tadala).

b) Use of variety Hatemi was found to be resistant (Pundir, *et al*. 2006).

c) Variety Khadrawi was found resistant with disease severity below 5% under field conditions of Haryana.

### Chemical control

i) Carbendazim (0.2%) is most effective followed by thiophanatemethyl.

ii) Two sprays and soil drenching of copper oxychloride (0.2%) at fortnight interval in checking the infection and further disease spread.

## iii) Wilt disease

*Fusarium* wilt in date palm was first reported from Saudi Arabia in 1990. It is noticed at date palm block of CIAH, Bikaner and other date palm growing areas nearby Bikaner.

### Symptoms

Spines begin to whitened from bottom to top, then whitening turn to the spines starting from top to bottom with a brown discoloration. Symptoms extend from the outer leaves to the young ones, apical meristem lead to tree death. Pathogen block the vascular system and leaves are drying.

Wilt of date palm

**Causal organism:** *Fusarium* spp.

### Epidemiology

Disease is severe at temperature between 23-30°C. Light intensity and higher RH coupled with high evaporation rate increase the disease development.

## Disease management

### Cultural control

a) The infected crop debris collected and burnt.
b) Planting the offshoots produced only from the healthy date palm trees.
c) Sterilization of pruning tools.
d) Proper pruning.

### Chemical control

a) Dipping of seedlings in carbendazim (0.1%) before planting to reduce the wilt disease.

b) Soil drenching with carbendazim (0.1%) fungicide after planting of 1-2 months can be effective against this disease.

## iv) Fruit rot

This disease was also recorded during rainy season from moderate to severe form in Western Rajasthan. Disease incidence was recorded from 10.0 and 30.5% in Bajju and Bikaner

(Rajasthan), respectively. Losses vary from one country to another and from one variety to another, they can between 10 % and 50 % of the harvest.

### Symptoms

The rot begins as a small, circular spots which enlarge and turn brown to black spores. Fruit rot damage varies from one year to another depending on the humidity and rain and time up to fruit maturation.

**Causal organism:** *Aspergillus niger*

### Disease management

#### Cultural control

a) Lowering the humidity inside the bunch by the use of wire rings, and by removing a few fruit from the bunch centre will facilitate ventilation and drying of wet fruit.

b) Protection from rain or dew is reached by using paper covers in the early Khalal stage.

c) To prevent injury to the fruits and remove fruits showing sign of injury.

#### Chemical control

a) Fungus spoilage could also be limited by dusting the fruit bunches during the Khalal stage with 5% ferbam and 50% sulphur.

b) A prophylactic spray schedule with mancozeb (0.2%), copper oxychloride (0.2%) and mancozeb (0.1%) + copper oxychloride (0.1%) effectively controlled the diseases of date palm.

## A-4) Pomegranate (*Punica granatum*)

Pomegranate (*Punica granatum* L.) is an important fruit crop grown in arid and semi-arid regions of India. It is native to Iran. However, it has wider application both in Ayurvedic and Unani traditional medicinal systems of medicine. It has several health benefits to treat many human diseases (coronary heart diseases, cancer, inflammation, diabetes, cardiac disorders, ischemia, aging, brain disorders and AIDS (Seeram *et al.* 2006). The edible part of the fruit contains considerable amount of acids, sugars, vitamins, polysaccharides, polyphenols and important minerals. Presence of different alkaloids particularly tannins, constituted in pomegranate leaves and fruits. Area and production of pomegranate in India is 2.16 lakhs ha and 2.521 million tonnes, respectively during 2016-17 (Anonymous, 2017a).

Leaf and fruit spots are important diseases in humid regions of India. Leaf spots can indirectly reduce the yield and fruit spots affect the appearance and thereby market value of infected fruits is minimized. Fruit spot caused by *Alternaria alternata* (Fr.) Keissler occurs in pre-harvest and post harvest stages of pomegranate in some areas particularly in western parts

of the country. Being export oriented crop, fruit spots are important concern to combat for better returns. Additionally newly emerging problems such as aril necrosis or blackening of aril and wilt complex are to be effectively managed in coming years.

### i) Bacterial leaf and fruit spot

Bacterial leaf spot is a major constraints for productivity and quality of fruits in Southern states particularly in Tamil Nadu, Maharashtra and Karnataka as well as in some parts of Gujarat and Rajasthan. It appeared as an epidemic form in Bangalore, Karnataka, causing 60-80% fruit yield losses. Dhandar *et al.* (2004) have made in extensive survey in Solapur and Sangola districts of Maharashtra against this disease and other aspects. This disease is prevalent in all the pomegranate growing states of India. Highest severity (25.8%) was recorded in Anantapur district (Anonymous, 2010). Maximum disease incidence (58%) of bacterial fruit spot was recorded in variety 'Boskhlinski' at S.K. Nagar, Gujarat (Anonymous, 2017b).

#### Symptoms

Small, transluscent and water soaked spots appeared on the leaves and became necrotic and finally may turn dark brown. Many spots may coalesce and cover big area which are surrounded by chlorotic halo. Leaves are distorted and defoliated. Water soaked spots on fruits may turn dark brown. The spots are oily in appearance.

**Causal organism:** *Xanthomonas axonopodis* pv. p*unicae*

Bacterial leaf and fruit spot of pomegranate

#### Disease management

#### Cultural control

a) Removal of suckers and other infected plant parts.

b) Pruning should be done in pomegranate orchard.

#### Chemical control

Spraying of 200 ppm streptocycline can be controlled followed by pausamycin (0.05%) + copper oxychloride (0.2%) with 3 sprays at fortnightly intervals.

#### Host resistant

Variety Jalore seedless was resistant to this disease at Jobner (Rajasthan) under AICRP on arid zone fruits (Nallathambi *et al.* 2006).

### ii) Anthracnose

Anthracnose of pomegranate

#### Symptoms

Symptoms appear as minute and black spots on leaf, which are surrounded by yellow region. Spots enlarges and coalesce to form bigger. Severely infected leaves fall off. In fruits, dark brown spots appear earlier and slowly enlarge in size. In advance stage of infection, few spots coalesce together and big lesions are formed on rind.

**Causal organism**- *Colletotricum gloeosporioides*

#### Epidemiology

The temperature between 30-35°C with more than 75% relative humidity is favourable conditions for the disease incidence.

#### Management practices

a) 1-2 sprays of mancozeb or blitox 50% (0.2%) are required to manage the disease.
b) Sprays of kitazin (iprobenfos) at 0.15-0.20% gave an effective control of this disease.
c) Spraying of mancozeb (0.1%) + carbendazim (0.1%) were most effective in reducing the disease (Jamadar *et al*. 2000).

## A-5) Bael (*Aegle marmelos*)

Bael (*Aegle marmelos* Correa) belongs to family Rutaceae is an important indigenous fruit crop to dry forest in hills, plains of central and southern parts as well as arid and semi-arid regions of India. It is one of the important minor fruit crops with curative properties and high nutritive (edible fruit quality) value. The fruit pulp contains fair amount of vitamin A, C and high amount of riboflavin (Saroj *et al*. 2006). The fruit pulp contains marmelosin, which is laxative, diuretic, astringent, digestive, stomachic and also posses anti-amoebic and hypoglycemic properties. It is the only member of the monotypic genus *Aegle*. Fruits are mostly utilized in form of beverages. Moreover, candy and bael powder are another products and becoming popular among consumers. The bael is gaining popularity among the farmers of arid and semi-arid areas for economic cultivation.

However, the quality of fruits and productivity is not obtained up to the standard due to infection of major diseases (*Alternaria* leaf spot and wilt) as well as abiotic.

### i) *Alternaria* Leaf spot

This disease was observed in Chomu area (Jaipur district) of Rajasthan. It was also found in some districts of Uttar Pradesh.

### Symptoms

The minute and brown spots appear on the leaves which enlarge and become prominent with reddish brown lesions. These lesions later on coalesce into irregular patches. The affected leaves drop down finally.

***Causal organism:*** *Alternaia* sp.

### Disease management

### Cultural control

a) Field sanitation.

b) Pruning of the plants in orchard.

### Chemical control

Two sprays of mancozeb (0.2%) at 15 days regular interval.

### ii) Wilt disease

Wilting/drying of bael plants have been observed in Chomu area of Jaipur district.

### Symptoms

Yellowing and necrotic areas are appeared on the leaves. Brown colour and chocking of vascular bundles are the characteristic symptoms. Sometimes, whole plants may die due to insufficient water and nutrient supply.

**Causal organism:** *Fusarium* spp.

### Disease management

i) Removal of infected plant parts & pruning.
ii) Drenching of carbendazim (0.1%) at regular interval can effective.

## A-6) Citrus (*Citrus spp.*)

Citrus plants are native to subtropical and tropical regions of Asia and they were firstly domesticated in these areas. Area and production of citrus in India is 10.37 lakhs ha and 12.053 million tonnes, respectively during 2016-17 (Anonymous, 2017a). Citrus is affected by many diseases (Citrus canker, quick decline and *Phytophthora* blight) are very severe diseases.

### i) Citrus canker

It is a widespread disease in all the citrus growing areas of the world. It is stated to have originated from China and spread to Europe and USA the disease became so severe that mass eradication of diseased plants, often entire orchards had prevent its spread. The disease is still quite serious in India, China, Japan and Java.

## Symptoms


Citrus canker

Cankerous lesions occur on leaves, twigs, older branches and fruits. Leaf lesions first appear as small, round, watery and translucent spots. They are raised and become yellowish brown. They first develop on the lower surface of the leaf and then on both the surface. As the disease advances the surface of the spots becomes white or greyish and finally ruptures in the centre giving a rough, corky and crater-like appearance. The spots increase in size and may coalesce to form elongated lesions on fruits and twigs. The rough lesions are surrounded by a yellowish-brown to green raised margin and watery yellow halo. Spots occurring on petioles and midrib cause premature defoliation. Cankers on fruits are similar to those on leaves except that the yellow halo is absent and a crater like depression in the centre is more prominent. Pathogen attacks acid lime roots too.

**Causal organism** : *Xanthomonas axonopodis* pv. *citri*

## Disease spread

The bacterium enters the host through natural openings (stomata and wounds). It multiplies rapidly in the intercellular spaces, dissolves the middle lamella and establishes in the cortical region.

## Epidemiology

The disease is favoured by mild temperature and wet weather. The temperatures between 20° and 30° C with good distributed rains are most suitable. Presence of free moisture on host surface for at least 20 minutes is essential for infection.

## Disease management

a) Two pruning of infected plant parts along with 4 sprays of copper oxychloride (0.5 %) or bordeaux mixture (1%) have been reported effective and economical.

b) Streptomycin sulphate (0.05 %) is also effective when sprayed with glycerine (1%) on acid lime.

c) Application of neem cake solution on the foliage has also been reported effective against this disease in nurseries.

d) Give three sprays of 50 g of streptocycline+ 25 g copper sulphate in 500 litres of water/acre, one each during the month of October, December and February (Singh, 2009).

### ii) Quick decline

It is the most destructive disease of citrus in India and also has a worldwide distribution. Failure of sweet orange, or grapefruit budded onto sour orange stock, is diagnostic for tristeza virus. The virus commonly latently infects tolerant combinations of scions and rootstock varieties, such as mandarin and trifoliate orange. The virus particles are located in the phloem of the host plant, and disturb its transportation systems.

#### Symptoms

Leaves appeared deficiency like symptoms. Roots decay and twigs die back. Fruit set diminishes; only skeleton remains. Fine pitting of inner face of bark of sour orange stock. Grapefruit and acid lime are susceptible irrespective of root stock. Tree stunted and dies, yield very much reduced. Fruits are small in size.

Citrus decline Kinnow decline

**Causal organism:** Tristeza virus

#### Mode of spread

Use of infected bud wood and *Toxoptera citricida* (citrus brown aphid) is the important vector. The probability that the virus will be transmitted by the aphid after feeding on an affected plant is from 5- 70%.

#### Disease management

a) The certification of bud-stock and the use of resistant rootstock e.g. trifoliate orange, Sunki, and Shiikuwasha (*C. depressa* Hayata) found effective.
b) The production of virus-free trees by shoot-tip grafting or heat treatment is very effective.
c) Bud-stock trees should be inoculated with a mild CTV strain at least four to six months prior to propagation. They should keep in a screenhouse under aphid-free conditions.
d) It is necessary to spray nursery plants and young trees with insecticide occasionally, to control aphids. This should retard any re-infection with the virus.
e) Mandarin and sweet orange seedlings on rough lemon, trifoliate orange, citrange; Rangpur lime root stocks show tolerance.

## A-7) Karonda (*Carissa carandas*)

Karonda or Christ's thorn (*Carissa carandas* L.) of the family Apocynaceae, is a hardy evergreen spiny shrub of Indian origin. It is a multi-branched bushy tree and is generally planted as a hedge. It can tolerate the hot and dry conditions and intense solar radiation in the arid and plateau region (Ghosh, 2014). In India, karonda plants are found in wild form in several

regions including the Siwalik Hills, Bihar, West Bengal, the Western Ghats, Karnataka and the Nilgiri hills. Most karonda shrubs are ornamental, though the tribal areas of Madhya Pradesh, Chhattisgarh, Rajasthan, Gujarat and Jharkhand are known to grow the fruit on a limited scale. Karonda is commonly used as a condiment or additive to Indian pickles and spices. Its fruits have been utilized in processed products such as in the preparation of jam, jelly, squash, syrup and chutney and is in great demand in the international market. The notable biological activities reported are analgesic, anti inflammatory, anti pyretic, cardiotonic and histamine releasing. The health benefits of karonda are attributed mainly to the presence of some phytochemicals, which are referred as antioxidants (Panda *et al*., 2014). Karonda is affected by bacterial leaf spot and other diseases.

### i) Bacterial leaf spot

#### Symptoms

Small, round and water-soaked brown spots for the first time on the lower surface of the leaves. A yellowish green halo may surround the spots which causes necrosis.

**Causal organism** –*Xanthomonas campestris*

Bacterial leaf spot of karonda

#### Management practices

a) Removal of diseased leaves or plant parts.

b) Sprays with phytomycin 200 ppm/lit. of water at 10 days interval.

## A-8) Mulberry (*Morus* spp.)

Mulberry (*Morus* sp.; Family- Moraceae) is widely distributed in the temperate, subtropical, or tropical regions of the world and can grow in a wide range of climatic, topographical, and soil conditions. The mulberry growing states in India are Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal, Rajasthan, Himachal Pradesh and Assam. The ripe fruit is highly appreciated for its delicious taste which is consumed fresh or after extraction of juice. Immature fruits are used for chutney preparation. Mulberry fruit is used to treat weakness, dizziness, tinnitus, fatigue, anemia, and incontinence. The dominant taste of the ripe fruit is sweet but usually with sub-acidic blend due to the high water content and low level of other flavouring ingredients (Singh *et al.* 2016).

Mulberry is also considered as "*Kalpa Vriksha*" as all the parts of the plant have many uses. Mulberry is highly appreciated for its delicious and thirst quenching fruits, which is consumed fresh, or in the form of juice or conserves.

### i) Powdery mildew

#### Symptoms

Whitish patches are formed on lower surface of leaves and corresponding area on upper surface gradually turns yellow and brown. Entire leaf area covered under its severe infection. The leaf dries and falls on orchard.

**Causal organism**- *Phyllactinia corylea*

#### Disease management

a) Sprays of dinocap (0.1%) at 15 days interval.

b) Collecting and destroying the affected leaves.

### ii) *Cercospora* leaf spot

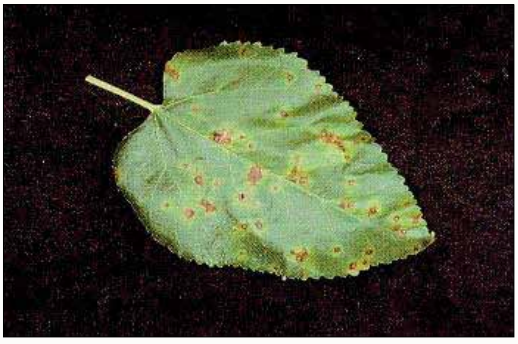
#### Symptoms

Circular to irregular, brownish spots were appeared on infected leaves. These infected leaves are not suitable for feeding silkworms.

**Causal organism**- *Cercospora moricola*

**Taxonomic position**

- Sub –Division-Deuteromycotina
- Class-Hyphomycetes
- Order-Moniliales
- Family- Dematiaceae
- Genus- *Cercospora*
- Species- *moricola*



*Cercospora* leaf spot of mulberry

#### Disease management

i) Collection and destruction of affected plant parts and weeds.

ii) Sprays of indofil Z-78 (0.2%) on the young leaves at 15 days intervals is effective.

## B) Integrated disease management in arid vegetable crops

### B-1) Bottle gourd (*Lagenaria siceraria)*

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] is one of the most commonly grown cucurbitaceous vegetable crops in India. It is grown in warmer regions of the world. Nowadays, it is becoming popular for several health benefits and easy digestion. The fruits can be used as a vegetable or for making sweets. It is gaining importance due to its high yield potential, steady market price throughout the season. It also has a wide medicinal property such as laxative, digestive and to prevent constipation. Bottle gourd is an important crop of Rajasthan and widely grown in open field conditions as well as in river beds to harvest early crop. Area and

production of bottle gourd in India is 1.55 lakhs ha and 2.57 million tonnes, respectively during 2016-17 (Anonymous, 2017a). The crop is affected by various fungal diseases, out of which *Alternaria* leaf blight, downy mildew, powdery mildew, *Cercospora* leaf spot and anthracnose are important.

### i) *Alternaria* leaf blight

This disease affects the leaves of cucurbits like bottle gourd, watermelon, muskmelon, and pumpkin. It was observed in U.P., M.P. and Bihar. Disease severity varies depending on the prevailed weather conditions. Disease incidence was recorded up to 34% in bottle gourd genotypes under hot arid conditions.

#### Symptoms

Characteristic symptoms first appear on leaves as small, circular and light brown spots of different size which later enlarge in a concentric rings and margins appear. These spots mix together to form larger necrotic areas on leaves.

**Causal organism:** *Alternaria cucumerina*

**Taxonomic position**

- Sub –Division-Deuteromycotina
- Class-Hyphomycetes
- Order-Moniliales
- Family- Dematiaceae
- Genus- *Alternaria*
- Species- *cucumerina*

*Alternaria* leaf blight of bottle gourd

#### Disease management

#### Cultural control

a) Removal of infected crop debris, collateral hosts and weeds.

b) Use certified seed.

c) Deep ploughing of the soil

#### Chemical control

a) Sprayings of indofil M- 45 (0.2%) at regular interval was very effective for reducing this disease.

b) Integrated management measures against *Alternaria* leaf blight were developed under field conditions. Combined treatment of carbendazim @ 0.1% (seed treatment) + mancozeb @ 0.25% (foliar spray) + *Pseudomonas fluorescens* @ 5% (foliar spray) + neem leaf extract @ 5% (foliar spray) was the most effective with minimum disease incidence of 9.25%, minimum disease severity of 7.07% and maximum disease control (78.23%) (Maheshwari *et al.* 2017).

### ii) *Cercospora* leaf spot

This disease caused by *C. citrulina* Cooke was observed on cucurbits (Sarbhoy 2006). Disease incidence was noted from 6.70 to 39.25% in different bottle gourd genotypes under arid conditions.

#### Symptoms

Symptoms occur primarily on foliage. Small, circular to irregular spots and tan to light brown lesions with dark margins appear on older leaves. The number and size of lesions increases. These lesions coalesce with each other and causing entire leaves to become diseased. Infected leaves turn yellow under severe conditions and finally fall off.

**Causal organism:** *Cercospora citrulina*

**Taxonomic position**

- Sub –Division-Deuteromycotina
- Class-Hyphomycetes
- Order-Moniliales
- Family- Dematiaceae
- Genus- *Cercospora*
- Species- *citrulina*

*Cercospora* leaf spot of bottle gourd

#### Disease management

#### Cultural control

a) Removal of infected crop debris.

b) Deep plough.

c) Growing the crop with non-host crop.

d) Destruction of weeds and collateral hosts.

#### Host resistance

Use of moderately resistant varieties such as Pusa Naveen, Pusa Santushti, Pusa Samridhi and Pusa Sandesh against *Cercospora* leaf spot (Maheshwari *et al.* 2015).

### iii) Powdery mildew

Powdery mildew affects the leaves of cucurbits like bottle gourd, cucumber, muskmelon, squash and pumpkin. The disease causes maximum damage in the warm and dry areas where moisture is present as dew. In India, the disease is prevalent in almost all the states and causes losses in terms of fruit yield and also quality (Gupta *et al.*, 2001). Maximum disease incidence (up to 58%) was observed in different bottle gourd genotypes.

### Symptoms

The symptoms appear as small floury patches on leaves first on the lower surface followed by upper surface. Fungal growth on these spots results in production of powdery growth. Severely affected leaves lose their dark green colour and become pale yellow green to brown and are shriveled and premature defoliation, drying and collapse. Fruits remain undersized.

**Causal organism:** *Sphaerotheca fuliginea*

**Taxonomic position**

- Division-Ascomycotina
- Class-Pyrenomycetes
- Order-Erysiphales
- Family-Erysiphaceae
- Genus-*Sphaerotheca*
- Species- *fuliginea*

Powdery mildew of bottle gourd

### Disease management

#### Cultural control

a) Removal of infected crop debris.
b) Deep ploughing may burry the pathogen where it may be killed by soil microflora of the pathogen present in below soil layers, after ploughing, may be brought to the soil surface and inactivated by solar radiation.
c) Introduction of resistance or non-host crops in rotation helps in disease reduction.

#### Host resistance

Use of moderately resistant bottle gourd varieties (Pusa Naveen, Pusa Santushti, Pusa Sandesh and Arka Bahar) against this disease (Maheshwari *et al*. 2012)

#### Chemical control

a) Two to three sprays of wettable sulphur (0.2%) at 20 days interval at the time of symptoms appearance was found effective.
b) Three sprays of hexaconazole (0.05%) were found effective (Gupta and Gupta, 2001).
c) Foliar sprays of non-target chemicals (monopotassium phosphate @ 200-500 ppm) and neem kernel extract (5%) were effective
(d) Foliar sprays of systemic fungicides like benomyl (0.1%) or carbendazim (0.1%) are very effective.

## B-2) Muskmelon (*Cucumis melo* L.)

Muskmelon (*Cucumis melo* L.) popularly known as 'kharbuja' in India is one of the most important cucurbits grown as a 'Dessert fruit' throughout the world. The leading muskmelon producing countries are China, Iran, turkey, Egypt, India, U.S.A. and Spain. In

India, its production is concentrated in the tropical and sub-tropical regions. In India, It is widely cultivated in Rajasthan, Punjab, West Bengal, Uttar Pradesh, Madhya Pradesh and Maharashtra (Anonymous, 2011). It is grown under both riverbed and irrigated conditions for local and interstate sales and it is a high value dessert fruit compared to other fruits. Area of muskmelon crop was 0.47 lakh ha with production of 0.987 million tonnes in India during 2016-17 (Anonymous, 2017a).

### i) Wilt

It is a threat to the cucurbitaceous crops (bottle gourd, cucumber, muskmelon and watermelon) of all over the world. Wilt in cucurbits is found in Ukraine and Japan. The disease is the most destructive at places wherever soil temperatures are high enough for the pathogen to grow but unsuitable for the plants. Yield losses up to 80% have been reported in the worst affected areas (Gupta *et al.*, 2001). Disease incidence was also observed from 5.0 to 60% at experimental field of CIAH, Bikaner.

#### Symptoms

Disease appears at flowering stage of the crop. The leaves are accompanied by yellowing and marginal necrosis. The infection results in lesion formation on the collar region and infected areas appear brown and water soaked. Wilting starts sudden after fungal infection. As a result of softening of the tissue, the plants shriveled, followed by rapid mortality of whole plant. The older plants wither and die during the growing season.

**Causal organism:** *Fusarium acuminatum* (identified from Div. of Plant Pathology, IARI, PUSA, New Delhi in 2014)

**Taxonomic position**

- Division- Eumycota
- Subdivision- Deuteromycotina
- Class- Hyphomycetes
- Order: Tuberculariales
- Family: Tuberculariaceae
- Genus- *Fusarium*
- Species- *acuminatum*

Wilt of muskmelon

#### Epidemiology

A large population favoured by continuous cropping of susceptible cultivars is required for serious disease outbreaks. Saprophytic activity of this disease is highest 60% moisture holding capacity of the soil, at pH 5.0-6.0 and temperature of 25 to 35° C. Most severe symptoms are observed between 18 and 22° C.

## Disease management

### Cultural control

a) Crop rotation with garlic, radish, onion has been found to reduce the disease in melons.
b) Field sanitation and uprooting of the infected plants.
c) Wilt suppressiveness can be induced in soil by repeated croppings of resistant varieties of melons.
d) Certain soil amendments which may directly reduce the *Fusarium* population in soil or promote beneficial microflora which in turn destroy the soil inoculums, are used to control of this disease.

### Host resistance

a) In muskmelon, the Indian cultivars (Durgapura Madhu and Punjab Sunehri) are resistant to *Fusarium oxysporum* and *F. solani*.
b) Mark *et al.* (2005) found Hannahs Choice F1 as resistance source against *Fusarium* race 2 as well as powdery mildew in muskmelon.

### Biological control

Wilt in cucurbits can be suppressed by *Pseudomonads* isolates. One mechanism depends on production by the pseudomonads of siderophores which have a higher chelation efficiency for iron than siderophores produced by fungal pathogens. The second is that the bacterium produces antibiotics effective against wilt pathogen. The production of siderophores and antibiotics requires adequate nutrition for the pseudomonads. In the field, association of the pseudomonads with plant root surfaces may provide a constant and appropriate nutrient supply to the bacteria. Thus, properties of the bacteria involved in colonization of the root surfaces are an integral part of the suppressive phenomenon.

### Chemical control

Drenching of carbendazim (0.1%) is very effective against this disease.

## B-3) Watermelon (*Citrullus lanatus*)

Watermelon [*Citrullus lanatus* (Thunb) Mansf.] is a popular desert crop throughtout the tropics and the Mediterranean regions of the world. The fruits are rich source of β-carotene, vitamin B, C and E, minerals (K, Mg, Ca and Fe), citrulline amino acid and phenolics. *Mateera* is drought hardy landraces crop. It is an indigenous type of watermelon and is extensively grown with mixed cropping on sand-dunes landscape in Thar desert. *Mateera* fruits are attributed to sweet and refreshing edible flesh (pulp) and consumed fresh and have juicy properties. Area and production of watermelon in India is 0.91lakh ha and 2.169 million tonnes respectively during 2016-17 (Anonymous, 2017a).

*Mateera* is subjected to attack some viral diseases, which inflict heavy damage to the crop every year. Among the viral diseases, mosaic and bud necrosis are an important diseases in Rajasthan as well as major watermelon growing states of India.

### i) Mosaic disease

It is a viral disease and causes severe losses in Rajasthan. During 1999 crop season an epidemic of mosaic disease was prevalent on muskmelon, cucumber and squash in Punjab and in adjoining states causing huge fruit losses to the crops. Disease incidence was appeared from 14.29 to 50.0% and 5.0-33.33% in different genotypes of watermelon/ *mateera* and ridge gourd, respectively at experimental field of the institute.

#### Symptoms

Plants showed characteristic symptoms of wilting and dry, necrotic lesions on leaves and internode shortening, mottling of leaves and development of vein clearing. Plants are stunted.

Mosaic disease of watermelon

**Causal organism:** This disease is caused by virus and transmitted by aphid.

#### Disease management

#### Cultural control

a) Removal of infected plant.
b) Use of disease free seed.

#### Chemical control

a) Application of insecticides like dimethote (0.1%) are recommended for the control of vectors (aphid).
b) Spraying of imidacloprid (3-5 ml/ 10 lit. of water) is also very effective for vector control.

### ii) Bud necrosis

It is also a serious problem and causes yield losses in Bikaner district and also in western Rajasthan of watermelon/*mateera* growing areas. It is also a viral disease.

#### Symptoms

Symptoms are leaf crinkling, mottling, yellowing, necrotic streaks on vines, shortened internodes, upright branches and necrosis and dieback of the buds.

Bud necrosis of watermelon

**Causal organism:** This disease is caused by virus and transmitted by thrips

#### Disease cycle

Diseases occur throughout the entire year but the disease incidence is generally higher during dry and hot periods when thrips populations increase rapidly. The virus is transmitted

by thrips species, in a persistent (propagative) manner (vector can acquire and transmit the virus after feeding for several minutes to hours: virus replicates inside the vector) young thrips (larval stage) acquire the virus and adult thrips spread the virus from plant to plant during feeding. The virus is not seed transmitted.

### Disease management

#### Cultural control

a) Use virus free seedlings
b) Remove infected plants as early as virus symptoms are observed to prevent/minimize spread of the virus by thrips.
c) Ploughing and harrowing may help to reduce vector population in the soil.
d) Control thrips population by using plastic mulch and blue sticky traps.

#### Chemical control

a) Spray acephate (0.15%) at fortnight intervals after transplanting till flowering stage.
b) Chemical spray followed by neem seed kernel extract (2%) is also effective..
c) Spraying imidacloprid at the rate of 0.5 ml/litre of water to control of sucking insects.

## B-4) Ridge gourd (*Luffa acutangula)*

Ridge gourd [*Luffa acutangula* (Roxb.) L.] is one of the important warm season vegetable crop which belongs to cucurbitaceae family and grown in different parts of India. The immature fruits are consumed as vegetable and used in the preparation of chutneys and curries. The fruits contain good amount of calcium, phosphorus, ascorbic acid, iron and fibre content. Being a warm season vegetable crop, it has the ability to tolerate high temperature which ensures its adaptability for widespred cultivation throughout the tropics.

This crop is affected by many diseases. Among the diseases, mosaic, downy mildew and *Alternaria* leaf blight are very severe diseases.

### i) Mosaic disease

It is a viral disease and causes severe losses in Northern India. Disease incidence was appeared from 7.14 to 50.0% in different genotypes of ridge gourd at experimental field of the institute.

#### Symptoms

Plants showed characteristic symptoms of wilting and dry, necrotic lesions on leaves and internode shortening, mottling of leaves and development of vein clearing. Plants are stunted.

**Causal organism:** This disease is caused by virus and transmitted by aphid.

Mosaic disease in ridge gourd

### Disease management

#### Cultural control

a) Removal of infected plant.
b) Use of disease free seed.

#### Chemical control

a) Spraying of imidacloprid (3-5 ml/ 10 lit. of water) is very effective for vector control.

## B-5) Chilli (*Capsicum annuum* )

Chilli (*Capsicum annuum* L.) is the fourth major crop cultivated worldwide and is one of the most important constituent of the cuisines of tropical and subtropical countries. Several varieties of chilli are grown for vegetables, spices, condiments, sauces and pickles. Besides, it is also used in other forms like medicines and beverages. Nutrition wise these are rich in vitamin A and C with appreciably high contents of iron, potassium, and magnesium, which have the ability to boost the immune system and lower the cholesterol levels (Grubben and Mohamed, 2004). India has been a leading producer, consumer and exporter of chilli, especially, dried one.

This crop is affected by many diseases, out of them, anthracnose, damping-off and leaf curl are very severe diseases.

### i) Anthracnose disease

Chilli production, in tropical subtropical countries, is severely impacted by occurrence of anthracnose disease, which causes substantial losses. In past, India had been the largest producer and exporter of chilli. However for last few years, a significant decline had been witnessed in its production and as a result presently, India stands at the third position in chilli production (FAOSTAT, 2012). The estimated annual loss of about 29.5%, amounting US$ 491.67 million has been reported from India alone (Garg *et al*., 2014). In India, a calculated loss of 10–54% has been reported in yield of the crop due to the anthracnose disease to both mature fruits in the field as well as during their storage (Lakshmesha *et al*., 2005). Significant losses have been reported from other parts of the globe as well, like a significant amount of 20–80% loss has been accounted from Vietnam (Don *et al*. 2007). Fungi *Colletotrichum capsici* and *C. gleosporoides* are reported to cause major damage (approx. 20-45%) at the ripe fruit stage of the plant (Saxena *et al.* 2014).

#### Symptoms

The small lesion is the most economically important aspects of the disease as on the fruit is enough to lower its market value thereby affecting the profitable yield of the crop. The disease is reported to affect almost all aerial parts of the plant. Chiefly, it causes fruit rot at both green and red stages primarily attacking ripe fruits, hence is also known by the name ripe fruit rot of chilli (Agrios, 2005). The disease may lead to damage at the seedling stage or on the aerial parts of the plants. On leaves, small, irregular to circular, brownish black, scattered spots appear. Defoliation

takes place in case of severe infection. The entire branch becomes dark brown to black but these necrotic tissues wither away. On ripe fruits, small, circular, yellowish to pinkish sunken spots appear. These become brownish to black with time.

**Causal organism:** *Colletotrichum capsici* and *C. gleosporoides*

**Taxonomic position**

- Division-Eumycota
- Subdivision-Deuteromycotina
- Class-Coelomycetes
- Order-Melanconiales
- Family- Melanconiaceae
- Genus- *Colletotrichum*
- Species- *capsici* and *gloeosporioides*

Chilli anthracnose

## Epidemiology

Environmental factors play an important role in deciding the severity and spread of any disease. Leaf surface wetness has been directly linked with disease severity owing to the better establishment of the pathogen in respect of germination, attachment and penetration into host tissues (Than *et al*., 2008). Temperature around 27°C with relative humidity of 80% have reported to be the most optimum conditions for successful establishment of the disease. Maximum spore germination takes place at temperatures between 28-30°C at 100 % RH.

## Disease spread

Water splashes may easily spread the conidia of the pathogen from infected to uninfected plant parts. Also, relative humidity aids successful colonization of the pathogen.

## Disease management

### Cultural control

a) Proper drainage, crop rotation and removal of any infected plant parts of the field.
b) Proper distance between the plants should be maintained so as to reduce dense canopy.
c) Transplants raised from disease free seeds of the chilli variety. The transplants should be kept weed free and away from other solanaceous crops.

### Chemical control

a) Newer chemicals like strobilurins based fungicides (azoxystrobin, pyraclostrobin @ 50-100g /ha) have also been used for its management under large field trials (Chen *et al.* 2009).
c) Rotation of two or more different classes of fungicides is highly recommended for increasing the chance of better protection against the disease (Forster *et al.* 2007).
d) Seed treatment with thiram (2 g /kg seed).

### Use of resistant varieties

a) Use of chilli resistant varieties such as B- 61 and Lorai.

b) Use of resistant varieties (BS-35, BS-20, BS-28, Punjab Lal, Bhut Jolokia, Taiwan-2, and Pant C-1) are recommended against this disease (Garg *et al.*, 2014).

### Use of botanicals

Disease management by the application of botanicals and crude extracts of medicinal plants has been investigated for their efficient antifungal and antimicrobial properties. Different degree of effectiveness of extracts of *Ocimum sanctum* leaf extract, neem oil, garlic, *Piper betle* and *Coleus aromaticus* against the pathogen growth and spore germination have been noted by various workers.

### Use of bio-agents

The bio-agents (*Psuedomonas fluorescens, Trichoderma* spp., *Bacillus subtilis* and *Pichia guilliermondi)* used against *Colletotrichum* spp. are effective under arid environment .

## ii) Leaf curl disease

It was prevalent in Bikaner, Jodhpur and Jaisalmer district of Rajasthan and nearby areas. This disease causes heavy yield losses.

### Symptoms

Leaves are yellowing, followed by slight curling. The interveinal areas puckered, shortening of the internodes and reduction in leaves size giving witch's broom appearance. Plants remain stunted and appear as bushy.

Chilli leaf curl

### Integrated disease management practices:

### Cultural control

a) Removal of infected plant and weeds.
b) Use of disease free seedlings.
c) Grow the maize crop as barrier crop and also trap crop for reducing the disease.

### Chemical control

a) Combined use of yellow traps followed by cypermethrin spray (100-130 g/ha) reduces the vector population.

## iii) Damping-off

Damping-off of the young seedlings is quite prevalent in the tropical and subtropical zones.

### Symptoms

Seedlings may die prior to emergence (pre-emergence damping off) or the base of the hypocotyls may be attacked when the cotyledonary leaves are opening. A water-soaked lesion at the collar region and toppling down of seedings after 2-3 days are characteristic symptoms of post- emergence damping off.

**Causal organism**- *Pythium aphanidermatum* and *Phytophthora* spp.

**Taxonomic position**

- Division-Eumycota
- Subdivision-Mastigomycotina
- Class-Oomycetes
- Order-Peronosporales
- Family- Pythiaceae
- Genus- *Pythium*
- Species- *aphanidermatum*

### Epidemiology

Pathogens are affected by soil temperature and moisture as well as rainfall during the seedling stage. The optimum temperature for growth and infection by *Pythium and Phytophthora* are 25 and 20 °C, respectively.

### Disease management

a) Proper drainage and removal of any infected plant parts of the field.

b) Seed treatment with metalaxyl for *Pythium and Phytophthora* spp., iprodione for *Rhizoctonia* as well as thiram/captan have been recommended.

c) In cucumber, disease reduces with *Pseudomonas fluorescens.*

## B-6) Brinjal (*Solanum melongena* L.)

Brinjal (*Solanum melongena* L., Family- Solanaceae) is one of the most commonly grown vegetable crops in India. It is adapted to a wide range of climatic conditions. It has a long bearing period when grown under mild climate of southern states but its bearing is shortened under hot summer and cold winter seasons of northern India. In addition to India, other major brinjal producing countries are China, Turkey, Japan, Egypt, Italy, Iraq, Spain and Phillipines. India contributes 0.727 million tonnes to the global production with 123.23 lakh ha area (Anonymous, 2017a). In India, it is well cultivated in Orissa, Bihar, Karnataka, west Bengal, Andhra Pradesh, Maharashtra and Uttar Pradesh. Brinjal fruits are a fairly good source of calcium, phosphorus, iron and vitamins particularly 'B' group.

This crop is affected by many diseases, out of them, *Phomopsis* blight and damping-off are very severe diseases.

### i) *Phomopsis* blight :

This disease is more severe in tropical and sub-tropical areas but it is not observed in hot arid environment.

#### Symptoms

On leaves, small, circular to irregular and grayish brown spots appear turn grey later with light coloured centre. The diseases leaves become yellowish and may drop off. On old fruits, small pale sunken spots appear which cover entire fruit surface. The infection of fruits through calyx leads to development of dry rot and fruits appear black and mummified.

**Causal organism**- *Phomopsis vexans*

**Taxonomic position**

- Division-Eumycota
- Subdivision-Deuteromycotina
- Class-Coelomycetes
- Order-Sphaeropsidales
- Family- Sphaeropsidiaceae
- Genus- *Phomopsis*
- Species- *vexans*

*Phomopsis* blight of brinjal

#### Epidemiology

High relative humidity coupled with high temperatures are favourable for the disease development. Maximum disease takes place at 26°C under wet weather conditions with 55% RH.

#### Disease management

a) Proper drainage and removal of any infected plant parts of the field.
b) Use of healthy seed/seedlings.
c) Hot water treatment at 50°C for 30 minutes to remove infection.
d) Grow resistant varieties like Pusa Bhairav.
e) Seed treatment (1g/kg) + seedling treatment with bavistin for 30 minutes and also spray at 10-15 days interval

## B-7) Tomato (*Lycopersicon esculentum* L.)

Tomato (*Lycopersicon esculentum* L.) is one of the most popular vegetables grown all over the world. In India, tomato has wider coverage in comparison to other vegetables. The leading tomato growing states are Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab and Bihar. It is a very good source of income to small and marginal farmers and contributes to the nutrition

of the consumers. It is a rich source of minerals, vitamins and organic acid. There are various types of flavouring compounds found in the fruits, which enrich the taste. The total sugar content is 2.5% in ripe fruit and amount of ascorbic acid varies from 16-65mg/100g of fruit weight. Tomatoes are used directly as raw vegetables in sandwiches, *salad* etc. Many processed items like paste, syrup, juice, ketchup, drinks, whole peeled tomato, etc. are prepared on a large scale. The area and production of tomato in our country was about 7.99 lakh hectare and 19.542 million tones, respectively (Anonymous, 2017a). Tomato is affected by many diseases (*Fusarium* wilt, damping-off and bacterial wilt) are very severe diseases.

### i) *Fusarium* wilt

This is an important disease of tomato occurring in both temperate and warmer areas. The degree of loss caused by pathogen varies depending upon host cultivar, race of the pathogen and environmental factors.

#### Symptoms

The young plants on infection initially show clearing of veinlets on the leaves and drooping of petioles followed by sudden wilting. In older plants, the symptoms first appear on lower leaves and later, on younger ones which may become yellow, droop and die. Such symptoms may appear only on a few branches or on the entire plant leading to stunted plant growth and wilting. The vascular bundles of lower part of stem become brown and the roots black.

**Causal organism:** *Fusarium oxysporum* f.sp. *lycopersici*

**Taxonomic position**

- Division- Eumycota
- Subdivision- Deuteromycotina
- Class- Hyphomycetes
- Order: Tuberculariales
- Family: Tuberculariaceae
- Genus- *Fusarium*
- Species- *oxysporum* f.sp. *lycopersici*

*Fusarium* wilt

#### Epidemiology

Soil temperature, moisture and pH are known to affect the development of this disease. The disease develops optimum at 28°C. In Indian plains, the pathogen does not perpetuate in soil as it can not survive temperature above 37 °C for more than 3-4 days.

### Disease management

#### Cultural control

a) Collection and burn of infected plant debris.

b) Use of healthy seed for planting

c) Deep plough of field in summer to expose soil to hot sun.

d) Reduction in disease severity in soil amended with groundnut foliage.

#### Chemical control

a) Seed treatment with bavistin (2 g/kg seed) has been recommended.

b) Soil drenching with benomyl (2 g/lit. of water) has also proved effective in reducing disease severity.

#### Biological control

Use of antagonistic microorganism is an attractive method of disease control. Damage to the hyphae and micro conidia of pathogen *in vitro* by *Penicilium oxalicum* and *Aspergillus nidulans.*

### ii) Bacterial wilt

#### Symptoms

Characteristic symptoms are the rapid and complete wilting of normal grown up plants. Drop lower leaves before wilting. It may invade the cortex and pith in addition to vascular region and cause yellow brown tissue discolouration. Infected plant parts when cut and immersed in clear water, a white streak of bacterial ooze is seen coming out from cut ends.

**Causal organism:** *Pseudomonas solanacearum*

Bacterial wilt of tomato

### Disease management

i) Crop rotations, viz., cowpea-maize-cabbage, okra-cowpea-maize, maize- cowpea-maize and finger millet-egg plant are reported effective in reducing this disease.

ii) Seedling treatment with streptocycline (1 g/20-40 litres of water) for 30 min protects the seedlings at initial stages of growth.

## B-8) Kachri (*Cucumis melo* var. *callosus*)

Kachri (*Cucumis melo* var. *callosus*) is likely to be a wild variety of melon and an underutilized cucurbitaceous vegetable, grown across arid regions of western Rajasthan. It grows naturally in desert areas. It is a drought tolerant annual climber found growing copiously during rainy and

summer season in arid and semi-arid regions of North-western India. It is a true earth food, flourishing wild and a protein rich vegetable for inhabitants of the harsh arid areas of western India. It is also found in Bengal, Punjab and the North Western states. The high temperature and dryness conditions are beneficial for crop, fruit maturity, quality and dehydration.

It is sold fresh in the markets. Unripe kachri tastes bitter. When it ripens it becomes sweet and a bit sour. Fresh fruits are usually cooked with various vegetable preparations and used in salad and for making chutney. Since fresh kachri is rarely available outside Rajasthan. It is one of the important components of the 'Panchkuta' in the desert district of North Western India. Regular use of kachri powder may help to cure minor skin diseases, lice, manifestation, itching and earache (Rana and Sadananda, 2018).

Ripe fruits are peeled and dried whole or slice and stored as such or in powder form and used as souring agent in combination with chilli, turmeric, coriander, cumin and fenugreek to manufacture various kinds of curry powder (Pareek and Samadia, 2002). Major diseases such as *Fusarium* wilt, powdery mildew, downy mildew and cucumber green mottle mosaic virus are not commonly found in kachri under arid region but viral disease appears occasionally in semi-arid region.

### i) Cucumber green mottle mosaic virus

The prominent symptoms are slight clearing of veins and crumpling of young leaves followed by a light or dark green mottling together with blistering and distortion of leaves. The virus spreads naturally or through red pumpkin beetle.

**Causal organism:** Cucumber green mottle mosaic virus (CGMMV).

#### Disease spread

The virus is very stable and mechanically transmissible at the time of cultural operation. The disease is never transmitted through seed.

#### Disease management

#### Cultural control

a) Field sanitation.
b) Avoid contamination by workers and implements.

#### Chemical control

a) Spray the crop with dimethoate (1 ml/l) at 10-day intervals (Rana and Sadananda, 2018).

## B-9) Snap melon (*Cucumis melo* var. *momordica*)

Snap melon (*Cucumis melo* var. *momordica*) is a indigenous crop of India and is extensively grown in 19$^{th}$ century in northern India, where it is commonly called as *phoot* and *Phoot kakari* which means 'to split'. It is one of the most important cucurbits being grown in Rajasthan, Uttar

Pradesh, Haryana, Punjab and Bihar. It is usually grown as mixture crop with maize, sorghum and pearl millet.

The ripe fruits are used as a alternative of muskmelon due to its cooling effect. ICAR-CIAH has identified a promising variety 'AHS-82' which is not cracked on ripening under hot arid region of western Rajasthan. The tender fruits are also used as salad and as a cooked vegetable and prepared pickle of immature fruits. Ripe fruits are used for making squash as a light drink. Its seed kernel is used in bakery products and thandai. It has prospects of value addition in pickles, jam, chutney, squash and as dehydrated.

Snap melon germplasm has been found to be a good source of disease and insect resistance (Singh *et al*. 2009). Major diseases such as *Fusarium* wilt, powdery mildew, downy mildew and *Cercospora* leaf spot are not observed in Bikaner and nearby areas but it is occasionally affected by *Alternaria* leaf blight and anthracnose in semi-arid region.

### i) *Alternaria* leaf blight

*Alternaria* leaf blight was observed in the field and in river beds of different parts of Rajasthan, Uttar Pradesh, Haryana and Punjab. This disease is largely confined to the leaves. It is considerably influenced by humid weather. The intensity of this fungal disease varies depending up on the favourable weather conditions and genotypes.

#### Symptoms

Characteristic symptoms first appear on leaves as small, circular and light brown to reddish brown spots of different size which later enlarge in a concentric pattern/rings and margins appear. These spots coalesce to form larger necrotic areas on leaves.

**Causal organism:** *Alternaria cucumerina*

#### Epidemiology

The disease ranged in trace to moderate form depending on the environmental factors during rainy season. Availability of high humidity (80-95%) coupled with a temperature of about 25-28°C with bright sunlight and dew or rain was conducive for fungal spore germination at which maximum disease development is obtained.

#### Disease management

#### Cultural control

a) The infected crop debris and weeds collected and burnt.
b) Use of disease free and certified seed.

#### Chemical control

a) Sprayings of indofil M- 45 (0.2%) at regular interval was very effective against this disease.

b) Among the fungicides, topsin (0.05%) was effective against the leaf spot disease caused by *Alternaria cucumerina*.

### ii) Anthracnose

Anthracnose is most common on cucumber, muskmelon, gourds and watermelon; sometimes, it may also occur on snap melon, squash and pumpkin. Losses in storage can occur when freshly harvested fruit becomes infected.

#### Symptoms

Small yellowish or water soaked areas appears on leaves which enlarge rapidly and turn brown in most cucurbits. When infection occurs in fruit pedicle, the young fruit may be darken, shrivel and dry. Circular black spots or cankers appear on fruits. On maturing fruit, lesions appear as small, circular, sunken areas which may grow to the size of a quarter or larger on melons based on the host and environmental conditions. In the sunken black spots, salmon-pink coloured masses of spores can be seen under humid conditions.

**Causal organism:** *Colletotrichum lagenarium and Colletotrichum orbiculare*

#### Disease spread

This fungus survives between crops in disease residue and cucurbit seed. Water splashes, people, animals, and machinery may easily spread the conidia of the pathogen from infected to uninfected fruits, infected crop trash and infected see in wet conditions. Also, relative humidity aids successful colonization of the pathogen.

### Disease management

#### Cultural control

a) Proper drainage in the field.

b) Proper distance between the plants should be maintained so as to reduce dense canopy.

c) Practice crop rotations with unrelated crops for at least 2 years.

d) Follow good sanitation practices, such as cleaning up crop debris at the end of the growing season.

#### Chemical control

a) Spray the crop with blitox-50 (0.2%), or bavistin (0.1%) and repeat at 7 to 10 day intervals if necessary (Rana and Brar, 2018).

b) Treat the seeds with bavistin @ 2 g /kg seed (Rana and Brar, 2018).

c) Spray the crop with chlorothalonil @ 0.2 %.

## Gaps in prevailing system

Following gaps need to be addressed for effective implementation of integrated disease management practices in arid horticultural crops:

- Lack of disease free planting material of horticultural crops.
- Lack of awareness regarding crop rotation/sequence.
- Lack of awareness about uses of proper doses/measurement for fungicides with farmers as higher/lower doses may lead to resistance in fungal races.
- Lack of broad spectrum activity of fungicides in its action.
- Lack of effective forecasting systems against major diseases of horticultural crops.
- Lack of timely provision of useful information, training and instruction to workers

## Advance approaches for fruits and vegetables in the arid region

Plant biotechnology users a new era for plant scientists working to maintain healthy plants; thereby, optimizing crop yields and minimizing pesticide usage. One of the ultimate aims of agricultural biotechnology is to feed an expanding world population. In the new millennium, the horticultural production is facing the uphill task of feeding the ever burgeoning global population, which seems quite distant with traditional means of production. In independent India, increasingly farmers are adopting modern methods of cultivation to get the maximum returns, which often involve the higher uses of pesticides. Further, the increasing use of pesticides with the emergence of new diseases has posed great threats to consumer's health and environmental safety as well. Therefore, exploiting genetically engineered crop plants to meet the increasing global food demand while preserving the environment is need of time. It is possible to introduce genes conferring disease resistance into crop plants, which could be accomplished either by direct methods or vector-mediated methods. These practices together reduce the pesticide uses in horticultural production and hence, hailed environmental-friendly. Besides, there are several other tools such as PCR, ELISA diagnostic kits, transgenic plant disease management and molecular markers, which are increasingly used for the timely and rapid diagnosis and management of plant diseases. Such practices will ultimately leads to reduced pesticide applications. Therefore due to minimal uses of pesticides, such foods are considered safe for consumption and; hence, farmers/growers are likely to fetch remunerative price for their produce, which in turn will also lead to improving their socio-economic status.

## Future scope and research need

i) Standardization of cultural practices integrated with reduced doses of fungicides.

ii) Assessment of the efficacy of botanicals and bio-agents against major diseases of arid horticultural crops. Besides, the rearing feasibilities of the promising bio-agents should be further investigated under natural field conditions.

iii) Development of fungicides/pesticides with less toxicity.

iv) Study the residual effect of fungicides/chemicals on human beings and environment and to advise residue tolerance limit.

v) Collaboration between research organization and pesticides industries for developing new molecules with minimum persistence and their commercialization.

vi) Identification of crop rotation practices for individual horticultural crops.

vii) Identification of alternate hosts for pathogens.

## Future prospects

In view of the various apprehensions associated with the different environmental factors and their impact on pathogenic resistance, it is imperative to develop an efficient integrated management strategy to combat pathogenic stresses. Therefore, insights into the disease-etiology and pathogen's proliferation would render valuable information required to develop effective management strategies for instances development of resistant varieties against the targeted pathogen. Also, modifications in conventionally recommended cultural practices tailor-made to a particular agro-climatic region will be useful in improved management of the diseases. More information are sought for acquiring in-depth understanding concerning various modes of infection by the pathogen and the pathogenic variability associated within a region with the post-harvest as well as pre-harvest losses in the crop production. The overall improved knowledge about the key facets of a disease triangle will facilitate effective management of the disease, while sustaining both quality and quantity of the crop produced. This on one hand save expenses towards pesticide usage, while preserving food quality on the other hand; thereby, contributing immensely to the country's economy.

## Conclusion

In toto by adopting of agronomic practices, which are environmentally benign and entail a gamut of features of disease management, an enhanced yield with optimum quality in horticultural crops can comfortably be realized. Therefore, the need of the hour is to identify a holistic strategy integrating various approaches, beginning from the selection of planting material, various stages of crop development and harvest to till storage, to ward off disease occurrence. However, such strategies need a thorough pre-planning and pro-active spirit to work out viable and crop-specific recommendations for the safe and economic management of major diseases of arid horticultural crop.

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