

**STUDIES ON DISEASES OF BOTTLE GOURD,
[*Lagenaria siceraria* (Molina) standl] AND ITS
MANAGEMENT STRATEGIES**

M.Sc. (Ag.) Thesis

by

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**DEPARTMENT OF PLANT PATHOLOGY
COLLEGE OF AGRICULTURE
FACULTY OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA,
RAIPUR**

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MANAGEMENT STRATEGIES**

M.Sc. (Ag.) Thesis

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Indira Gandhi Krishi Vishwavidyalaya, Raipur**

by

Vivekanand Uraiha

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CERTIFICATE-I

This is to certify that the thesis entitled “**Studies on diseases of bottle gourd, [*Lagenaria siceraria* (Molina) standl] and its management strategies**” submitted in partial fulfilment of the degree of **Master of Science in Agriculture** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Vivekanand Uraiha** under my guidance and supervision. The subject of the thesis has been approved by student’s Advisory Committee and Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.


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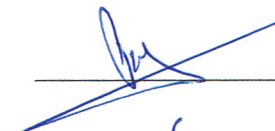
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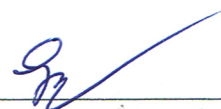
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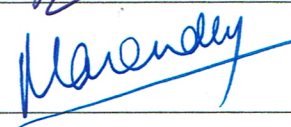
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This is to certify that the thesis entitled “**Studies on diseases of bottle gourd, [*Lagenaria siceraria* (Molina) standl] and its management strategies**” by **Vivekanand Uraiha** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture** in the **Department of Plant Pathology** has been approved by the external examiner and student’s Advisory Committee after oral examination.

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LIST OF NOTATIONS /SYMBOLS

Abbreviation	Description
%	Per cent
@	At the rate of
S. N.	Serial Number
°C	Degree Celsius
cm	Centimeter
g	Gram
CD	Critical Difference
SEm	Standard error of mean
CV	Coefficient of variance
C.G.	Chhattisgarh
<i>et al.</i>	And others
Fig.	Figure
<i>i.e.</i>	That is
<i>viz.,</i>	namely
kg	Kilo gram
No.	Number
mm	Millimeter
ml	Milliliter
L	Litre
q/ha	Quintal per hectare
g/l	Gram per litre
SL	Soluble liquid
WP	Wettable powder
WG	Water granule
RH	Relative humidity

LIST OF ABBREVIATIONS

Abbreviation	Description
DAT	Days After Transplanting
DAS	Days After Sowing
FYM	Farm Yard Manure
NPK	Nitrogen Phosphorus Potassium
LSI	Location Severity Index
RBD	Randomized Block Design

THESIS ABSTRACT

- a) Title of Thesis : **Studies on diseases of bottle gourd, [*Lagenaria siceraria* (Molina) standl] and its management strategies**
- b) Full Name of the Student : Vivekanand Uraiha
- c) Major Subject : Plant Pathology
- d) Name and Address of the Major Advisor : Dr. C. P. Khare (Scientist)
Department of Plant Pathology, CoA, I.G.K.V. Raipur (C. G.).
- e) Degree to be awarded : Master of Science in Plant Pathology



Signature of Major Advisor

Date: 28/07/18



Signature of the Student



Signature Head of Department

ABSTRACT

The present study entitled “**Studies on diseases of bottle gourd, [*Lagenaria siceraria* (Molina) standl] and its management strategies**”. was conducted at Horticultural Research Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya Raipur (C.G.) during December 2017 to April 2018.

Five diseases viz. downy mildew, leaf curl, leaf blight, mosaic and powdery mildew appeared during the course of investigation. Leaf curl and mosaic observed earlier than the downy mildew and leaf blight. Disease severity and incidence reached at maximum in April. Seed treatment with carbendazim 12% + mancozeb 63% (3 g/kg seed) significantly stimulated germination percentage, root length, shoot length, fresh weight, dry weight and vigour index of bottle gourd. Among the thirteen varieties of bottle gourd three (Amrit, Ankit and Anmol) and two (Manya and NS-433) were immune and resistant to downy mildew respectively. However, five (Angad, Ankit, Anmol, Chutki and Naveen) varieties showed Immune response against leaf curl. Five varieties (Amrit, Ankit, Latto, Manya and NS-443) were highly resistant and other five viz. Angad, Anmol, Divya, Naveen and Sarita were resistant against mosaic. Out of thirteen varieties of bottle gourd six varieties (Chutki, Amrit

Angad, Ankit, Mahima and NS-433) were moderately resistant against powdery mildew. Three management practices viz. T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %], T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₂ [seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] significantly reduced the incidence and severity of diseases with better flowering, fruiting, fruit size, yield attributes, yield and cost benefit ratio.

शोध ग्रन्थ सारांश

शोध ग्रन्थ का शीर्षक	लौकी, लैजेनेरिया, सिसेरिया, मोलिना, एल. स्टैंडल की बीमारियों का अध्ययन और इसकी प्रबंधन नीतियां
छात्र का पूर्ण नाम	विवेकानंद उरैहा
मुख्य विषय	पादप रोग विज्ञान
मुख्य सलाहकार का नाम और पता	डॉ. सी. पी. खरे (प्रमुख वैज्ञानिक) पादप रोग विज्ञान विभाग, कृषि महाविद्यालय रायपुर
प्रदान की जाने वाली उपाधि	एम.एस.सी. (कृषि) पादप रोग विज्ञान
मुख्य सलाहकार के हस्ताक्षर	 छात्र के हस्ताक्षर
दिनांक	28/07/18  विभागाध्यक्ष के हस्ताक्षर

सारांश

वर्तमान शोध शीर्षक "लौकी, लैजेनेरिया, सिसेरिया, मोलिना, एल. स्टैंडल की बीमारियों का अध्ययन और इसकी प्रबंधन नीतियां" उद्यानिकी अनुसंधान प्रक्षेत्र, कृषि महाविद्यालय, इंदिरा गांधी कृषि विश्व विद्यालय रायपुर, छत्तीसगढ़ में नवम्बर 2017-18 के दौरान किया गया।

अध्ययन के दौरान पांच रोगों कमशः मृदुरोमिल आसिता, पर्ण कुंचन, पत्ती झुलसा, चित्ती (मोजेक), चूर्णील आसिता को प्रकट होते देखा गया है। पर्ण कुंचन एवं चित्ती (मोजेक) को मृदुरोमिल आसिता एवं पत्ती झुलसा से पहले देखा गया। अप्रैल माह में रोग उग्रता एवं प्रकोप अधिकतम पाया गया। कार्बेन्डाजिम 12 प्रतिशत + मैन्कोजेब 63 प्रतिशत (3 ग्राम प्रति किलोग्राम बीज) से बीज उपचार में अंकुरण प्रतिशत, जड़ लंबाई, प्ररोह लंबाई, ताजा भार, शुष्क भार, ओज सूचिका अधिकतम पाया गया। लौकी के समस्त 13 किस्मों के मूल्यांकन के पश्चात् तीन किस्म (अंकित, अमृत एवं अनमोल,) एवं दो किस्म (मान्या एवं एन.एस.-443,) मृदुरोमिल आसिता के प्रति रोगमुक्त एवं अधिक प्रतिरोधक पाया गया। वैसे ही, पांच किस्म (अंगद अंकित अनमोल, चुटकी, एवं नवीन) पर्ण कुंचन से रोगमुक्त पाया गया। मोजेक के प्रति पांच किस्म (अमृत अंकित लटटो, मान्या एवं एन.एस.-443) अधिक प्रतिरोधक एवं पांच किस्म (अंगद, अनमोल दिव्या, नवीन एवं सरिता) प्रतिरोधक पाया गया एवं समस्त 13 किस्मों में चूर्णील आसिता के प्रति छः किस्म (चुटकी, महिमा, अंगद, अंकित एन.एस. 443, अमृत) मध्यम प्रतिरोधक पाया गया। तीन प्रबंधन तकनिक में अर्थात् T_5 -बीज उपचार (कार्बेन्डाजिम 12 प्रतिशत + मैन्कोजेब 63 प्रतिशत की दर से 3 ग्रम/ कि.ग्रा) + ड्रेंचिंग (कैप्टान 70 प्रतिशत + हेक्साकोनाजोल 5 प्रतिशत डब्ल्यू. पी. दस ग्राम प्रति लीटर दर) + स्प्रे (टेबुकोनाजोल 50 प्रतिशत + ट्राईफ्लोक्सीस्ट्रॉबिन 25 प्रतिशत डब्ल्यू. जी. एक ग्राम प्रति लीटर दर) + (इमिडाक्लोप्रिड 17.8 एस. एल 7.5 मिली.लीटर प्रति 15 लीटर की दर से + नीम तेल 0.2 प्रतिशत) + (फोसेटाईल-एल 0.1 प्रतिशत की दर से) (टेबुकोनाजोल 50 प्रतिशत + ट्राईफ्लोक्सीस्ट्रॉबिन 25 प्रतिशत डब्ल्यू. जी. एक ग्राम प्रति लीटर दर) + (इमिडाक्लोप्रिड 17.8 एस. एल 7.5 मिली.लीटर प्रति 15 लीटर की दर से + नीम तेल 0.2 प्रतिशत) +

(फोसेटाईल-एल 0.1 प्रतिशत की दर से), T_3 – बीज उपचार त (सीड प्रो 25 ग्राम प्रति किलोग्राम बीज)+ ड्रेंचिंग (सीड प्रो 5 प्रतिशत प्रति लीटर दर से) + स्प्रे (कैप्टान 70 प्रतिशत + हेक्साकोनाजोल 5 प्रतिशत डब्ल्यू. पी 0.1 प्रतिशत दर से) + (इमिडाक्लोप्रिड 17.8 एस. एल 7.5 मिली.लीटर प्रति 15 लीटर की दर से + नीम तेल 0.2 प्रतिशत) + (फोसेटाईल-एल 0.1 प्रतिशत की दर से) + स्प्रे (कैप्टान 70 प्रतिशत + हेक्साकोनाजोल 5 प्रतिशत डब्ल्यू. पी 0.1 प्रतिशत दर से) + (इमिडाक्लोप्रिड 17.8 एस. एल 7.5 मिली.लीटर प्रति 15 लीटर की दर से + नीम तेल 0.2 प्रतिशत) + (फोसेटाईल-एल 0.1 प्रतिशत की दर से) एवं T_2 –बीज उपचार (कार्बेन्डाजीम 12 प्रतिशत + मैनकोजेब 63 प्रतिशत की दर से 3 ग्राम/ कि.ग्रा) + ड्रेंचिंग (कैप्टान 70 प्रतिशत + हेक्साकोनाजोल 5 प्रतिशत डब्ल्यू. पी दस ग्राम प्रति लीटर दर) + स्प्रे छ; वैकल्पिक स्प्रे सीड प्रो 1 प्रतिशत एवं नीम तेल 0.2 प्रतिशत ने बेहतर फूल, फल, फल आकार, उपज गुण, उपज, लागत लाभ अनुपात के साथ रोग उग्रता को काफी कम किया।

CHAPTER – I

INTRODUCTION

The family cucurbitaceous includes important vegetable crops, such as bottle gourd (*Lagenaria siceraria*), cucumber (*Cucumis sativus*), melon (*Cucumis melo*), pumpkin (*Cucurbita pepo*), squashes (*Cucurbita maxima*) and water melon (*Citrinella lanatus*). Bottle gourd is one of the earliest domesticated food plants which are originated from Africa. Bottle gourd may have been spread by ocean currents to the shores of the New World or by human migration in pre-historic times. It is known to have been cultivated in Africa, Asia and America. The earliest evidence of its use comes from Peru dating from 13,000 to 8000 B.C. Young tender, non-bitter fruits are used as vegetable. Young shoots and flower buds of less bottle types are occasionally eaten as green vegetable. In African countries, people extract edible oil from the seeds of bottle gourd. In Asia, some bottle gourd cultivars are used as root stock for grafting musk melon and cucumber to control soil-borne diseases. Roots and fruits are sometimes used as purgative. The leaves are used as a medicine for stomach-ache, skin rashes and swelling due to snake poison. The dry shells of the fruit known as calabashes are used for storing milk, water, honey, ghee, salt, tobacco, crop seeds or food grains. Calabashes are also used for making variety of musical instruments (Morimoto and Mvere, 2004).

Among medicinal uses bottle gourd is traditionally used as a cardio-tonic, aphrodisiac and general tonic, liver tonic, anti-inflammatory, expectorant and diuretic agent. Recently, the antioxidant activity of ethanolic extract of epicarp and fresh juice of bottle gourd has been reported (Deshpande *et al.*, 2008). The fruit of bottle gourd is also reported to have good source of Vitamin-B complex and Chlorine along with fair source of vitamin-C and β -carotene (Kirtikar and Basu, 2001). It is also reported to contain cucurbitacin, fibers and polyphenol (Nadkarni, 1954). Lignin, a ribosome inactivating protein (RIP) isolated from the seeds of bottle gourd possesses immune- protective, antitumor, anti HIV and anti

proliferative properties (Wang and Ng, 2000). The fruits of bottle gourd are widely used in Ayurveda and other folk medicines traditionally used for its cardio protective, cardio tonic, general tonic, diuretic, aphrodisiac, antidote to certain poisons, scorpion stings, purgative and cooling effects. It cures pain, ulcers and fever and used for pectoral cough, asthma and other bronchial disorders especially syrup prepared from the tender fruits (Anjaria *et al.*, 2012).

It is a monoecious, annual, climbing or trailing herb, with proximally bifid tendrils. Leaves are alternate, simple, stipules absent, petiole 2.5 to 12.5 cm long pubescent with pair of tiny glands at apex, blade broadly ovate to kidney-shaped in outline. Flowers are unisexual (rarely bisexual), regular, solitary on leaf axils. Male flowers are on long pedicles where as female flowers are on short pedicles. Fruits are variable in size and shape, often globular bottle or club-shaped up to one meter long, white yellow to dark green when young, sometimes whitish speckled, usually brown when mature and dried.

In India, bottle gourd is grown as a commercial vegetable crop in an area of 1.55 lakh ha with an annual production of 24.58 lakh tonnes (Anonymous, 2015-16). As regard the status of this crop in Chhattisgarh state, the area is 12766 hectares and 2.40 lakh tones production. It is one of the most preferred vegetable by local dwellers of Chhattisgarh. Among the 27 districts of the state, Durg district covers highest area (1560) with production of 40560 metric tones followed by Surguja and Raipur Hence it is cultivated round the year except few winter months in the region.

Bottle gourd is commonly attacked by number of diseases such as downy mildew, powdery mildew, Phytophthora blight , Cercospora leaf spot , Fusarium wilt and fungal root rots, root knot nematode, bacterial wilt, bacterial leaf spot, mosaic, watermelon bud necrosis, leaf curl and leaf distortion virus. These diseases are of national importance and cause important economic losses in cucurbits (Mathew and Alice, 2002, Pandey *et al.*, 2002, Palada and Change, 2003, Rai *et al.*, 2008 and Khan *et al.*, 2014). Among them downy mildew (Hansen, 2000 and Rai

and Yadav, 2005), powdery mildew (Watson and Napier, 2009), mosaic (Ashwini *et al.*, 2016), leaf curl (Raj *et al.*, 2010), Fusarium wilt (Rakhholiya *et al.*, 2003) and leaf spot are commonly affecting diseases that cause considerable loss to the crop (Balachandran, 2011 and Abraham *et al.*, 2015).

Downy mildew caused by *Pseudoperonospora cubensis* is one of the important foliar diseases of bottle gourd. It was reported for the first time in 1868 and still it is considered as one of the serious problem. In India, it is present all over the country except in high altitude temperate zone in the Himalaya. The losses are severe in bottle gourd, muskmelon, watermelon, cucumber, sponge gourd and ridge gourd (Hansen, 2000 and Rai and Yadav, 2005). The initial symptoms appear as pale green areas on the upper leaf surfaces which change to yellow angular spots. A fine white to grayish downy growth soon appears on the lower leaf surface. Infected leaves generally die but may remain erect while the edges of the leaf blades curl inward. Usually, the leaves near the center of a hill or row are infected first. The infected area spreads outward, causing defoliation, stunted growth, and poor fruit development which reduces yield. The entire plant may eventually be killed (Kuepper, 2003 and Rai and Yadav, 2005). During moist weather the corresponding lower leaf surface is covered with a downy, pale gray to purple mildew. The colour of the mildew ranges from white to near black. In rainy humid weather entire vein is killed (Babadoost, 2001). Early infection of downy mildew can cause reduction in crop yield upto 60% where as late infection is less damaging (Colucci and Holmes, 2010 and Wallace *et al.*, 2014).

Powdery mildew caused by *Sphaerotheca fuliginea* and *Erysiphe cichoracearum* produce white powdery growth on the upper surfaces of leaves and on the stems of infected plants. Infected areas are often stunted and distorted and may drop prematurely from the plant. Fruits are usually not directly affected, but their size and growth may be stunted. Infection can occur when temperatures are between 10 and 32.2 °C, during dry weather with high relative humidity (Anonymous, 2016).

Among the viral diseases bottle guard mosaic and leaf curl disease have become a most limiting factor for the cultivation of the crop in many places. The disease is responsible for a yield loss up to 100 per cent. Infection of bottle gourd with *Bottle gourd distortion mosaic virus* (BDMV) and *Cucumber mosaic virus* (CMV) was reported for the first time from Coimbatore, India (Nagarajan and Ramakrishnan, 1971). Symptoms appear as light and dark green mottling of the leaves, distortion of leaves and stunting of the plant might occur. Sometimes fruit might show sunken concentric circles or a raised marbled pattern. It is transmitted by five different species of aphid vectors and was tentatively named as *Bottle gourd mosaic virus*. The symptoms of BDMV infection in bottle gourd consists of upward curling, shortening of internodes, distortion of leaves, stunting of plants and deformation of fruits (Giri and Mishra, 1986, Mathew and Alice, 2002, Khan *et al.*, 2002, Tripathi and Varma, 2002, Watson, 2009 and Ashwini *et al.*, 2016).

Among the all measures to raise the productivity level, plant protection is in central position. Plant protection is a basic exercise in any crop for control of insect-pests, diseases, weeds etc. to avoid economic losses. Reports indicate these losses ranging from 20-30 per cent by each of the insect-pests, diseases and weeds, but on a holistic basis about 30 per cent average cumulative loss by them appears a fair estimate. This implies that suitable control measures must be followed to keep these losses to the minimum (Muthuraman and Kumar, 2013 and Jana, 2014).

Disease management strategies such as use of tolerant varieties, sowing date, sowing depth, barrier crops, white plastic mulch, perforated plastic mulch, roughing of infected plants, destruction of collateral host plant, seed treatment and application of suitable fungicide and insecticides may considerably reduce the yield loss caused by fungal and viral diseases (Mathew and Alice, 2002, Tripathi and Varma, 2002, Kaur and Kang, 2005 and Watson, 2009).

Bottle gourd is an important vegetable of Chhattisgarh, and the losses due to the diseases caused by pathogen cannot be ignored. Also less information regarding disease management strategies in this crop is available. Therefore the following objectives were framed for the present study.

1. To record the seasonal occurrence of bottle gourd diseases.
2. To evaluate important commercial varieties (bottle gourd) against prevalent diseases.
3. To work out the suitable combination of methods for management of the disease.
4. To study the response of various treatments on yield and yield attributes of bottle gourd.
5. To work out the economics of different treatments under the study.

CHAPTER- II REVIEW OF LITERATURE

This chapter deals with the brief review of the research work done earlier related to integrated disease management of bottle gourd (*Lagenaria siceraria*.) and various parameters affecting its growth and yield.

The bottle gourd (*Lagenaria siceraria* (Molina) standl., F: Cucurbitaceae), is a tropical vegetable of Afro-Asian origin and is cultivated in India throughout the year for its young and tender fruits eaten as popular domestic vegetable called 'Lauki' or 'Dudhi'. The serious diseases like downy mildew, powdery mildew, root rot and fruit rot that attack the crop during various stages of growth and also in post-harvest are among the major limiting factors responsible for low productivity of bottle gourds (Neeraj and Verma, 2010).

The review of literature pertaining to this dissertation is divided into the following headings:

- 2.1 Diseases and Causal Organisms
- 2.2 Symptomatology
- 2.3 Host Range
- 2.4 Etiology
- 2.5 Epidemiology
- 2.6 Effect Of Various Seed Treatments On Seedling Parameters
- 2.7 Varietal Screening
- 2.8 Cultural Practices
- 2.9 Bio-Control and Botanical Control
- 2.10 Chemical Control
- 2.11 Integrated Disease Management
- 2.12 Economics of Management Practices

2.1 Disease and causal organisms

The bottle gourd (*Lagenaria siceraria* (Molina) standl) is affected many more diseases. It occurs practically on all the cultivated cucurbits. The diseases are confined mostly to the leaves, although the fruit of infected. Plants may be of poor quality resulting from the loss of foliage.

The previous history and the literature pertaining to the experiment with respect to the disease severity, its effect on yield and disease management practice etc influencing the overall yield and marketability of bottle gourd is reviewed as under.

Raj *et al.* (2008) reported that Cucurbits are affected by a number of diseases like downy mildew, powdery mildew, gummosis, Phytophthora blight, anthracnose, Cercospora leaf spot, phoma blight, collar rot, Fusarium wilt, white rot, root knot nematode, bacterial wilt, watermelon bud necrosis and leaf distortion virus. These diseases are of national importance and cause important economic losses in cucurbits.

Neeraj and Verma, (2010) and Zhang, *et al.* (2015) The serious diseases like downy mildew, powdery mildew, root rot and fruit rot that attack the crop during various stages of growth and also in post-harvest are among the major limiting factors responsible for low productivity of bottle gourds.

Pawar and Chavan (2010) studied the incidence of powdery mildew on different cucurbits hosts in different seasons and its biocontrol. They reported that in Kharif season *Sphaerotheca fuliginea* was dominantly present on *Cucurbita maxima*, *Lagenaria siceraria* and *Cucurbita pepo*, where as *Erysiphe cichoracearum* noted on *Citrullus lanatus* was not reported in 2005 and 2006. *Cucurbita maxima*, *Lagenaria siceraria*, *Luffa acutangula* and *Luffa cylindrica* showed maximum occurrence of *Sphaerotheca fuliginea* in the rabi season.

Table 2.1 Major diseases of bottle gourd

Name of disease Causal organism	Name of disease Causal organism
I. FUNGAL DISEASES	
1) Anthracnose	<i>Colletotrichum lagenarium</i> (Pass) Ell. and Halst
2) Powdery mildew.	<i>Erysiphe cichoracearum</i> De Candolle
3) Seedling blight	<i>Pythium aphanidermatum</i> (Eds) Fitz .
4) Downy mildew	<i>Pseudoperonospora cubensis</i> (Berk. and Curt.)
5) Fusarium wilt	<i>Fusarium oxysporum</i> f.sp. <i>lagenariae</i> . Matuo and Yamamoto
5) Cercospora leaf spot	. <i>Cercospora lagenariae</i> Rang
7) Necrotic black fruit rot	<i>Alternaria alternata</i> (Fr.) Keissler
8) leaf blight	<i>Alternaria</i>
II. VIRAL DISEASES	
1)Cucumber green mottle mosaic	Cucumber green mottle mosaic virus
2)Cucumber mosaic	Cucumber mosaic virus
3)Watermelon mosaic	Watermelon mosaic virus
4)Pumpkin yellow vein	mosaic Pumpkin yellow vein mosaic virus
III BACTERIAL DISEASES	
1) Angular leaf spot	<i>Pseudomonas syringae</i> pv. <i>lachrymansngae</i>
2) Bacterial wilt	<i>Erwinia tracheiphila</i>

2.1.1 Downey Mildew

Palti and Cohen (1980) reported that the mycelium of *Pseudoperonospora cubensis* is hyaline, coenocytic and intercellular. Sporangiophore (180-400 to 54-72 μ m) is dichotomously branched at the tip. Sporangia single, ovoid to ellipsoid and borne singly. They are grayish to olivaceous purple with a papilla at distal end. Oospores are globose, yellow or hyaline and 23-25 μ m in size.

Gangopadhyay, (1984). The mycelium of *Pseudoperonospora cubensis* is coenocytic and intercellular with small, ovate haustoria. Sporangiophore arises in group of 1-5 through stomata. The upper-third of sporangiophore is either dichotomous or monopodial branched. The sterigmata are sub-acute. Sporangia is grayish olivaceous purple, ovoid to ellipsoidal thin walled and with a apical papilla. They measure 2139 x 14-23 micron in size. Zoospores are biflagellate and 12-13 microns in diameter

Mondal *et al.* (2014) reported that the downy mildew in pointed gourd appears in December and continues up to the end of March. It causes drying up of leaves in growth stage of the crop.

Wallace *et al.* (2014) observed cucurbit downy mildew (CDM), caused by the oomycete *Pseudoperonospora cubensis*, on bitter melon and balsam apple between August and October 2013 in six North Carolina sentinel plots belonging to the CDM IPM PIPE program. Leaves with symptoms typical of CDM were collected from the *Momordica* spp. and symptoms varied from irregular chlorotic lesions to circular lesions with chlorotic halos on the adaxial leaf surface.

Colucci and Holmes (2010) reported that *Pseudoperonospora cubensis* (Berkeley & Curtis) Rostovtsev is the causal agent of downy mildew of plants in the Cucurbitaceae (gourd family), including cucumbers, melons, squashes, gourds and watermelons. Berkeley and Curtis first reported the disease in Cuba in 1868. Downy mildew of cucurbits can be found in temperate areas, such as the Americas, Europe, Japan, Australia and South Africa, tropical regions and some semi-arid regions, such as the Middle East. The disease affects cucurbit crops in the field and those grown in passive or traditional greenhouses. Downy mildew is especially damaging in warm, humid climates where the pathogen thrives.

2.1.2 Powdery Mildew

Two different fungi commonly cause powdery mildew on cultivated cucurbits i.e., *Sphaerotheca fuliginea* (Schlecht) Pollaci and *Erysiphe cichoracearum* DC (Sitterly, 1978). *Sphaerotheca fuliginea* is predominant in many countries like China, Japan and Russia (Vakalounakis *et al.*, 1994, Mc Grath, 1996; Mohamed *et al.*, 1995). *Erysiphe cichoracearum* seem to be common in temperate zones (Nagy, 1976; Lebeda, 1983; Corbaz, 1992). In France, both the species were recorded (Bertrand, 1991).

In India, Butler (1918) reported the occurrence of both the organisms in cucurbits. On the basis of conidial characters, Jhooty (1967) claimed that *S. fuliginea* was responsible for the disease in Punjab. In CMI descriptions, Kapoor (1967) described that *S. fuliginea* exclusively attacks cucurbits in Aligarh and Uttar Pradesh. Siradhana and Chaudari (1972) stated the occurrence of both the species on cucurbits at Udaipur, Rajasthan.

In India, several states like Bihar, Madhya Pradesh (Dave *et al.*, 1971; Khosla *et al.*, 1974), Uttar Pradesh and Andhra Pradesh (Sharma, 1978) reported similar dominance of *S. fuliginea*.

In India, bottle guard and as instant was identified as *Sphaerotheca fuliginea* (Gupta and Singhvi, 1979). Patel *et. al.*, (1990) reported appearance of powdery mildews on bottle gourd during rabbi season on *Lagenaria siceraria*, due to *Sphaerotheca fuliginea*.

Powdery mildews fungi were identified by using the standard literature of Hirata (1942), Boesewinkel (1980), Zheng (1985), Braun (1987), Eriksson and Hawksworth (1987), Bappamal *et al.* (1995) and Hosagoudar (1997).

2.1.3 Leaf Blight

Alternaria leaf blight caused by *Alternaria cucumerina* (E. & E.) Elliot is found to cause serious losses throughout Rajasthan and other states.

Alternaria cucurbitae Let. and Roum. has been cited as the cause or a disease of cucurbits by Boughey (1) and Schwarze (13). Elliot (2) in his study of the genus, did not include *A. cucurbitae* because he was unable to obtain sufficient material. Peglion (9) believed *A. cucurbitae* to be distinct from the pathogen he described as the great difference in spore-body diameter, although *A. cucurbitae*

may be regarded as a valid species, it's not the causal agent of the leafspot disease of cucurbits most frequently reported throughout the world.

In 1893, Peglion (9) described *Alternaria brassiae* f.sp. *nigrescens* Pegl. As the cause of a disease of muskmelons in Italy. He gave conidial size as 60-80 x 14-18 μ and incorrectly described conidial shape as clavate. In a second report Peglion (10) revised the dimensions to 100-160 x 14-20 μ , reaching 200 μ in length when the filiform tip.

The crop is attacted by a number of diseases, amongst which leaf spot and blight incited by *Alternaria cucumerina* is found to cause serious losses throughout the state. In India the disease was first reported by Khandelwal and Prasad (1970).

2.1.4 Leaf Curl and Mosaic

Ashwini *et al.* (2016) reported the three different viruses causing mosaic in bitter melon are *Cucumber mosaic virus* (CMV) and *Bottle gourd distortion mosaic virus* (BDMV). As these viruses cause mixed infection in field, the separation of individual viruses was carried out using systemic indicator host plants. Systemic indicator host plants were used for separation of CMV, whereas white fly transmission was adopted for separation of BDMV.

. There are two major strains of ZYMV (ZYMV-FL and ZYMV-CT) and symptoms of ZYMV-CT are more severe. Its natural infection on bottle melon was detected in India (Verma *et al.*, 2004), Hawaii (Ullman *et al.*, 1991) and Serbia (Dukic *et al.*, 2006).

ZYMV is the type species of the genus Potyvirus in the family Potyviridae, was first reported from Italy in 1973 (Lisa *et al.* 1981) which causes devastating epidemics in commercial cucurbits worldwide and several biologically distinct strains have been described (Lisa and Lecoq 1984, Greber *et al.* 1988, Wang *et al.* 1992).

Brunt *et al.* (1996). Reported natural occurrence of Watermelon mosaic virus 1 (WMV-1) on Cucurbitaceous hosts was first reported in *Citrullus lanatus*. WMV-1 is also known as papaya ringspot virus type W (PRSV-W) and watermelon papaya ringspot. Virions are filamentous, but not enveloped and are usually flexuous with a clear modal length of 760-800 nm and 12 nm wide. WMV-

It has worldwide distribution and known to be prevalent in the Middle East, South and Central American region, Australia, China, France, Germany, India, Italy, Mexico, and USA. It produces mosaic, green blistering, leaves and fruit malformation in *Cucumis sativus*, *Cucurbita pepo*, *Citrullus lanatus*, *Cucumis melo*, *Melothria pendula* and *Momordica charantia* hosts. WMV-1 is known to be transmitted by insect vectors in a non-persistent manner such as *Myzus persicae*, *Acyrtosiphon* (Aulacorthum) *solani*, *Aphis craccivora* and *Macrosiphum euphorbiae*. The virus is transmissible through mechanical inoculation but there are no reports of transmission by seed. The virus has a thermal inactivation point (TIP), longevity in vitro (LIV) and dilution end point of 60°C, 40-60 days, and 10⁻⁴ to 10⁻⁵, respectively. It produces inclusions in infected cells in the form of amorphous Xbodies and pinwheels which do not contain virions. Only a few families of plants are infected by WMV-1 and cucumber isolate could not infect papaya (*Carica papaya*) under natural conditions. Natural infection of WMV-1(=PRSV-W) is reported from Cucurbitaceae and Leguminosae hosts.

Raj *et al.* (2010) observed a severe yellow mosaic disease with a significant disease incidence on bottle gourd (*Lagenaria siceraria*.) during a survey of different locations around Gorakhpur, Uttar Pradesh, India in 2008. They confirmed the association of *Pepper leaf curl Bangladesh virus* strain with bottle gourd yellow mosaic disease.

Khan *et al.* (2002) reported leaf curl symptoms on bitter melon (*Momordica charantia*) consisted of upward curling, shortening, and distortion of leaves. Diseased melon fruits were stunted and deformed.

CMV was first reported by Jagger (1916) and Dolittle (1916) as the causal agent of plant diseases. Bhargava (1951) first reported CMV as causal agent of mosaic in summer squash. Infection of 25 per cent samples of summer squash by CMV was reported by Bansal and Singh (1990).

2.2 Symptomatology

A symptom of plant disease is a visible effect of disease on the plant. Symptoms may include a detectable change in color, shape or function of the plant as it responds to the pathogen. Leaf wilting, mosaic, leaf curling, stunting, spot,

leaf blight, mildew and mottle etc. You are not actually seeing the disease pathogen, but rather a symptom that is being caused by the pathogen.

Zhang *et al.* (2015) observed downy mildew, powdery mildew and fusarium wilt diseases on bitter melon. The symptoms of downy mildew first appear as small, water-soaked, yellow, angular lesions on the upper surface of the leaves that are restricted by the leaf veins. In later stages of infection, infected tissues become bright yellow and the center of the lesions turns brown. Under high humidity, whitish to gray powdery growth may appear on the lower leaf surface. The disease spreads rapidly, resulting in defoliation and death if not controlled. The typical symptoms of powdery mildew appear as white powdery residue primarily on the upper leaf surface. On the lower leaf surface, symptoms occur as circular patches or spots. Powdery mildew symptoms on foliage at early stages are very similar to downy mildew, which often makes it difficult to identify the disease accurately. It is always wise to seek a laboratory diagnosis in order to identify the pathogen correctly. In severe cases, these spots spread, coalesce, and cover both surfaces of the leaves, then spread to other parts of the plant. Severely affected foliage becomes brown and shriveled, and defoliation may occur. Fruits of the affected plants do not develop fully and remain small. Initially, runners show symptoms of temporary wilting that become permanent over time. The problem often develops progressively and affects more vines. The leaves of the infected plants become yellow and wilt. Eventually, the plant dies. In older plants, leaves wilt suddenly, and when stems are cut, vascular tissues in the xylem appear yellow or brown.

2.2.1 Downey mildew

Downy mildew (*Pseudoperenospora cubensis*) is an extremely destructive disease of cucurbits. It occurs practically on all the cultivated cucurbits. The disease is confined mostly to the leaves, although the fruit of infected plants may be of poor quality resulting from the loss of foliage.

The first symptoms of *P.cubensis* infection in Cucurbitaceae are pale-yellow, oily lesions on the upper side of the leaf, sometimes restricted by leaf veins which are described as angular leaf spots (Lebeda 1986)

Thomas (1996) reported downy mildew of cucurbits is a foliar disease, and is easily recognizable by the development of chlorotic lesions on the adaxial leaf surface, sometimes with necrotic centers. These lesions can be restricted by the leaf vein, as in cucumber, giving them an angular appearance. In other cucurbits, the symptoms may vary slightly in terms of shape and colour. For example, in both melon and watermelon, foliar lesions are less defined than those on cucumber, and are not always bound by leaf veins. As infection progresses, the chlorotic lesions expand and may become necrotic (Oerke *et al.*, 2006), with necrosis occurring more quickly in hot, dry weather (Cohen and Rotem, 1971c). Leaves colonized by *P. cubensis* undergo changes in temperature and transpiration rates, which vary during the course of infection and over the leaf surface (Lindenthal *et al.*, 2005; Oerke *et al.*, 2006)

Lebeda and Schwinn (1994) *P. cubensis* causes irregular, localized, yellow lesions restricted by leaf veins whereas in cantaloupe and watermelon, lesions are not restricted by leaf veins and are more circular and irregular. Unlike some other members of the Peronosporaceae

Rai and Yadav (2005) Symptoms appear on upper surface of the leaves as angular yellow spots. During favorable condition, the undersides of these spots are covered with a grayish mouldy growth. The yellow spots on the upper portion of leaves, it appear just like in definite mosaic pattern lesion on the upper surface, As the spots enlarge, a general yellowing of the leaves occurs followed by the death of the tissue. The leaves subsequently wither and die

2.2.2 Powdery mildew

Vakalounakis *et al.* (1994) reported that both *Erysiphe sp.* and *Sphaerotheca fuliginea* were characterized by circular, talc-like powdery spots on the foliage. These spots expand until the entire surface is covered. Under severe conditions, stems, petioles and tendrils were affected.

Walker (1952) described the symptoms of the disease as tiny, white, round, Superficial spots on stems and leaves of cucumber, squash, cantaloupe, becoming Powdery as they enlarge. These white lesions increase in number and coalesce and eventually may cover the stems and both surfaces of leaves. Infection on young leaves may result in general chlorosis and eventually death of the leaves.

Severely affected leaves become brown and shriveled. Under ideal conditions premature defoliation may occur as the fungus covers the leaf surfaces. Black pin point bodies the cleistothecia rarely occur but are conspicuous when they do occur. Fruits of cucumber, bottle gourd, cantaloupe and squash are free of visible infection, even when the foliage is heavily infested though fruits may ripen prematurely and lack flavor.

Sharma (1984). Powdery mildew fungi produce a conspicuous white to grayish growth of mycelium on the surface of diseased plant parts. Conidia or spores of the fungi are produced on the mycelium

Masood *et al.* (2013) reported that powdery mildew is a serious disease of cucurbits, including melon, bottle gourd, pumpkin, squashes and cucumber. Powdery mildew is first seen as white powdery spots on both sides of the leaves, shoots, and sometimes the flowers and fruit. Small spots then join together to form larger patches of white mildew. Infected leaves yellow, die, and fall off. This exposes the fruits to the sun, which can result in sunburn. Older leaves are affected first. Severe attack reduces yield, and fruit quality is low.

2.2.3 Leaf blight

Leaf spots first appear on the older leaves in the middle and upper part of the plant. The spots start as small, necrotic flecks. They enlarge and contain concentric rings and are surrounded by a yellow halo. Other parts of the plant are not directly affected. An indirect effect is seen the fruit production. *Alternaria* leaf spot may cause reduced yield and smaller fruit.

Maheshwari *et al.* (2017) Characteristic symptoms first appear as small, circular and light to reddish brown spots, which later enlarge in a concentric manner. Lesions often coalesce to form larger necrotic areas and in the centre of the spot, olivaceous sporulation occurs. So far, information available on disease management of *Alternaria* leaf blight of bottle gourd under hot arid condition is scanty. Keeping in view, the present study was undertaken to aware the management of *Alternaria* leaf blight of bottle gourd in Western Rajasthan.

Gannibal (2011) The observed leaf spots were up to 8-12 mm in diameter with a round grayish to pale brown centre and dark brown edges. Up to 30% of the surface area of older leaves was affected by the disease. Fungal isolates with

morphological characteristics similar to those of *A. cucumerina* were collected from diseased leaves.

2.2.4 Mosaic and leaf curl

.Chalam *et al.* (2003) reported the occurrence of Zucchini yellow mosaic disease on summer squash from Uttar Pradesh, India. Summer squash plants showed symptoms of mosaic, vein clearing, leaf distortion and reduction in fruit size.

Sohrab *et al.* (2010). It is a first *Begomovirus* and causes severe disease in bottle gourd in India. The affected plants are severely stunted and bear very small chlorotic and mildly curled leaves. It is transmitted by white fly and to manage the virus, vector control is essential.

Kim *et al.* (2010). A putative Potex virus was detected from bottle gourd in Burma showing mosaic and mottle symptoms in Myanmar in 2007.

Ali *et al.* (2010) reported *Tomato leaf curl Palampur virus* on Bottle gourd in Pakistan and observed that Symptoms of the disease included chlorosis, leaf crumpling, vein thickening, and stunting of plants that were suggestive of a virus infection.

Ashwini *et al.* (2016) reported that the initial symptoms of bitter gourd mosaic developed on newly emerged leaves after 21 days of inoculation. Mosaic accompanied with yellowing was the initial symptom this was followed by vein clearing and mild curling. Leaf distortion and shoestring appearance were the prominent symptoms observed in later stages of infection. Necrosis of the infected leaves was also observed in severely infected plants. Leaf size of the infected plants was drastically reduced as compared to the healthy plants. Similar symptoms were reported *sulphureus*, on mechanical inoculation of CMV.

Tiwari *et al.* (2010) the most characteristic symptoms in the early stage of the disease were yellow mosaic followed by curling of leaves. However, in case of severity of the disease, extensive chlorosis and vein banding was also noticed.

2.3 Host range

The capacity of pathogens to infect a large set of host species, i.e. to possess a large host range of the species. Host range of plant parasites has been used for decades as observed for the entire dataset,

2.3.1 Downy mildew

Colucci and Holmes (2010) reported that forty species in 20 genera within the Cucurbitaceae are known to be hosts to *P. cubensis*. Downy mildew on *Cucumis* spp., including cucumber and true melons, alone has been reported in 70 countries. While it has the widest distribution on all continents on the genus *Cucumis*, downy mildew is common on *Cucurbita* crops, including squashes and pumpkins, in Australia, North America and the Pacific region and occurs less commonly in Asia and Africa. Downy mildew is virtually absent from *Cucurbita* in Europe. Downy mildew is widely distributed on *Citrullus* spp., including watermelon, in the Americas but scattered elsewhere and absent in Europe and the Middle East, even though the climate is similar to areas where the disease is a severe problem. The disease is found on *Luffa* only in Southeast Asia

Salati *et al.* (2010) conducted an experiment to evaluate the host range of cucurbit downy mildew in Malaysia. A total of 29 isolates of *Pseudoperonospora cubensis* were collected from various cucurbit farms in West Malaysia. Sporangia of 13 isolates had the ability to germinate at 14 °C and were used for host range (pathotype) study using leaf disc assay on a set of twelve cucurbit cultivars. Twelve different pathotypes of *P. cubensis* were determined and this demonstrated that *P. cubensis* isolates from cucurbit farms in West Malaysia are highly variable. Based on the host range study, majority of *P. cubensis* isolates were categorized into medium and high pathogenicity groupings and this fact shows the potential of this pathogen in invading cucurbit fields in the tropical regions. However, the pathotypes could not be differentiated based on morphological characterization of the sporangia and sporangiophores. Therefore, molecular characterization of the 13 isolates of *P. cubensis* will be useful to study the relationships among them.

Pseudoperonospora cubensis has a broad host range, infecting over 49 species in 20 genera within the Cucurbitaceae, including 19 species in the genus *Cucumis* (Lebeda and Widrlechner, 2003; Palti and Cohen, 1980). Cucumber (*Cucumis sativus* L.), melon (*Cucumis melo* L.), watermelon (*Citrullus lanatus* Matsum. And Nakai) and squash (*Cucurbita* spp.) are the four major food crops that are hosts to *Ps. cubensis*. Other cucurbits infected by *P. cubensis* include loofa [*Luffa acutangula* (L.) Roxb.], bottle gourd [*Lagenaria siceraria* (Molina) Stand.],

wax gourd [*Benincasa hispida* (Thunb.) Cogn.] and bitter melon (*Momordica charantia* L.) (Palti and Cohen, 1980).

2.3.2 Powdery mildew

Patel *et al.* (2010) *Sphaerotheca fuliginea* was dominantly present on *Cucurbita maxima*, *Lagenaria siceraria* and *Cucurbita pepo*, where as *Erysiphe cichoracearum* noted on *Citrullus lanatus* was not reported in 2005 and 2006. *Cucurbita maxima*, *Lagenaria siceraria*, *Luffa acutangula* and *Luffa cylindrica* showed maximum occurrence of *Sphaerotheca fuliginea* in the rabbi season. Incidence of powdery mildew was mainly reported on the mature leaves followed by stem. Where as in some cases it was reported on tendril, flower and fruit.

McCreight (2011) The two powdery mildew fungi most frequently reported to cause disease on field and greenhouse cucurbit crops are *Podosphaera xanthii* and *Golovinomyces cichoracearum* Both pathogens belong to the family Erysiphaceae consisting of 16 genera and approximately 650 species (Braun *et al.*, 2002).

2.3.3 Leaf blight

Alternaria cucumerina is an important pathogen of some *Cucumis*, *Cucurbita*, *Lagenaria siceraria* and *Citrullus* species with a wide distribution, including several European and Asian countries (Ellis, 1971)

The fungus has been found in the Far East of Russia on *Cucumis melo*, *Cucumis sativus*, and *Citrullus lanatus* (Egorova, 1999)

2.3.4 Mosaic and leaf curl

ZYMV, a member of the genus *Potyvirus* in the family Potyviridae, is one of the major viruses of cucurbits. Cultivars of *Cucurbita pepo* L., *Cucumis melo* L., and *Citrullus lanatus* (Thunb.) Matsum. & Nakai are particularly affected. However, other cucurbits, including bottle gourd, *Lagenaria siceraria* (Mol.) Standl., are also infected easily by ZYMV.

Bhargava and Bhargava (1977) in a survey of viruses attacking cucurbits in Gorakhpur area of Uttar Pradesh noted that pumpkin yellow-vein mosaic virus, pumpkin mosaic virus, *cucumis virus 3* (cucumber green mottle mosaic virus) , 3

strains of *cucumber mosaic virus* and 7 of *watermelon mosaic 18 virus* affecting 7 cultivated and 2 wild cucurbits were widely spread.

2.4 ETIOLOGY

The investigation or attribution of the cause or reason for something, often expressed in terms of historical or mythical explanation.

2.4.1 Downey mildew

Wallace *et al.* (2014) reported sporulation of *Pseudoperonospora cubensis* on the abaxial side of the leaves was observed and a compound microscope revealed sporangiophores (180 to 200 μm height) bearing lemon-shaped, dark sporangia (20 to 35 $\times$ 10 to 20 μm diameter) with papilla on one end.

Neufeld (2012) *Pseudoperonospora cubensis* is a biotrophic foliar pathogen that infects many species of the family Cucurbitaceae. The disease was first described by Berkeley and Curtis in herbarium plant material from Cuba in 1868. members of *Peronospora* have sporangia that germinate directly via a germ tube where as within *Pseudoperonospora*, sporangia germinate indirectly via cytoplasmic cleavage to produce zoospores (Palti and Cohen, 1980). Sporangia of *P. cubensis* typically are grey to purple in color, lemon-shaped with a papilla at the distal end and measure about 20 to 40 $\times$ 14 to 25 μm in diameter (Lebeda and Cohen, 2011).

Colucci and Holmes (2010) *Pseudoperonospora cubensis* is a fungal-like organism that belongs in the Kingdom Straminipila and Phylum Oomycota. *Pseudoperonospora cubensis* is a member of Peronosporaceae (the downy mildew family) in the order Peronosporales within the class Oomycetes. Like other downy mildew organisms, *P. cubensis*, is a biotroph or obligate parasite, meaning that the organism requires living host tissue to grow and reproduce. The organism cannot be propagated on artificial media. The intercellular mycelium is hyaline (colourless, transparent) and coenocytic (aseptate). The mycelium develops in the mesophyll, but also penetrates the palisade tissue. The hyphal diameter is 5.4-7.2 μm . Haustoria are formed within the host cells and allow for the absorption of nutrients. Haustoria are varied in shape and appear stunted, inflated or as branched clusters of hyphae. *Pseudoperonospora cubensis* forms large (20-40 $\times$ 14-25 μm in diameter), lemon-shaped sporangia with a conspicuous papilla. Sporangia appear

smooth under the compound microscope, but with the scanning electron microscope the finely decorated surface of the sporangium is evident. The sporangia are borne singly on the pointed tips of sporangiophores that branch at acute angles. The sporangiophore ranges from 180-600 μm in height, 20 μm in diameter and 5-7 μm in width. Moisture prompts the sporangia to release 5 to 15 asexual, ovoid zoospores that measure 10-13 μm in diameter. The zoospores are biflagellate, with one posterior whiplash and one anterior tinsel flagellum. The purpose of the flagella is to assist the zoospores as they swim through free moisture on the leaf surface to a stomate. Once a stomate is located, the zoospore will encyst (produce a cell wall) and then form a germ tube (50-95 μm), which will penetrate the stomate and infect the host plant cell. Sexual reproduction and formation of oospores in *P. cubensis* are rare. Oospores have only been reported from India, China, Italy, Japan and Russia and their germination was not observed. Oospores could function as survival structures when living hosts are not present, but this has not been demonstrated.

3.4.2 Powdery mildew

Liu and Kirschner (2015) observed the mycelium of *Podosphaera xanthii* was amphigenous on the leaves, with hyphae thin walled, smooth or almost so, and 5 to 8 μm wide. The appressoria were indistinct to slightly nipple shaped, and solitary. The conidiophores arose mostly from one end of the mother cell but sometimes centrally, and were erect, straight, smooth to slightly rough, 48 to 200 $\times$ 7 to 17 μm , composed of a cylindrical, rarely somewhat flexuous footcell, slightly rough, 30 to 70 $\times$ 9 to 12 μm , and following 1 to 4 shorter cells. The conidia were catenate, ellipsoid, ovoid, doliform to subcylindrical, 24 to 33 $\times$ 3 to 19 μm , and contained fibrosin bodies when fresh. These characteristics fit those of *Podosphaera xanthii*.

Singh (2009) reported that the young cleistothecia are globose and at first white, then brown and finally black when mature. The mature cleistothecia also have several mycelioid appendages, which are flaccid, indefinite hyphae arising from cells of the cleistothecium. The cleistothecia are more or less buried in the mycelia wefts on the plant tissues. The ascospores continue to develop during the falls and in spring they are mature and ready for dissemination. In spring, the

cleistothecia absorb water and crack open. The single ascus in each cleistothecium protrudes its tip, bursts open and discharges its mature ascospore, which are carried away by the wind. The ascospores are about the size of conidia and behave exactly like conidia with respect to germination, infection, and formation of subsequent structure. Single conidia, called hyaline, are borne singly and measuring 20.25-27.9 (24.1) $\times$ 13.5-18.0 (14.25) μm . Cleistothecia are dark, spherical appendage myceloid, measuring 90-180 μm in diameter; cleistothecia contain a single ascus measuring 50.75-74.50 (61.80) $\times$ 49.50 –67.50 (57.44) μm , single ascospore, called hyaline, spherical, 6-10 per ascus and measuring 11.12-20.25 (14.62) $\times$ 9.0 –15.75 (11.25) μm .

Bosco (2006) observed both, asexual stage (conidia) and sexual stage (Cleistothecia) were present on the infected muskmelon plants. The conidia together with cleistothecia were present during the period from November to March, where as only cleistothecia were detected in October and April. Morphologically, the fruiting structures i.e. cleistothecia were sub globosely light brown to dark black in color, oval, round to semi round and sometime sub cylindrical in shape with myceloid appendages. On the other hand, the newly infected leaves were found bearing conidia and conidiophores. The conidia were in chain on conidiophores and sometimes were seen detached into separate conidia. Conidiophores measured 107.98 μm long and 12.97 μm thick bearing conidia which measured on average 29.9 μm long and 15.06 μm thick. The average mature cleistothecia were calculated to measure 117.47 $\times$ 95.07 μm .

Gupta *et al.* (2001) observed the anamorphic and teliomorphic characters of *Sphaerotheca fuliginea* (Schlecht.) Pollaci., causing powdery mildew of cucumber. The anamorphic characters revealed that the mycelium was ectophytic, conidiospores were unbranched and aseptate with a cylindrical foot cell. Conidia were ellipsoidal in shape and arranged in long chains in basipetal succession. The size of the conidia was about 34.43 $\times$ 20.77 μm when observed under high power (450 x). Length/ Breadth (L/B) index value was less than 2 (mostly 1.6). About 90.24 per cent conidia exhibited the presence of fibrosin bodies and an average number of fibrosin bodies per conidium were 6.4. Germination of conidia was observed to be 44.90 per cent. Observations on germtube morphology revealed that

germinating conidia produced two types of germtubes i.e. simple and forked, which emerged laterally from the sidewall of the conidium. Conidia bearing simple or forked germ tubes were 34.15 and 65.85 per cent, respectively. Appressorial formation was found to be absent in all the samples examined. Teliomorphic characters revealed that the cleistothecia were scattered to densely gregarious, globular, brown, $62.01-79.08 \times 52.72-76.76 \mu\text{m}$ size. Appendages variable in number, usually as long as the diameter of the ascocarp, sometimes longer, myceloid, brown, attached at the base of the cleistothecium. Ascus single, elliptical, subglobose, $54-80 \times 4565 \mu\text{m}$, containing 8 ascospores, ellipsoid to nearly spherical, $17-23 \times 12-20 \mu\text{m}$ in size.

Tores *et al.* (1990) reported that the two fungal species *Sphaerotheca fuliginea* (Schlecht. ex Fr.) Poll and *Erysiphe cichoracearum* DC ex Merat. have been referred to as the causal agents of powdery mildew. However, recent work showed that in the last years only *S. fuliginea* has been detected.

2.4.3 Leaf blight

After seven days, large solitary conidia were formed on the surface of the agar. The average size of the conidia was $70-94 \times 22-25 \mu\text{m}$ with a conidial beak length of $40-45 \mu\text{m}$. In general, these measurements are within the size range determined by Immons (2007) for *A. cucumerina*. On potato-carrot agar, the conidial body was smaller ($43-70 \times 16-20 \mu\text{m}$), whereas the beak was appreciably longer ($70-220[-284] \mu\text{m}$).

2.4.4. Mosaic and leaf curl

Astier *et al.* (2007) particles of *Cucumber mosaic virus* (CMV) is of 25 nm with isometric symmetry. The capsid is made up of 180 subunits. Nucleic acid is positive sense single stranded RNA, which is tripartite in nature. Three species of *Cucumber mosaic virus* (CMV) are described. Mechanical transmission is possible. It can be transmitted by aphids (more than 75 species) in the non persistent mode, as well as through the seed in some species.

ZYMV is a member of the potyvirus genus (Hollings and Brunt; Murphy *et al.*, 1995). The flexuous filamentous particles, 750 nm long (Lisa *et al.*, 1981) consist of a single-stranded RNA about 9600 nucleotides long (Balint *et al.*, 1990) with a 5' viral protein genome linked (VPg) and 3' poly (A) tail encapsidated in a

36kDa coat protein. The RNA is translated as a single polypeptide cleaved by three viral proteases (Riechmann *et al.*, 1992, Shukla *et al.*, 1994).

2.5 Epidemiology

Epidemiology is the study and analysis of the distribution (who, when, and where) and determinants of health and disease conditions in defined populations.

2.5.1 Downy Mildew

Grabowski (2016) reported that downy mildew can start an infection in a wide range of temperatures (41-86°F) but is most severe from 59-68°F. The pathogen needs moisture on the leaf surface in order to germinate and start a new infection. Under humid conditions downy mildew rapidly reproduces and spreads, resulting in severe crop damage. The pathogen can move on air currents, splashing water and on the tools and hands of workers.

Neufeld (2012) sporangia are easily dislodged from sporangiophores and dispersed by rain or air. Following germination of sporangia, the development of zoospores is dependent upon environmental conditions, especially temperature and moisture. Once sporangia are dislodged from the tips of sporangiophores, their lifespan is not usually longer than 48 h. Dispersal of sporangia onto susceptible host tissue is required during this time period for germination to occur. At higher temperatures (35°C and 40°C) and humidity combinations (84 to 90%), infectivity of sporangia decreases. However, in presence of low humidity (5 to 28%), infectivity of sporangia is maintained even at higher temperatures. Contact with moisture is required for the germination and release of zoospores from sporangia. Germination of sporangia will be disrupted when they are exposed to a dry period for 10 to 15 min.

Shishid (2011) reported that temperature ranges from 20-25 °C and high relative humidity favour downy mildew (*Pseudoperonospora cubensis*) severity in cucumber and melon. However low relative humidity and 25°C temperature favour incidence and severity of powdery mildew (*Sphaerotheca fuliginea*) in cucumber and melon

Celetti and Roddy (2010) reported that downy mildew of cucurbits is favoured by cool, wet and humid conditions. The pathogen produces microscopic sac-like structures called sporangia over a wide range of temperatures (5°C - 30°C).

Optimum sporangia production occurs between 15°C - 20°C and requires at least 6 hours of high humidity. Sporangia are easily transferred to healthy plant tissue by air currents or splashing rain. High relative humidity sporangia burst open and release many zoospores. The disease may progress slowly or stop temporarily when temperatures rise above 30°C during the day time. Night time temperatures of 12°C - 23°C will promote disease development, especially when accompanied with heavy dews, fog or precipitation. With night time temperatures around 15°C and daytime temperatures around 25°C, downy mildew infections on cucurbits produce more sporangia within 4 days.

3.5.2 Powdery Mildew

Lopez *et al.* (2012) reported that in general, high moisture and temperature must be favourable and act together in the initiation, development of plant diseases, as well as germination and proliferation of fungal spores of the vast majority of pathogens. Moreover, powdery mildew conidia are anomalous in their ability to germinate in low moisture. Some do so even at 0 % relative humidity (RH) that is conidias of *Erysiphe cichoracearum* germinate from 7 to 32°C with a RH of 60 to 80%. Spores of *Erysiphe necator* germinate at temperatures from 6 to 23°C with a RH from 33 to 90 %.

Bosco (2006) reported that although powdery mildew infection can occur at temperatures of 59 to 90°F, temperatures of 68 to 77°F are optimal for infection and disease development. Temperatures above 95°F inhibit germination of conidia and temperatures above 104°F kill them, while high relative humidity is conducive to production of conidia. Atmospheric moisture in the range of 40% to 100% relative humidity is sufficient for germination of conidia and infection, but free moisture, especially rainfall, is detrimental to the survival of conidia.

Gupta *et al.* (2001) recorded severity of powdery mildew on cucumber plants at weekly intervals during 1997 crop season starting from the last week of June. Simultaneously, meteorological data on temperature, relative humidity, cumulative rainfall and sunshine hours were also recorded for the intervening period between two consecutive disease data recordings and simple, partial and multiple correlations among disease severity and above four independent factors were worked out. The perusal of simple correlations revealed highly significant

and positive correlation between powdery mildew severity, mean relative humidity and cumulative rainfall. However, correlation coefficient between mean temperature and disease severity was found to be significant and negative while it was positive but non-significant with sunshine hours. Partial correlation between disease severity and sunshine hours was highly significant and negative (-0.7041). Similarly, mean relative humidity showed significant and positive partial correlation with disease severity (0.6392), while that of mean temperature and cumulative rainfall with disease severity were found to be positive but non-significant.

2.5.3 Leaf blight

Mikhailova *et al.*, (2002) then incubated at 24°C under a light/dark cycle (12/12h). Cucurbit plants in leaf stage were sprayed with conidia of *alternaria cucurnima* incubation at 16-28°C in 100% relative humidity with wetted leaves for 24 hrs. was required for infection temperature above 12 °C during night hrs. along with wetted leaves were necessary for disease development (standberg, 1988)

2.5.4 Mosaic and leaf curl

Alonso-Prados *et al.* (2003) reported that maximum temperature particularly, with the average of the mean temperature was positively correlated with epidemics of both the viruses viz. *Cucumber mosaic virus* (CMV) and *Watermelon mosaic virus -2* (WMV-2). However, there was negative correlation between epidemics of CMV and precipitation (rainfall) during spring season. In winter and spring WMV-2 was negatively correlated with minimum temperatures. The fact that spring temperatures were positively correlated with epidemics of both viruses could be explained by the build up of aphid populations vectoring both viruses.

Tripathi and Varma (2002) observed a high degree of leaf curl disease (LCD) incidence (83%) in the winter tomato planted in October as compared to the summer crop planted in February where only 14% incidence of LCD was recorded. During the summer crop whitefly population was less at the initial stages of the crop, whereas during the winter crop the whitefly population was very high at the similar stages of the crop. This variation in the whitefly population was due to the differences in temperature and relative humidity

Purcifull *et al.* (1984) observed that ZYMV had flexuous filamentous particle. It was found to be transmitted both by sap as well as by the aphid *Aphis citricola* in a non-persistent manner. The biophysical properties of the virus included thermal inactivation point (TIP) of 55-60°C, longevity in vitro was between 3 days and 5 days at room temperature and dilution end point (DEP) was 1:10000 -1:100000..

2.6 Effect of various seed treatments on seedling parameters

Sharma *et al.* (2015) reported that seed treatment of crop seeds with fungicides found to speed up germination process, increased germination rate and seedling vigour, improved resistance to water and salinity stress and increased crop yields.

Tsai *et al.* (1992) reported that the most effective fungicides for treating seedlings before inoculation were metalaxyl + mancozeb and chlorothalonil

Dhanamanjuri *et al.* (2013) carried out in relation to treatment of the seeds *Cicer arietinum* and *Zea mays* with various concentrations of fungicides. Effect of fungicides on the seed germination, growth and biomass production of *Cicer arietinum* and *Zea mays* were observed *in vitro*. The fungicides (*i.e.* Captan, Bavistin, Domarck, Blitox and Sitara) solution for growing the seeds with the following concentrations were used; 1 ppm, 10 ppm, 50ppm and 100 ppm were taken to observe their growth promoting/ inhibiting effects on the Maize and gram seeds on their germination and growth (radicle and plumule). The data obtained indicates that germination percentage of seeds and biomass production were slightly affected with the differences in the two crops under investigation. The fungicide Bavistin (Carbendazim) at 10 ppm concentration was the best among the treatments of *Cicer arietinum* while in case of *Zea mays*, 1ppm concentration of Bavistin (Carbendazim) has shown better stimulating effect on the seed germination and plant growth (radicle and plumule) as compared to Control. Significant differences in the growth values of seeds between treated and control plants were observed.

Kumar *et al.* (2018) seed treatment with seed pro @ 25g/kg, carbendazim 12%+ mancozeb 63% @ 3g/kg, which found significantaly plant growth flowering fruiting yield of bitter gourd

2.7 Varietal screening

Ling (2007) the 190 *L. siceraria* PIs screened, 36 accessions were in complete resistance (no disease symptom with negative ELISA on all tested plants), 64 PIs showed partial resistance (some of the tested plants were resistant, whereas others were susceptible), and 90 PIs were susceptible (severe symptom and positive ELISA on all tested plants). The ZYMVFL resistance exists mostly among *L. siceraria* PIs collected in India. Thirty-three of the 36 *L. siceraria* PIs showing ZYMV-FL resistance were collected in India, one in Indonesia, one in South Africa, and one in Zimbabwe. To rule out any potential escapes in the primary screening, a repeated test using representative accessions, including 10 susceptible, three partially resistant, and three completely resistant PIs, was done to confirm the ZYMV-FL resistance. Furthermore, the resistance to ZYMV-FL was shown to be heritable in progenies generated through self-pollination of single plants in each of five resistant PIs as well as in three F1 hybrids.

The cultivar BL240 had the lowest disease index for *P. cubensis* incidence reported (Thakur *et al.*, 1996). Hybrid BTH-7, BTH-165 and Phule Green, RHR BGH 1 are tolerant to downy mildew (Rai and Yadav, 2005).

Akbar *et al.* (2015) screened seventeen cucumber germplasm against *Cucumber mosaic virus*. Seeds of these germplasms were sown in earthen pots in which fourteen germinated and exhibited characteristics symptoms of the virus. Out of fourteen germinated germplasms nine (Punjab, Beitalpha, pointpett-76, Baran, Local green, Summer green, Diomond 2F l, Sahill and Kumar) showed moderately susceptible reaction remaining (Khyber, Yousaf, VEGAF1, Diamond and Waleed) showed highly susceptible reaction.

Metwally and Rakha (2015) conducted a study to identify sources of resistance to downy mildew among Plant Introduction (PI) cucumber accessions from the U.S. National Plant Germplasm System. They evaluated 133 such accessions for downy mildew resistance under natural field epidemics during the summer 2013 at El-Beheira Governorate, Egypt. Mean ratings for downy mildew leaf damage ranged from 1 to 9 on a 0 to 9 scale. They classified 18 PI accessions (13.5%) as highly resistant (rating of 1.0–2.0), 46 (34.5%) as moderately resistant (rating 2.1–4.0), 40 (30%) as intermediate (rating 4.1–6.0), 12 (9%) as moderately

susceptible (rating 6.1–7), and 17 (13%) as highly susceptible (rating > 7.1). The most resistant PI accessions were PI 432870, PI 432873, PI 432878, PI 432884, and PI 432886 with a rating of 1, which originated from China. The most susceptible PI accessions were Ames7736, PI 211979, PI 288991, PI 288992 and PI 289698 with a rating of 9. The five most resistant and five most susceptible accessions were further evaluated in replicated experiments during the summer 2014. Results from the repeated test confirmed the results from the first screening. No PI accession was found immune to downy mildew. However, high levels of resistance were observed in several PI accessions that could be useful for the breeding for resistance to *P. cubensis* in cucumber.

Call *et al.* (2012) evaluated 86 cultivars and breeding lines of cucumber (hereafter collectively referred to as cultigens) for downy mildew in Clinton, NC, in 2007 and 2009, in Castle Hayne, NC, in 2008 and 2009, and in Bath, MI, in 2007 to 2009. Plots were rated weekly on a 0 to 9 scale (0 = none, 1–2 = trace, 3–4 = slight, 5–6 = moderate, 7–8 = severe, and 9 = dead). Mean ratings for downy mildew leaf damage ranged from 2.9 to 5.7 in Michigan in 2008 and 2009 and from 3.8 to 6.8 in North Carolina in 2007 to 2009. None of the cultigens tested in this study showed a high level of resistance, although differences in resistance were detected. Lines WI 2757 and M21 and cultivar Picklet were consistently among the top resistant lines in North Carolina and Michigan. The cultivars Coolgreen, Wis. SMR 18, and Straight 8 were identified as moderately to highly susceptible. An unreleased hybrid, ‘Nun 5053 F1’, and the cultivar Cates were the top yielding lines overall. The highest yield in a single year and location was from the cultivar Cates in Clinton, NC, in 2009, with 25.6 Mg ha⁻¹. The best cultivars in this study were only moderately resistant and would likely require fungicide applications to achieve high yield and quality in the presence of downy mildew. Until high resistance becomes available, growers would benefit by using fungicides in combination with tolerant and moderately resistant cultigens.

Zitter and Murphy (2009) suggested that development of genetic resistance is the simplest and most effective method of controlling virus diseases and is especially appropriate for *Cucumber mosaic virus*.

Yasmin *et al.* (2008) evaluated sixty two germplasm of sweet gourd against powdery mildew caused by *Erysiphe cichocearum* under field condition. Four lines of sweet gourd namely BD 4388, BD 204, BD 205, BD 210 were found resistant to powdery mildew.

Jain and Sharma (2001) evaluated eight multiple disease resistance genotypes of *Cucumis melo* viz. Honeydew, MR-1, Nantais Oblong, Ogon-9, PMR-5, PI 414723, Topmark bush, and WMR-29 to Fusarium wilt by soil inoculation method under artificial condition. PDI was <25% for all 8 genotypes, and they were therefore classified as Fusarium resistant genotypes.

Thomas and Jourdain (1992) conducted field evaluations for resistance against downy mildew, incited by *Pseudoperonospora cubensis* [(Berk. and Cart.) Rostow], on 942 U.S. Plant Introductions (PI) of *Cucumis melo* L. A disease index (DI) was calculated for each entry. Based on DI, PI 124112 was highly resistant (DI = 3.7), and PIs 124111, 122847, 124210, 145594, and 165525 were resistant (DI = 3.0, 2.8, 2.6, 2.7, and 2.5, respectively). PIs 124111 and 124112 had one or more plants that exhibited a highly resistant reaction type (RT 4). Resistant (RT 3) plants were identified in 31 accessions, and 49 accessions had moderately resistant (RT 2) plants.

2.8 Cultural practices

Watson (2009) suggested that use of tolerant varieties, white plastic mulch, roughing of infected plants, and destruction of collateral host plant and application of suitable insecticide may considerably reduce the yield loss due to mosaic in watermelon.

Damicone *et al.* (2007) successfully controlled aphid-transmitted, nonpersistent virus diseases on pumpkin, caused mostly by the *Potyvirus*es Watermelon mosaic virus (WMV) and Papaya ringspot virus type-W (PRSV-W) by intercropping with grain sorghum, as opposed to clean tillage in five field trials over 3 years. Reductions in disease incidence ranged from 43 to 96% ($P \leq 0.05$). Surrounding pumpkin plots with borders of peanut, soybean, or corn was not effective. Borders of grain sorghum were effective, but disease control was generally less than for the intercrop treatment. Intercropping soybean and peanut with pumpkin reduced disease incidence by 27 to 60% ($P \leq 0.05$), but disease

control generally was less than for grain sorghum. Peak periods of alate aphid immigration generally preceded virus disease outbreaks by 7 to 14 days. However, a late landing rate, as measured in green tile traps, did not differ among treatments. Marketable yield was not increased by the intercrop treatments, and yield was reduced by up to 50% for the intercrop treatment with grain sorghum in two trials.

Bhokare and Ranpise (2004) observed the effects of different training systems, *i.e.* ground, bush (dry bamboo sticks along with thorny branches), kniffin and bower (both prepared with iron angles and galvanized iron wire), on the incidence of major diseases and on the yield of bottle gourd. Except for the ground training system, vines were trained on the support. The bower system had significantly less incidence of diseases, *i.e.* powdery mildew (23.80%) and downy mildew (30.80%), as well as the highest number of fruits per plant (30.46%), longer and dark green fruits, and maximum yield (78.25 q/ha). The percentage of increase in yield over the ground training system was 71.83, 200.65 and 243.80% in the bush, kniffin and bower systems, respectively, which was attributed to low incidence of diseases.

Tripathi and Varma (2002) observed that least incidence of the leaf curl disease (LCD) was found in polythene mulch (PM) treatment and in perforated polythene cover (PC) treatment as compared to the other treatments. The use of polythene bags to cover tomato plants (PC) and polythene sheets as mulch (PM) were found most effective in reducing the disease incidence and promoting the growth and yield of tomato plants as compared to other treatments.

Green and Kali (1994) suggested that tomato yellow leaf curl can be effectively controlled by use of reflective mulches, mixed cropping with plants more attractive to the vector, elimination of collateral and alternate host plants which may serve as virus reservoirs and adjusting the date of transplanting so that it does not coincide with higher vector population.

2.9 Bio-control and botanical control

Gava and Pinto (2016) evaluated the ability of *Trichoderma spp.* to control melon wilt under field condition, and the application of liquid compost as a food-based strategy to improve the biocontrol efficiency of the selected strain. In a first experiment, they evaluated the use of *Trichoderma harzianum* LCB47,

Trichoderma viride LCB48, *Trichoderma koningii* LCB49, and *Trichoderma polysporum* LCB50 to control melon wilt in a naturally infested soil. The treatment with *T. polysporum* LCB50 (Tp) showed the highest efficiency to control melon wilt (44.85%), increasing the fruit yield in 43%. In the second experiment, Tp was applied as seed treatment, and repeated on at 15 days after transplanting. Two doses of liquid compost; 25 (LC25) and 50 ml pl^{-1} (LC50), were applied by fertigation on a weekly basis along the crop development. In this experiment, *T. polysporum* LCB50 applied alone resulted in a significant ($P < 0.05$) control of wilt (32.20%), and 27 increase in fruit production. Single application of both doses of LC did not significantly reduced disease incidence. However, a strong synergistic effect was observed applying Tp and LC25 and LC50, resulting in a highly significant wilt control (68 and 72%, respectively) and an increase in productivity. The use of Tp + LC50 treatment increased in 100% the production of commercial fruit from the results, a strategy based on the use of *T. polysporum* LCB50 and an organic matter source is proposed for the integrated management for melon wilt.

Sundaramoorthy and Balabaskar (2013) evaluated the efficacy of the native isolates of *Trichoderma* species to promote the growth and yield parameters of tomato and to manage Fusarium wilt disease under in vitro and in vivo conditions. The dominant pathogen, which causes Fusarium wilt of tomato, was isolated and identified as *Fusarium oxysporum* f. sp. *lycopersici* (FOL). Fifteen native *Trichoderma* antagonists were isolated from healthy tomato rhizosphere soil in different geographical regions. Under in vitro conditions, the results revealed that *Trichoderma harzianum* (ANR-1) isolate was found to effectively inhibit the radial mycelial growth of the pathogen (by 53%) when compared to all other isolates. Under greenhouse conditions, the application of *Trichoderma harzianum* (ANR-1) exhibited the least disease incidence (by 15.33%). Also tomato plants treated with *Trichoderma harzianum* (ANR-1) isolate showed a significant stimulatory effect on plant height (by 73.62 cm) and increased the dry weight (by 288.38 g) of tomato plants in comparison to other isolates and untreated control.

Almqvist (2012) investigated the effect of two biological control products in order to evaluate their ability to prevent or reduce powdery mildew infection to an acceptable level in greenhouse produced cucumber. In the experiments,

different application regimes were also studied. In one of the products the active organism was *Ampelomyces quisqualis* and in the other *Pythium oligandrum*. The effect of using the biocontrol agents prophylactically was significantly better with *P. oligandrum* compared to the untreated control but not with *A. quisqualis*. The effect of using *A. quisqualis* with an application interval of fourteen days was significantly better compared to a seven days application interval. For *P. oligandrum*, there was no difference between the two application intervals.

Anonymous (2010) reported that neem seed extracts products are effective against insect vectors such as aphid, whitefly of several viruses causing diseases in cucurbits. Neem seed extracts contain azadiractin which is chemically similar to ecdysonlids, the hormone having anti-feedant property and may cause insect to stop feeding. Efficacy of neem oil products against powdery mildews of cucurbits and grapes has been demonstrated. To prevent thrips and aphids they apply cow dung ash on foliage of vegetables e. g., chilli, onion, garlic, and cucurbit

Pawar and Chavan (2010) found that Neem leaf extract at 15% concentration, *Parthenium* leaf at 10% concentrations. *Ocimum* leaf at 20% concentration, Citrus leaf at 20% concentration, *Annona squamosa* leaf at 10% concentration, Ipomea at 15% and Jowar leaf at 20% control the powdery mildew of cucurbits. Cow urine at 15% concentration proved to be effective to control powdery mildew on cucurbit. 20% to 25% of Butter milk spray successfully controlled the powdery mildew of cucurbit. Similarly 20% ash spray also found to be successful to control the growth of powdery mildew of cucurbits. Spray of dashparni ark, a bi-product of plant and animal at 10% concentration inhibited the growth of *Erysiphe cichoracearum* and *Sphaerotheca fuliginea*.

Beckerman (2008) suggested that at a 70 percent concentration, neem oil kills powdery mildew spores; minimize the spread of viruses by controlling the insects that transmit them such as aphids, white fly, mites and the eggs of numerous insect pests. Aphids transmit the viruses that cause many common landscape and garden diseases, including *Cucumber mosaic virus*, *Potato virus Y* (potyvirus), and *Watermelon mosaic virus*. Neem oil is pressed from the fruit and seeds of the neem tree (*Azadirachta indica*).

Palenius *et al.* (2006) reported that Neem oil has multipurpose insecticide, miticide and fungicide property. Application of Neem oil protects cucurbits from powdery mildew, downy mildew, mosaic and leaf curl diseases. E-RASE™ is another natural product made from jojoba oil (*Buxus chinensis*). It is a contact fungicide that can be applied to control powdery mildew in cucurbits. Cinnamon oil (Cinnamite®, Valero®, etc) has also proved to be effective to control powdery mildew in cucurbits.

Keinath and Du Bose (2004) demonstrated that preventive application of a biofungicide (*Bacillus subtilis* 0.2%) was more effective than curative application for the control of water melon powdery mildew caused by *E. cichoracearum*. Similarly, powdery mildew and downy mildew of cucumber under green house conditions was controlled by *B. subtilis* spray (Abd El Moiety *et al.*, 2003)

Mashewari (2017) management of Alternaria leaf blight of bottle gourd through botanical, fungicides, bio-agent and their different combinations. The spacing maintained between rows was 2.0 m and between plants 0.50 m. Seventeen treatments such as 01 botanical (neem leaf extract @ 5.0%), 01 bio-agent (*Pseudomonas fluorescens* strain CIAH-196 @ 5.0%,

2.10 Chemical control

Gupta *et al.* (2001) reported that three sprays of hexaconazole (0.05%) at fortnightly highly effective for the management of powdery mildew caused by *Sphaerotheca fuliginea*. Anvil (Hexaconazole) and Karathane were the most effective fungicides against powdery mildew of cucumber than flovable sulfur, benomyl (Shami *et al.* 1995)

Mondal *et al.* (2014) observed that Spraying of Krilaxyl Gold (Metalaxyl 8% WP + Mancozeb 64% WP), Blitox (Copper Oxy-chloride 50% WP) and Indofil M-45 (Mancozeb 75% WP) recorded better and gave good protection against downy mildew in pointed gourd. Spraying should be done just before sunset. Retarded growth of vine of pointed gourd was noticed due to spraying of Contaf (Hexaconazole 5% EC) and Tilt (Propiconazole 25% EC).

Narkhede *et al.* (2014) suggested that fortnight spray of Carbendazim (0.1%), Culixin (0.05%), Karathane (0.5%) and Sulfex (0.2%) have been found effective. Seed treatment and seed drenching with systemic fungicides also give

protection to young seedlings from powdery mildew. Downy mildew can be effectively controlled with sprays of Dithane M45 (0.2%), Daconil and Difolatan (0.2%). One spraying gives protection for nine days. Copper oxychloride spray has also given good control. The sprays of Dithane M 45 if given early and repeated 2-3 times can control the disease effectively.

Lam and Lim (1993) stated that weekly spraying of hexacanzole (0.2%) and its mixture with protectant fungicides significantly reduced the powdery mildew (*Sphaerotheca pannosa*) of roses and white rust (*Puccinia horiana*) of Chrysanthemum.

Masood *et al.* (2013) suggested that usually two to three applications of chemicals e.g. difenoconazole (2ml/1litre) in a month after sowing, and later on mancozeb (2g/1 litre) or propiconazole (1ml/1litre) or carbendazim (1g/1 litre) when symptoms appear with 10-14 day intervals found effective against powdery mildew of cucurbits.

Chaudhry *et al.* (2009) conducted a field experiment to evaluate the performance of different fungicides against downy mildew on cucumber (*Cucumis sativus* L.) cultivated in high plastic tunnel at the farm of Ch. Khair Din and Sons, Mandiala Warriach, Gujranwala during Rabi, 2006-2007. Five different fungicides namely Dithane M-45, Copper oxychloride 50 WP, Ridomil Gold 72 WP, Success 72 WP and Alliet 80 WP were used at dose rate 5, 4, 2, 2.5 and 2 g/L-1 of water, respectively. Minimum disease incidence was recorded by spraying Success (9%), Ridomil (9.%) and Alliet (11%) compared with control (78%). Number of fruit per plant, length and yield of fruit was significantly higher in treated plots with Ridomil, Success and Alliet as compared to control and other fungicides.

Rai *et al.* (2008) recommended spraying of Dithane M-45 (0.3 %) at 15 days interval to control downy mildew under Ludhiana conditions. Three sprays of Calixin (0.05 %) or sulfex (0.25 %) effectively controlled powdery mildew at Rahuri at an interval of 15 days starting from 30-40 days after sowing. Five sprays of Dithane M-45, Dithane Z-78 or Aliette (all 0.3 %) at 10 days interval have been recommended to control downy mildew disease under Bangalore conditions.

Yasmin *et al.* (2008) evaluated eight fungicides against powdery mildew caused by *Erysiphe cichocearum* under field condition. Mycosulf, Thiovit and

Insuf were found best in controlling severity of disease by >80% not depending on locations. Additional yield 14.58t/ha was found from Thiovit treated plot which was 65.35% higher compared to control. Net income increased almost two times and the farmers having more options for controlling powdery mildew as more than one fungicide were found effective.

Manjusha (2007) carried out an experiment at Horticultural Research farm, College of Agriculture, Indira Gandhi Agricultural University Raipur (C.G) during the year 2006-2007 and found that integration of various management practices as seed treated with Ridomil MZ and spray of Allite and Curzate considerably reduces the downy mildew disease severity and influenced the growth and yield.

Memane and Khetmalas (2003) reported that a studied to determine the most effective treatment for controlling downy and powdery mildew (caused by *Pseudoperonospora cubensis* and *Erysiphe cichoracearum*, respectively) on bottle gourd and among all treatments, eight sprays of 0.3% copper oxychloride + 0.3% wettable sulfur at 10-day intervals from 30 days after crop sowing was the most effective for the control of downy and powdery mildew diseases of bottle gourd during the rainy season, recording the highest yields and economic returns.

Maheshwari (2017) the field trials were conducted during rainy season of 2013 and 2014 for disease management of Alternaria leaf blight in bottle gourd through botanicals, fungicides, bio-agent and their combinations. Among 17 treatments, combined treatment of carbendazim (Seed treatment) @ 0.1% + mancozeb (Foliar spray) @ 0.25% + *Pseudomonas fluorescens* (Foliar spray) @ 5.0% + neem leaf extract (Foliar spray) @ 5.0% was found the most effective with minimum disease incidence of 9.25%, minimum disease severity of 7.07% and maximum disease control (78.23%), followed by mancozeb ST @ 0.25% + carbendazim (FS) @ 0.1% + *Pseudomonas fluorescens* CIAH-196 (FS) @ 5.0% + neem leaf extract (FS) @ 5.0% having disease incidence (11.15%), disease severity (8.98%) and disease control (72.35%) for management of Alternaria leaf blight of bottle gourd.

2.11 Integrated diseases management

Beura *et al.* (2014) conducted an experiment to test the different integrated approaches for management of bottle gourd along with bower system and non

bower system. Four years pooled data revealed that all the treatments of bower system of planting lowered the disease severity as compared to non bower system of planting. Among the fourteen treatments tested, integrated disease management components like seed treatment with ridomil mz (metalaxyl 8 % + mancozeb 64 %) @ 0.25 % + three times removal of lower infected leaves in the morning and spray of mancozeb 75 % @ 0.25 % in the afternoon on bower system recorded significantly lowest disease severity of downy mildew (4.7 %) with maximum fruit yield of 90.2 q ha⁻¹. The same treatment also registered 92.24 % disease control over control plots followed by seed treatment with ridomil mz (metalaxyl 8 % + mancozeb 64 %) @ 0.25 % along with one foliar spray of alliete (fosetyl-al) @ 0.25 % on bower system of planting registered 79.87 % disease control. However, the check plot recorded the maximum disease severity of 60.60 % and 46.60 % with minimum green fruit yield of 33.50 % q ha⁻¹ and 41.1 q ha⁻¹ in non bower and bower system of planting respectively.

Kumar *et al.* (2008) evaluated different treatments including chemical and non-chemical for management of powdery mildew disease under field condition. The treatments included thirteen chemical fungicides, eight biological control agents, thirteen plant extracts (botanicals) and the study was conducted in two experimental seasons during 2004-05 in bell pepper varieties 'California Wonder' and 'Indra'. Dinocap (1 ml l⁻¹) among chemical fungicides, *Ampelomyces quisqualis* (20 g l⁻¹) among biological control agents and neem oil (20 ml l⁻¹) among botanicals recorded as the best components by recording a minimum percent of disease and the maximum yield compared to untreated controls. The same trend was observed in both seasons. In a second set of experiments, the most effective components were integrated to further minimise the use of fungicide thus an Integrated Disease Management (IDM) package was developed and tested in the field. By adopting this IDM the yield of 'California Wonder' and 'Indra' bell pepper showed an increase of 342.8 and 122.3 %, respectively the corresponding values for the control were 93.6 and 93.2 % respectively.

Kurowski *et al.* (2015) suggested that management of mosaic and leaf curl of cucurbits has been only marginally successful through vector control (e.g., insecticides, stylet oils). Avoid planting near older cucurbits and perennial

ornamental crops, which may serve as reservoirs for the virus. Control weeds, use reflective mulches, deep plow crop residues and dispose of infected greenhouse material to manage these viruses. Implement a comprehensive sanitation program for workers and equipment to minimize disease spread. Commercial varieties with resistance offer the best means to control mosaic and leaf curl. Resistance in cucumber has been shown to be very effective on a global scale. Progress in finding resistance in other cucurbit species has not been as successful.

Rajinimala *et al.* (2009) reported that bottle gourd yellow mosaic disease attains significance because the virus causing this disease is capable of attacking the crop at all stages. There was a severe yield loss in bottle gourd plants due to the infection of BGYMV. Bottle gourd plants treated with *Bougainvillea spectabilis* challenge inoculated with BGYMV reduced the disease incidence and increased the plant growth. In the above treatment the disease incidence was 33.33% at 75 Days After Sowing (DAS). But in the inoculated untreated control the disease incidence was 100% at 75 DAS. The mean maximum plant height was 92.24 cm in plants inoculated at 65 DAS. *Bougainvillea spectabilis* treated plants challenge inoculated with BGYMV showed an increased activity of peroxidase, polyphenoloxidase and phenol content from 4 Days after Inoculation (DAI) to 12 DAI. The activity of all the enzymes was reduced from 16 DAI in all the treatments.

Shankar *et al.* (2014) suggested that application of some fungicides as protective treatment reduce the incidence and severity of downy mildew in cucurbits. Mancozeb (Dithane M-45) 2g/litre used as a protective application at 5-7 days interval or Azoxystrobin (amistar) 0.5ml/litre no more than two application per season, can be tank mixed with protectant fungicide, Dimethomorph (Acrobat) 1g/litre at 5-10 days interval not more than five application per season, Cymoxanil + Mancozeb (Curzate) 2g/litre at 5-7 day interval no more than four application, Fosetylaluminium (Aliette) 3g/litre preventive treatment prior to disease onset foliar application or Chlorothalonil (kavach) 2g/litre can be used as a protective application at 5-7 days interval. Tebuconazole (Folicur) 1ml/litre at 10-14 day interval for suppression only protective treatment effectively reduce the incidence and severity of powdery mildew in cucurbits.

Zhang *et al.* (2015) reported that an integrated approach using a combination of several practices is most effective in managing downy mildew, powdery mildew and wilt diseases of bottle gourd.

2.12 Economics of management practices

Nwogbaga and Iwuagwu (2015) reported that the assessment of the economic benefit of fungicide and foliar fertilizer application showed that the gross margin (net revenue) was higher in N.P.K. foliar fertilizer compared to the fungicide. This was because N.P.K. foliar fertilizer gave higher yield (480 kg^{ha}) compared to the fungicide (320kg^{ha}), even though the total variable cost (TVC) was almost the same. The marginal revenue (Cost-benefit ratio) was equally higher in N.P.K foliar fertilizer (1:4.8) compared to the fungicide (1:3.4).

Mahrishi and Siradhana (1988) stated that treatment with 0.2% Dithane M-45 [mancozeb] decreased disease intensity. Plots receiving no spray, 3 and 4 sprays at 10 days intervals registered 79.06, 47.67 and 28.49% yield losses, respectively, compared with plots receiving 5 sprays of mancozeb at 7 days intervals.

Yasmin *et al.* (2008) evaluated eight fungicides against powdery mildew caused by *Erysiphe cichoracearum* under field condition. Mycosulf, Thiovit and Insuf were found best in controlling severity of disease by >80% not depending on locations. Additional yield 14.58t/ha was found from Thiovit treated plot which was 65.35% higher compared to control. Net income increased almost two times and the farmers having more options for controlling powdery mildew as more than one fungicide were found effective.

Yeon *et al.* (1996) found that when Fosetyl was applied 4times from the start of the disease (downy mildew) at 10 days interval, a yield index of 161% was obtained. Control decreased when 10 or 20 days from initial disease occurrence delayed the first fungicide application

Rahman and Bhattiprolu (2005) conducted a field trial at Agricultural Research Institute, Rajendranagar, Hyderabad, Andhra Pradesh, India during kharif 1993-94 to 1996-97 to find out the effective fungicidal application for management of powdery mildew of okra caused by *Erysiphe cichoracearum* DC. The crop was sprayed with seven different fungicides starting from the first appearance of the disease. Four sprays of wettable sulfur (Sulfex) 0.3% (T₁), penconazole (Topas)

0.05% (T₂), triadimefon (Bayleton) 0.05% (T₃), thiophanate-methyl (Topsin M) 0.1% (T₄), chlorothalonil (Chlorothalonil W-75) 0.1% (T₅), dinocap (Karathane) 0.1% (T₆) and tridemorph (Calixin) 0.1% (T₇) were taken up in the treated plots. Effect of each treatment on the disease incidence and yield was recorded. The disease index was significantly reduced in plots treated when compared to the untreated control. Analysis of the data for four seasons/years showed that okra powdery mildew can be significantly reduced by spraying 0.1% dinocap followed by 0.05% penconazole and triadimefon 0.05% along with significant increase in the yield. Maximum net profit was obtained by spraying 0.05% penconazole (Rs. 20, 895/-) followed by 0.1% dinocap (Rs.17, 890/-). Highest benefit cost ratio was realized with wettable sulfur 0.3% followed by penconazole 0.05% and triadimefon 0.05%. However, the benefit cost ratios assessed would be by 0.3% wettable sulfur (6.80) > 0.05% penconazole (6.58) > 0.05% triadimefon (5.39) > 0.1% tridemorph (4.73) > 0.1% dinocap (3.33) > 0.1% thiophanate methyl (3.28) > 0.1% chlorothalonil (2.00).

CHAPTER – I

INTRODUCTION

The family cucurbitaceous includes important vegetable crops, such as bottle gourd (*Lagenaria siceraria*), cucumber (*Cucumis sativus*), melon (*Cucumis melo*), pumpkin (*Cucurbita pepo*), squashes (*Cucurbita maxima*) and water melon (*Citrinella lanatus*). Bottle gourd is one of the earliest domesticated food plants which are originated from Africa. Bottle gourd may have been spread by ocean currents to the shores of the New World or by human migration in pre-historic times. It is known to have been cultivated in Africa, Asia and America. The earliest evidence of its use comes from Peru dating from 13,000 to 8000 B.C. Young tender, non-bitter fruits are used as vegetable. Young shoots and flower buds of less bottle types are occasionally eaten as green vegetable. In African countries, people extract edible oil from the seeds of bottle gourd. In Asia, some bottle gourd cultivars are used as root stock for grafting musk melon and cucumber to control soil-borne diseases. Roots and fruits are sometimes used as purgative. The leaves are used as a medicine for stomach-ache, skin rashes and swelling due to snake poison. The dry shells of the fruit known as calabashes are used for storing milk, water, honey, ghee, salt, tobacco, crop seeds or food grains. Calabashes are also used for making variety of musical instruments (Morimoto and Mvere, 2004).

Among medicinal uses bottle gourd is traditionally used as a cardio-tonic, aphrodisiac and general tonic, liver tonic, anti-inflammatory, expectorant and diuretic agent. Recently, the antioxidant activity of ethanolic extract of epicarp and fresh juice of bottle gourd has been reported (Deshpande *et al.*, 2008). The fruit of bottle gourd is also reported to have good source of Vitamin-B complex and Chlorine along with fair source of vitamin-C and β -carotene (Kirtikar and Basu, 2001). It is also reported to contain cucurbitacin, fibers and polyphenol (Nadkarni, 1954). Lignin, a ribosome inactivating protein (RIP) isolated from the seeds of bottle gourd possesses immune- protective, antitumor, anti HIV and anti

proliferative properties (Wang and Ng, 2000). The fruits of bottle gourd are widely used in Ayurveda and other folk medicines traditionally used for its cardio protective, cardio tonic, general tonic, diuretic, aphrodisiac, antidote to certain poisons, scorpion stings, purgative and cooling effects. It cures pain, ulcers and fever and used for pectoral cough, asthma and other bronchial disorders especially syrup prepared from the tender fruits (Anjaria *et al.*, 2012).

It is a monoecious, annual, climbing or trailing herb, with proximally bifid tendrils. Leaves are alternate, simple, stipules absent, petiole 2.5 to 12.5 cm long pubescent with pair of tiny glands at apex, blade broadly ovate to kidney-shaped in outline. Flowers are unisexual (rarely bisexual), regular, solitary on leaf axils. Male flowers are on long pedicles where as female flowers are on short pedicles. Fruits are variable in size and shape, often globular bottle or club-shaped up to one meter long, white yellow to dark green when young, sometimes whitish speckled, usually brown when mature and dried.

In India, bottle gourd is grown as a commercial vegetable crop in an area of 1.55 lakh ha with an annual production of 24.58 lakh tonnes (Anonymous, 2015-16). As regard the status of this crop in Chhattisgarh state, the area is 12766 hectares and 2.40 lakh tones production. It is one of the most preferred vegetable by local dwellers of Chhattisgarh. Among the 27 districts of the state, Durg district covers highest area (1560) with production of 40560 metric tones followed by Surguja and Raipur Hence it is cultivated round the year except few winter months in the region.

Bottle gourd is commonly attacked by number of diseases such as downy mildew, powdery mildew, Phytophthora blight , Cercospora leaf spot , Fusarium wilt and fungal root rots, root knot nematode, bacterial wilt, bacterial leaf spot, mosaic, watermelon bud necrosis, leaf curl and leaf distortion virus. These diseases are of national importance and cause important economic losses in cucurbits (Mathew and Alice, 2002, Pandey *et al.*, 2002, Palada and Change, 2003, Rai *et al.*, 2008 and Khan *et al.*, 2014). Among them downy mildew (Hansen, 2000 and Rai

and Yadav, 2005), powdery mildew (Watson and Napier, 2009), mosaic (Ashwini *et al.*, 2016), leaf curl (Raj *et al.*, 2010), Fusarium wilt (Rakholya *et al.*, 2003) and leaf spot are commonly affecting diseases that cause considerable loss to the crop (Balachandran, 2011 and Abraham *et al.*, 2015).

Downy mildew caused by *Pseudoperonospora cubensis* is one of the important foliar diseases of bottle gourd. It was reported for the first time in 1868 and still it is considered as one of the serious problem. In India, it is present all over the country except in high altitude temperate zone in the Himalaya. The losses are severe in bottle gourd, muskmelon, watermelon, cucumber, sponge gourd and ridge gourd (Hansen, 2000 and Rai and Yadav, 2005). The initial symptoms appear as pale green areas on the upper leaf surfaces which change to yellow angular spots. A fine white to grayish downy growth soon appears on the lower leaf surface. Infected leaves generally die but may remain erect while the edges of the leaf blades curl inward. Usually, the leaves near the center of a hill or row are infected first. The infected area spreads outward, causing defoliation, stunted growth, and poor fruit development which reduces yield. The entire plant may eventually be killed (Kuepper, 2003 and Rai and Yadav, 2005). During moist weather the corresponding lower leaf surface is covered with a downy, pale gray to purple mildew. The colour of the mildew ranges from white to near black. In rainy humid weather entire vein is killed (Babadoost, 2001). Early infection of downy mildew can cause reduction in crop yield upto 60% where as late infection is less damaging (Colucci and Holmes, 2010 and Wallace *et al.*, 2014).

Powdery mildew caused by *Sphaerotheca fuliginea* and *Erysiphe cichoracearum* produce white powdery growth on the upper surfaces of leaves and on the stems of infected plants. Infected areas are often stunted and distorted and may drop prematurely from the plant. Fruits are usually not directly affected, but their size and growth may be stunted. Infection can occur when temperatures are between 10 and 32.2 °C, during dry weather with high relative humidity (Anonymous, 2016).

Among the viral diseases bottle guard mosaic and leaf curl disease have become a most limiting factor for the cultivation of the crop in many places. The disease is responsible for a yield loss up to 100 per cent. Infection of bottle gourd with *Bottle gourd distortion mosaic virus* (BDMV) and *Cucumber mosaic virus* (CMV) was reported for the first time from Coimbatore, India (Nagarajan and Ramakrishnan, 1971). Symptoms appear as light and dark green mottling of the leaves, distortion of leaves and stunting of the plant might occur. Sometimes fruit might show sunken concentric circles or a raised marbled pattern. It is transmitted by five different species of aphid vectors and was tentatively named as *Bottle gourd mosaic virus*. The symptoms of BDMV infection in bottle gourd consists of upward curling, shortening of internodes, distortion of leaves, stunting of plants and deformation of fruits (Giri and Mishra, 1986, Mathew and Alice, 2002, Khan *et al.*, 2002, Tripathi and Varma, 2002, Watson, 2009 and Ashwini *et al.*, 2016).

Among the all measures to raise the productivity level, plant protection is in central position. Plant protection is a basic exercise in any crop for control of insect-pests, diseases, weeds etc. to avoid economic losses. Reports indicate these losses ranging from 20-30 per cent by each of the insect-pests, diseases and weeds, but on a holistic basis about 30 per cent average cumulative loss by them appears a fair estimate. This implies that suitable control measures must be followed to keep these losses to the minimum (Muthuraman and Kumar, 2013 and Jana, 2014).

Disease management strategies such as use of tolerant varieties, sowing date, sowing depth, barrier crops, white plastic mulch, perforated plastic mulch, roughing of infected plants, destruction of collateral host plant, seed treatment and application of suitable fungicide and insecticides may considerably reduce the yield loss caused by fungal and viral diseases (Mathew and Alice, 2002, Tripathi and Varma, 2002, Kaur and Kang, 2005 and Watson, 2009).

Bottle gourd is an important vegetable of Chhattisgarh, and the losses due to the diseases caused by pathogen cannot be ignored. Also less information regarding disease management strategies in this crop is available. Therefore the following objectives were framed for the present study.

1. To record the seasonal occurrence of bottle gourd diseases.
2. To evaluate important commercial varieties (bottle gourd) against prevalent diseases.
3. To work out the suitable combination of methods for management of the disease.
4. To study the response of various treatments on yield and yield attributes of bottle gourd.
5. To work out the economics of different treatments under the study.

CHAPTER- II REVIEW OF LITERATURE

This chapter deals with the brief review of the research work done earlier related to integrated disease management of bottle gourd (*Lagenaria siceraria*.) and various parameters affecting its growth and yield.

The bottle gourd (*Lagenaria siceraria* (Molina) standl., F: Cucurbitaceae), is a tropical vegetable of Afro-Asian origin and is cultivated in India throughout the year for its young and tender fruits eaten as popular domestic vegetable called 'Lauki' or 'Dudhi'. The serious diseases like downy mildew, powdery mildew, root rot and fruit rot that attack the crop during various stages of growth and also in post-harvest are among the major limiting factors responsible for low productivity of bottle gourds (Neeraj and Verma, 2010).

The review of literature pertaining to this dissertation is divided into the following headings:

- 2.1 Diseases and Causal Organisms
- 2.2 Symptomatology
- 2.3 Host Range
- 2.4 Etiology
- 2.5 Epidemiology
- 2.6 Effect Of Various Seed Treatments On Seedling Parameters
- 2.7 Varietal Screening
- 2.8 Cultural Practices
- 2.9 Bio-Control and Botanical Control
- 2.10 Chemical Control
- 2.11 Integrated Disease Management
- 2.12 Economics of Management Practices

2.1 Disease and causal organisms

The bottle gourd (*Lagenaria siceraria* (Molina) standl) is affected many more diseases. It occurs practically on all the cultivated cucurbits. The diseases are confined mostly to the leaves, although the fruit of infected. Plants may be of poor quality resulting from the loss of foliage.

The previous history and the literature pertaining to the experiment with respect to the disease severity, its effect on yield and disease management practice etc influencing the overall yield and marketability of bottle gourd is reviewed as under.

Raj *et al.* (2008) reported that Cucurbits are affected by a number of diseases like downy mildew, powdery mildew, gummosis, Phytophthora blight, anthracnose, Cercospora leaf spot, phoma blight, collar rot, Fusarium wilt, white rot, root knot nematode, bacterial wilt, watermelon bud necrosis and leaf distortion virus. These diseases are of national importance and cause important economic losses in cucurbits.

Neeraj and Verma, (2010) and Zhang, *et al.* (2015) The serious diseases like downy mildew, powdery mildew, root rot and fruit rot that attack the crop during various stages of growth and also in post-harvest are among the major limiting factors responsible for low productivity of bottle gourds.

Pawar and Chavan (2010) studied the incidence of powdery mildew on different cucurbits hosts in different seasons and its biocontrol. They reported that in Kharif season *Sphaerotheca fuliginea* was dominantly present on *Cucurbita maxima*, *Lagenaria siceraria* and *Cucurbita pepo*, where as *Erysiphe cichoracearum* noted on *Citrullus lanatus* was not reported in 2005 and 2006. *Cucurbita maxima*, *Lagenaria siceraria*, *Luffa acutangula* and *Luffa cylindrica* showed maximum occurrence of *Sphaerotheca fuliginea* in the rabi season.

Table 2.1 Major diseases of bottle gourd

Name of disease Causal organism	Name of disease Causal organism
I. FUNGAL DISEASES	
1) Anthracnose	<i>Colletotrichum lagenarium</i> (Pass) Ell. and Halst
2) Powdery mildew.	<i>Erysiphe cichoracearum</i> De Candolle
3) Seedling blight	<i>Pythium aphanidermatum</i> (Eds) Fitz .
4) Downy mildew	<i>Pseudoperonospora cubensis</i> (Berk. and Curt.)
5) Fusarium wilt	<i>Fusarium oxysporum</i> f.sp. <i>lagenariae</i> . Matuo and Yamamoto
5) Cercospora leaf spot	. <i>Cercospora lagenariae</i> Rang
7) Necrotic black fruit rot	<i>Alternaria alternata</i> (Fr.) Keissler
8) leaf blight	<i>Alternaria</i>
II. VIRAL DISEASES	
1)Cucumber green mottle mosaic	Cucumber green mottle mosaic virus
2)Cucumber mosaic	Cucumber mosaic virus
3)Watermelon mosaic	Watermelon mosaic virus
4)Pumpkin yellow vein	mosaic Pumpkin yellow vein mosaic virus
III BACTERIAL DISEASES	
1) Angular leaf spot	<i>Pseudomonas syringae</i> pv. <i>lachrymansngae</i>
2) Bacterial wilt	<i>Erwinia tracheiphila</i>

2.1.1 Downey Mildew

Palti and Cohen (1980) reported that the mycelium of *Pseudoperonospora cubensis* is hyaline, coenocytic and intercellular. Sporangiophore (180-400 to 54-72 μ m) is dichotomously branched at the tip. Sporangia single, ovoid to ellipsoid and borne singly. They are grayish to olivaceous purple with a papilla at distal end. Oospores are globose, yellow or hyaline and 23-25 μ m in size.

Gangopadhyay, (1984). The mycelium of *Pseudoperonospora cubensis* is coenocytic and intercellular with small, ovate haustoria. Sporangiophore arises in group of 1-5 through stomata. The upper-third of sporangiophore is either dichotomous or monopodial branched. The sterigmata are sub-acute. Sporangia is grayish olivaceous purple, ovoid to ellipsoidal thin walled and with a apical papilla. They measure 2139 x 14-23 micron in size. Zoospores are biflagellate and 12-13 microns in diameter

Mondal *et al.* (2014) reported that the downy mildew in pointed gourd appears in December and continues up to the end of March. It causes drying up of leaves in growth stage of the crop.

Wallace *et al.* (2014) observed cucurbit downy mildew (CDM), caused by the oomycete *Pseudoperonospora cubensis*, on bitter melon and balsam apple between August and October 2013 in six North Carolina sentinel plots belonging to the CDM IPM PIPE program. Leaves with symptoms typical of CDM were collected from the *Momordica* spp. and symptoms varied from irregular chlorotic lesions to circular lesions with chlorotic halos on the adaxial leaf surface.

Colucci and Holmes (2010) reported that *Pseudoperonospora cubensis* (Berkeley & Curtis) Rostovtsev is the causal agent of downy mildew of plants in the Cucurbitaceae (gourd family), including cucumbers, melons, squashes, gourds and watermelons. Berkeley and Curtis first reported the disease in Cuba in 1868. Downy mildew of cucurbits can be found in temperate areas, such as the Americas, Europe, Japan, Australia and South Africa, tropical regions and some semi-arid regions, such as the Middle East. The disease affects cucurbit crops in the field and those grown in passive or traditional greenhouses. Downy mildew is especially damaging in warm, humid climates where the pathogen thrives.

2.1.2 Powdery Mildew

Two different fungi commonly cause powdery mildew on cultivated cucurbits i.e., *Sphaerotheca fuliginea* (Schlecht) Pollaci and *Erysiphe cichoracearum* DC (Sitterly, 1978). *Sphaerotheca fuliginea* is predominant in many countries like China, Japan and Russia (Vakalounakis *et al.*, 1994, Mc Grath, 1996; Mohamed *et al.*, 1995). *Erysiphe cichoracearum* seem to be common in temperate zones (Nagy, 1976; Lebeda, 1983; Corbaz, 1992). In France, both the species were recorded (Bertrand, 1991).

In India, Butler (1918) reported the occurrence of both the organisms in cucurbits. On the basis of conidial characters, Jhooty (1967) claimed that *S. fuliginea* was responsible for the disease in Punjab. In CMI descriptions, Kapoor (1967) described that *S. fuliginea* exclusively attacks cucurbits in Aligarh and Uttar Pradesh. Siradhana and Chaudari (1972) stated the occurrence of both the species on cucurbits at Udaipur, Rajasthan.

In India, several states like Bihar, Madhya Pradesh (Dave *et al.*, 1971; Khosla *et al.*, 1974), Uttar Pradesh and Andhra Pradesh (Sharma, 1978) reported similar dominance of *S. fuliginea*.

In India, bottle guard and as instant was identified as *Sphaerotheca fuliginea* (Gupta and Singhvi, 1979). Patel *et. al.*, (1990) reported appearance of powdery mildews on bottle gourd during rabbi season on *Lagenaria siceraria*, due to *Sphaerotheca fuliginea*.

Powdery mildews fungi were identified by using the standard literature of Hirata (1942), Boesewinkel (1980), Zheng (1985), Braun (1987), Eriksson and Hawksworth (1987), Bappamal *et al.* (1995) and Hosagoudar (1997).

2.1.3 Leaf Blight

Alternaria leaf blight caused by *Alternaria cucumerina* (E. & E.) Elliot is found to cause serious losses throughout Rajasthan and other states.

Alternaria cucurbitae Let. and Roum. has been cited as the cause or a disease of cucurbits by Boughey (1) and Schwarze (13). Elliot (2) in his study of the genus, did not include *A. cucurbitae* because he was unable to obtain sufficient material. Peglion (9) believed *A. cucurbitae* to be distinct from the pathogen he described as the great difference in spore-body diameter, although *A. cucurbitae*

may be regarded as a valid species, it's not the causal agent of the leafspot disease of cucurbits most frequently reported throughout the world.

In 1893, Peglion (9) described *Alternaria brassiae* f.sp. *nigrescens* Pegl. As the cause of a disease of muskmelons in Italy. He gave conidial size as 60-80 x 14-18 μ and incorrectly described conidial shape as clavate. In a second report Peglion (10) revised the dimensions to 100-160 x 14-20 μ , reaching 200 μ in length when the filiform tip.

The crop is attacted by a number of diseases, amongst which leaf spot and blight incited by *Alternaria cucumerina* is found to cause serious losses throughout the state. In India the disease was first reported by Khandelwal and prasada (1970).

2.1.4 Leaf Curl and Mosaic

Ashwini *et al.* (2016) reported the three different viruses causing mosaic in bitter gourd are *Cucumber mosaic virus* (CMV) and *Bottle gourd distortion mosaic virus* (BDMV). As these viruses causes mixed infection in field, the separation of individual viruses was carried out using systemic indicator host plants. Systemic indicator host plants were used for separation of CMV, where as white fly transmission was adopted for separation of BDMV.

. There are two major strains of ZYMV (ZYMV-FL and ZYMV-CT) and symptoms of ZYMV-CT are more severe. Its natural infection on bottle gourd was detected in India (Verma *et al.*, 2004), Hawaii (Ullman *et al.*, 1991) and Serbia (Dukic *et al.*, 2006).

ZYMV is the type species of the genus Potyvirus in the family Potyviridae, was first reported from Italy in 1973 (Lisa *et al* 1981) which causes devastating epidemics in commercial cucurbits worldwide and several biologically distinct strains have been described (Lisa and Lecoq 1984, Greber *et al* 1988, Wang *et al* 1992).

Brunt *et al.* (1996). Reported is natural occurrence of Watermelon mosaic virus 1 (WMV-1) on Cucurbitaceous hosts was first reported in *Citrullus lanatus*. WMV-1 is also known as papaya ringspot virus type W (PRSV-W) and watermelon papaya ringspot. Virions are filamentous, but not enveloped and are usually flexuous with a clear modal length of 760-800 nm and 12 nm wide. WMV-

It has worldwide distribution and known to be prevalent in the Middle East, South and Central American region, Australia, China, France, Germany, India, Italy, Mexico, and USA. It produces mosaic, green blistering, leaves and fruit malformation in *Cucumis sativus*, *Cucurbita pepo*, *Citrullus lanatus*, *Cucumis melo*, *Melothria pendula* and *Momordica charantia* hosts. WMV-1 is known to be transmitted by insect vectors in a non-persistent manner such as *Myzus persicae*, *Acyrtosiphon* (Aulacorthum) *solani*, *Aphis craccivora* and *Macrosiphum euphorbiae*. The virus is transmissible through mechanical inoculation but there are no reports of transmission by seed. The virus has a thermal inactivation point (TIP), longevity in vitro (LIV) and dilution end point of 60°C, 40-60 days, and 10⁻⁴ to 10⁻⁵, respectively. It produces inclusions in infected cells in the form of amorphous Xbodies and pinwheels which do not contain virions. Only a few families of plants are infected by WMV-1 and cucumber isolate could not infect papaya (*Carica papaya*) under natural conditions. Natural infection of WMV-1(=PRSV-W) is reported from Cucurbitaceae and Leguminosae hosts.

Raj *et al.* (2010) observed a severe yellow mosaic disease with a significant disease incidence on bottle gourd (*Lagenaria siceraria*.) during a survey of different locations around Gorakhpur, Uttar Pradesh, India in 2008. They confirmed the association of *Pepper leaf curl Bangladesh virus* strain with bottle gourd yellow mosaic disease.

Khan *et al.* (2002) reported leaf curl symptoms on bitter melon (*Momordica charantia*) consisted of upward curling, shortening, and distortion of leaves. Diseased melon fruits were stunted and deformed.

CMV was first reported by Jagger (1916) and Dolittle (1916) as the causal agent of plant diseases. Bhargava (1951) first reported CMV as causal agent of mosaic in summer squash. Infection of 25 per cent samples of summer squash by CMV was reported by Bansal and Singh (1990).

2.2 Symptomatology

A symptom of plant disease is a visible effect of disease on the plant. Symptoms may include a detectable change in color, shape or function of the plant as it responds to the pathogen. Leaf wilting, mosaic, leaf curling, stunting, spot,

leaf blight, mildew and mottle etc. You are not actually seeing the disease pathogen, but rather a symptom that is being caused by the pathogen.

Zhang *et al.* (2015) observed downy mildew, powdery mildew and fusarium wilt diseases on bitter melon. The symptoms of downy mildew first appear as small, water-soaked, yellow, angular lesions on the upper surface of the leaves that are restricted by the leaf veins. In later stages of infection, infected tissues become bright yellow and the center of the lesions turns brown. Under high humidity, whitish to gray powdery growth may appear on the lower leaf surface. The disease spreads rapidly, resulting in defoliation and death if not controlled. The typical symptoms of powdery mildew appear as white powdery residue primarily on the upper leaf surface. On the lower leaf surface, symptoms occur as circular patches or spots. Powdery mildew symptoms on foliage at early stages are very similar to downy mildew, which often makes it difficult to identify the disease accurately. It is always wise to seek a laboratory diagnosis in order to identify the pathogen correctly. In severe cases, these spots spread, coalesce, and cover both surfaces of the leaves, then spread to other parts of the plant. Severely affected foliage becomes brown and shriveled, and defoliation may occur. Fruits of the affected plants do not develop fully and remain small. Initially, runners show symptoms of temporary wilting that become permanent over time. The problem often develops progressively and affects more vines. The leaves of the infected plants become yellow and wilt. Eventually, the plant dies. In older plants, leaves wilt suddenly, and when stems are cut, vascular tissues in the xylem appear yellow or brown.

2.2.1 Downey mildew

Downy mildew (*Pseudoperenospora cubensis*) is an extremely destructive disease of cucurbits. It occurs practically on all the cultivated cucurbits. The disease is confined mostly to the leaves, although the fruit of infected plants may be of poor quality resulting from the loss of foliage.

The first symptoms of *P.cubensis* infection in Cucurbitaceae are pale-yellow, oily lesions on the upper side of the leaf, sometimes restricted by leaf veins which are described as angular leaf spots (Lebeda 1986)

Thomas (1996) reported downy mildew of cucurbits is a foliar disease, and is easily recognizable by the development of chlorotic lesions on the adaxial leaf surface, sometimes with necrotic centers. These lesions can be restricted by the leaf vein, as in cucumber, giving them an angular appearance. In other cucurbits, the symptoms may vary slightly in terms of shape and colour. For example, in both melon and watermelon, foliar lesions are less defined than those on cucumber, and are not always bound by leaf veins. As infection progresses, the chlorotic lesions expand and may become necrotic (Oerke *et al.*, 2006), with necrosis occurring more quickly in hot, dry weather (Cohen and Rotem, 1971c). Leaves colonized by *P. cubensis* undergo changes in temperature and transpiration rates, which vary during the course of infection and over the leaf surface (Lindenthal *et al.*, 2005; Oerke *et al.*, 2006)

Lebeda and Schwinn (1994) *P. cubensis* causes irregular, localized, yellow lesions restricted by leaf veins whereas in cantaloupe and watermelon, lesions are not restricted by leaf veins and are more circular and irregular. Unlike some other members of the Peronosporaceae

Rai and Yadav (2005) Symptoms appear on upper surface of the leaves as angular yellow spots. During favorable condition, the undersides of these spots are covered with a grayish mouldy growth. The yellow spots on the upper portion of leaves, it appear just like in definite mosaic pattern lesion on the upper surface, As the spots enlarge, a general yellowing of the leaves occurs followed by the death of the tissue. The leaves subsequently wither and die

2.2.2 Powdery mildew

Vakalounakis *et al.* (1994) reported that both *Erysiphe sp.* and *Sphaerotheca fuliginea* were characterized by circular, talc-like powdery spots on the foliage. These spots expand until the entire surface is covered. Under severe conditions, stems, petioles and tendrils were affected.

Walker (1952) described the symptoms of the disease as tiny, white, round, Superficial spots on stems and leaves of cucumber, squash, cantaloupe, becoming Powdery as they enlarge. These white lesions increase in number and coalesce and eventually may cover the stems and both surfaces of leaves. Infection on young leaves may result in general chlorosis and eventually death of the leaves.

Severely affected leaves become brown and shriveled. Under ideal conditions premature defoliation may occur as the fungus covers the leaf surfaces. Black pin point bodies the cleistothecia rarely occur but are conspicuous when they do occur. Fruits of cucumber, bottle gourd, cantaloupe and squash are free of visible infection, even when the foliage is heavily infested though fruits may ripen prematurely and lack flavor.

Sharma (1984). Powdery mildew fungi produce a conspicuous white to grayish growth of mycelium on the surface of diseased plant parts. Conidia or spores of the fungi are produced on the mycelium

Masood *et al.* (2013) reported that powdery mildew is a serious disease of cucurbits, including melon, bottle gourd, pumpkin, squashes and cucumber. Powdery mildew is first seen as white powdery spots on both sides of the leaves, shoots, and sometimes the flowers and fruit. Small spots then join together to form larger patches of white mildew. Infected leaves yellow, die, and fall off. This exposes the fruits to the sun, which can result in sunburn. Older leaves are affected first. Severe attack reduces yield, and fruit quality is low.

2.2.3 Leaf blight

Leaf spots first appear on the older leaves in the middle and upper part of the plant. The spots start as small, necrotic flecks. They enlarge and contain concentric rings and are surrounded by a yellow halo. Other parts of the plant are not directly affected. An indirect effect is seen the fruit production. *Alternaria* leaf spot may cause reduced yield and smaller fruit.

Maheshwari *et al.* (2017) Characteristic symptoms first appear as small, circular and light to reddish brown spots, which latter enlarge in a concentric manner. Lesions often coalesce to form larger necrotic areas and in the centre of the spot, olivaceous sporulation occurs. So far, information available on disease management of *Alternaria* leaf blight of bottle gourd under hot arid condition is scanty. Keeping in view, the present study was undertaken to aware the management of *Alternaria* leaf blight of bottle gourd in Western Rajasthan.

Gannibal (2011) The observed leaf spots were up to 8-12 mm in diameter with a round grayish to pale brown centre and dark brown edges. Up to 30% of the surface area of older leaves was affected by the disease. Fungal isolates with

morphological characteristics similar to those of *A. cucumerina* were collected from diseased leaves.

2.2.4 Mosaic and leaf curl

.Chalam *et al.* (2003) reported the occurrence of Zucchini yellow mosaic disease on summer squash from Uttar Pradesh, India. Summer squash plants showed symptoms of mosaic, vein clearing, leaf distortion and reduction in fruit size.

Sohrab *et al.* (2010). It is a first *Begomovirus* and causes severe disease in bottle gourd in India. The affected plants are severely stunted and bear very small chlorotic and mildly curled leaves. It is transmitted by white fly and to manage the virus, vector control is essential.

Kim *et al.* (2010). A putative Potex virus was detected from bottle gourd in Burma showing mosaic and mottle symptoms in Myanmar in 2007.

Ali *et al.* (2010) reported *Tomato leaf curl Palampur virus* on Bottle gourd in Pakistan and observed that Symptoms of the disease included chlorosis, leaf crumpling, vein thickening, and stunting of plants that were suggestive of a virus infection.

Ashwini *et al.* (2016) reported that the initial symptoms of bitter gourd mosaic developed on newly emerged leaves after 21 days of inoculation. Mosaic accompanied with yellowing was the initial symptom this was followed by vein clearing and mild curling. Leaf distortion and shoestring appearance were the prominent symptoms observed in later stages of infection. Necrosis of the infected leaves was also observed in severely infected plants. Leaf size of the infected plants was drastically reduced as compared to the healthy plants. Similar symptoms were reported *sulphureus*, on mechanical inoculation of CMV.

Tiwari *et al.* (2010) the most characteristic symptoms in the early stage of the disease were yellow mosaic followed by curling of leaves. However, in case of severity of the disease, extensive chlorosis and vein banding was also noticed.

2.3 Host range

The capacity of pathogens to infect a large set of host species, i.e. to possess a large host range of the species. Host range of plant parasites has been used for decades as observed for the entire dataset,

2.3.1 Downy mildew

Colucci and Holmes (2010) reported that forty species in 20 genera within the Cucurbitaceae are known to be hosts to *P. cubensis*. Downy mildew on *Cucumis* spp., including cucumber and true melons, alone has been reported in 70 countries. While it has the widest distribution on all continents on the genus *Cucumis*, downy mildew is common on *Cucurbita* crops, including squashes and pumpkins, in Australia, North America and the Pacific region and occurs less commonly in Asia and Africa. Downy mildew is virtually absent from *Cucurbita* in Europe. Downy mildew is widely distributed on *Citrullus* spp., including watermelon, in the Americas but scattered elsewhere and absent in Europe and the Middle East, even though the climate is similar to areas where the disease is a severe problem. The disease is found on *Luffa* only in Southeast Asia

Salati *et al.* (2010) conducted an experiment to evaluate the host range of cucurbit downy mildew in Malaysia. A total of 29 isolates of *Pseudoperonospora cubensis* were collected from various cucurbit farms in West Malaysia. Sporangia of 13 isolates had the ability to germinate at 14 °C and were used for host range (pathotype) study using leaf disc assay on a set of twelve cucurbit cultivars. Twelve different pathotypes of *P. cubensis* were determined and this demonstrated that *P. cubensis* isolates from cucurbit farms in West Malaysia are highly variable. Based on the host range study, majority of *P. cubensis* isolates were categorized into medium and high pathogenicity groupings and this fact shows the potential of this pathogen in invading cucurbit fields in the tropical regions. However, the pathotypes could not be differentiated based on morphological characterization of the sporangia and sporangiophores. Therefore, molecular characterization of the 13 isolates of *P. cubensis* will be useful to study the relationships among them.

Pseudoperonospora cubensis has a broad host range, infecting over 49 species in 20 genera within the Cucurbitaceae, including 19 species in the genus *Cucumis* (Lebeda and Widrlechner, 2003; Palti and Cohen, 1980). Cucumber (*Cucumis sativus* L.), melon (*Cucumis melo* L.), watermelon (*Citrullus lanatus* Matsum. And Nakai) and squash (*Cucurbita* spp.) are the four major food crops that are hosts to *Ps. cubensis*. Other cucurbits infected by *P. cubensis* include loofa [*Luffa acutangula* (L.) Roxb.], bottle gourd [*Lagenaria siceraria* (Molina) Stand.],

wax gourd [*Benincasa hispida* (Thunb.) Cogn.] and bitter melon (*Momordica charantia* L.) (Palti and Cohen, 1980).

2.3.2 Powdery mildew

Patel *et al.* (2010) *Sphaerotheca fuliginea* was dominantly present on *Cucurbita maxima*, *Lagenaria siceraria* and *Cucurbita pepo*, where as *Erysiphe cichoracearum* noted on *Citrullus lanatus* was not reported in 2005 and 2006. *Cucurbita maxima*, *Lagenaria siceraria*, *Luffa acutangula* and *Luffa cylindrica* showed maximum occurrence of *Sphaerotheca fuliginea* in the rabbi season. Incidence of powdery mildew was mainly reported on the mature leaves followed by stem. Where as in some cases it was reported on tendril, flower and fruit.

McCreight (2011) The two powdery mildew fungi most frequently reported to cause disease on field and greenhouse cucurbit crops are *Podosphaera xanthii* and *Golovinomyces cichoracearum* Both pathogens belong to the family Erysiphaceae consisting of 16 genera and approximately 650 species (Braun *et al.*, 2002).

2.3.3 Leaf blight

Alternaria cucumerina is an important pathogen of some *Cucumis*, *Cucurbita*, *Lagenaria siceraria* and *Citrullus* species with a wide distribution, including several European and Asian countries (Ellis, 1971)

The fungus has been found in the Far East of Russia on *Cucumis melo*, *Cucumis sativus*, and *Citrullus lanatus* (Egorova, 1999)

2.3.4 Mosaic and leaf curl

ZYMV, a member of the genus *Potyvirus* in the family Potyviridae, is one of the major viruses of cucurbits. Cultivars of *Cucurbita pepo* L., *Cucumis melo* L., and *Citrullus lanatus* (Thunb.) Matsum. & Nakai are particularly affected. However, other cucurbits, including bottle gourd, *Lagenaria siceraria* (Mol.) Standl., are also infected easily by ZYMV.

Bhargava and Bhargava (1977) in a survey of viruses attacking cucurbits in Gorakhpur area of Uttar Pradesh noted that pumpkin yellow-vein mosaic virus, pumpkin mosaic virus, *cucumis virus 3* (cucumber green mottle mosaic virus), 3

strains of *cucumber mosaic virus* and 7 of *watermelon mosaic 18 virus* affecting 7 cultivated and 2 wild cucurbits were widely spread.

2.4 ETIOLOGY

The investigation or attribution of the cause or reason for something, often expressed in terms of historical or mythical explanation.

2.4.1 Downey mildew

Wallace *et al.* (2014) reported sporulation of *Pseudoperonospora cubensis* on the abaxial side of the leaves was observed and a compound microscope revealed sporangiophores (180 to 200 μm height) bearing lemon-shaped, dark sporangia (20 to 35 $\times$ 10 to 20 μm diameter) with papilla on one end.

Neufeld (2012) *Pseudoperonospora cubensis* is a biotrophic foliar pathogen that infects many species of the family Cucurbitaceae. The disease was first described by Berkeley and Curtis in herbarium plant material from Cuba in 1868. members of *Peronospora* have sporangia that germinate directly via a germ tube where as within *Pseudoperonospora*, sporangia germinate indirectly via cytoplasmic cleavage to produce zoospores (Palti and Cohen, 1980). Sporangia of *P. cubensis* typically are grey to purple in color, lemon-shaped with a papilla at the distal end and measure about 20 to 40 $\times$ 14 to 25 μm in diameter (Lebeda and Cohen, 2011).

Colucci and Holmes (2010) *Pseudoperonospora cubensis* is a fungal-like organism that belongs in the Kingdom Straminipila and Phylum Oomycota. *Pseudoperonospora cubensis* is a member of Peronosporaceae (the downy mildew family) in the order Peronosporales within the class Oomycetes. Like other downy mildew organisms, *P. cubensis*, is a biotroph or obligate parasite, meaning that the organism requires living host tissue to grow and reproduce. The organism cannot be propagated on artificial media. The intercellular mycelium is hyaline (colourless, transparent) and coenocytic (aseptate). The mycelium develops in the mesophyll, but also penetrates the palisade tissue. The hyphal diameter is 5.4-7.2 μm . Haustoria are formed within the host cells and allow for the absorption of nutrients. Haustoria are varied in shape and appear stunted, inflated or as branched clusters of hyphae. *Pseudoperonospora cubensis* forms large (20-40 $\times$ 14-25 μm in diameter), lemon-shaped sporangia with a conspicuous papilla. Sporangia appear

smooth under the compound microscope, but with the scanning electron microscope the finely decorated surface of the sporangium is evident. The sporangia are borne singly on the pointed tips of sporangiophores that branch at acute angles. The sporangiophore ranges from 180-600 μm in height, 20 μm in diameter and 5-7 μm in width. Moisture prompts the sporangia to release 5 to 15 asexual, ovoid zoospores that measure 10-13 μm in diameter. The zoospores are biflagellate, with one posterior whiplash and one anterior tinsel flagellum. The purpose of the flagella is to assist the zoospores as they swim through free moisture on the leaf surface to a stomate. Once a stomate is located, the zoospore will encyst (produce a cell wall) and then form a germ tube (50-95 μm), which will penetrate the stomate and infect the host plant cell. Sexual reproduction and formation of oospores in *P. cubensis* are rare. Oospores have only been reported from India, China, Italy, Japan and Russia and their germination was not observed. Oospores could function as survival structures when living hosts are not present, but this has not been demonstrated.

3.4.2 Powdery mildew

Liu and Kirschner (2015) observed the mycelium of *Podosphaera xanthii* was amphigenous on the leaves, with hyphae thin walled, smooth or almost so, and 5 to 8 μm wide. The appressoria were indistinct to slightly nipple shaped, and solitary. The conidiophores arose mostly from one end of the mother cell but sometimes centrally, and were erect, straight, smooth to slightly rough, 48 to 200 $\times$ 7 to 17 μm , composed of a cylindrical, rarely somewhat flexuous footcell, slightly rough, 30 to 70 $\times$ 9 to 12 μm , and following 1 to 4 shorter cells. The conidia were catenate, ellipsoid, ovoid, doliform to subcylindrical, 24 to 33 $\times$ 3 to 19 μm , and contained fibrosin bodies when fresh. These characteristics fit those of *Podosphaera xanthii*.

Singh (2009) reported that the young cleistothecia are globose and at first white, then brown and finally black when mature. The mature cleistothecia also have several mycelioid appendages, which are flaccid, indefinite hyphae arising from cells of the cleistothecium. The cleistothecia are more or less buried in the mycelia wefts on the plant tissues. The ascospores continue to develop during the falls and in spring they are mature and ready for dissemination. In spring, the

cleistothecia absorb water and crack open. The single ascus in each cleistothecium protrudes its tip, bursts open and discharges its mature ascospore, which are carried away by the wind. The ascospores are about the size of conidia and behave exactly like conidia with respect to germination, infection, and formation of subsequent structure. Single conidia, called hyaline, are borne singly and measuring 20.25-27.9 (24.1) $\times$ 13.5-18.0 (14.25) μm . Cleistothecia are dark, spherical appendage myceloid, measuring 90-180 μm in diameter; cleistothecia contain a single ascus measuring 50.75-74.50 (61.80) $\times$ 49.50 –67.50 (57.44) μm , single ascospore, called hyaline, spherical, 6-10 per ascus and measuring 11.12-20.25 (14.62) $\times$ 9.0 – 15.75 (11.25) μm .

Bosco (2006) observed both, asexual stage (conidia) and sexual stage (Cleistothecia) were present on the infected muskmelon plants. The conidia together with cleistothecia were present during the period from November to March, where as only cleistothecia were detected in October and April. Morphologically, the fruiting structures i.e. cleistothecia were sub globosely light brown to dark black in color, oval, round to semi round and sometime sub cylindrical in shape with myceloid appendages. On the other hand, the newly infected leaves were found bearing conidia and conidiophores. The conidia were in chain on conidiophores and sometimes were seen detached into separate conidia. Conidiophores measured 107.98 μm long and 12.97 μm thick bearing conidia which measured on average 29.9 μm long and 15.06 μm thick. The average mature cleistothecia were calculated to measure 117.47 $\times$ 95.07 μm .

Gupta *et al.* (2001) observed the anamorphic and teliomorphic characters of *Sphaerotheca fuliginea* (Schlecht.) Pollaci., causing powdery mildew of cucumber. The anamorphic characters revealed that the mycelium was ectophytic, conidiospores were unbranched and aseptate with a cylindrical foot cell. Conidia were ellipsoidal in shape and arranged in long chains in basipetal succession. The size of the conidia was about 34.43 $\times$ 20.77 μm when observed under high power (450 x). Length/ Breadth (L/B) index value was less than 2 (mostly 1.6). About 90.24 per cent conidia exhibited the presence of fibrosin bodies and an average number of fibrosin bodies per conidium were 6.4. Germination of conidia was observed to be 44.90 per cent. Observations on germ tube morphology revealed that

germinating conidia produced two types of germtubes i.e. simple and forked, which emerged laterally from the sidewall of the conidium. Conidia bearing simple or forked germ tubes were 34.15 and 65.85 per cent, respectively. Appressorial formation was found to be absent in all the samples examined. Teliomorphic characters revealed that the cleistothecia were scattered to densely gregarious, globular, brown, $62.01-79.08 \times 52.72-76.76 \mu\text{m}$ size. Appendages variable in number, usually as long as the diameter of the ascocarp, sometimes longer, myceloid, brown, attached at the base of the cleistothecium. Ascus single, elliptical, subglobose, $54-80 \times 4565 \mu\text{m}$, containing 8 ascospores, ellipsoid to nearly spherical, $17-23 \times 12-20 \mu\text{m}$ in size.

Tores *et al.* (1990) reported that the two fungal species *Sphaerotheca fuliginea* (Schlecht. ex Fr.) Poll and *Erysiphe cichoracearum* DC ex merat. have been referred to as the causal agents of powdery mildew. However, recent work showed that in the last years only *S. fuliginea* has been detected.

2.4.3 Leaf blight

After seven days, large solitary conidia were formed on the surface of the agar. The average size of the conidia was $70-94 \times 22-25 \mu\text{m}$ with a conidial beak length of $40-45 \mu\text{m}$. In general, these measurements are within the size range determined by Immons (2007) for *A. cucumerina*. On potato-carrot agar, the conidial body was smaller ($43-70 \times 16-20 \mu\text{m}$), whereas the beak was appreciably longer ($70-220[-284] \mu\text{m}$).

2.4.4. Mosaic and leaf curl

Astier *et al.* (2007) particles of *Cucumber mosaic virus* (CMV) is of 25 nm with isometric symmetry. The capsid is made up of 180 subunits. Nucleic acid is positive sense single stranded RNA, which is tripartite in nature. Three species of *Cucumber mosaic virus* (CMV) are described. Mechanical transmission is possible. It can be transmitted by aphids (more than 75 species) in the non persistent mode, as well as through the seed in some species.

ZYMV is a member of the potyvirus genus (Hollings and Brunt; Murphy *et al.*, 1995). The flexuous filamentous particles, 750 nm long (Lisa *et al.*, 1981) consist of a single-stranded RNA about 9600 nucleotides long (Balint *et al.*, 1990) with a 5' viral protein genome linked (VPg) and 3' poly (A) tail encapsidated in a

36kDa coat protein. The RNA is translated as a single polypeptide cleaved by three viral proteases (Riechmann *et al.*, 1992, Shukla *et al.*, 1994).

2.5 Epidemiology

Epidemiology is the study and analysis of the distribution (who, when, and where) and determinants of health and disease conditions in defined populations.

2.5.1 Downy Mildew

Grabowski (2016) reported that downy mildew can start an infection in a wide range of temperatures (41-86°F) but is most severe from 59-68°F. The pathogen needs moisture on the leaf surface in order to germinate and start a new infection. Under humid conditions downy mildew rapidly reproduces and spreads, resulting in severe crop damage. The pathogen can move on air currents, splashing water and on the tools and hands of workers.

Neufeld (2012) sporangia are easily dislodged from sporangiophores and dispersed by rain or air. Following germination of sporangia, the development of zoospores is dependent upon environmental conditions, especially temperature and moisture. Once sporangia are dislodged from the tips of sporangiophores, their lifespan is not usually longer than 48 h. Dispersal of sporangia onto susceptible host tissue is required during this time period for germination to occur. At higher temperatures (35°C and 40°C) and humidity combinations (84 to 90%), infectivity of sporangia decreases. However, in presence of low humidity (5 to 28%), infectivity of sporangia is maintained even at higher temperatures. Contact with moisture is required for the germination and release of zoospores from sporangia. Germination of sporangia will be disrupted when they are exposed to a dry period for 10 to 15 min.

Shishid (2011) reported that temperature ranges from 20-25 °C and high relative humidity favour downy mildew (*Pseudoperonospora cubensis*) severity in cucumber and melon. However low relative humidity and 25°C temperature favour incidence and severity of powdery mildew (*Sphaerotheca fuliginea*) in cucumber and melon

Celetti and Roddy (2010) reported that downy mildew of cucurbits is favoured by cool, wet and humid conditions. The pathogen produces microscopic sac-like structures called sporangia over a wide range of temperatures (5°C - 30°C).

Optimum sporangia production occurs between 15°C - 20°C and requires at least 6 hours of high humidity. Sporangia are easily transferred to healthy plant tissue by air currents or splashing rain. High relative humidity sporangia burst open and release many zoospores. The disease may progress slowly or stop temporarily when temperatures rise above 30°C during the day time. Night time temperatures of 12°C - 23°C will promote disease development, especially when accompanied with heavy dews, fog or precipitation. With night time temperatures around 15°C and daytime temperatures around 25°C, downy mildew infections on cucurbits produce more sporangia within 4 days.

3.5.2 Powdery Mildew

Lopez *et al.* (2012) reported that in general, high moisture and temperature must be favourable and act together in the initiation, development of plant diseases, as well as germination and proliferation of fungal spores of the vast majority of pathogens. Moreover, powdery mildew conidia are anomalous in their ability to germinate in low moisture. Some do so even at 0 % relative humidity (RH) that is conidias of *Erysiphe cichoracearum* germinate from 7 to 32°C with a RH of 60 to 80%. Spores of *Erysiphe necator* germinate at temperatures from 6 to 23°C with a RH from 33 to 90 %.

Bosco (2006) reported that although powdery mildew infection can occur at temperatures of 59 to 90°F, temperatures of 68 to 77°F are optimal for infection and disease development. Temperatures above 95°F inhibit germination of conidia and temperatures above 104°F kill them, while high relative humidity is conducive to production of conidia. Atmospheric moisture in the range of 40% to 100% relative humidity is sufficient for germination of conidia and infection, but free moisture, especially rainfall, is detrimental to the survival of conidia.

Gupta *et al.* (2001) recorded severity of powdery mildew on cucumber plants at weekly intervals during 1997 crop season starting from the last week of June. Simultaneously, meteorological data on temperature, relative humidity, cumulative rainfall and sunshine hours were also recorded for the intervening period between two consecutive disease data recordings and simple, partial and multiple correlations among disease severity and above four independent factors were worked out. The perusal of simple correlations revealed highly significant

and positive correlation between powdery mildew severity, mean relative humidity and cumulative rainfall. However, correlation coefficient between mean temperature and disease severity was found to be significant and negative while it was positive but non-significant with sunshine hours. Partial correlation between disease severity and sunshine hours was highly significant and negative (-0.7041). Similarly, mean relative humidity showed significant and positive partial correlation with disease severity (0.6392), while that of mean temperature and cumulative rainfall with disease severity were found to be positive but non-significant.

2.5.3 Leaf blight

Mikhailova *et al.*, (2002) then incubated at 24°C under a light/dark cycle (12/12h). Cucurbit plants in leaf stage were sprayed with conidia of *alternaria cucurnima* incubation at 16-28°C in 100% relative humidity with wetted leaves for 24 hrs. was required for infection temperature above 12 °C during night hrs. along with wetted leaves were necessary for disease development (standberg, 1988)

2.5.4 Mosaic and leaf curl

Alonso-Prados *et al.* (2003) reported that maximum temperature particularly, with the average of the mean temperature was positively correlated with epidemics of both the viruses viz. *Cucumber mosaic virus* (CMV) and *Watermelon mosaic virus -2* (WMV-2). However, there was negative correlation between epidemics of CMV and precipitation (rainfall) during spring season. In winter and spring WMV-2 was negatively correlated with minimum temperatures. The fact that spring temperatures were positively correlated with epidemics of both viruses could be explained by the build up of aphid populations vectoring both viruses.

Tripathi and Varma (2002) observed a high degree of leaf curl disease (LCD) incidence (83%) in the winter tomato planted in October as compared to the summer crop planted in February where only 14% incidence of LCD was recorded. During the summer crop whitefly population was less at the initial stages of the crop, whereas during the winter crop the whitefly population was very high at the similar stages of the crop. This variation in the whitefly population was due to the differences in temperature and relative humidity

Purcifull *et al.* (1984) observed that ZYMV had flexuous filamentous particle. It was found to be transmitted both by sap as well as by the aphid *Aphis citricola* in a non-persistent manner. The biophysical properties of the virus included thermal inactivation point (TIP) of 55-60°C, longevity in vitro was between 3 days and 5 days at room temperature and dilution end point (DEP) was 1:10000 -1:100000..

2.6 Effect of various seed treatments on seedling parameters

Sharma *et al.* (2015) reported that seed treatment of crop seeds with fungicides found to speed up germination process, increased germination rate and seedling vigour, improved resistance to water and salinity stress and increased crop yields.

Tsai *et al.* (1992) reported that the most effective fungicides for treating seedlings before inoculation were metalaxyl + mancozeb and chlorothalonil

Dhanamanjuri *et al.* (2013) carried out in relation to treatment of the seeds *Cicer arietinum* and *Zea mays* with various concentrations of fungicides. Effect of fungicides on the seed germination, growth and biomass production of *Cicer arietinum* and *Zea mays* were observed *in vitro*. The fungicides (*i.e.* Captan, Bavistin, Domarck, Blitox and Sitara) solution for growing the seeds with the following concentrations were used; 1 ppm, 10 ppm, 50ppm and 100 ppm were taken to observe their growth promoting/ inhibiting effects on the Maize and gram seeds on their germination and growth (radicle and plumule). The data obtained indicates that germination percentage of seeds and biomass production were slightly affected with the differences in the two crops under investigation. The fungicide Bavistin (Carbendazim) at 10 ppm concentration was the best among the treatments of *Cicer arietinum* while in case of *Zea mays*, 1ppm concentration of Bavistin (Carbendazim) has shown better stimulating effect on the seed germination and plant growth (radicle and plumule) as compared to Control. Significant differences in the growth values of seeds between treated and control plants were observed.

Kumar *et al.* (2018) seed treatment with seed pro @ 25g/kg, carbendazim 12%+ mancozeb 63% @ 3g/kg, which found significantaly plant growth flowering fruiting yield of bitter gourd

2.7 Varietal screening

Ling (2007) the 190 *L. siceraria* PIs screened, 36 accessions were in complete resistance (no disease symptom with negative ELISA on all tested plants), 64 PIs showed partial resistance (some of the tested plants were resistant, whereas others were susceptible), and 90 PIs were susceptible (severe symptom and positive ELISA on all tested plants). The ZYMVFL resistance exists mostly among *L. siceraria* PIs collected in India. Thirty-three of the 36 *L. siceraria* PIs showing ZYMV-FL resistance were collected in India, one in Indonesia, one in South Africa, and one in Zimbabwe. To rule out any potential escapes in the primary screening, a repeated test using representative accessions, including 10 susceptible, three partially resistant, and three completely resistant PIs, was done to confirm the ZYMV-FL resistance. Furthermore, the resistance to ZYMV-FL was shown to be heritable in progenies generated through self-pollination of single plants in each of five resistant PIs as well as in three F1 hybrids.

The cultivar BL240 had the lowest disease index for *P. cubensis* incidence reported (Thakur *et al.*, 1996). Hybrid BTH-7, BTH-165 and Phule Green, RHR BGH 1 are tolerant to downy mildew (Rai and Yadav, 2005).

Akbar *et al.* (2015) screened seventeen cucumber germplasm against *Cucumber mosaic virus*. Seeds of these germplasms were sown in earthen pots in which fourteen germinated and exhibited characteristics symptoms of the virus. Out of fourteen germinated germplasms nine (Punjab, Beitalpha, pointpett-76, Baran, Local green, Summer green, Diomond 2F l, Sahill and Kumar) showed moderately susceptible reaction remaining (Khyber, Yousaf, VEGAF1, Diamond and Waleed) showed highly susceptible reaction.

Metwally and Rakha (2015) conducted a study to identify sources of resistance to downy mildew among Plant Introduction (PI) cucumber accessions from the U.S. National Plant Germplasm System. They evaluated 133 such accessions for downy mildew resistance under natural field epidemics during the summer 2013 at El-Beheira Governorate, Egypt. Mean ratings for downy mildew leaf damage ranged from 1 to 9 on a 0 to 9 scale. They classified 18 PI accessions (13.5%) as highly resistant (rating of 1.0–2.0), 46 (34.5%) as moderately resistant (rating 2.1–4.0), 40 (30%) as intermediate (rating 4.1–6.0), 12 (9%) as moderately

susceptible (rating 6.1–7), and 17 (13%) as highly susceptible (rating > 7.1). The most resistant PI accessions were PI 432870, PI 432873, PI 432878, PI 432884, and PI 432886 with a rating of 1, which originated from China. The most susceptible PI accessions were Ames7736, PI 211979, PI 288991, PI 288992 and PI 289698 with a rating of 9. The five most resistant and five most susceptible accessions were further evaluated in replicated experiments during the summer 2014. Results from the repeated test confirmed the results from the first screening. No PI accession was found immune to downy mildew. However, high levels of resistance were observed in several PI accessions that could be useful for the breeding for resistance to *P. cubensis* in cucumber.

Call *et al.* (2012) evaluated 86 cultivars and breeding lines of cucumber (hereafter collectively referred to as cultigens) for downy mildew in Clinton, NC, in 2007 and 2009, in Castle Hayne, NC, in 2008 and 2009, and in Bath, MI, in 2007 to 2009. Plots were rated weekly on a 0 to 9 scale (0 = none, 1–2 = trace, 3–4 = slight, 5–6 = moderate, 7–8 = severe, and 9 = dead). Mean ratings for downy mildew leaf damage ranged from 2.9 to 5.7 in Michigan in 2008 and 2009 and from 3.8 to 6.8 in North Carolina in 2007 to 2009. None of the cultigens tested in this study showed a high level of resistance, although differences in resistance were detected. Lines WI 2757 and M21 and cultivar Picklet were consistently among the top resistant lines in North Carolina and Michigan. The cultivars Coolgreen, Wis. SMR 18, and Straight 8 were identified as moderately to highly susceptible. An unreleased hybrid, ‘Nun 5053 F1’, and the cultivar Cates were the top yielding lines overall. The highest yield in a single year and location was from the cultivar Cates in Clinton, NC, in 2009, with 25.6 Mg ha⁻¹. The best cultivars in this study were only moderately resistant and would likely require fungicide applications to achieve high yield and quality in the presence of downy mildew. Until high resistance becomes available, growers would benefit by using fungicides in combination with tolerant and moderately resistant cultigens.

Zitter and Murphy (2009) suggested that development of genetic resistance is the simplest and most effective method of controlling virus diseases and is especially appropriate for *Cucumber mosaic virus*.

Yasmin *et al.* (2008) evaluated sixty two germplasm of sweet gourd against powdery mildew caused by *Erysiphe cichocearum* under field condition. Four lines of sweet gourd namely BD 4388, BD 204, BD 205, BD 210 were found resistant to powdery mildew.

Jain and Sharma (2001) evaluated eight multiple disease resistance genotypes of *Cucumis melo* viz. Honeydew, MR-1, Nantais Oblong, Ogon-9, PMR-5, PI 414723, Topmark bush, and WMR-29 to Fusarium wilt by soil inoculation method under artificial condition. PDI was <25% for all 8 genotypes, and they were therefore classified as Fusarium resistant genotypes.

Thomas and Jourdain (1992) conducted field evaluations for resistance against downy mildew, incited by *Pseudoperonospora cubensis* [(Berk. and Cart.) Rostow], on 942 U.S. Plant Introductions (PI) of *Cucumis melo* L. A disease index (DI) was calculated for each entry. Based on DI, PI 124112 was highly resistant (DI = 3.7), and PIs 124111, 122847, 124210, 145594, and 165525 were resistant (DI = 3.0, 2.8, 2.6, 2.7, and 2.5, respectively). PIs 124111 and 124112 had one or more plants that exhibited a highly resistant reaction type (RT 4). Resistant (RT 3) plants were identified in 31 accessions, and 49 accessions had moderately resistant (RT 2) plants.

2.8 Cultural practices

Watson (2009) suggested that use of tolerant varieties, white plastic mulch, roughing of infected plants, and destruction of collateral host plant and application of suitable insecticide may considerably reduce the yield loss due to mosaic in watermelon.

Damicone *et al.* (2007) successfully controlled aphid-transmitted, nonpersistent virus diseases on pumpkin, caused mostly by the *Potyvirus*es Watermelon mosaic virus (WMV) and Papaya ringspot virus type-W (PRSV-W) by intercropping with grain sorghum, as opposed to clean tillage in five field trials over 3 years. Reductions in disease incidence ranged from 43 to 96% ($P \leq 0.05$). Surrounding pumpkin plots with borders of peanut, soybean, or corn was not effective. Borders of grain sorghum were effective, but disease control was generally less than for the intercrop treatment. Intercropping soybean and peanut with pumpkin reduced disease incidence by 27 to 60% ($P \leq 0.05$), but disease

control generally was less than for grain sorghum. Peak periods of alate aphid immigration generally preceded virus disease outbreaks by 7 to 14 days. However, a late landing rate, as measured in green tile traps, did not differ among treatments. Marketable yield was not increased by the intercrop treatments, and yield was reduced by up to 50% for the intercrop treatment with grain sorghum in two trials.

Bhokare and Ranpise (2004) observed the effects of different training systems, *i.e.* ground, bush (dry bamboo sticks along with thorny branches), kniffin and bower (both prepared with iron angles and galvanized iron wire), on the incidence of major diseases and on the yield of bottle gourd. Except for the ground training system, vines were trained on the support. The bower system had significantly less incidence of diseases, *i.e.* powdery mildew (23.80%) and downy mildew (30.80%), as well as the highest number of fruits per plant (30.46%), longer and dark green fruits, and maximum yield (78.25 q/ha). The percentage of increase in yield over the ground training system was 71.83, 200.65 and 243.80% in the bush, kniffin and bower systems, respectively, which was attributed to low incidence of diseases.

Tripathi and Varma (2002) observed that least incidence of the leaf curl disease (LCD) was found in polythene mulch (PM) treatment and in perforated polythene cover (PC) treatment as compared to the other treatments. The use of polythene bags to cover tomato plants (PC) and polythene sheets as mulch (PM) were found most effective in reducing the disease incidence and promoting the growth and yield of tomato plants as compared to other treatments.

Green and Kali (1994) suggested that tomato yellow leaf curl can be effectively controlled by use of reflective mulches, mixed cropping with plants more attractive to the vector, elimination of collateral and alternate host plants which may serve as virus reservoirs and adjusting the date of transplanting so that it does not coincide with higher vector population.

2.9 Bio-control and botanical control

Gava and Pinto (2016) evaluated the ability of *Trichoderma spp.* to control melon wilt under field condition, and the application of liquid compost as a food-based strategy to improve the biocontrol efficiency of the selected strain. In a first experiment, they evaluated the use of *Trichoderma harzianum* LCB47,

Trichoderma viride LCB48, *Trichoderma koningii* LCB49, and *Trichoderma polysporum* LCB50 to control melon wilt in a naturally infested soil. The treatment with *T. polysporum* LCB50 (Tp) showed the highest efficiency to control melon wilt (44.85%), increasing the fruit yield in 43%. In the second experiment, Tp was applied as seed treatment, and repeated on at 15 days after transplanting. Two doses of liquid compost; 25 (LC25) and 50 ml pl^{-1} (LC50), were applied by fertigation on a weekly basis along the crop development. In this experiment, *T. polysporum* LCB50 applied alone resulted in a significant ($P < 0.05$) control of wilt (32.20%), and 27 increase in fruit production. Single application of both doses of LC did not significantly reduced disease incidence. However, a strong synergistic effect was observed applying Tp and LC25 and LC50, resulting in a highly significant wilt control (68 and 72%, respectively) and an increase in productivity. The use of Tp + LC50 treatment increased in 100% the production of commercial fruit from the results, a strategy based on the use of *T. polysporum* LCB50 and an organic matter source is proposed for the integrated management for melon wilt.

Sundaramoorthy and Balabaskar (2013) evaluated the efficacy of the native isolates of *Trichoderma* species to promote the growth and yield parameters of tomato and to manage Fusarium wilt disease under in vitro and in vivo conditions. The dominant pathogen, which causes Fusarium wilt of tomato, was isolated and identified as *Fusarium oxysporum* f. sp. *lycopersici* (FOL). Fifteen native *Trichoderma* antagonists were isolated from healthy tomato rhizosphere soil in different geographical regions. Under in vitro conditions, the results revealed that *Trichoderma harzianum* (ANR-1) isolate was found to effectively inhibit the radial mycelial growth of the pathogen (by 53%) when compared to all other isolates. Under greenhouse conditions, the application of *Trichoderma harzianum* (ANR-1) exhibited the least disease incidence (by 15.33%). Also tomato plants treated with *Trichoderma harzianum* (ANR-1) isolate showed a significant stimulatory effect on plant height (by 73.62 cm) and increased the dry weight (by 288.38 g) of tomato plants in comparison to other isolates and untreated control.

Almqvist (2012) investigated the effect of two biological control products in order to evaluate their ability to prevent or reduce powdery mildew infection to an acceptable level in greenhouse produced cucumber. In the experiments,

different application regimes were also studied. In one of the products the active organism was *Ampelomyces quisqualis* and in the other *Pythium oligandrum*. The effect of using the biocontrol agents prophylactically was significantly better with *P. oligandrum* compared to the untreated control but not with *A. quisqualis*. The effect of using *A. quisqualis* with an application interval of fourteen days was significantly better compared to a seven days application interval. For *P. oligandrum*, there was no difference between the two application intervals.

Anonymous (2010) reported that neem seed extracts products are effective against insect vectors such as aphid, whitefly of several viruses causing diseases in cucurbits. Neem seed extracts contain azadiractin which is chemically similar to ecdysonlids, the hormone having anti-feedant property and may cause insect to stop feeding. Efficacy of neem oil products against powdery mildews of cucurbits and grapes has been demonstrated. To prevent thrips and aphids they apply cow dung ash on foliage of vegetables e. g., chilli, onion, garlic, and cucurbit

Pawar and Chavan (2010) found that Neem leaf extract at 15% concentration, *Parthenium* leaf at 10% concentrations. *Ocimum* leaf at 20% concentration, Citrus leaf at 20% concentration, *Annona squamosa* leaf at 10% concentration, Ipomea at 15% and Jowar leaf at 20% control the powdery mildew of cucurbits. Cow urine at 15% concentration proved to be effective to control powdery mildew on cucurbit. 20% to 25% of Butter milk spray successfully controlled the powdery mildew of cucurbit. Similarly 20% ash spray also found to be successful to control the growth of powdery mildew of cucurbits. Spray of dashparni ark, a bi-product of plant and animal at 10% concentration inhibited the growth of *Erysiphe cichoracearum* and *Sphaerotheca fuliginea*.

Beckerman (2008) suggested that at a 70 percent concentration, neem oil kills powdery mildew spores; minimize the spread of viruses by controlling the insects that transmit them such as aphids, white fly, mites and the eggs of numerous insect pests. Aphids transmit the viruses that cause many common landscape and garden diseases, including *Cucumber mosaic virus*, *Potato virus Y* (potyvirus), and *Watermelon mosaic virus*. Neem oil is pressed from the fruit and seeds of the neem tree (*Azadirachta indica*).

Palenius *et al.* (2006) reported that Neem oil has multipurpose insecticide, miticide and fungicide property. Application of Neem oil protects cucurbits from powdery mildew, downy mildew, mosaic and leaf curl diseases. E-RASE™ is another natural product made from jojoba oil (*Buxus chinensis*). It is a contact fungicide that can be applied to control powdery mildew in cucurbits. Cinnamon oil (Cinnamite®, Valero®, etc) has also proved to be effective to control powdery mildew in cucurbits.

Keinath and Du Bose (2004) demonstrated that preventive application of a biofungicide (*Bacillus subtilis* 0.2%) was more effective than curative application for the control of water melon powdery mildew caused by *E. cichoracearum*. Similarly, powdery mildew and downy mildew of cucumber under green house conditions was controlled by *B. subtilis* spray (Abd El Moiety *et al.*, 2003)

Mashewari (2017) management of Alternaria leaf blight of bottle gourd through botanical, fungicides, bio-agent and their different combinations. The spacing maintained between rows was 2.0 m and between plants 0.50 m. Seventeen treatments such as 01 botanical (neem leaf extract @ 5.0%), 01 bio-agent (*Pseudomonas fluorescens* strain CIAH-196 @ 5.0%,

2.10 Chemical control

Gupta *et al.* (2001) reported that three sprays of hexaconazole (0.05%) at fortnightly highly effective for the management of powdery mildew caused by *Sphaerotheca fuliginea*. Anvil (Hexaconazole) and Karathane were the most effective fungicides against powdery mildew of cucumber than flovable sulfur, benomyl (Shami *et al.* 1995)

Mondal *et al.* (2014) observed that Spraying of Krilaxyl Gold (Metalaxyl 8% WP + Mancozeb 64% WP), Blitox (Copper Oxy-chloride 50% WP) and Indofil M-45 (Mancozeb 75% WP) recorded better and gave good protection against downy mildew in pointed gourd. Spraying should be done just before sunset. Retarded growth of vine of pointed gourd was noticed due to spraying of Contaf (Hexaconazole 5% EC) and Tilt (Propiconazole 25% EC).

Narkhede *et al.* (2014) suggested that fortnight spray of Carbendazim (0.1%), Culixin (0.05%), Karathane (0.5%) and Sulfex (0.2%) have been found effective. Seed treatment and seed drenching with systemic fungicides also give

protection to young seedlings from powdery mildew. Downy mildew can be effectively controlled with sprays of Dithane M45 (0.2%), Daconil and Difolatan (0.2%). One spraying gives protection for nine days. Copper oxychloride spray has also given good control. The sprays of Dithane M 45 if given early and repeated 2-3 times can control the disease effectively.

Lam and Lim (1993) stated that weekly spraying of hexacanzole (0.2%) and its mixture with protectant fungicides significantly reduced the powdery mildew (*Sphaerotheca pannosa*) of roses and white rust (*Puccinia horiana*) of Chrysanthemum.

Masood *et al.* (2013) suggested that usually two to three applications of chemicals e.g. difenoconazole (2ml/1litre) in a month after sowing, and later on mancozeb (2g/1 litre) or propiconazole (1ml/1litre) or carbendazim (1g/1 litre) when symptoms appear with 10-14 day intervals found effective against powdery mildew of cucurbits.

Chaudhry *et al.* (2009) conducted a field experiment to evaluate the performance of different fungicides against downy mildew on cucumber (*Cucumis sativus* L.) cultivated in high plastic tunnel at the farm of Ch. Khair Din and Sons, Mandiala Warriach, Gujranwala during Rabi, 2006-2007. Five different fungicides namely Dithane M-45, Copper oxychloride 50 WP, Ridomil Gold 72 WP, Success 72 WP and Alliet 80 WP were used at dose rate 5, 4, 2, 2.5 and 2 g/L-1 of water, respectively. Minimum disease incidence was recorded by spraying Success (9%), Ridomil (9.%) and Alliet (11%) compared with control (78%). Number of fruit per plant, length and yield of fruit was significantly higher in treated plots with Ridomil, Success and Alliet as compared to control and other fungicides.

Rai *et al.* (2008) recommended spraying of Dithane M-45 (0.3 %) at 15 days interval to control downy mildew under Ludhiana conditions. Three sprays of Calixin (0.05 %) or sulfex (0.25 %) effectively controlled powdery mildew at Rahuri at an interval of 15 days starting from 30-40 days after sowing. Five sprays of Dithane M-45, Dithane Z-78 or Aliette (all 0.3 %) at 10 days interval have been recommended to control downy mildew disease under Bangalore conditions.

Yasmin *et al.* (2008) evaluated eight fungicides against powdery mildew caused by *Erysiphe cichocearum* under field condition. Mycosulf, Thiovit and

Insuf were found best in controlling severity of disease by >80% not depending on locations. Additional yield 14.58t/ha was found from Thiovit treated plot which was 65.35% higher compared to control. Net income increased almost two times and the farmers having more options for controlling powdery mildew as more than one fungicide were found effective.

Manjusha (2007) carried out an experiment at Horticultural Research farm, College of Agriculture, Indira Gandhi Agricultural University Raipur (C.G) during the year 2006-2007 and found that integration of various management practices as seed treated with Ridomil MZ and spray of Allite and Curzate considerably reduces the downy mildew disease severity and influenced the growth and yield.

Memane and Khetmalas (2003) reported that a studied to determine the most effective treatment for controlling downy and powdery mildew (caused by *Pseudoperonospora cubensis* and *Erysiphe cichoracearum*, respectively) on bottle gourd and among all treatments, eight sprays of 0.3% copper oxychloride + 0.3% wettable sulfur at 10-day intervals from 30 days after crop sowing was the most effective for the control of downy and powdery mildew diseases of bottle gourd during the rainy season, recording the highest yields and economic returns.

Maheshwari (2017) the field trials were conducted during rainy season of 2013 and 2014 for disease management of Alternaria leaf blight in bottle gourd through botanicals, fungicides, bio-agent and their combinations. Among 17 treatments, combined treatment of carbendazim (Seed treatment) @ 0.1% + mancozeb (Foliar spray) @ 0.25% + *Pseudomonas fluorescens* (Foliar spray) @ 5.0% + neem leaf extract (Foliar spray) @ 5.0% was found the most effective with minimum disease incidence of 9.25%, minimum disease severity of 7.07% and maximum disease control (78.23%), followed by mancozeb ST @ 0.25% + carbendazim (FS) @ 0.1% + *Pseudomonas fluorescens* CIAH-196 (FS) @ 5.0% + neem leaf extract (FS) @ 5.0% having disease incidence (11.15%), disease severity (8.98%) and disease control (72.35%) for management of Alternaria leaf blight of bottle gourd.

2.11 Integrated diseases management

Beura *et al.* (2014) conducted an experiment to test the different integrated approaches for management of bottle gourd along with bower system and non

bower system. Four years pooled data revealed that all the treatments of bower system of planting lowered the disease severity as compared to non bower system of planting. Among the fourteen treatments tested, integrated disease management components like seed treatment with ridomil mz (metalaxyl 8 % + mancozeb 64 %) @ 0.25 % + three times removal of lower infected leaves in the morning and spray of mancozeb 75 % @ 0.25 % in the afternoon on bower system recorded significantly lowest disease severity of downy mildew (4.7 %) with maximum fruit yield of 90.2 q ha⁻¹. The same treatment also registered 92.24 % disease control over control plots followed by seed treatment with ridomil mz (metalaxyl 8 % + mancozeb 64 %) @ 0.25 % along with one foliar spray of alliete (fosetyl-al) @ 0.25 % on bower system of planting registered 79.87 % disease control. However, the check plot recorded the maximum disease severity of 60.60 % and 46.60 % with minimum green fruit yield of 33.50 % q ha⁻¹ and 41.1 q ha⁻¹ in non bower and bower system of planting respectively.

Kumar *et al.* (2008) evaluated different treatments including chemical and non-chemical for management of powdery mildew disease under field condition. The treatments included thirteen chemical fungicides, eight biological control agents, thirteen plant extracts (botanicals) and the study was conducted in two experimental seasons during 2004-05 in bell pepper varieties 'California Wonder' and 'Indra'. Dinocap (1 ml l⁻¹) among chemical fungicides, *Ampelomyces quisqualis* (20 g l⁻¹) among biological control agents and neem oil (20 ml l⁻¹) among botanicals recorded as the best components by recording a minimum percent of disease and the maximum yield compared to untreated controls. The same trend was observed in both seasons. In a second set of experiments, the most effective components were integrated to further minimise the use of fungicide thus an Integrated Disease Management (IDM) package was developed and tested in the field. By adopting this IDM the yield of 'California Wonder' and 'Indra' bell pepper showed an increase of 342.8 and 122.3 %, respectively the corresponding values for the control were 93.6 and 93.2 % respectively.

Kurowski *et al.* (2015) suggested that management of mosaic and leaf curl of cucurbits has been only marginally successful through vector control (e.g., insecticides, stylet oils). Avoid planting near older cucurbits and perennial

ornamental crops, which may serve as reservoirs for the virus. Control weeds, use reflective mulches, deep plow crop residues and dispose of infected greenhouse material to manage these viruses. Implement a comprehensive sanitation program for workers and equipment to minimize disease spread. Commercial varieties with resistance offer the best means to control mosaic and leaf curl. Resistance in cucumber has been shown to be very effective on a global scale. Progress in finding resistance in other cucurbit species has not been as successful.

Rajinimala *et al.* (2009) reported that bottle gourd yellow mosaic disease attains significance because the virus causing this disease is capable of attacking the crop at all stages. There was a severe yield loss in bottle gourd plants due to the infection of BGYMV. Bottle gourd plants treated with *Bougainvillea spectabilis* challenge inoculated with BGYMV reduced the disease incidence and increased the plant growth. In the above treatment the disease incidence was 33.33% at 75 Days After Sowing (DAS). But in the inoculated untreated control the disease incidence was 100% at 75 DAS. The mean maximum plant height was 92.24 cm in plants inoculated at 65 DAS. *Bougainvillea spectabilis* treated plants challenge inoculated with BGYMV showed an increased activity of peroxidase, polyphenoloxidase and phenol content from 4 Days after Inoculation (DAI) to 12 DAI. The activity of all the enzymes was reduced from 16 DAI in all the treatments.

Shankar *et al.* (2014) suggested that application of some fungicides as protective treatment reduce the incidence and severity of downy mildew in cucurbits. Mancozeb (Dithane M-45) 2g/litre used as a protective application at 5-7 days interval or Azoxystrobin (amistar) 0.5ml/litre no more than two application per season, can be tank mixed with protectant fungicide, Dimethomorph (Acrobat) 1g/litre at 5-10 days interval not more than five application per season, Cymoxanil + Mancozeb (Curzate) 2g/litre at 5-7 day interval no more than four application, Fosetylaluminium (Aliette) 3g/litre preventive treatment prior to disease onset foliar application or Chlorothalonil (kavach) 2g/litre can be used as a protective application at 5-7 days interval. Tebuconazole (Folicur) 1ml/litre at 10-14 day interval for suppression only protective treatment effectively reduce the incidence and severity of powdery mildew in cucurbits.

Zhang *et al.* (2015) reported that an integrated approach using a combination of several practices is most effective in managing downy mildew, powdery mildew and wilt diseases of bottle gourd.

2.12 Economics of management practices

Nwogbaga and Iwuagwu (2015) reported that the assessment of the economic benefit of fungicide and foliar fertilizer application showed that the gross margin (net revenue) was higher in N.P.K. foliar fertilizer compared to the fungicide. This was because N.P.K. foliar fertilizer gave higher yield (480 kg^{ha}) compared to the fungicide (320kg^{ha}), even though the total variable cost (TVC) was almost the same. The marginal revenue (Cost-benefit ratio) was equally higher in N.P.K foliar fertilizer (1:4.8) compared to the fungicide (1:3.4).

Mahrishi and Siradhana (1988) stated that treatment with 0.2% Dithane M-45 [mancozeb] decreased disease intensity. Plots receiving no spray, 3 and 4 sprays at 10 days intervals registered 79.06, 47.67 and 28.49% yield losses, respectively, compared with plots receiving 5 sprays of mancozeb at 7 days intervals.

Yasmin *et al.* (2008) evaluated eight fungicides against powdery mildew caused by *Erysiphe cichoracearum* under field condition. Mycosulf, Thiovit and Insuf were found best in controlling severity of disease by >80% not depending on locations. Additional yield 14.58t/ha was found from Thiovit treated plot which was 65.35% higher compared to control. Net income increased almost two times and the farmers having more options for controlling powdery mildew as more than one fungicide were found effective.

Yeon *et al.* (1996) found that when Fosetyl was applied 4times from the start of the disease (downy mildew) at 10 days interval, a yield index of 161% was obtained. Control decreased when 10 or 20 days from initial disease occurrence delayed the first fungicide application

Rahman and Bhattiprolu (2005) conducted a field trial at Agricultural Research Institute, Rajendranagar, Hyderabad, Andhra Pradesh, India during kharif 1993-94 to 1996-97 to find out the effective fungicidal application for management of powdery mildew of okra caused by *Erysiphe cichoracearum* DC. The crop was sprayed with seven different fungicides starting from the first appearance of the disease. Four sprays of wettable sulfur (Sulfex) 0.3% (T₁), penconazole (Topas)

0.05% (T₂), triadimefon (Bayleton) 0.05% (T₃), thiophanate-methyl (Topsin M) 0.1% (T₄), chlorothalonil (Chlorothalonil W-75) 0.1% (T₅), dinocap (Karathane) 0.1% (T₆) and tridemorph (Calixin) 0.1% (T₇) were taken up in the treated plots. Effect of each treatment on the disease incidence and yield was recorded. The disease index was significantly reduced in plots treated when compared to the untreated control. Analysis of the data for four seasons/years showed that okra powdery mildew can be significantly reduced by spraying 0.1% dinocap followed by 0.05% penconazole and triadimefon 0.05% along with significant increase in the yield. Maximum net profit was obtained by spraying 0.05% penconazole (Rs. 20, 895/-) followed by 0.1% dinocap (Rs.17, 890/-). Highest benefit cost ratio was realized with wettable sulfur 0.3% followed by penconazole 0.05% and triadimefon 0.05%. However, the benefit cost ratios assessed would be by 0.3% wettable sulfur (6.80) > 0.05% penconazole (6.58) > 0.05% triadimefon (5.39) > 0.1% tridemorph (4.73) > 0.1% dinocap (3.33) > 0.1% thiophanate methyl (3.28) > 0.1% chlorothalonil (2.00).



Experimental field 20 days after transplanting



Experimental field 35 days after transplanting



Experimental field 65 days after transplanting

Plate 4.1: Overview of experimental field

CHAPTER- III

MATERIALS AND METHODS

The details of the materials used and the methods or techniques adopted during the course of this investigation are presented in the following sections.

3.1 Geographical situation

Raipur is situated in the mid-eastern part of Chhattisgarh state and lies at 21°16 N latitude, 81°36 E longitudes and altitude of 298.56 m.

3.2 Climate

Raipur, the capital of Chhattisgarh has sub humid agro climatic condition. The average rainfall of this region is 1200-1400 mm, out of which about 88 per cent is received during rainy season (June-September) and 8 per cent is received during winter season (October-February). The rainfall pattern has a great variation during rainy season from year to year. May is the hottest and December is the coolest month of the year. The maximum and minimum temperature during the summer months reaches as high as 48.1°C and the mercury drops to as low as 6 °C during December-January.

3.3 Experimental site

Field experiment was carried out during *rabi* 2017-18 at the horticultural instructional-cum research farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G).

3.4 Soil of the experimental field

Soil of the experimental field was clay loam in nature (*Alfisols*) locally known as Dorsa. The soil was slightly acidic with a pH of 6.3. It had low nitrogen and medium phosphorus and potassium contents.

3.5 Test crop

The bottle gourd hybrid cultivar *Varad* was used during the period of study.

3.6 Evaluation of various bottle gourd varieties against prevalent diseases

Thirteen varieties of bottle gourd as described below in Table 3.1 were evaluated against prevalent diseases at Horticultural Instructional-cum Research Farm, College of Agriculture, IGKV, Raipur, Chhattisgarh.

Table 3.1: Various bottle gourd varieties and their source

S. N.	Variety	Nature	Packet size (g)	Producer/Firm/Source
1.	NS 443	F ₁	10	Namdhari Seeds Pvt. Ltd.
2.	Anmol	F ₁	10	East West Seeds India Pvt. Ltd.
3.	Manya	F ₁	18.5	Semillas Fito India Pvt. Ltd
4.	Angad	F ₁	10	Ujjawal Seeds Pvt. Ltd
5.	Latto	F ₁	10	Ujjawal Seeds Pvt. Ltd
6.	Amrit	F ₁	10	Clause India Pvt. Ltd
7.	Mahima	F ₁	10	Dhanya Seeds Pvt. Ltd
8.	Ankit	F ₁	10	Indus Seeds Pvt. Ltd
9.	Naveen	F ₁	10	Tokita Seed India Pvt. Ltd
10.	Chutki	F ₁	50	Shriram Fertiliser and Chemical Pvt. Ltd
11.	Divya	F ₁	50	VNR Seeds Pvt. Ltd.
12.	Haruna	F ₁	50	VNR Seeds Pvt. Ltd.
13.	Sarita	F ₁	50	VNR Seeds Pvt. Ltd.

3.6.1 Experimental details

Number of varieties	: 9
Number of rows for each variety	: 3
Distance between two rows	: 1.5 m
Number of plants per row	: 5
Total number of rows	: 27
Spacing	: 1×1.5 m (P×R)

Each variety of bottle gourd was raised in twenty polyethene bags having one seed in each bag. Seed sowing of bottle gourd was done in *rabi* season on 27th December 2017. The twenty three day old seedlings were transplanted on 10th

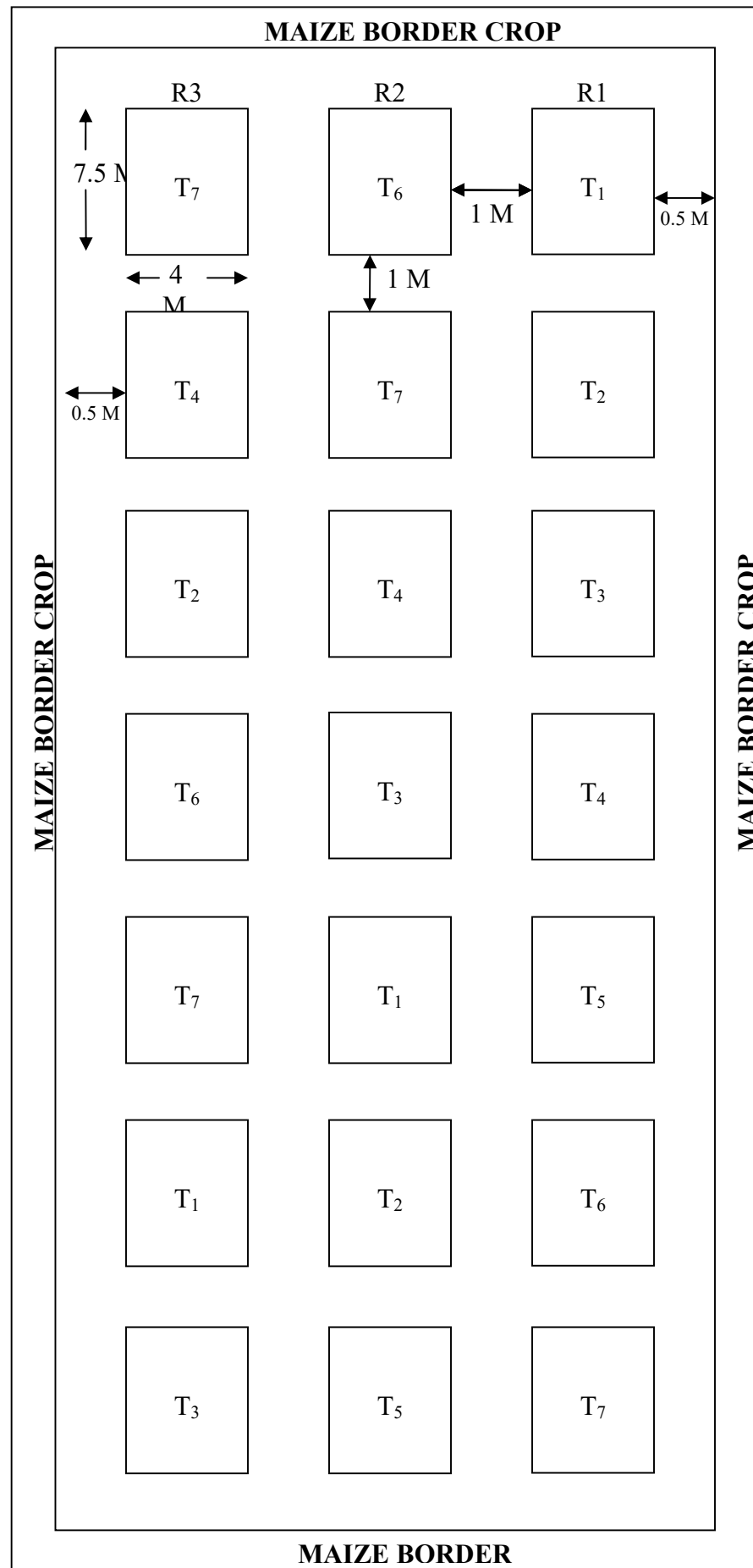
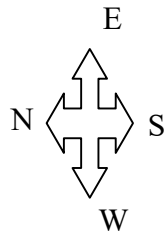
February 2018 in rows. Each variety was planted in three rows and each row had five plants. No any chemical pesticides were applied during the course of study.

3.7 Management of bottle gourd diseases

Seven different treatment combinations were tested against prevalent diseases of bottle gourd to find out best management combinations under organic condition at Horticultural Instructional-cum Research Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

3.7.1 Experimental details

Experimental design	: RBD
Number of treatments	: 7
Number of replication	: 3
Distance between replication to replication	: 1 m
Plot size	: 7.5×4 m
Distance between two plots	: 1 m
Gross area	: 892.50 sq m
Number of plants per plot	: 4×5=20
Spacing	: 1.5×1 m (P×R)



Plants of bottle gourd Seeds were treated with bio-control seed pro 25g/kg and Carbendazim 12% + Mencozeb 63% 3g/kg before sowing and one untreated control was also maintained. Treated seeds were sown on 23rd December 2017 in polythene bags. The twenty three days old seedlings were transplanted on 10th February 2018 in main plots. The maize seeds were also sown fifteen days before transplanting of bottle gourd seedlings.

3.7.2 Treatment details

* All the spray will be done at 10 days interval.

Treat ment	T0: Growing of Maize as border crop 15 days before sowing + Silver mulching							
	Seed treatment	Drenching at 1 st true leaf stage	1 st	2 nd	3 rd	4 th	5 th	6 th
T ₁ : T ₀ +	Seed pro 25 g/kg	Seed pro @5 %	Seed Pro (1%)	Neem Oil (0.2%)	Seed Pro (1%)	Neem Oil (0.2%)	Seed Pro (1%)	Neem Oil (0.2%)
T ₂ : T ₀ +	Carbendazim 12%+ mancozeb 63% @ 3 g/kg	Captan 70% + Hexaconazole 5%WP @ 0.1 %	Seed Pro (1%)	Neem Oil (0.2%)	Seed Pro (1%)	Neem Oil (0.2%)	Seed Pro (1%)	Neem Oil (0.2%)
T ₃ : T ₀ +	Seed pro 25 g/kg	Seed pro @5 %	Captan 70% + Hexaconazole 5%WP @ 0.1 %	(Imidacloprid 17.8 SL @7.5ml/15 L + Neem oil 0.2%)	Fosetyl- Al 0.1%	Captan 70% + Hexaconazole 5%WP @ 0.1 %	Imidacloprid 17.8 SL @ 7.5 ml/15 L + Neem oil 0.2%	Fosetyl- Al 0.1%
T ₄ : T ₀ +	Seed pro 25 g/kg	Seed pro @5 %	Imidacloprid 17.8 SL @ 7.5ml/15 L + Neem oil 0.2%	Tebuconazole 50% + Trifloxystrobin 25%WG @1g/l	Fosetyl- Al 0.1%	Tebuconazole 50% + Trifloxystrobin 25%WG @1g/l	Imidacloprid 17.8 SL @ 7.5ml/15 L + Neem oil 0.2%	Fosetyl- Al 0.1%
T ₅ : T ₀ +	Carbendazim 12%+ mancozeb 63% @ 3 g/kg	Captan 70% + Hexaconazole 5%WP @ 0.1 %	Tebuconazole 50% + Trifloxystrobin 25%WG @ 1g/l	Imidacloprid 17.8 SL @ 7.5ml/15 L + Neem oil 0.2%	Fosetyl- Al 0.1%	Tebuconazole 50% + Trifloxystrobin 25%WG @ 1g/l	Imidacloprid 17.8 SL @ 7.5ml/15 L + Neem oil 0.2%	Fosetyl- Al 0.1%
T ₆ : T ₀ +	Carbendazim 12%+ mancozeb 63% @3 g/kg	Captan 70% + Hexaconazole 5%WP @ 0.1 %	Imidacloprid 17.8 SL @ 7.5ml/15 L + Neem oil 0.2%	Captan 70% + Hexaconazole 5%WP @ 0.1 %	Fosetyl- Al 0.1%	Captan 70% + Hexaconazole 5%WP @ 0.1 %	Imidacloprid 17.8 SL @7.5ml/15 L + Neem oil 0.2%	Fosetyl- Al 0.1%
T ₇	Control							

* All the spray will be done at 10 days interval.

3.8 Field preparation

Field preparation was done with the help of harrow. Prior to harrowing, well-decomposed FYM @ 20q/ha was incorporated uniformly in the soil.

3.9 Nutrient management

3.9.1 Source and dosage of nutrient

Nutrients	Dose (kg/ha)	Source of nutrients	Quantity of fertilizer (kg)
Nitrogen	100	Urea	217.39
Phosphorus	80	Single Super Phosphate	500
Potash	60	Murate of potash	100

3.9.2 Application

Fertilizers were applied to the plots and mixed well with soil. Entire dose of phosphorus (P) and potash (K) and half dose of nitrogenous (N) fertilizers were applied as a basal dose. Remaining half dose of nitrogen (N) fertilizer was applied in two split doses, *i.e.*, twenty per cent at 30 days after planting and 30 per cent at 50 days after planting.

3.10 Irrigation and Intercultural operation

At the time of planting sufficient moisture was kept in the soil through irrigation for proper establishment of the plant. Irrigations were given whenever required. Gap filling was done once at 10 DAT. Three hand weeding was done at 25, 50 and 75 DAT to raise a good crop.

3.11 Harvesting

Picking of fruits were done when it is tender and green. Total thirteen picking were done during the whole crop season.

3.12 Date of sowing, planting and treatment applications

Cultural and technical work	Date
Date of sowing	23-12-2017
Date of Transplanting	27-01-2018
Date of first spraying of fungicide	07-02-2018
Date of second spraying of fungicide	17-02-2018
Date of third spraying of fungicide	27-02-2018
Date of forth spraying of fungicide	09-03-2018
Date of fifth spraying of fungicide	19-03-2018
Date of sixth spraying of fungicide	29-03-2018

3.13 Observation Schedule

In order to get representative samples, five plants (net and border) were selected in each plot and marked with tags for studying the diseases at various growth factors and the assessment of the other parameters and yield.

3.13.1 Disease severity and incidence

Percent disease severity was calculated for downy mildew, powdery mildew and leaf blight however, incidence was calculated for leaf curl and mosaic by implying following formulae then the data were analyzed statistically.

$$\text{Per cent disease severity} = \frac{\text{Total leaf tissue damaged}}{\text{Total healthy tissue of leaf}} \times 100$$

$$\text{Per cent disease incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plants observed}} \times 100$$

For evaluation of different varieties of bottle gourd per cent disease severity and incidence was recorded after 30, 60, 90 and 100 days after transplanting. Location severity index (LSI) for each disease was calculated using the formula suggested by Wheeler (1969) as given below:

$$\text{LSI} = \frac{\text{Sum of multiplication of variety and scales}}{\text{Total number of entries}}$$

The following scales were used for scoring the disease reaction for different diseases thereafter different genotypes were categories as follows:

3.13.1.1 Downy mildew (Metwally and Rakha, 2015 and Santos *et al.*, 2009)

Grade/ Rating	Reaction	Disease severity (%)	Symbol
0	Immune	0	I
1	Resistant	0.10-15.0	R
2	Moderately resistant	15.1-25.0	MR
3	Moderately susceptible	25.1-50.0	MS
4	Susceptible	50.1-75.0	S
5	Highly susceptible	>75	HS

3.13.1.2 Leaf curl (Singh, 2014)

Grade / Rating	Reaction	Per cent infection	Symbol
1	Immune	0	I
2	Highly resistant	0.1-5.0	HR
3	Moderately resistant	5.1-10.0	MR
4	Moderately susceptible	10.1-25.0	MS
5	Susceptible	25.1-50	S
6	Highly susceptible	>50	HS

3.13.1.3 Mosaic (Akbar *et al.*, 2015)

Grade / Rating	Symptoms and per cent infection	Reaction	Symbol
1	No symptom, 0-10%	Highly resistant	HR
2	Vein clearing after some time, 11-20%	Resistant	R
3	Vein clearing and mild mottle, 21-30%	Moderately resistant	MR
4	Mild mosaic on few leaves, 31-40%	Moderately susceptible	MS
5	Mosaic, wrinkling and mottling, 41- 60%	Susceptible	S
6	Mosaic, wrinkling and mottling, >60%	Highly susceptible	HS

3.13.1.4 Powdery mildew (Kushnereva, 2001)

Grade / Rating	Reaction	Per cent severity	Symbol
1	Immune	0	I
2	Resistant	0.1-5.0	R
3	Moderately resistant	5.1-25.0	MR
4	Moderately susceptible	25.1-50.0	MS
5	Susceptible	50.1-75.0	S
6	Highly Susceptible	> 75	HS

3.13.2 Yield contributing parameters

3.13.2.1 Days to first flowering

First flowering days were recorded from the plants of each plot at an interval of one day and mean was calculated.

3.13.2.2 Days to 50% flowering

Fifty per cent flowering days were recorded from the plants of each plot at an interval of one day and mean was calculated.

3.13.2.3 Days to first fruiting

First fruiting days were recorded from the plants of each plot at an interval of one day and mean was calculated.

3.13.2.4 Days to first harvest

First harvest days were recorded from the plants of each plot at an interval of one day and mean was calculated.

3.13.2.5 Fruit length

Five fruits from each plot were randomly selected. The length of selected fruits from each treatment was measured with the scale and average was calculated.

3.13.2.6 Fruit girth

Fruit girth of five randomly selected fruits per plot was measured with the help of thread and scale and average was computed.

3.13.2.7 Number of fruit / plant

Number of edible fruits was counted at each picking and summed up for all the pickings for a plot. Numbers of fruits per plant were calculated after dividing total number of fruits in a plot by total number of plants in a plot

3.13.2.8 Average fruit weight (kg/plant)

Average weight of fruits was recorded on five fruits in gram from five randomly selected plants of each plot in each replication and then average fruit weight was calculated.

3.13.2.9 Average fruit yield (kg / plant)

The total fruit yield over all the pickings was recorded in kilogram for each plot and divided by total number of plant to obtain fruit yield per plant (kg).

3.13.2.10 Average fruit yield per plot

This was recorded as average of cumulative marketable fruit yield of all pickings.

3.13.2.11 Yield

Total weight (Net and Border) of bottle gourd harvested per plot from all the pickings was calculated and finally the yield quintal per hectare was worked out.

3.13.3 Economics and statistical analysis

Economics analysis of different treatments was worked out as per the rates of input applied for disease management and wages prevailing during the course of study. Present experimental data was analyzed statistically by techniques of analysis of variance applicable to Randomized Block Design. The significance of treatments was tested by F-test value. Critical value at 5% level of significance was worked out for comparison and statistical interpretation of significant treatment means. The standard error of difference was given in each case for significant treatment effect, critical difference of different treatment combinations per interaction at 5% level of probability was calculated, wherever F-test was significant.

Table 3.2 Skeleton of Analysis of variance (ANOVA)

Source	Df	SS	MSS	F value (Calculated)
Replication	r-1	SSr	$\frac{SSr}{r-1} = MST$	$\frac{MST}{MSE}$
Treatment	t-1	SSt	$\frac{SSt}{t-1} = MST$	
Error	(r-1)(t-1)	SSe	$\frac{SSe}{(r-1)(t-1)} = MSE$	
Total	Rt-1	TSS		

Where,

r = number of replications

t = number of treatments

df = degree of freedom

SSr = replication sum of square

SSt = treatment sum of square

SSe = error sum of square

TSS = Total sum of square

MST = treatment mean sum of square

MSR = replication mean sum of square

MSE = error mean sum of square

3.13.3.1 Test of significance

If the variance ratio (or) F calculated value $[Vt/EMS]$ of treatment was greater than the F-table value at 5% and 1% level of significance, the variance between treatments was considered to be significant. If the F-calculated value is less than F-tabulated value, the differences between treatments were considered to be non-significant

3.13.3.2 Critical differences (CD)

The critical difference was calculated by following formula

$$CD = \frac{\sqrt{2EMS}}{r}$$

Where,

t value = table value at error degree of freedom at 5% level of significance

r = Number of replication

EMS = Error mean sum of squares.

Significant 'F' value indicates that there is significant difference among the treatment. But to compare any two particular treatments, it is tested against CD value

3.13.3.3 Coefficient of variation (CV)

A measurement of variance which is independent of the unit of measurements provided by the standard deviation expressed as percentage of mean. This is known as coefficient of variation (CV).

$$CV(\%) = \frac{\text{standard deviation}}{\text{Mean}} \times 100$$

CHAPTER- IV

RESULTS AND DISCUSSION

The data on various aspects of investigation have been presented in this chapter along with appropriate tables, figures and possible interpretations. The results have been given under the following headings:

4.1 Seasonal occurrence of prevalent diseases of bottle gourd diseases

Seasonal occurrence of prevalent diseases of bottle gourd was recorded from the first fortnight of February 2018 to the end of April 2018 (Table 4.1 and Fig. 4.1). The occurrence of downy mildew and leaf blight were observed in the first fortnight of March and progressed to the end of April 2018. The occurrences of leaf curl and mosaic were observed in the second fortnight of February 2018 and continued to the end of April 2018. However the occurrence of powdery mildew was recorded from the first fortnight of April and progressed to the end of April 2018. Similar kind of work also carried out by powdery mildew of bottle gourd occurs throughout the world both in glasshouse and field. It is particularly destructive in New South Wales, Australia, New York (Ballantyne, 1974), Iowa (Clark, 1975), Georgia (Sowell and Clark, 1971) and in Wisconsin (Shanmugasundaram *et al.*, 1971) in USA. Khan *et al.* (1971, 1972, 1974) reported that powdery mildew is a serious wide spread disease of cucurbits in India. In India yield losses due to powdery mildew of bottle gourd was 50-75 per cent (CMIE, 2004). Maheshwari *et al.* (2017) reported the crop is attacked by a number of diseases such as *Alternaria* leaf blight, *Cercospora* leaf spot, powdery mildew, downy mildew and mosaic, amongst which *Alternaria* leaf blight caused by *Alternaria cucumerina* (E. & E.) Elliot is found to cause serious losses throughout Rajasthan and other states. Wallace *et al.* (2014) observed cucurbit's downy mildew (CDM) caused by the oomycetes *Pseudoperonospora cubensis*, on bitter melon and balsam apple between August and October 2013 in six North Carolina sentinel plots belonging to the CDM IPM PIPE program. Rai *et al.* (2004) First report of *Zucchini yellow mosaic virus* in bottle gourd (*Lagenaria siceraria*) in India plant showed severe mosaic, interveinal chlorosis, and leaf deformation that resulted in fern-leaf appearance and severe fruit distortion in approximately 70% of the plants.

Table 4.1: Seasonal occurrence of prevalent diseases of bottle guard during 2017-18

S. N.	Disease	February		March		April	
		15	30	15	30	15	29
1.	Downy Mildew	- (0.0)	- (0.0)	+ (4.53)	+ (23.82)	+ (23.76)	+ (20.90)
2.	Leaf Curl	- (0.0)	+ (2.47)	+ (7.90)	+ (13.48)	+ (17.95)	+ (23.14)
3.	Mosaic	- (0.0)	+ (4.05)	+ (4.29)	+ (11.19)	+ (13.57)	+ (21.23)
4.	Powdery Mildew	- (0.0)	- (0.0)	- (0.0)	- (0.0)	+ (0.49)	+ (0.70)
5.	Leaf blight	- (0.0)	- (0.0)	+ (6.22)	+ (11.36)	+ (14.04)	+ (21.26)

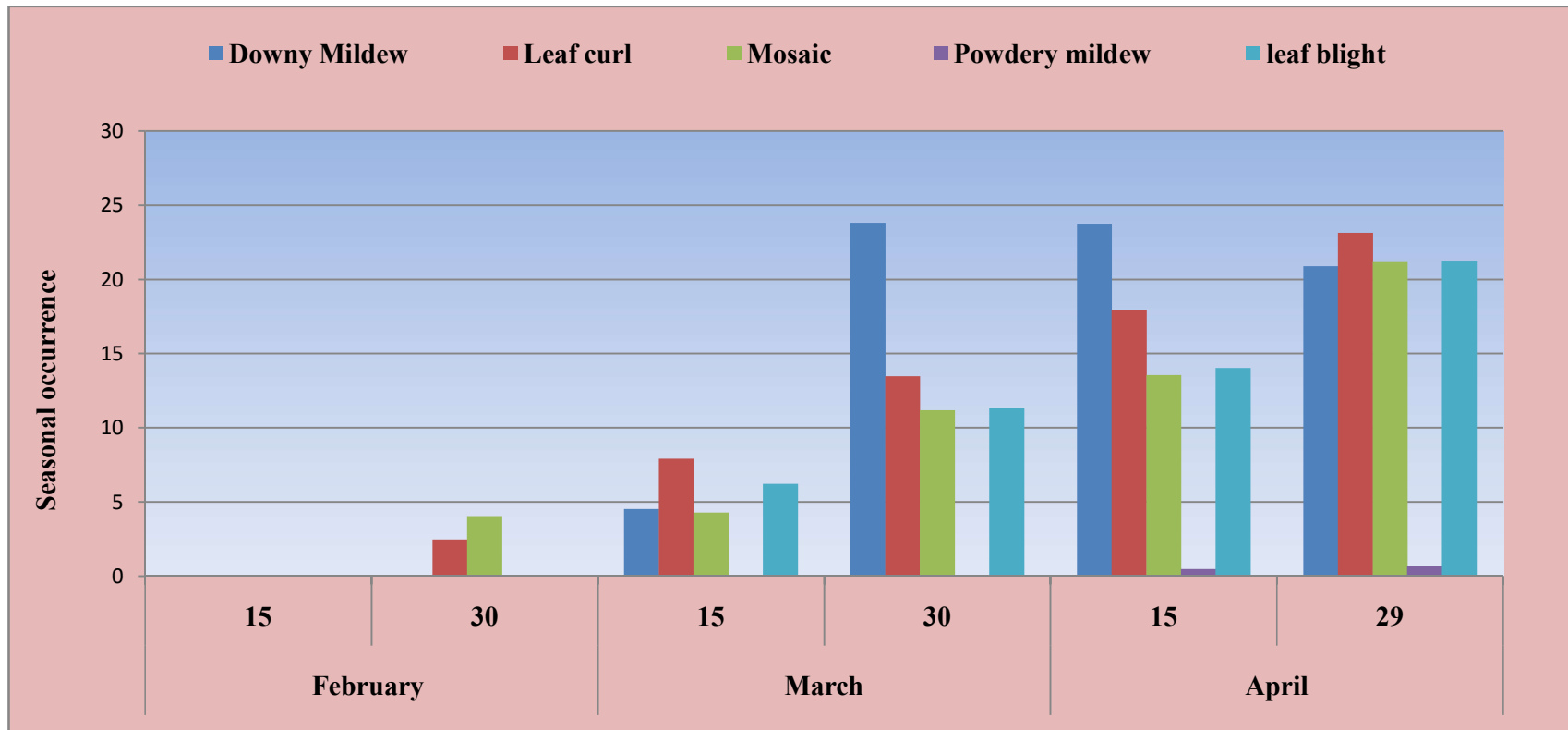


Fig. 4.1: Seasonal occurrence of prevalent diseases of bottle guard during 2017-18



Experimental field 20 days after transplanting



Experimental field 35 days after transplanting



Experimental field 65 days after transplanting

Plate 4.1: Overview of experimental field



Sporangiospores of *Psuedoperonospora cubensis*



Symptoms of downy mildew on upper surface of leaf



Symptoms of downy mildew on lower surface of leaf

Plate 4.2: Symptoms of downy mildew



Symptoms of leaf curl



Symptoms of leaf curl



Plate 4.3: Symptoms of leaf curl



Symptoms of mosaic



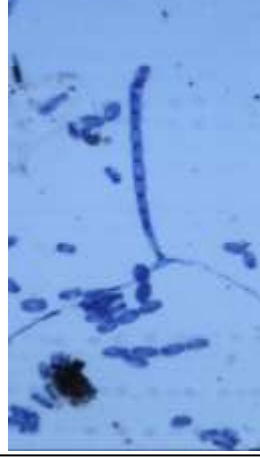
Symptoms of mosaic



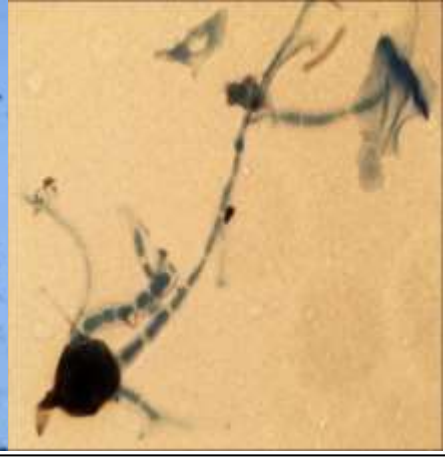
Plate 4.4: Symptoms of mosaic



Sphaerotheca fuliginea spore



Erysiphe cichoracearum



Symptoms of powdery mildew



Symptoms of powdery mildew

Plate 4.5: Symptoms of powdery mildew



Alternaria cucumerina (leaf blight of bottle gourd)



Symptoms of Leaf blight



Plate 4.6: Symptoms of Leaf blight

4.2. Evaluation of various bottle gourd varieties against prevalent diseases

Thirteen varieties of bottle gourd were evaluated against prevalent diseases of the crop at Horticultural Instructional-cum Research Farm, College of Agriculture, IGKV, Raipur, during 2017-18. Three diseases *viz.* downy mildew, powdery mildew, leaf curl and mosaic were observed during the period of experiment. The reactions of all varieties of bottle gourd against different diseases have been given below:

4.2.1 Downy mildew

Among the thirteen varieties of bottle gourd evaluated three varieties *viz.* Amrit, Ankit and Anmol were free from the disease and showed immune reaction against disease. However, two (Manya, Ns-433), four (Chutki, Haruna, Latto and Naveen) and three (Angad, Mahima and Sarita) varieties were resistant, moderately resistant and moderately susceptible, respectively. One variety *i.e.* Divya showed susceptible reaction against downy mildew while none of the variety was found highly susceptible (Table 4.2 to 4.3 and Fig. 4.2). Metwally and Rakha (2015) evaluated 133 Plant Introduction (PI) cucumber accessions from the U.S. National Plant Germplasm System for downy mildew resistance under natural field conditions during the summer 2013 at El-Beheira Governorate, Egypt. The most resistant PI accessions were PI 432870, PI 432873, PI 432878, PI 432884, and PI 432886 with a rating of 1, which originated from China. The most susceptible PI accessions were Ames 7736, PI 211979, PI 288991, PI 288992 and PI 289698 with a rating of 9. They further evaluated five most resistant and five most susceptible accessions in the next year. Results from the repeated test confirmed the results from the first screening. (Hariska and Gasti 2012) reaction of bottle gourd genotypes to downy mildew and fruit fly infestation was done under natural condition at the Kittur Rani Channamma College of Horticulture, Arabhavi during *kharif* season of 2009-2010. Each treatment was replicated thrice. The material for the present study consisted 25 diverse genotypes which comprise of six open pollinated varieties and 19 hybrids. The genotypes Gutkha, Sarika and Kaveri were found to show resistant reaction (disease score of 1.0) against downy mildew while

Arka Bahar, INDAM-204, NS-421, NBOH-1, Bio Gaurav, US-15, Reena, Super Dhana, Anand and Sharada were found to exhibit moderately resistant reaction.

Table 4.2: Evaluation of different varieties of bottle gourd against downy mildew

S. N.	Variety	Duration (Days)	Per cent disease severity (DAT)				Reaction
			30	60	90	100	
1.	Sarita	90-100	0	12.5	37.5	37.5	MS
2.	Haruna	90-110	0	25	25	25	MR
3.	Divya	90-110	0	37.5	62.5	62.5	S
4.	Chutki	90-115	0	12.5	25	25	MR
5.	Manya	90-115	0	12.5	12.5	12.5	R
6.	Ankit	90-110	0	0	0	0	I
7.	Anmol	90-115	0	0	0	0	I
8.	Mahima	90-115	0	25	37.5	50	MS
9.	Naveen	90-110	0	25	25	25	MR
10.	Ns-433	90-115	0	0	12.5	12.5	R
11.	Latto	90-115	0	12.5	25	25	MR
12.	Angad	90-110	0	37.5	37.5	37.5	MS
13.	Amrit	90-110	0	0	0	0	I

Table 4.3: Grouping of bottle gourd varieties on the basis of their reactions against downy mildew

Grade	Per cent disease severity	Reaction	No. of variety	Variety
0	0	Immune	3	Amrit, Ankit, Anmol
1	0.10-15.0	Resistant	2	Manya, Ns-433
2	15.1-25.0	Moderately resistant	4	Chutki, Haruna, Latto, Naveen
3	25.1-50.0	Moderately susceptible	3	Angad, Mahima, Sarita
4	50.1-75.0	Susceptible	1	Divya
5	>75	Highly susceptible	0	-
LSI = 1.769				

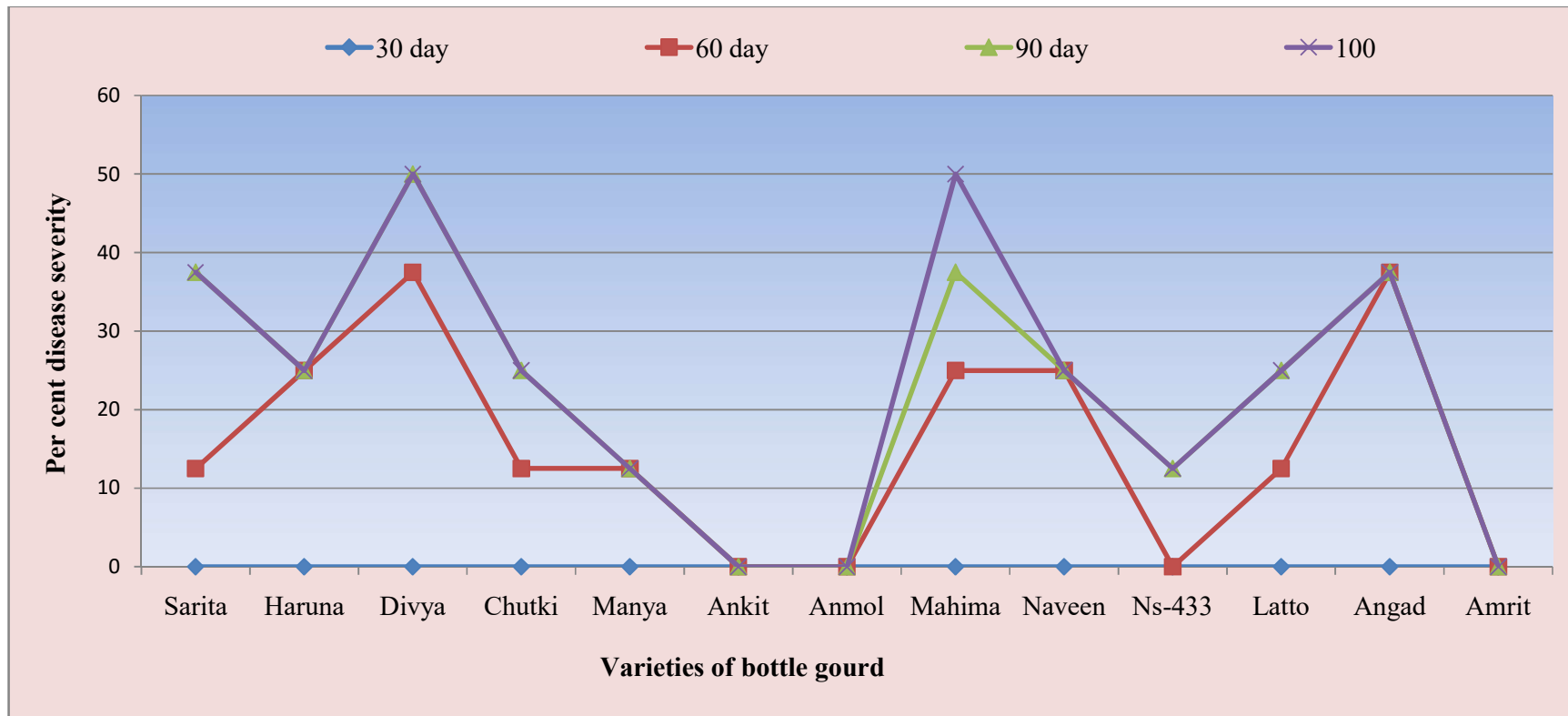


Fig. 4.2: Evaluation of different varieties of bottle gourd against downy mildew

4.2.2 Leaf curl

Out of thirteen varieties of bottle gourd evaluated five (Angad, Ankit, Anmol, Chutki and Naveen) were free from the disease with immune response, not a single variety too showed resistant or moderately resistant reaction against leaf curl disease. However, five varieties i.e. Haruna, Latto, Manya, NS-443 and Sarita showed moderately susceptible reaction while three viz. Amrit, Divya and Mahima were susceptible against leaf curl disease (Table 4.4 to 4.5 and Fig 4.3). The results are corroborating with the findings of Singh (2014), who screened thirty two tomato genotypes for its resistance/ susceptible reaction against tomato leaf curl disease under greenhouse condition during winter cropping seasons (*Rabi*) 2009-10 and 2010-11. Among the screened genotypes, one wild accession, H-88-78-1 showed immune reaction against ToLCV without producing any symptoms of leaf curl disease. Three genotypes viz., Hissar Lalima, TLBRH-6 and NS-515 showed resistant reaction and eight genotypes viz., Hissar Anmol, Kishi Vishesh, Kashi Amrit, Kashi Sharad, KS-17, KS-118, Avinash-2 and US-1008 found moderately resistant to ToLCV. (Lingl, K.S. and Levi, A. 2007) one-hundred ninety U.S. PIs of bottlegourd [*Lagenaria siceraria* (Mol.) Standl.] were evaluated for their resistance to the Florida strain of Zucchini yello IV mosaic virus (ZYMV-FL). Seedlings in the first leaf stage were mechanically inoculated with freshly prepared ZYMV-FL tissue extract in a greenhouse. Of the 190 *Lagenaria siceraria* PIs screened, 36 accessions were in complete resistance (no disease symptom with negative ELISA on all tested plants), 64 PIs showed partial resistance (some of the tested plants were resistant, whereas others were susceptible), and 90 PIs were susceptible (severe symptom and positive ELISA on all tested plants).

Table 4.4: Evaluation of different varieties of bottle gourd against leaf curl

S. N.	Variety	Duration (Days)	Per cent disease incidence (DAT)				Reaction
			30	60	90	100	
1.	Sarita	90-100	0	25	25	25	MS
2.	Haruna	90-110	0	12.5	12.5	12.5	MS
3.	Divya	90-110	0	0	0	37.5	S
4.	Chutki	90-115	0	0	0	0	I
5.	Manya	90-115	0	0	12.5	12.5	MS
6.	Ankit	90-110	0	0	0	0	I
7.	Anmol	90-115	0	0	0	0	I
8.	Mahima	90-115	0	12.5	37.5	37.5	S
9.	Naveen	90-110	0	0	0	0	I
10.	Ns-433	90-115	0	0	0	12.5	MS
11.	Latto	90-115	0	0	25	25	MS
12.	Angad	90-110	0	0	0	0	I
13.	Amrit	90-110	0	0	0	37.5	S

Table 4.5: Grouping of bottle gourd varieties on the basis of their reactions against leaf curl

Grade	Per cent infection	Reaction	No. of variety	Variety
1	0	Immune	5	Angad, Ankit, Anmol, Chutki, Naveen
2	0.1-5.0	Highly resistant	0	-
3	5.1-10.0	Moderately resistant	0	-
4	10.1-25.0	Moderately susceptible	5	Haruna, Latto, Manya, NS-443, Sarita
5	25.1-50	Susceptible	3	Amrit, Divya, Mahima
6	>50	Highly susceptible	0	-
LSI = 3.076				

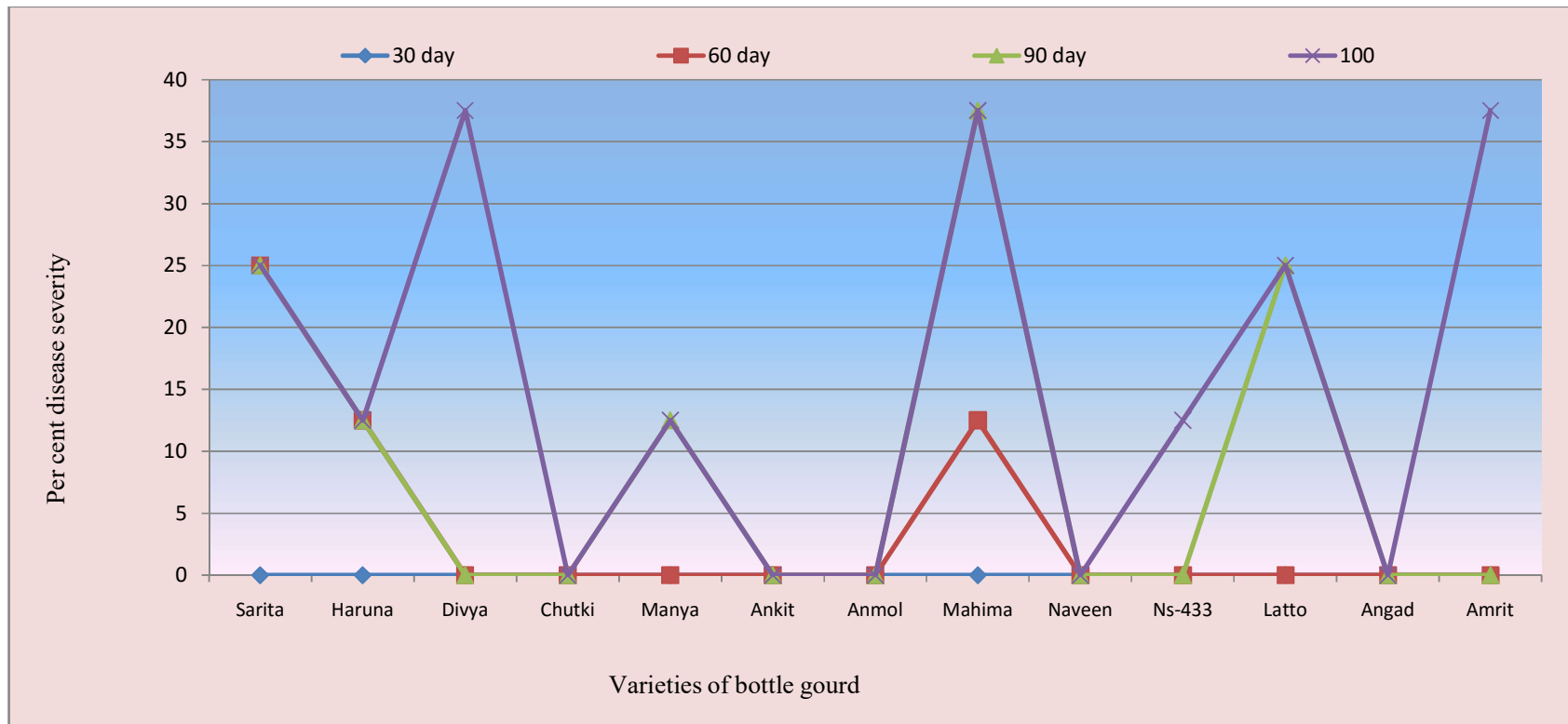


Fig. 4.3: Evaluation of different varieties of bottle gourd against leaf curl

4.2.3 Mosaic

Among the thirteen varieties of bottle gourd five varieties viz. Amrit, Ankit, Latto, Many and NS-443 showed highly resistant reaction. However, five (Angad, Anmol, Divya, Naveen and Sarita) and two (Chutki and Haruna) were resistant and moderately resistant, respectively. One variety i.e. Mahima showed moderately susceptible reaction against mosaic while none of the variety was either susceptible or highly susceptible (Table 4.6 to 4.7 and Fig 4.4). Akbar *et al.* (2015) screened seventeen cucumber germplasm against *Cucumber mosaic virus*. Seeds of these germplasms were sown in earthen pots in which fourteen germinated and exhibited characteristics symptoms of the virus. Out of fourteen germinated germplasms nine (Punjab, Beitalpha, pointpett-76, Baran, Local green, Summer green, Diomond 2F l, Sahill and Kumar) showed moderately susceptible reaction remaining (Khyber, Yousaf, VEGAF1, Diamond and Waleed) showed highly susceptible reaction. Reshmi and Sreelathakumary (2015) evaluated 33 genotypes of bitter gourd for mosaic disease in Kerala. Among the 33 genotypes evaluated, ten genotypes were highly resistant, ten genotypes were resistant, ten genotypes were moderately resistant and remaining three was susceptible to the disease.

Table 4.6: Evaluation of different varieties of bottle gourd against mosaic

S. N.	Variety	Duration (Days)	Per cent disease incidence (DAT)				Reaction
			30	60	90	100	
1.	Sarita	90-100	0	0	12.5	12.5	R
2.	Haruna	90-110	0	12.5	25	25	MR
3.	Divya	90-110	0	0	12.5	12.5	R
4.	Chutki	90-115	12.5	0	25	25	MR
5.	Manya	90-115	0	0	0	0	HR
6.	Ankit	90-110	0	0	0	0	HR
7.	Anmol	90-115	0	0	0	12.5	R
8.	Mahima	90-115	0	12.5	12.5	37.5	MS
9.	Naveen	90-110	12.5	12.5	12.5	12.5	R
10.	NS-433	90-115	0	0	0	0	HR
11.	Latto	90-115	0	0	0	0	HR
12.	Angad	90-110	0	12.5	12.5	12.5	R
13.	Amrit	90-110	0	0	0	0	HR

Table 4.7: Grouping of bottle gourd varieties on the basis of their reactions against mosaic

Grade	Per cent infection	Reaction	No. of variety	Variety
1	0-10	Highly resistant	5	Amrit, Ankit, Latto, Manya, NS-443
2	11-20	Resistant	5	Angad, Anmol, Divya, Naveen, Sarita
3	21-30	Moderately resistant	2	Chutki, Haruna
4	31-40	Moderately susceptible	1	Mahima
5	41-60	Susceptible	0	-
6	>60	Highly susceptible	0	-
LSI= 1.923				

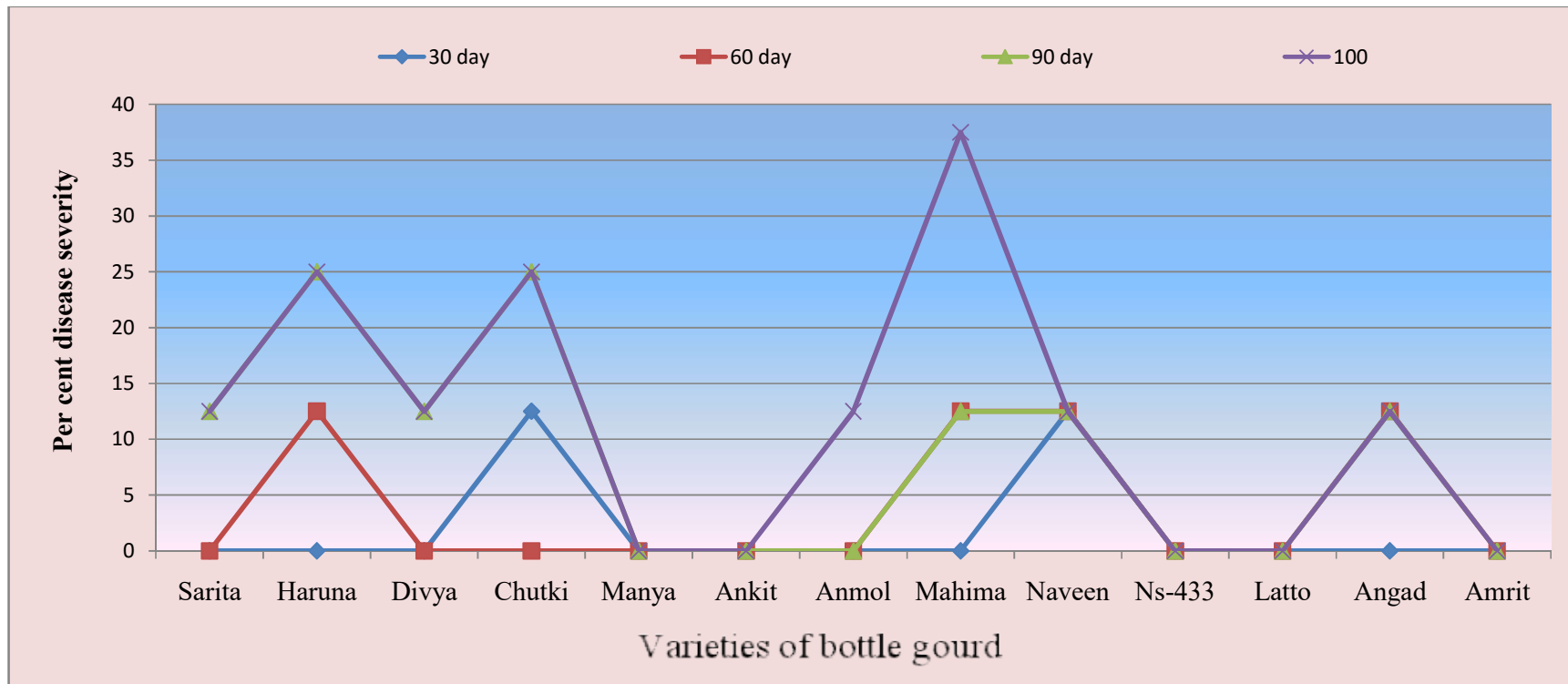


Fig. 4.4: Evaluation of different varieties of bottle gourd against mosaic

4.2.4 Powdery mildew

Out of thirteen varieties of bottle gourd evaluated not a single variety too showed immune or resistant reaction against powdery mildew disease. However, six (Chutki, Amrit Angad, Ankit, Mahima and NS-433) and four (Anmol, Haruna, Many and Naveen) varieties were moderately resistant and moderately susceptible, respectively. Three varieties viz. Divya, Latto and Sarita showed susceptible response against powdery mildew (Table 4.8 and 4.9 Fig 4.5). Chandrasekar *et al.* (2008) evaluated 234 U.S. PIs (plant introductions) of *Lagenaria siceraria* for tolerance to powdery mildew in two greenhouse tests. Young seedlings were inoculated by dusting powdery mildew spores of melon race 1 on the cotyledons. Plants were rated 2 weeks after inoculation using a 1 to 9 scale of increasing disease severity. Although none of the *L. siceraria* PIs were immune to powdery mildew, several PIs had significantly lower levels of powdery mildew severity compared with susceptible watermelon cultivar Mickey Lee. The experiment was repeated with 26 select PIs on whole seedlings and cotyledon disks. Significant variability in the level of resistance to powdery mildew on plants within PI was observed. Moderate resistance in several PIs to powdery mildew was confirmed. PI 271353 had consistently lower ratings in the various tests and can be considered the most resistant to *P. xanthii* race 1 among the *L. siceraria* accessions evaluated in this study. A few other PIs with moderate resistance to powdery mildew included PI 271357, PI 381840, and PI 273663. These results suggest that novel sources of resistance could be developed by careful selection and screening of several of the PIs with moderate resistance described in our study.

Table 4.8: Evaluation of different varieties of bottle gourd against powdery mildew

S. N.	Variety	Duration (Days)	Per cent disease severity (DAT)				Reaction
			30	60	90	100	
1.	Sarita	90-100	0	50	62.5	75	S
2.	Haruna	90-110	0	37.5	37.5	50	MS
3.	Divya	90-115	0	62.5	62.5	62.5	S
4.	Chutki	90-100	0	0	12.5	25	MR
5.	Manya	90-100	0	25	25	37.5	MS
6.	Ankit	90-110	0	12.5	12.5	25	MR
7.	Anmol	90-115	0	0	0	37.5	MS
8.	Mahima	90-100	0	25	25	25	MR
9.	Naveen	90-115	0	0	0	37.5	MS
10.	NS-433	90-110	0	0	0	25	MR
11.	Latto	90-110	0	62.5	62.5	62.5	S
12.	Angad	90-115	0	25	25	25	MR
13.	Amrit	90-115	0	12.5	12.5	25	MR

Table 4.9: Grouping of bottle gourd varieties on the basis of their reactions against powdery mildew

Grade	Per cent disease severity	Reaction	No. of variety	Variety
1	0	Immune	0	-
2	0.1-5.0	Resistant	0	-
3	5.1-25.0	Moderately resistant	6	Chutki, Amrit Angad, Ankit, Mahima, NS-433
4	25.1-50.0	Moderately susceptible	4	Anmol, Haruna, Manya, Naveen
5	50.1-75.0	Susceptible	3	Divya, Latto, Sarita
6	> 75	Highly Susceptible	0	-
LSI= 3.769				

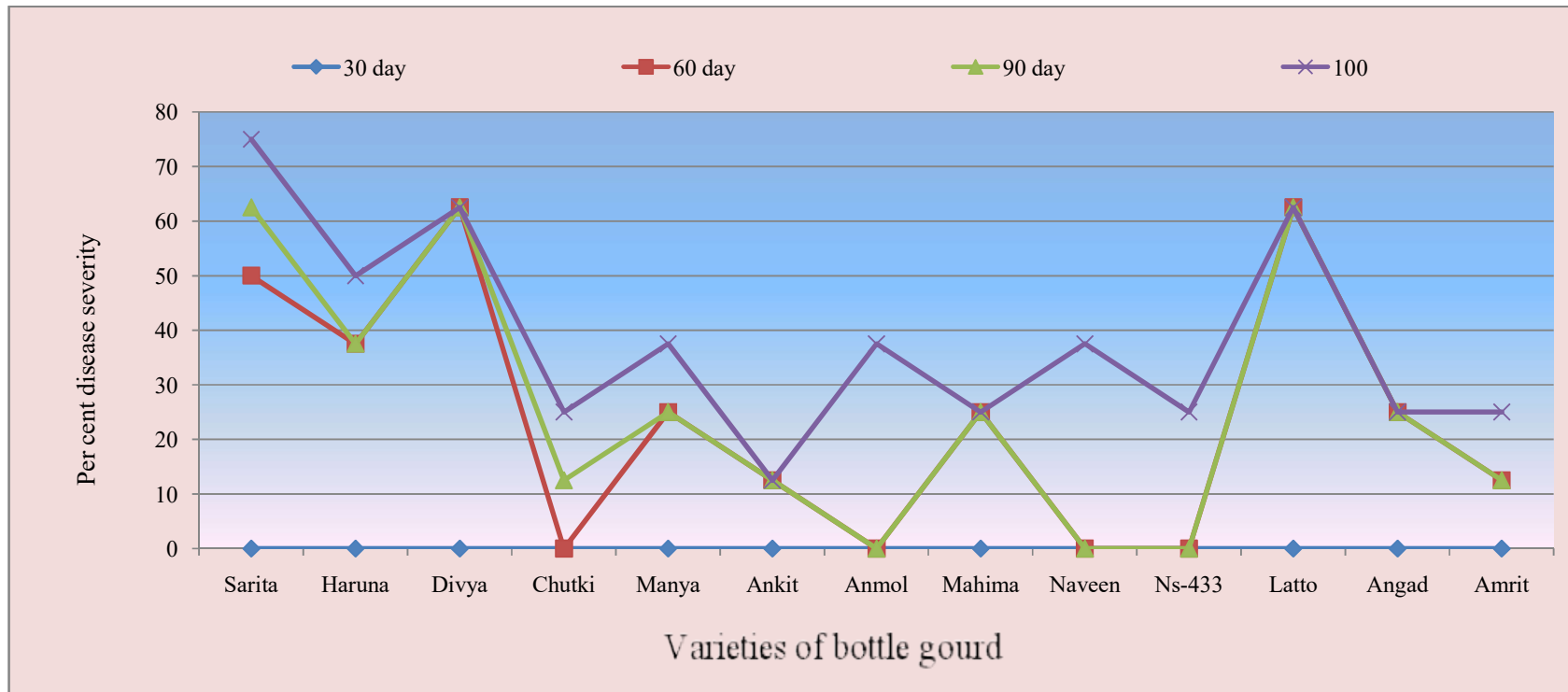


Fig. 4.5: Evaluation of different varieties of bottle gourd against powdery mildew

4.3. To work out the suitable combination of methods for management of the disease for organic farming situation

4.3.1 Effect of various seed treatments on seedling parameters of bottle gourd

Effect of various seed treatments on seedling attributes *viz.* germination percentage, root and shoot length, fresh weight, dry weight and vigor index of bottle gourd seedlings were evaluated during 2017-18 (Table 4.10 and 4.11 and Fig 4.6). Among all the treatments chemical treatment provided best result in comparison to untreated (control). The highest germination percentage (98.14%), root length (9.14 cm), shoots length (13.11 cm), fresh weight (5.67 g), dry weight (0.66 mg) and vigor index (2183.65) were observed when seeds were treated with chemical *i.e.* carbendazim 12% + mancozeb 63% (3 g/kg seed). This was followed by bio control (seed pro 25 g/kg seed). Poor seedling attributes *viz.* germination percentage, root and shoot length, fresh weight, dry weight and vigor index of bottle gourd were obtained when seeds were not treated with any chemical or bio control substance. The results are in agreement with the findings of Sharma *e. al.* (2015) they reported that seed treatment of crop seeds with fungicides found to speed up germination process, increased germination rate and seedling vigor, improved resistance to water and salinity stress and increased crop yields. Dhanamanjuri *et al.* (2013) found that seed treatment of *Cicer arietinum* and *Zea mays* seeds with Bavistin significantly stimulate the seed germination and seedling growth.

Table 4.10: Effect of various seed treatments on seed emergence of bottle gourd

Treatment	Number of seed emerge on various date				Germination (%)
	08 Feb 2018	10 Feb 2018	14 Feb 2018	Total	
Bio control	129	74	38	241	96.29
Chemical	157	71	17	245	98.14
Untreated	50	43	-	93	93.00

Table 4.11: Effect of various seed treatments on seedling parameters of bottle gourd

Seedling parameters	Different seed treatment		
	Bio control	Chemical	Untreated
Germination (%)	96.29	98.14	93
Root length (cm)	6.55	9.14	5.8
Shoot length (cm)	9.15	13.11	7.12
Fresh weight (g)	3	5.67	2.02
Dry weight (g)	0.51	0.66	0.41
Vigor index	1511.75 (1)	2183.65 (1)	1201.56 (1)
	49.10 (2)	64.77 (2)	38.13 (2)

Salar Monajjem (2016) Gorgan University of Agricultural Sciences and Natural Resources developed formula (SVI-I= Seedling length × Germination Percentage and SVI-II= Seedling Dry Wt. × Germination Percentage) is most used in studies.

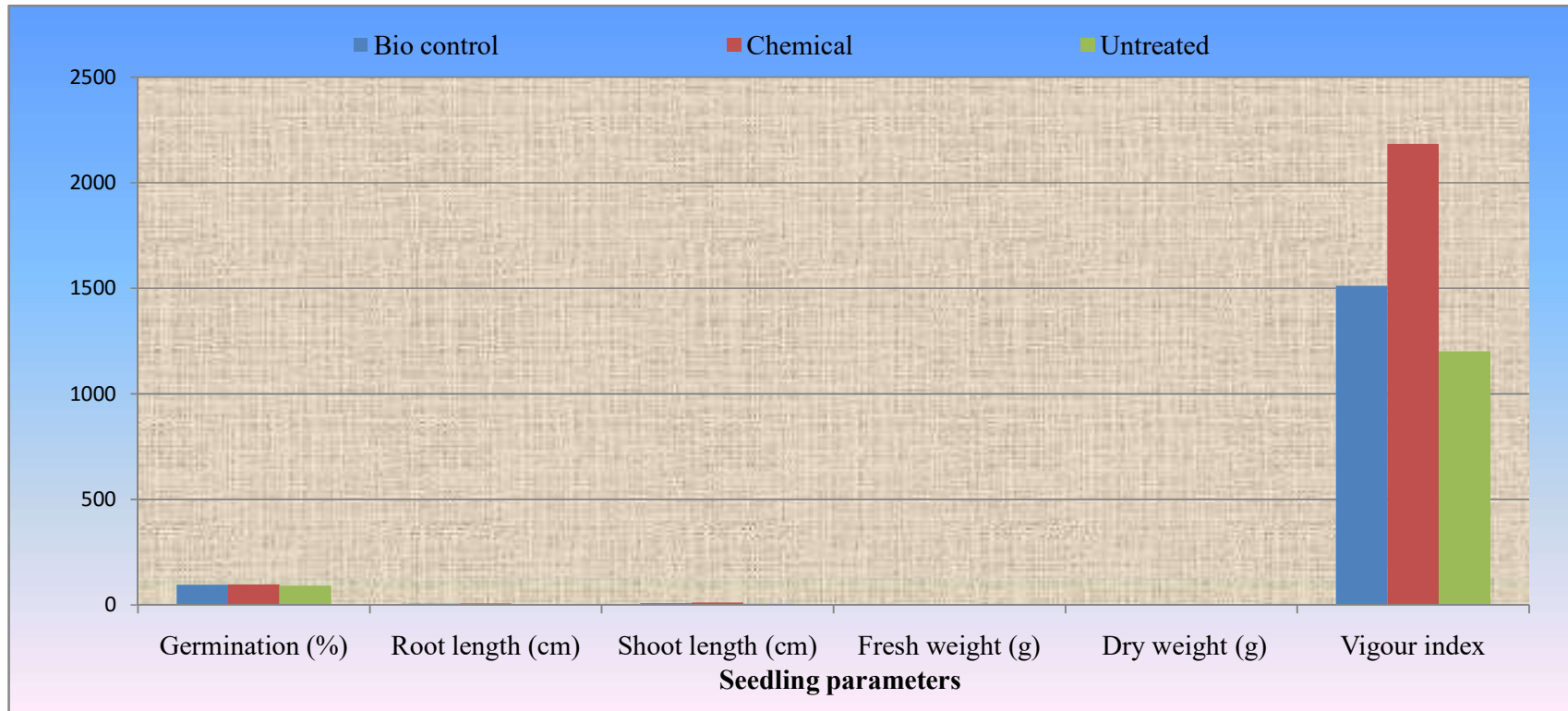


Fig. 4.6: Effect of various seed treatments on seedling parameters of bottle gourd



Polythene bags ready for sowing



Seed pro

Control

Fungicide



Plate 4.7: Effect of seed treatments on germination

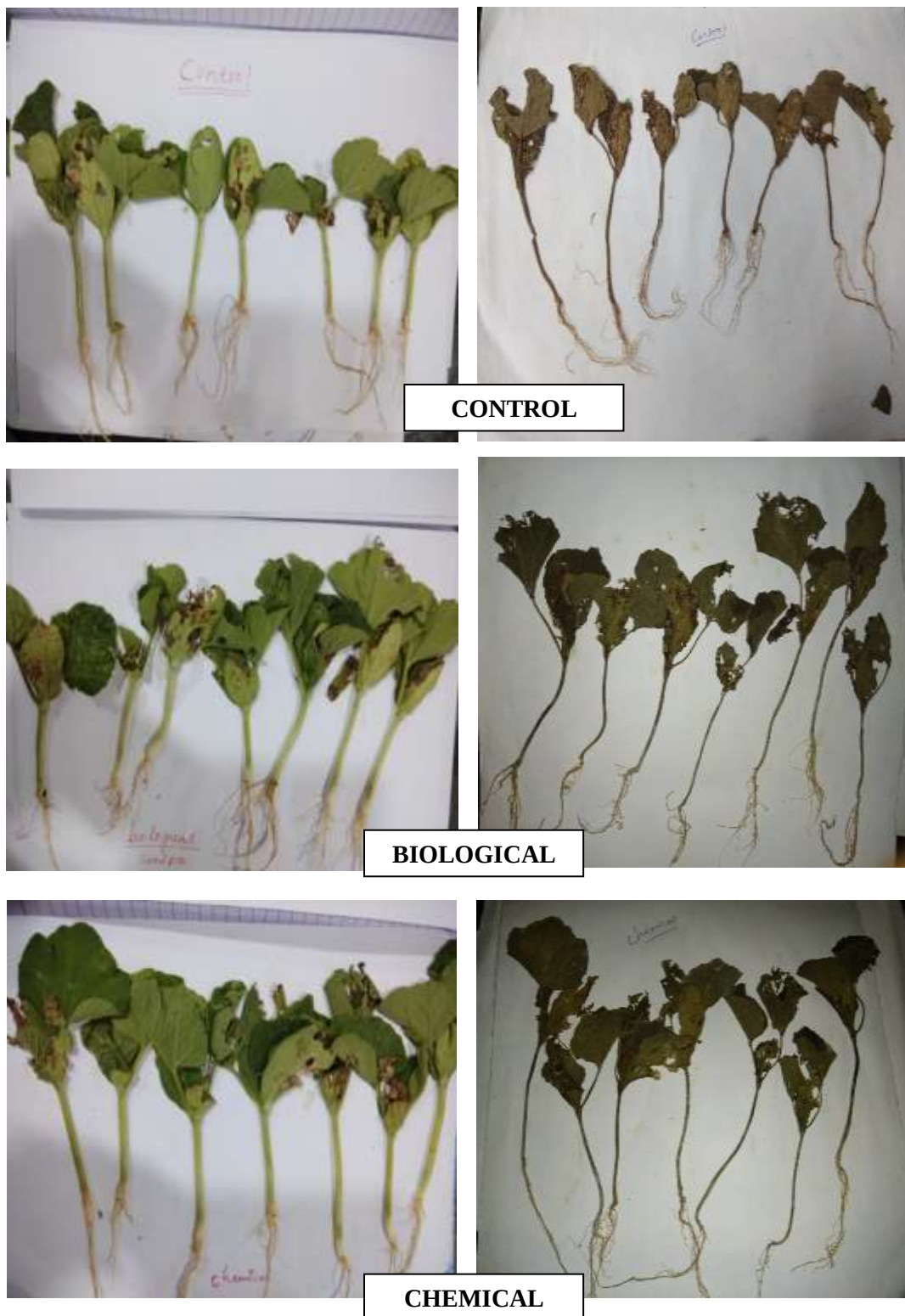


Plate 4.8: Effect of seed treatments on bottle guard seedlings

4.3.2: Suitable combination of methods for management of the disease

The experimental data presented in Table 4.12 and Fig 4.7 indicated that disease severity of downy mildew in bottle gourd plant ranged from 10.51 to 23.35 per cent. Minimum disease severity (10.51%) was recorded in treatment T₅ [Seed treatment with (carbendazim 12% + mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%]. This was followed by treatment T₃ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] 10.74 % which was statistically at par with T₅. The highest disease severity was recorded in treatment T₇ (Control) i.e. 23.35 followed by T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] 14.25 per cent.

Similar kind of work also done by Beura *et al.* (2014), they conducted an experiment to test the different integrated approaches for management of bitter melon along with bower system and non bower system. Four years pooled data revealed that all the treatments of bower system of planting lowered the disease severity as compared to non bower system of planting. Among the fourteen treatments tested, integrated disease management components like seed treatment with ridomil mz (metalaxyl 8 % + mancozeb 64 %) @ 0.25 % + three times removal of lower infected leaves in the morning and spray of mancozeb 75 % @ 0.25 % in the afternoon on bower system recorded significantly lowest disease severity of downy mildew (4.7 %) with maximum fruit yield of 90.2 q ha⁻¹. The same treatment also registered 92.24 % disease control over control plots followed

by seed treatment with ridomil mz (Metalaxyl 8 % + Mancozeb 64 %) @ 0.25 % along with one foliar spray of alliete (Fosetyl-Al) @ 0.25 % on bower system of planting registered 79.87 % disease control. However, the check plot recorded the maximum disease severity of 60.60 % and 46.60 % with minimum green fruit yield of 33.50 % q ha⁻¹ and 41.1 q ha⁻¹ in non bower and bower system of planting respectively. Shankar *et al.* (2014) suggested that application of some fungicides as protective treatment reduce the incidence and severity of downy mildew in cucurbits. Mancozeb (Dithane M-45) 2g/litre used as a protective application at 5-7 days interval or Azoxystrobin (amistar) 0.5ml/litre no more than two application per season, can be tank mixed with protectant fungicide, Dimethomorph (Acrobat) 1g/litre at 5-10 days interval not more than five application per season, Cymoxanil + Mancozeb (Curzate) 2g/litre at 5-7 day interval no more than four application, Fosetylaluminium (Aliette) 3g/litre preventive treatment prior to disease onset foliar application or Chlorothalonil (kavach) 2g/litre can be used as a protective application at 5-7 days interval. They also suggested that application of some fungicides such as Azoxystrobin (Amistar) 0.5ml/litre no more than two application per season, Chlorothalonil (kavach) 2g/litre can be used as a protective application at 5-7 days interval, Myclobutanil (Systhane) 1g/litre at 7-10 day interval; 30 day plant back restriction, Pyraclostrobin (cabrio) 1g/litre at 7-14 day interval; no more than two sequential application or Tebuconazole (Folicur) 1ml/litre at 10-14 day interval for suppression only protective treatment effectively reduce the incidence and severity of powdery mildew in cucurbits.

It was revealed from the Table 4.12 and Fig 4.7 that the severity of powdery mildew in bottle gourd ranged from 0.0 to 3.72 per cent. Treatments such as T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%) and neem oil (0.2%)], T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₆ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) +

drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] were free from powdery mildew. The highest disease severity (3.72%) was recorded in treatment T₇ (Control) followed by T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] 0.54 per cent.

Kumar *et al.* (2018) reported that the bitter gourd plants were free from powdery mildew in treatments such as T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%], T₄ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₅ [seed treatment with (carbendazim 12% + mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with the highest disease severity (6.46%) in treatment untreated control.

The severity of leaf blight of bottle gourd ranged from 15.01 to 35.00 per cent. The minimum disease severity (15.01%) was recorded in treatment T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first

true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%]. This was followed by treatment T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] 17.13 per cent, which is statistically at par with T₅. The highest disease severity (35.00%) was recorded in treatment T₇ (Control) followed by the T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] 23.12 per cent (Table 4.12 and Fig 4.7).

Maheshwari (2017) conducted field trials during rainy season of 2013 and 2014 for disease management of *Alternaria* leaf blight in bottle gourd through botanicals, fungicides, bio-agent and their combinations. Among 17 treatments, combined treatment of carbendazim (Seed treatment) @ 0.1% + mancozeb (Foliar spray) @ 0.25% + *Pseudomonas fluorescens* (Foliar spray) @ 5.0% + neem leaf extract (Foliar spray) @ 5.0% was found the most effective with minimum disease incidence of 9.25%, minimum disease severity of 7.07% and maximum disease control (78.23%), followed by mancozeb ST @ 0.25% + carbendazim (FS) @ 0.1% + *Pseudomonas fluorescens* CIAH-196 (FS) @ 5.0% + neem leaf extract (FS) @ 5.0% having disease incidence (11.15%), disease severity (8.98%) and disease control (72.35%) for management of *Alternaria* leaf blight of bottle gourd.

The incidence of leaf curl ranged from 20.00 to 41.67 per cent. The minimum disease incidence of leaf curl (20.00%) was observed in treatment T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @

7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%]. This was followed by treatment T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] 21.67 per cent and T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] 21.67% respectively. The highest disease incidence of leaf curl (41.67%) was recorded in T₇ (control) followed by T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] 23.33 per cent (Table 4.12 and Fig 4.7).

Kumar *et al.* (2018) recorded the minimum disease incidence of leaf curl (18.67%) and mosaic (12.33%) in treatment T₄ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with the highest disease incidence of leaf curl (30.33%) and mosaic (54.33%) in untreated control.

The incidence of mosaic ranged from 10.00 to 30.00 per cent. The lowest incidence of mosaic (10.00%) was recorded from the treatments such as T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₆ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L +

neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%]. However, the highest disease incidence (30.00%) was recorded in treatment T₇ (Control) followed by T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%) and neem oil (0.2%) and T₂ -Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] 13.33 (Table 4.12 and Fig 4.7).

Kurowski *et al.* (2015) suggested that management of mosaic and leaf curl of cucurbits has been only marginally successful through vector control (e.g., insecticides, stylet oils). Avoid planting near older cucurbits and perennial ornamental crops, which may serve as reservoirs for the virus. Control weeds, use reflective mulches, deep plow crop residues and dispose of infected greenhouse material to manage these viruses. Implement a comprehensive sanitation program for workers and equipment to minimize disease spread. Commercial varieties with resistance offer the best means to control mosaic and leaf curl. Resistance in cucumber has been shown to be very effective on a global scale. Progress in finding resistance in other cucurbit species has not been as successful. Khan *et al.* (2006) reported that regular spraying of insecticide at every 21 days interval was found to be effective for management of mosaic and leaf curl disease of chilli. An improvement in growth and yield performance of treated plants was noticed as compared to the non-treated plants. Kaur and Kang (2005) conducted field experiments in Punjab, India, to determine the effect of cultural practices, i.e. sowing date, sowing depth and the use of barrier crops, i.e. sunflower, gobhi sarson (*Brassica campestris* var. *sarson*) and raya (*Brassica juncea*) alone and in combination with sprays of malathion and Thiodan (endosulfan) either on the barrier crop or on the main crop for the management of cucurbit mosaic caused by *Watermelon mosaic virus* and *Potato virus Y* on summer squash PB Chappan, Kadoo-1 and musk melon Pb Sunehri. The treatments reduced mosaic incidence in both crops. Crops sown in the second fortnight of March registered the least disease

incidence (52.1 and 54.0%) and severity (54.3 and 57.9%) in summer squash and muskmelon, respectively, without reductions in yield. Further delay in sowing up to the end of April reduced the disease incidence but yield was also reduced. Increase in sowing depth up to 9.00 cm reduced the disease incidence by 23.34% in summer squash and 24.61% in muskmelon but adversely affected the germination and the crop stand. The disease was also lowest in these crops when sunflower was grown as a barrier crop. However, sowing of sunflower as barrier crop and spray of Thiodan on the main crop further reduced the disease incidence (37.24%) and severity (40.34%). The sowing of gobhi sarson and raya alone or the sprays of insecticides on these crops had no positive effect in disease reduction. However, the sprays of insecticides on the main crop reduced disease incidence and severity even when gobhi *Sarson* and *Raya* were sown as barrier crops.

Table 4.12: Effect of different combinations of methods for management of the disease for organic farming situation

Treatment	Per cent disease severity (90 DAT)			Per cent disease incidence (90 DAT)	
	Downy mildew	Powdery mildew	Leaf blight	Leaf curl	Mosaic
T ₁	11.25 (19.56)**	0.00 (1.00)*	20.08 (26.58)**	23.33 (28.85)**	13.33 (27.47)**
T ₂	11.36 (19.64)**	0.25 (1.12)*	17.13 (24.28)**	21.67 (27.71)	13.33 (26.55)**
T ₃	10.74 (19.09)**	0.40 (1.14)*	19.45 (26.03)**	23.33 (28.67)**	11.67 (25.82)**
T ₄	14.25 (22.09)**	0.00 (1.00)*	23.12 (28.61)**	20.00 (26.45)**	11.67 (25.10)**
T ₅	10.51 (17.95)**	0.54 (1.00)*	15.01 (22.46)**	21.67 (27.71)**	10.00 (24.99)**
T ₆	10.98 (19.33)**	0.00 (1.16)*	19.02 (25.75)**	23.33 (28.54)**	10.00 (24.99)**
T ₇	23.35 (28.61)**	3.72 (1.68)*	35.00 (36.23)**	41.67 (40.17)**	30.00 (34.76)**
SEm(±)	1.39	0.11	1.56	2.48	1.91
C.D. (5%)	4.30	0.35	4.82	7.66	5.96

* Data in parentheses are square root transformed

** Data in parentheses are arcsine (angular) transformed

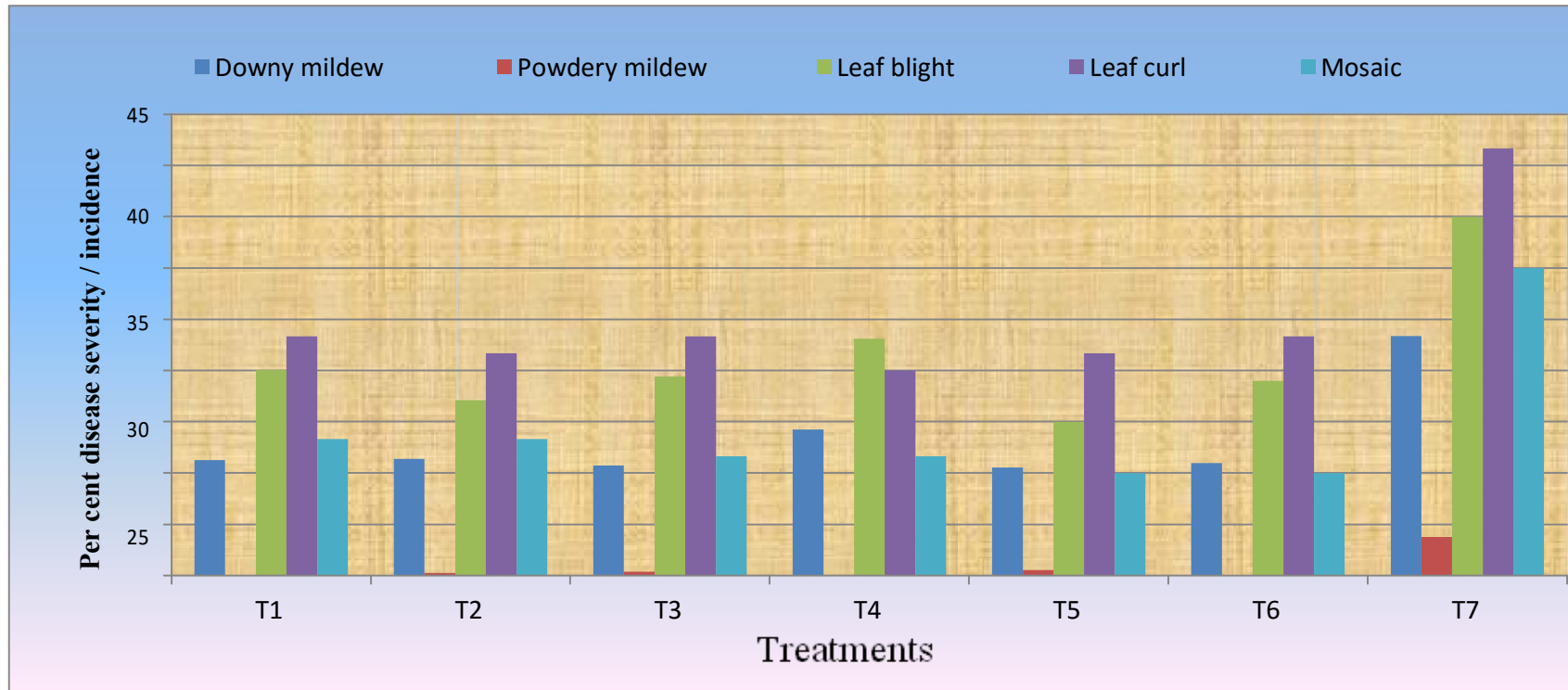


Fig 4.7: Effect of different combinations of methods for management of the disease for organic farming situation



Drenching at first true leaf stage



Spraying

Plate 4.9: Application of management practices

4.4. To study the response of various treatments on yield and yield attributes of bottle gourd

4.4.1 Days to first flowering

The data presented in Table 4.13 and Fig 4.8 indicated that the minimum days to first flowering was recorded under treatment T₂ (26.33 DAT) i.e. Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%). This was followed by T₁ i.e. [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%)] and T₆ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%] (26.66 DAT) which was statistically at par with T₂. Maximum number of days to first flowering was recorded in control (32.66 DAT).

4.4.2 Days to 50% flowering

The days to fifty per cent flowering ranged from 30.33 to 36.00 DAT. The minimum days to fifty per cent flowering (30.33 DAT) was recorded in treatment T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)]. This was followed by T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%)], T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole

50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with days to fifty per cent flowering of 31.33 DAT. The maximum number of days to fifty per cent flowering (36 DAT) was recorded in control (Table 4.13 and Fig 4.8).

4.4.3 Days to first fruiting

The experimental data presented in Table 4.13 and Fig 4.8 indicated that the minimum days to first fruiting (28.67 DAT) was recorded under treatment T₅ i.e. Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %. This was followed by T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%).(29.33)] and T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] with days to first fruiting of 29.33 and 29.67 DAT. However, taximum number of days to first fruiting (34.67 DAT) was recorded in control (T₇).

4.4.4 Day to first harvest

The minimum days to first fruit harvest (46.66 DAT) was recorded under treatment T₅ i.e. seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %. This was followed by T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6

alternate spray of seed pro (1%) and neem oil (0.2%)] and T₆ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%] with days to first harvest of 47.00 DAT. However, the maximum number of days to first harvest (49.66 DAT) was recorded in control (Table 4.13 and Fig 4.8).

4.4.5 Fruit length

The fruit length of bottle gourd ranged from 39.08 to 33.53 cm. The maximum length of fruit (39.08 cm) was measured from the plants of treatment T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %] which was significantly higher than the untreated control (33.53 cm). This was followed by T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with fruit length of 37.33 and 36.72 cm, respectively. The minimum fruit length (33.53 cm) was recorded in control as is evident from the Table 4.14 and Fig 4.9.

4.4.6 Fruit girth

Fruit girth of bottle gourd ranged from 21.59 to 18.12 cm among treatments. The maximum fruit girth (21.59 cm) was obtained by treatment T₅ [Seed treatment

with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] which was significantly higher than the untreated control (18.12 cm). This was followed by T₆ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%)] and T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with fruit girth of 21.00 and 20.31 cm respectively. The minimum fruit girth (18.12) was recorded in control, as is evident from the Table 4.14 and Fig4.9.

4.4.7 Number of fruit/plant

The non significant variation was observed in number of fruit per plant of treatments (Table 4.15 and Fig 4.10). The maximum number of fruit per plant (5.08) recorded in treatment T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%]. This was followed by T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₆ [Seed treatment with (carbendazim 12%+

mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%)] with 4.71 and 4.65 number of fruit per plant, respectively. The lowest number of fruit per plant was recorded in T₇ i.e. control (3.60).

4.4.8 Average fruit weight (kg/plant)

The non significant variation was observed in average fruit weight of treatments (Table 4.15 and Fig 4.10). Though the maximum average fruit weight per plant (0.93 kg) was recorded in treatment T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)]. This was at followed by T₆ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%)] and T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with average fruit weight of 0.91 and 0.90 kg per plant respectively. However, the lowest average fruit weight per plant was recorded in T₇ i.e. control (0.76).

4.4.9 Average fruit yield per plant (kg/plant)

The average fruit yield per plant of bottle gourd significantly varied from 4.43 to 2.70 kg per plant (Table 4.15 and Fig 4.10). The maximum average fruit yield per plant (4.43 kg) was obtained from treatment T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage

with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] which was significantly higher than untreated control (2.70 kg). This was followed by T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] with average fruit yield of 4.40 and 4.34 kg per plant respectively. However the lowest average fruit yield per plant (2.70 kg) was recorded in T₇ (control).

4.4.10 Average fruit yield per plot (kg/plot)

The data on average fruit yield per plot of bottle gourd varied from 88.75 to 53.97 kg under different treatments and presented in Table 4.15 and Fig 4.10. The maximum average fruit yield per plot (88.75 kg/plot) was recorded in treatment T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] which was significantly higher than the untreated control (53.97 kg). This was followed by T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @

0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] with average fruit yield per plot of 88.11 and 86.82 kg respectively. The lowest average fruit yield per plot was recorded in T₇ control (53.97 kg).

4.4.11 Yield (q/ha)

The data on total yield of bottle gourd was presented in Table 4.15 and Fig 4.10 that varied from 179.05 to 295.83 q per ha under different treatments. The maximum total yield (295.83 q/ha) was recorded in treatment T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] which was significantly higher than the untreated control (179.05 q/ha). This was followed by T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] with total yield of 293.70 and 289.40 q per ha respectively. The lowest total yield was recorded in T₇ control (179.05 q/ha).

Manjusha (2007) reported that the minimum days to first flowering were recorded under treatment T₁ i.e. spray of Curzate, the maximum length of fruit observed in treatment T₇ (seed treatment Ridomil MZ @ 2.5g/kg seed + spray of curzate @ 2.5 gm/litre of water), the maximum girth of the fruit is attained by treatment T₁ (seed treatment Ridomil MZ @ 2.5g/kg seed + need based spray of curzate @ 2.5 gm/litre of water and maximum yield was recorded in treatment T₁ (seed treatment Ridomil MZ @ 2.5 g/kg seed + need based spray of curzate @ 5 gm/litre of water) 57.44 q/ha.

Kumar *et al.* (2018) received the minimum days to first flowering (25.33 DAT), fifty per cent flowering (31.33 DAT) and first fruiting (29.67 DAT) and maximum days to fruit length (11.87 cm) and girth (5.43 cm), yield (108.96 q/ha) and benefit cost ratio (1:2.85) from seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%. They recorded the minimum disease severity of downy mildew (20.61%) in treatment T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with the highest disease severity (58.73%) in treatment T₇ (control). They obtained maximum yield (108.96 q/ha) of bitter gourd from treatment T₄ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with the lowest yield in untreated control (82.99 q/ha).

Table 4.13: Effect of different treatment combinations on flowering and fruiting of bottle gourd

Treatment	First flowering (DAT)	50% flowering (DAT)	First fruiting (DAT)	First fruit harvest (DAT)
T₁	26.66	31.33	29.67	47.33
T₂	26.33	30.33	29.33	47.00
T₃	29.00	31.66	31.00	47.33
T₄	28.66	31.33	31.67	47.66
T₅	27.00	31.33	28.67	46.66
T₆	26.66	31.66	30.00	47.00
T₇	32.66	36.00	34.67	49.66
SEm(±)	0.96	0.91	1.30	0.36
C.D. (5%)	2.99	2.85	4.04	1.12
C.V.	5.92	4.96	5.92	1.31

Table 4.14: Effect of different treatment combinations on fruit length and girth of bottle gourd

Treatment	Fruit parameters	
	Fruit length (cm)	Girth (cm)
T₁	35.33	19.32
T₂	35.66	19.36
T₃	37.33	20.31
T₄	36.72	20.14
T₅	39.08	21.59
T₆	36.16	21.00
T₇	33.53	18.12
SEm(±)	0.71	0.39
C.D. (5%)	2.21	1.23
C.V.	3.39	3.41

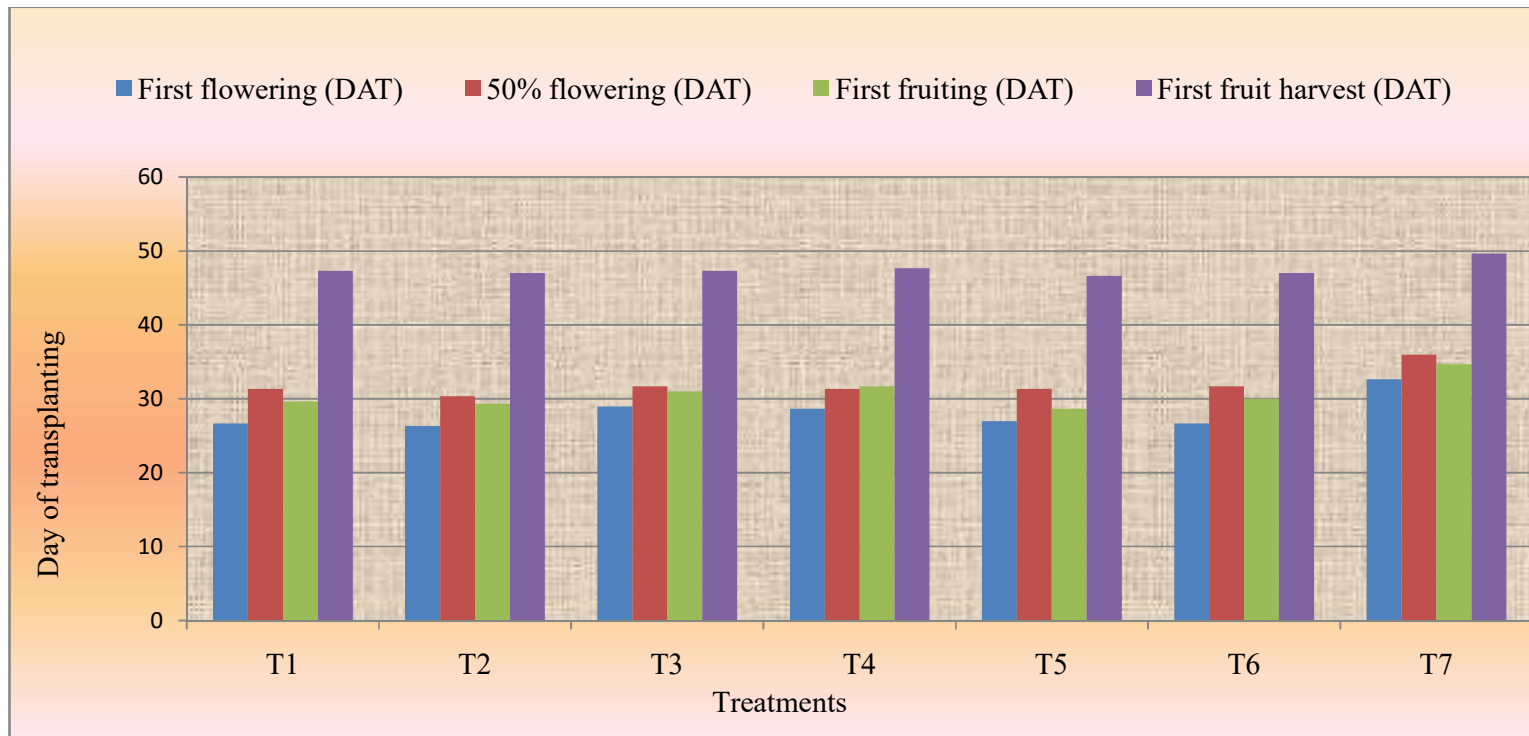


Fig: 4.8: Effect of different treatment combinations on flowering and fruiting of bottle gourd

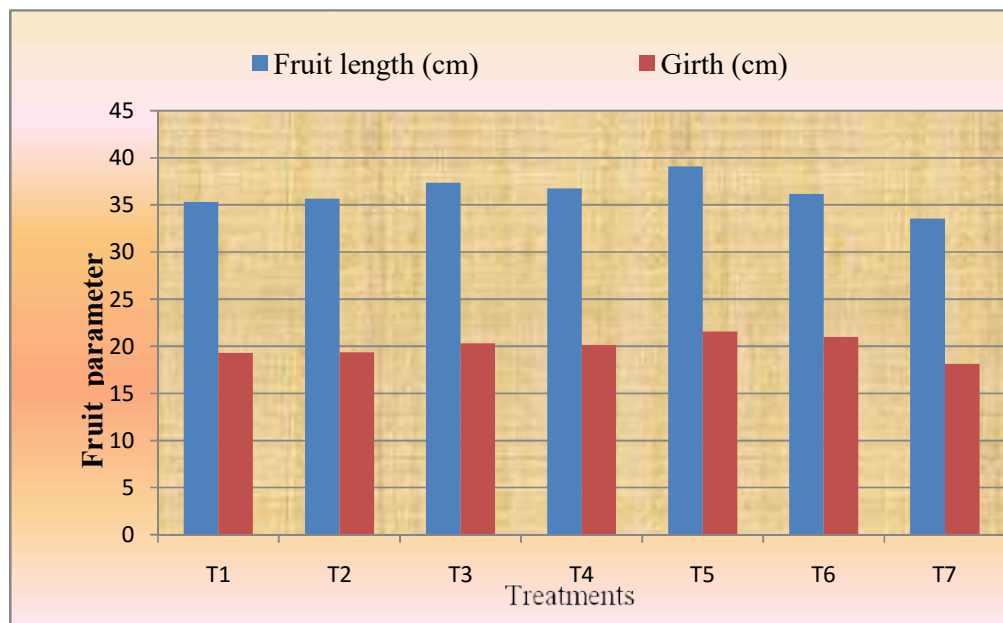


Fig 4.9: Effect of different treatment combinations on fruit length and girth of bottle gourd

Table 4.15: Effect of different treatment combinations on yield of bottle gourd

Treatment	No. of fruit / plant	Average fruit weight/ plant (kg/plant)	Average fruit yield/plant (kg/plant)	Average fruit yield/plot (kg/plot)	Total yield (q/ha)
T₁	4.61	0.82	3.64	72.90	243.00
T₂	4.60	0.93	4.34	86.82	289.40
T₃	4.71	0.83	4.40	88.11	293.70
T₄	4.33	0.86	4.09	81.77	272.19
T₅	5.08	0.90	4.43	88.75	295.83
T₆	4.65	0.91	4.30	85.96	286.39
T₇	3.60	0.76	2.70	53.97	179.05
SEm(±)	0.62	0.048	0.34	6.95	22.42
C.D. (5%)	N/A	N/A	1.08	21.67	69.09
C.V.	24.07	9.73	15.13	15.11	14.77

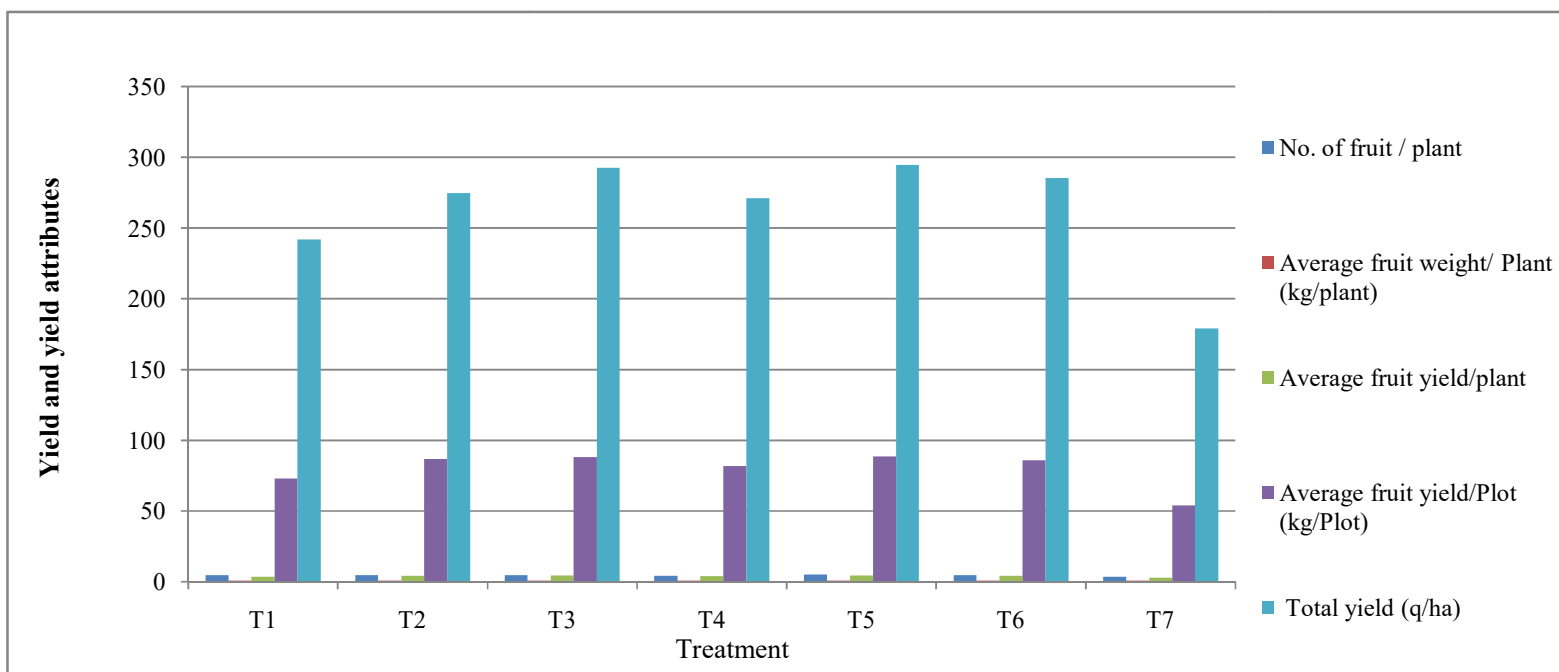


Fig 4.10: Effect of different treatment combinations on yield of bottle gourd.



Picking of mature bottle gourd fruits

4.10 Harvesting

4.5. Economics of different management practices

The economics of different management practices was shown in Table 4.16. The average rate of produce throughout the season was Rs. 10/kg (Rs. 1000/q). The value of produce was ranged from Rs. 295830 to 179050. The maximum value of produce (Rs. 295830) earned from from T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%]. This was followed by T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₂ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] with value of Rs. 293700 and 289400 respectively. However, the least value of produce was earned form untreated control (Rs.179050).

The total cost for management practices ranged from Rs. 61901.6 to 78847.6. The maximum cost (Rs. 78847.6) was invested in T₆ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%)] followed by T₅ (Rs. 76216.1) i.e. seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid

17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%. However the least cost (Rs. 61901.6) was invested in untreated control (T₇)

The cost benefit ratio was ranged from 1:1.57 to 1:0.94. It was revealed from the data presented in Table 4.16 that the best cost benefit ratio was obtained by T₃ (1:1.57) i.e. seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% followed by T₂ [seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] and T₅ [seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with cost benefit ratio of 1:1.56 and 1:1.53, respectively. The least cost benefit ratio (1:0.94) was obtained from treatment T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%) and neem oil (0.2%)].

The present results are more or less similar with the findings of Kumar *et al.* (2018) attained highest cost benefit ratio (1:2.85) from T₄ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with the least cost benefit ratio (1:0.27) in treatment T₂ [seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching

at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)]. Manjusha (2007) and Holmes (2005) reported that maximum return was recorded under spray of Curzate and Macozeb.

Table 4.16: Economics of different management practices of bottle gourd.

1 Treat- ment	2 Marketable yield (q/ha)	3 Rate of produce (Rs/q)	4 Value of produce (Rs)	5 Total cost (Rs)	6 Value of produce in treatment - Value of produce in control (Rs.)	7 Per Revalue (6/5)	8 B:C Ratio
T ₁	243.00	1000	243000	67882.6	63950	0.94	1:0.94
T ₂	289.40	1000	289400	70928.6	110350	1.56	1:1.56
T ₃	293.70	1000	293700	73010.9	114650	1.57	1:1.57
T ₄	272.19	1000	272190	74327.6	93140	1.25	1:1.25
T ₅	295.83	1000	295830	76216.1	116780	1.53	1:1.53
T ₆	286.39	1000	286390	78847.6	107340	1.36	1:1.36
T ₇	179.05	1000	179050	61901.6			-

CHAPTER- V

SUMMARY AND CONCLUSIONS

The present study entitled “**Studies on diseases of bottle gourd, [*Lagenaria siceraria* (Molina) standl] and its management strategies**” was conducted at Horticultural Instructional-cum Research Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during December 2017 to April 2018.

The investigation mainly consists of five parts *i.e.* (i) To record the seasonal occurrence of bottle gourd diseases, (ii) To evaluate important commercial varieties (bottle gourd) against prevalent diseases, (iii) To work out the suitable combination of methods for management of the disease, (iv) To study the response of various treatments on yield and yield attributes of bottle gourd. (v) To work out the economics of different treatments under the study.

4.1 Seasonal occurrence of prevalent diseases of bottle gourd diseases.

Five diseases viz. downy mildew, leaf curl, leaf blight, mosaic and powdery mildew appeared between first fortnights of February to the end of April 2018. The crop was first infected with leaf curl and mosaic in the second fortnight of February 2018 then downy mildew and leaf blight in the first fortnight of March. However, powdery mildew occurred in the first fortnight of April.

Out of thirteen varieties of bottle gourd tested three (Amrit, Ankit and Anmol), two (Manya, Ns-433), four (Chutki, Haruna, Latto and Naveen) and three (Angad, Mahima and Sarita) varieties showed sequentially immune, resistant, moderately resistant and moderately susceptible reactions. One variety (Divya) was found susceptible against the downy mildew.

Five varieties viz. Angad, Ankit, Anmol, Chutki and Naveen showed immune reaction against leaf curl. However, five (Haruna, Latto, Manya, NS-443 and Sarita) and three (Amrit, Divya and Mahima) varieties were moderately susceptible and susceptible respectively.

Five varieties viz. Amrit, Ankit, Latto, Manya and NS-443 showed highly resistant reaction against mosaic. Five (Angad, Anmol, Divya, Naveen and Sarita) and two (Chutki and Haruna) varieties of bottle gourd were found resistant and

moderately resistant, respectively. One variety i.e. Mahima showed moderately susceptible reaction against mosaic while none of the variety was either susceptible or highly susceptible.

Among the thirteen varieties of bottle gourd evaluated none of them was either immune or resistant against leaf curl disease but six (Chutki, Amrit Angad, Ankit, Mahima and NS-433) and four (Anmol, Haruna, Manya and Naveen) varieties showed moderately resistant and moderately susceptible response, respectively. However three varieties viz. Divya, Latto and Sarita were found susceptible to powdery mildew.

The seeds treated with chemical *i.e.* carbendazim 12% + mancozeb 63% (3 g/kg seed) considerably increased germination percentage (98.14%), root length (9.14 cm), shoots length (13.11 cm), fresh weight (5.67 g), dry weight (0.66 g) and vigour index (2183.65). Poor seedling attributes *viz.* germination percentage, root and shoot length, fresh weight, dry weight and vigour index of bottle gourd were obtained when seeds were not treated with any chemical or bio control substance.

The lowest severity of downy mildew (10.51%) was recorded in treatment T₅ [Seed treatment with (carbendazim 12% + mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] with the highest severity in untreated control (23.35%).

The plants of bottle gourd were free from the powdery mildew disease when they are treated with T₁ [Seed treatment with bio-fungicide (seed pro @ 25g/kg seed) for organic farming + drenching at first true leaf stage with seed pro @ 5% + 6 alternate spray of seed pro (1%) and neem oil (0.2%)], T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₆ [Seed treatment with

(carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl- Al @ 0.1%].

The crop treated with T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] had lowest severity of leaf blight (15.01%).

The minimum incidence of leaf curl (20.0%) was recorded in T₄ [Seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%]. However, the maximum leaf curl incidence (41.67%) was recorded in T₇ (control).

The plants of bottle gourd in T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₆ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + spray of (imidacloprid 17.8 SL @7.5 ml/15L+ neem oil 0.2%) + (captan 70% + hexaconazole 5%WP @ 0.1%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5%WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%)+ Fosetyl- Al @ 0.1%] plots showed least infection of mosaic (10.0%).

The minimum days to first flowering (26.66 DAT), fifty per cent flowering (30.33 DAT) were recorded under treatment T₂ i.e. Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%). However the days to first fruiting (28.67 DAT) and first harvest (46.66 DAT) were minimum under treatment T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %].

The plants of bottle gourd in treatment T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %.] produced largest fruit with fruit length and girth of 39.08 and 21.59 cm respectively.

The plants of bottle gourd in treatment T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %.] produced maximum number of fruits per plant (5.08).

The heaviest fruit (0.93 kg/plant) was recorded from treatment T₅ [Seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)].

The average fruit yield/plant (4.43), average fruit yield/plot (88.75) and total yield (295.83 q/ha) were received from treatment T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %].

The highest cost benefit ratio (1:1.57) was attained by T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %].

CONCLUSION

- Five diseases viz. downy mildew, leaf curl, leaf blight, mosaic and powdery mildew appeared during the course of investigation. Leaf curl and mosaic observed earlier than the downy mildew and leaf blight.
- Seed treatment with carbendazim 12% + mancozeb 63% (3 g/kg seed) significantly stimulated germination percentage, root length, shoot length, fresh weight, dry weight and vigour index of bottle gourd.
- Among the thirteen varieties of bottle gourd three (Amrit, Ankit and Anmol) and two (Manya and Ns-433) were immune and resistant to downy mildew respectively. However, five (Angad, Ankit, Anmol, Chutki and Naveen) varieties showed Immune response against leaf curl.
- Five varieties (Amrit, Ankit, Latto, Manya and NS-443) were highly resistant and other five viz. Angad, Anmol, Divya, Naveen and Sarita were resistant against mosaic. Out of thirteen varieties of bottle gourd six varieties (Chutki, Amrit Angad, Ankit, Mahima and NS-433) were moderately resistant against powdery mildew.

- Three management practices viz. T₅ [Seed treatment with (carbendazim 12%+ mancozeb 63% @ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5%WP @ 0.1%) + Spray of (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (tebuconazole 50% + trifloxistrobin 25% WG @ 1g/l) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1 %], T₃ [seed treatment with seed pro @ 25g/kg + drenching at first true leaf stage with seed pro @ 5% + spray of (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @ 7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1% + (captan 70% + hexaconazole 5% WP @ 0.1%) + (imidacloprid 17.8 SL @7.5 ml/15L + neem oil 0.2%) + Fosetyl-Al @ 0.1%] and T₂ [seed treatment with carbendazim 12% + mancozeb 63% (@ 3g/kg) + drenching at first true leaf stage with (captan 70% + hexaconazole 5% WP @ 0.1%) + 6 alternate spray of seed pro (1%) and neem oil (0.2%)] significantly reduced the incidence and severity of diseases with better flowering, fruiting, fruit size, yield attributes, yield and cost benefit ratio

SUGGESTIONS FOR FUTURE RESEARCH WORK

1. Epidemiological studies have to be under taken for the development of effective forecasting model.
2. Role of vectors in dissemination of leaf curl and mosaic have to be carried out.
3. The survey of occurrence, severity, incidence and distribution of prevalent diseases in different regions of Chhattisgarh has to be under taken.
4. The study on host pathogen relationship has to be under taken.

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