STUDIES ON PHYLLODY DISEASE OF SESAMUM (*Sesamum indicum* L.) AND MANAGEMENT

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Thesis submitted to the

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in

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Affectionately Dedicated to

My parents

Mr. NATESHA

Mrs. DRAKSHAYANAMMA

And

FRIENDS

DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BENGALURU- 560 065

CERTIFICATE

This is to certify that, the thesis entitled "**STUDIES ON PHYLLODY DISEASE OF SESAMUM (*Sesamum indicum* L.) AND MANAGEMENT**" submitted by **Mr. MAHADEVAPRASAD, T. N., ID. No. PALB 4256**, in partial fulfillment of the requirements for the award of the degree of **MASTERS OF SCIENCE (Agriculture) in PLANT PATHOLOGY** to the University of Agricultural Sciences, GKVK, Bengaluru, is a record of research work carried out by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis of the award of any other degree, diploma, associate ship, fellowship or other similar titles.

BENGALURU
July, 2016

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Major Advisor

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(K. R. SHREENIVASA)

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July, 2016 ***MAHADEVAPRASAD, T. N.***

STUDIES ON PHYLLODY DISEASE OF SESAMUM (*Sesamum indicum* L.) AND MANAGEMENT

MAHADEVAPRASAD, T. N

THESIS ABSTRACT

Phyllody caused by phloem limiting phytoplasma is a very serious disease in most sesamum growing areas of Southern Karnataka. Sesamum phyllody is gaining importance in recent years because it causes an yield loss of upto 100 per cent. During survey phyllody infected plants showed excessive stunting, severe reduction in leaf size, reduced internodal length, excessive axillary proliferation and floral malformation like abnormal green structures in place of normal flowers. The incidence of sesamum phyllody ranged from 13.6 to 31.21 per cent during survey in sesamum growing areas of Southern Karnataka. The disease incidence was lowest in Ramanagar district with incidence of 13.6 per cent. Hassan district recorded the highest incidence of 31.21 per cent. Three genotypes showed resistant reaction, 27 genotypes showed moderately resistant reaction and 13 genotypes showed susceptible reaction against the phyllody disease under field conditions. Management of sesamum phyllody through two dates of sowing and vector (leafhopper) control revealed that lowest disease incidence (22.90 per cent) was observed in late sown crop compared to early sown crop (25.43 per cent). Seed yield was maximum (266.24 kg/ha) in late sown crop compared to early sown crop (249.15 kg/ha). Of the different treatment combinations, late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L and late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid17.8 % SL @ 0.5 ml/L at 20 days interval significantly reduced the disease incidence (18.51 and 19.78 per cent) and increased seed yield of 315.77 and 303.61 kg/ha respectively.

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ಎಳ್ಳು ಫಿಲ್ಲೋಡಿ ಫೈಟೋಪ್ಲಾಸ್ಮ ಅಣುವಿನ ಅಧ್ಯಯನ ಮತ್ತು ನಿರ್ವಹಣೆ

ಮಹದೇವಪ್ರಸಾದ್, ಟಿ. ಎನ್.

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಎಳ್ಳಿಗೆ ಬರುವ ಫಿಲ್ಲೋಡಿ ರೋಗವು ಫೈಟೋಪ್ಲಾಸ್ಮ ಎಂಬ ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಯಿಂದ ಉಂಟಾಗುತ್ತದೆ. ಇತ್ತೀಚಿನ ದಿನಗಳಲ್ಲಿ ಈ ರೋಗದ ತೀವ್ರತೆ ಹೆಚ್ಚಾಗಿದ್ದು, ಬೆಳೆಯ ಇಳುವರಿ ಶೇಕಡಾ ೧೦೦ ರಷ್ಟು ಕುಂಠಿತಗೊಳ್ಳುತ್ತಿದೆ. ಫಿಲ್ಲೋಡಿ ರೋಗ ತಗುಲಿದ ಎಳ್ಳಿನ ಗಿಡಗಳಲ್ಲಿ ಕುಬ್ಜತೆ, ಸಣ್ಣನೆಯ ಎಲೆಗಳು ಮತ್ತು ಹೂವಿನ ಭಾಗವು ಹಸಿರು ಎಲೆಗಳಾಗಿ ಮಾರ್ಪಾಡಾಗುತ್ತದೆ. ದಕ್ಷಿಣ ಕರ್ನಾಟಕದ ಜಿಲ್ಲೆಗಳಲ್ಲಿ ಸಮೀಕ್ಷೆಯನ್ನು ಕೈಗೊಂಡಾಗ ಶೇಕಡಾ ೧೩.೬ ರಿಂದ ೩೧.೨೧ ರವರೆಗೆ ಫಿಲ್ಲೋಡಿ ರೋಗದ ತೀವ್ರತೆ ಕಂಡುಬಂದಿದೆ. ರೋಗದ ತೀವ್ರತೆಯು ರಾಮನಗರ ಜಿಲ್ಲೆಯಲ್ಲಿ ಅತೀ ಕಡಿಮೆ ಇದ್ದು (ಶೇ. ೧೩.೬) ಹಾಗೂ ಹಾಸನ ಜಿಲ್ಲೆಯಲ್ಲಿ ಹೆಚ್ಚಿನ ತೀವ್ರತೆಯನ್ನು (ಶೇ. ೩೧.೨೧) ದಾಖಲಿಸಲಾಗಿದೆ. ನಲವತ್ತಮೂರು ಎಳ್ಳಿನ ಪ್ರಭೇದಗಳನ್ನು ಫಿಲ್ಲೋಡಿ ರೋಗಕ್ಕೆ ಅನ್ವೇಶಿಸಲಾಯಿತು. ಪರೀಕ್ಷಿಸಿದ ನಲವತ್ತಮೂರು ಎಳ್ಳಿನ ಪ್ರಭೇದಗಳಲ್ಲಿ ಮೂರು ಪ್ರಭೇದಗಳು ರೋಗ ನಿರೋಧಕ ಶಕ್ತಿಯನ್ನು, ೨೭ ಪ್ರಭೇದಗಳು ಸಾಧಾರಣ ರೋಗನಿರೋಧಕ ಶಕ್ತಿಯನ್ನು ಮತ್ತು ೧೩ ಪ್ರಭೇದಗಳು ಸಾಧಾರಣ ರೋಗಕ್ಕೆ ತುತ್ತಾಗುವ ಶಕ್ತಿಯನ್ನು ಹೊಂದಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಎಳ್ಳು ಫಿಲ್ಲೋಡಿ ಫೈಟೋಪ್ಲಾಸ್ಮ ರೋಗದ ನಿರ್ವಹಣೆಯನ್ನು ಮೇ ಮೊದಲನೇ ಹಾಗೂ ಮೂರನೇ ವಾರ ಬಿತ್ತನೆ ಕಾರ್ಯವನ್ನು ಮತ್ತು ರೋಗವಾಹಕ (ಜಿಗಿಹುಳು) ನಿಯಂತ್ರಣದ ಮೂಲಕ ಕೈಗೊಂಡಾಗ ತಡವಾಗಿ ಬಿತ್ತನೆ ಮಾಡಿದ ಬೆಳೆಯಲ್ಲಿ ಫಿಲ್ಲೋಡಿ ರೋಗದ ತೀವ್ರತೆ ಕಡಿಮೆಯಿದ್ದು (ಶೇ. ೨೨.೯೦), ಮುಂಚಿತ ಬಿತ್ತನೆ ಮಾಡಿದ ಬೆಳೆಯಲ್ಲಿ ರೋಗದ ತೀವ್ರತೆ ಅಧಿಕವಾಗಿರುತ್ತದೆ (ಶೇ. ೨೫.೪೩). ತಡವಾಗಿ ಬಿತ್ತನೆ ಮಾಡಿದ ಬೆಳೆಯಲ್ಲಿ ಬೀಜದ ಇಳುವರಿಯು ಹೆಚ್ಚಾಗಿರುವುದು (೨೬೬.೨೪ ಕೆ.ಜಿ./ಹೆ) ಕಂಡುಬಂದಿದೆ. ವಿವಿಧ ಉಪಚಾರ ಸಂಯೋಜನೆಯಲ್ಲಿ, ಇಮಿಡಾಕ್ಲೋಪ್ರಿಡ್ ೭೦ ಡಬ್ಲ್ಯೂಎಸ್ (೫ ಗ್ರಾಂ./ಕೆ.ಜಿ.) ಬೀಜ ಉಪಚರಿಸಿದ ಮತ್ತು ಅಸಿಟಾಮಾಪ್ರಿಡ್ ಶೇ. ೨೦ ಎಸ್‌ಪಿ (೦.೩ ಗ್ರಾಂ./ಲೀ.) ಸಿಂಪರಣೆ ಮತ್ತು ಇಮಿಡಾಕ್ಲೋಪ್ರಿಡ್ ೭೦ ಡಬ್ಲ್ಯೂಎಸ್ (೫ ಗ್ರಾಂ./ಕೆ.ಜಿ.) ಬೀಜ ಉಪಚರಿಸಿದ ಹಾಗೂ ಇಮಿಡಾಕ್ಲೋಪ್ರಿಡ್ ಶೇ. ೧೭.೮೦ ಎಸ್‌ಎಲ್ (೦.೫ ಮಿ.ಲೀ./ಲೀ.) ಸಿಂಪರಣೆ ಮಾಡಿದ ತಡವಾಗಿ ಬಿತ್ತನೆಯಾದ ಬೆಳೆಯಲ್ಲಿ ರೋಗದ ಹಾವಳಿ ಪ್ರಮಾಣ ಕಡಿಮೆ ಕಂಡುಬಂದಿದ್ದು, ಬೀಜದ ಇಳುವರಿಯು ಸಹ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ.

ಜುಲೈ, ೨೦೧೬
ಸಸ್ಯರೋಗಶಾಸ್ತ್ರ ವಿಭಾಗ,
ಕೃಷಿ ವಿಶ್ವ ವಿದ್ಯಾನಿಲಯ,
ಜಿ. ಕೆ. ವಿ. ಕೆ., ಬೆಂಗಳೂರು – ೬೫

(ಕೆ. ಕರುಣ)
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

Studies on phyllody disease of sesamum (*Sesamum indicum* L.) and management

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Introduction

Sesamum (*Sesamum indicum* L.) is one of the ancient oil seed crop grown in India. It is called as the queen of oil seeds in view of its high oil quality and protein. Its oil content generally varies from 46-52% and protein content varies between 20-26%. Sesamum oil is used as cooking medium in Southern India. Sesamum oil has excellent stability due to the presence of the natural antioxidants sesamoline, sesamin, and sesamol. Seeds with hulls are rich in calcium (1.3%) and provide valuable source of minerals (Anon., 2006).

The sesamum crop suffers from many diseases like powdery mildew caused by *Erysiphe cichoracearum, Alternaria* leaf spot caused by *Alternaria sesami* , Cercospora leaf spot , Fusarium wilt, Bacterial blight and phyllody caused by phytoplasma (Natarajan *et al*.,1983).

Among several diseases, sesamum phyllody caused by phytoplasma and transmitted by leafhopper is the most severe and affecting the plant partially or completely, resulting in loss in yield of 10-100% in India (Sahambi,1970).

Objectives

1. Survey for incidence of phyllody disease in major sesamum growing areas of Southern Karnataka
2. Strategies for management of sesamum phyllody

Material and Methods

➢ **Survey for incidence sesamum phyllody**

A field survey was carried out to know the disease incidence in Ramanagar , Tumakuru and Hassan districts of Karnataka during 2015. A minimum of 5 to 6 fields were selected randomly at each location. In an area of 10 m^2 , the number of plants showing the symptoms were counted and the percentage incidence was calculated using formula.

$$\text{Per cent disease incidence (PDI)} = \frac{\text{Total number of infected plants}}{\text{Total number of plants examined}} \times 100$$

➢ **Strategies for management of sesamum phyllody**

Experimental details

- Crop : Sesamum
- Duration : 3 Months
- Treatments: 8
- Replication: 3
- Plot size : 3m x 5m
- Cultivar : Navile-1
- Design : Split plot
- Soil : Red sandy soil
- Spacing : 30cm X 15cm

Treatments

Main treatments: dates of sowing- early and late sowing

Sub treatments:

T_1: Seed treatment with Imidacloprid 70 WS @ 5g/Kg of seeds

T_2: T_1 + Spray of Imidacloprid 17.8% SL @ 0.5ml/L

T_3: T_1 + Spray of Acetamiprid 20% SP @ 0.3g/L

T_4: T_1+ Spray of Thiacloprid 21.7% SC @ 1ml/L

T_5: T_1+ Spray of Thiamethoxam 25 WDG @ 0.3g/L

T_6: T_1+ Spray of Lambda-cyhalothrin 2.5% EC@ 1ml/L

T_7: T_1+ Spray of Azadirachtin 300 ppm @ 3ml/L

T_8: Untreated check

- The field experiment was conducted at KVK, Konehally, Tiptur. The insecticides were applied twice at 35 and 55 DAS. Observations on the percent incidence of disease was recorded at 45, 60 and 75 DAS by counting the total number of infected plants and total number of plants in each plot. Yield of sesamum was also recorded from each plot.

Results

- Survey results revealed maximum disease incidence of phyllody was 31.21 per cent in Hassan district followed by 27.51 per cent in Tumakuru and 13.60 per cent in Ramanagar. The most common symptoms observed were pale green leaves and bushy growth due to excessive stunting, axillary proliferation and development of abnormal green structures in place of flowers (Plate 2).

Table 1: Incidence of sesamum phyllody during *kharif* 2015.

Districts	Sesamum phyllody (PDI)
Ramanagar	13.60
Tumakuru	27.51
Hassan	31.21

- Imidacloprid 70 WS seed treatment @5g/kg + Imidacloprid 17.8% SL @0.5ml/L spray at the time of initiation of symptoms (35 DAS) accounted minimum incidence (13.09 %) followed by imidacloprid 70 WS seed treatment @5g/kg + Acetamiprid 20% SP @0.3g/L spray (13.32 %) in early sown crop. Untreated check accounted maximum (29.15 %) incidence and high seed yield (306.85 kg/ha) obtained in Imidacloprid 70 WS seed treatment @5g/kg + Imidacloprid 17.8% SL @0.25ml/L spray treated plot over untreated check (202.67 kg/ha) (Fig.1).

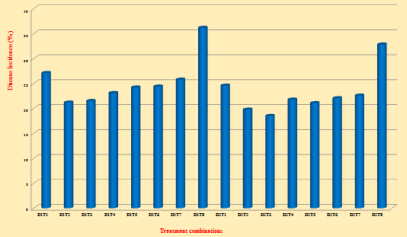

Fig.1: Effect of different treatments on disease incidence

- Imidacloprid 70 WS seed treatment @5g/kg + Acetamiprid 20% SP @0.3g/L spray accounted minimum incidence (13.67%) followed by Imidacloprid 70 WS seed treatment @5g/kg + Imidacloprid 17.8% SL @0.5ml/L spray (14.64%) and maximum incidence observed in untreated check (26.22%) in late sown crop. High seed yield (315.77 kg/ha) obtained in Imidacloprid 70 WS seed treatment @5g/kg + Acetamiprid 20% SP @0.3g/L spray treated plot over the untreated check plot (225.54 kg/ha) (Fig.2).

Discussion

- All the treatments were significantly effective in reducing the incidence of phyllody over untreated check.
- Incidence of sesamum phyllody was highest in Hassan (31.21%) and least in Ramanagar district (13.60%). Similar results were reported by Palanna *et al.*(2014).
- Reduction in disease incidence over untreated check plot was higher with T_2 followed by T_3 and T_3 followed by T_2 in early and late sown crop respectively. Similarly maximum yield was recorded in T_2 followed by T_3 in early sown crop and T_3 followed by T_2 treatment in late sown crop. In both the cases ST with Imidacloprid 70 WS and foliar spray of Imidacloprid 17.8% SL and Acetamiprid 20% SP was found to be effective over the untreated check. Similar results observed by Palanna *et al.* (2014).

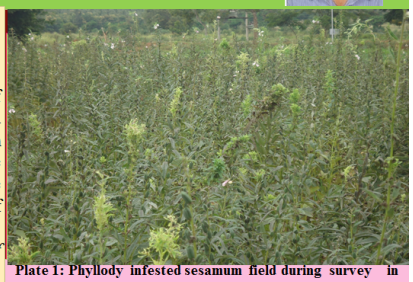

Plate 1: Phyllody infested sesamum field during survey in Tumakuru district

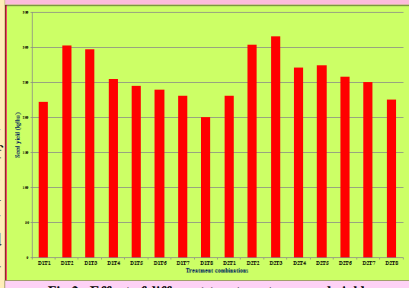

Fig.2: Effect of different treatments on seed yield

Plate 2: Abnormal green structures developed in place of flowers

Summary

- The incidence of sesamum phyllody in Southern Karnataka varied from 13.60% to 31.21%.
- Seed treatment with Imidacloprid 70 WS + foliar spray of Imidacloprid 17.8% SL and Seed treatment with Imidacloprid 70 WS + Spray of Acetamiprid 20% SP were found to be effective in reducing the disease incidence over untreated check.

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Advisory committee

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Dr. K. M. Srinivas Reddy
Dr. K. R. Shreenivasa

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I INTRODUCTION

Sesamum (*Sesamum indicum* L.) is an important oilseed crop domesticated over 3000 years ago and belongs to the family Pedaliaceae; its cultivation extends from 40^0 N to 40º S latitude, covering the tropical and subtropical areas of Asia and Africa. It is one of the most ancient and important oil seed crops with 6.5 million hectares cultivated worldwide, producing more than 3 million tonnes of seed. India, Sudan, Myanmar and China are the major contributors with 68 per cent of the world production (Chattopadhaya *et al*., 2015).

Sesamum seed is a rich source of protein (20 %) and edible oil (50 %) and contains high amount of saturated fatty acids (47 % oleic acid and 39 % linolenic acid). Sesamum oil has an excellent stability due to the presence of natural antioxidants sesamoline, sesamin and sesamol (Moazzami *et al*., 2006).

Seeds are used in various food preparations, especially in delicacies, bakery foods etc., as well as bird feed. Seeds are a store house of energy. As a matter of fact, 100 grams of seed provide as much as 600 calories of energy. Seeds are rich in fats, proteins and carbohydrates, besides containing several essential minerals and vitamins. Its proteins are composed of such essential amino acids like methionine and tryptophan which are important for healthy kidney and liver (Anon., 2006).

It is one of the best oils from the health point of view since it is known to reduce cholesterol leading to prevention of coronary disease. It is called "Queen of oils" because of its extra-ordinary cosmetic and skin-care properties. Hence it is extensively used in shampoos, massage and toilatery products. It is used in the manufacture of soaps, detergents, pharmaceuticals, perfumes etc. (Anon., 2006).

India is among the top five countries of the world in oilseed production. Which is estimated to be 25.5 million tonnes annually. Nine edible oilseeds are cultivated in India and sesamum ranks fifth in production, after groundnut, rape seed, soybean and sunflower (Chattopadhaya *et al*., 2015).

In India sesamum is grown in an area of 19.01 lakh hectares with a production of 8.10 lakh tonnes and an average yield of 426 kg/ha. In Karnataka it is being grown in 0.60 lakh hectares with a production of 0.30 lakh tonnes and an average yield of 500 kg/ha (Chattopadhaya *et al*., 2015).

In Karnataka the crop is cultivated extensively in Northern Karnataka, especially in Gulbarga, Raichur, Haveri, Dharwad, Bijapur districts and to a limited extent in Southern districts of Ramanagar, Hassan, Tumkur, Mysore, Chamarajanagar and Chitradurga.

The crop suffers from a number of diseases. Most important of them are powdery mildew caused by *Erysiphe cichoracearum*, *Alternaria* leaf spot caused by *Alternaria*

sesami, *Cercospora* leaf spot, *Fusarium* wilt, bacterial blight and phyllody caused by phytoplasma (Natarajan *et al*., 1983).

Phytoplasmas are phloem-restricted, cell wall-less prokaryotic parasites belonging to the class Mollicutes (Lee *et al*., 2000). They are associated with diseases affecting hundreds of plant species and are transmitted by phloem sucking insects (Weintraub and Beanland, 2006).

Mycoplasmas like organisms (MLOs) have been found to be associated with diseases in several hundred plant species. Doi *et al.* (1967) first discovered the presence of cell wall less prokaryotes within sieve cells of plants exhibiting yellow symptom. These unique plant pathogenic prokaryotes have been termed as MLOs belonging to class mollicutes. The members of the class mollicutes are characterized by lack of cell wall, small genome size (680 to 1660 kb), low guanine plus-cytosine (G+C) content and are unable to culture.

Sesamum phyllody phytoplasma causes disease in 91 plant species belonging to 36 genera distributed in 12 families including important crop plants like Egyptian clover, Bengal gram, carrot, Indian mustard, Lucerne, radish, sunhemp and Indian rape (Sahambi, 1970).

Insect vectors have a great role in the transmission of MLOs. Vasudeva and Sahambi (1955) reported that the vector of sesamum phyllody was *Deltocephalus* sp. and Ghauri (1966) identified the same vector as *Orosius albicinctus* Dist.. Prasad and Sahambi (1982) confirmed the nature of transmission of sesamum phyllody phytoplasma by leafhopper, *Orosius albicinctus*.

Sesamum phyllody could be managed either by using resistant cultivars or by using insecticides against leafhopper vectors. Crop hygiene practices which help to reduce phyllody incidence in sesamum are early rouging of symptomatic plants, restrictions on growing susceptible varieties and control of host plants of the leafhopper vectors. Some of the cultural methods, particularly rotation management, sowing dates could also be fruitfully applied (Beech, 1981).

In view of very little information on strategies for management of sesamum phyllody caused by phytoplasma. The present studies were undertaken to understand the management strategies of sesamum phyllody phytoplasma. The study was formulated with the following objectives.

1. Survey for incidence of phyllody disease in major sesamum growing areas of Southern Karnataka
2. Identification of resistance genotypes through field screening of available sesamum germplasm
3. Methods (Strategies) for management of sesamum phyllody

II REVIEW OF LITERATURE

Sesamum is found to be affected by diverse groups of plant pathogens like fungi, bacteria, viruses and mycoplasma like organisms MLO's/Phytoplasma. Among these, phyllody caused by phytoplasma is an important disease causing considerable yield loss. The literature pertaining to sesamum phyllody disease was reviewed and is presented in this chapter.

2.1 Occurrence

Sesamum phyllody phytoplasma is reported on 91 plant species belonging to 36 genera distributed in 12 families including important crop plants like Egyptian clover, bengal gram, carrot, Indian mustard, lucerne, radish, sunhemp and Indian rape (Sahambi, 1970).

Ghosh *et al*. (1999) observed witches' broom disease of lime (WBDL) in Nagpur district of Eastern Maharashtra during 1995. Subsequent surveys in 1995-98 revealed the presence of this disease up to 5 per cent in Maharashtra state and in other major acid lime growing states of Andhra Pradesh, Tamil Nadu and Karnataka.

Diseases of phytoplasmal origin have also been recorded by several workers on a number of crop plants *viz*., sesamum (Okashiram, 1930; Bindra and Bakhetia, 1976; Pal and Pushkarnath, 1935; Aiyadurai and Srinivasulu, 1956; Sahambi, 1970; Vasudeva and Sahambi, 1955; Vachani, 1945); mungbean (Dharmapal Singh, 1954; Beningoni, 1979; Kiratiya *et al*., 1984); blackgram (Shyam and Bhatnagar, 1965); soybean (Dingra and Chenulu, 1983; Fletcher *et al*., 1984; Iwaki *et al*., 1978); cowpea (Fang and Fan, 1985; Varma *et al*., 1978); dolichos (Singh, 1989a); legumes (Bowyer *et al*., 1969; Hutton and Gryllus, 1956; Thung and Hadimidjaja, 1957); groundnut (Iwaki *et al*., 1978; Kiratiya *et al*., 1984; Muthuswamy and Subramanian, 1985; Yang, 1985); frenchbean (Kitazima and Costa, 1979); broad bean (Jones *et al*., 1984); winged bean (Singh, 1991); lucerne (Bowyer, 1974; Hulse, 1991; Thompson and Peterson, 1988); aster phyllody (Rangaswamy *et al*., 1988; Kunkel, 1926; Ragazzino *et al*., 1977); brinjal (Anjaneyalu and Ramakrishnan, 1979); potato (Vijaya Singh *et al*., 1981); tomato (Bowyer, 1974); chilli (Singh, 1991); onion (Petre and Ploaie, 1973); radish (Misra and Gupta, 1977); rice (Ishii *et al*., 1969; Raychudhari *et al*., 1967; Muniyappa and Ramakrishnan, 1976); sandal spike (Subbarao, 1980); safflower phyllody (Salehi *et al*., 2009); and sunhemp (Bose and Misra, 1938; Rajagopalan and Venkataraman, 1963; Shivanathan *et al*., 1982; Suryanarayana, 1987 and Yang, 1979).

Phyllody disease has been recorded on number of weed species by various workers *viz*., *Pedalium murex* (Joshi and Misra, 1981); parthenium (Pathak *et al*., 1975; Mathur and Muniyappa, 1989; Padmanabhan, 1984; Kitazima and Costa, 1979); *Acanthospermum hispidum* Dc (Raju and Muniyappa, 1981); *Stachytarpeta indica* L. (Suryanarayana, 1993); *Datura stramonium* (Cousin and Grison, 1966); and *Cynodon* sp. Pers and *Brachiari distachya* Grises (Chen *et al*., 1972) and an ornamental plant like periwinkle (Valenta and Nour-Eldin, 1967; Moll *et al*., 1977; Dabek, 1982; Mc Coy and

Thomas, 1981; Kitazima and Costa, 1979; Kar *et al*., 1982; Rassel and Desmidis, 1976) was also been found infected naturally by phytoplasmas.

Phytoplasmas are phloem-restricted, cell wall-less prokaryotic parasites belonging to the class Mollicutes and genus Candidatus (Lee *et al*., 2000). They are associated with diseases affecting hundreds of plant species and are transmitted by phloem sucking insects (Weintraub and Beanland, 2006).

Vellios and Lioliopoulou (2007) reported that the percentage of tomato plants with symptoms resembling phytoplasma infection ranged between 1-2 per cent, although in some cases it reached 70-80 per cent during survey in different parts of Greece.

Plants of *Amaranthus* sp. growing in adjacent hedges of Lettuce (*Lactuca sativa*), carrot (*Daucus carota*) and French bean (*Phaseolus vulgaris*) exhibited leaf yellowing similar to those symptoms expressed by the main crop at the Vegetable Research Center, GBPUA&T, Pantnagar, Uttarakhand, India. It was the first record of a 16SrII phytoplasma isolate in lettuce, carrot, french bean and *Amaranth* sp. in India (Arocha *et al*., 2009).

During field visits in Barapani, Meghalaya (North East India) in June-July, 2008, typical witche's broom symptoms were observed in 46 per cent of *Crotalaria tetragona* plants (Baiswar *et al*., 2009).

Typical little leaf, chlorosis, witches' broom, yellowing and phyllody symptoms were recorded on *Zinnia elegans* plants grown in different gardens of Sugarcane Research Station, Kunraghat of Gorakhpur district, Uttar Pradesh, which were further processed for phytoplasma detection and characterization (Rao *et al*., 2012).

Survey conducted in Northern Karnataka during *kharif* 2009, indicated that phyllody disease incidence in sesamum ranged from 2.62-55.7 per cent (Sridhar, 2013).

2.2 Symptomatology, Transmission and Host range of phytoplasma

2.2.1 Symptomatology

Pal and Pushkarnath (1935) reported that in phyllody affected sesamum plants, all the flowers except the stamens transformed into leaf like structures or showed a marked tendency to become leafy. The stamens seldom contained functional pollen and plants were completely sterile.

Vasudeva and Sahambi (1955) characterized sesamum phyllody disease in the flowering stage and noted transformation of floral parts, abundant vegetative growth and shortened stature.

The diseased pigeonpea plants look stunted due to reduction in length of internodes. The bushy appearance without significant reduction in leaf size results in typical rosetting. Slight chlorosis was also observed around the base of the midrib of

many young leaflets. In diseased plants no abnormality of flowers was described (Maramorosch *et al*., 1976).

Abraham *et al*. (1977) reported that phyllody affected sesamum plants were stunted and floral parts were modified into leafy structures bearing no fruits and seeds causing yield loss of upto 33.9 per cent.

Ravi (1983) reported symptoms of pigeonpea phyllody as shortening of internodes, proliferation of auxiliary branches, reduction in leaf size, paling of leaves and their early senescence. All the floral parts were transformed into leaf like structures with elongated pedicel.

Plants infected by phytoplasma exhibit an array of symptoms that suggest profound disturbances in the normal balance of plant hormones or growth regulators. Symptoms include virescence (the development of green flowers and loss of normal flower pigments), phyllody (the development of floral parts into leafy structures), sterility of flowers, proliferation of axillary shoots resulting in a witches' broom appearance, abnormal elongations of internodes resulting in slender shoots, generalized stunting, discolorations of leaves or shoots, leaf curling or cupping, bunchy appearance of growth at the ends of the stems, and generalized decline (Lee *et al*., 2000).

The phytoplasma infected grapevine plants often show yellowing which is caused by the breakdown of chlorophyll and carotenoids, whose biosynthesis is also inhibited (Bertamini and Nedunchezhian, 2001).

A common symptom caused by phytoplasma infection is phyllody, the production of leaf like structures in place of flowers. Evidence suggests that the phytoplasma deregulates a gene involved in flower formation in tomato plants (Pracros *et al*., 2006).

Akhtar *et al*. (2009) observed different types of symptoms in phyllody affected sesame plants *viz*., floral virescence, phyllody, proliferation of flowers and cracking of seed capsule.

Abnormal anatomical features like excessive stem and bud proliferation, mosaics and unusual coloration were observed on grain amaranth species in experimental fields established in Central Mexico (Ochoa-Sanchez *et al*., 2009).

Symptoms of diseased plants may vary with the phytoplasma, host plant, stage of the disease, age of the plant at the time of infection and environmental conditions (Lee *et al*., 2000). Specific symptoms include flower discolorations and distortion such as virescence, phyllody, big bud, flower proliferation and other flower abnormalities- all resulting in sterility, witches' brooms, rosetting, internode elongation, enlarged stipules, off-season growth and brown discoloration of phloem tissue. Less specific and non-specific symptoms, which are most often common in woody plants, include foliar yellowing and reddening, small leaves, leaf roll, leaf curl, vein clearing, vein enlargement, vein necrosis, premature autumn coloration, premature defoliation,

undersized fruits, poor terminal growth, sparse foliage, dieback, stunting of overall plant growth and decline. In rare instances, phytoplasma infected plants are fully non-symptomatic over their lifespan; a temporary or permanent remission of symptoms may also occur (Marcone, 2010).

2.2.2 Transmission and Host range

Phyllody is an important disease caused by a pleomorphic MLO (phytoplasma) and transmitted by leaf hoppers (Vasudeva and Sahambi, 1955). Sesame phyllody phytoplasma causes disease in 91 plant species belonging to 36 genera distributed in 12 families including important crop plants like Egyptian clover, bengal gram, carrot, Indian mustard, lucerne, radish, sunhemp and Indian rape (Sahambi, 1970).

Vasudeva and Sahambi (1955) reported that the vector of sesame phyllody was *Deltocephalus* sp. Prasad and Sahambi (1982) confirmed the nature of transmission of sesamum phyllody phytoplasma by leafhopper, *Orosius albicinctus*.

2.3 Screening of sesamum germplasm lines

Rangaswamy *et al*. (1990) recorded severe outbreak of the pigeonpea phyllody disease during *kharif* season affecting most of the genotypes grown at the Zonal Agricultural Research Station, Gandhi Krishi Vignan Kendra, Bengaluru. None of the 41 entries of the Coordinated Varietal Trials were free from infection. The commonly grown cv. HY3C showed the highest incidence (61 %).

Information on the sources of resistance to sesame phyllody disease is less. However, TMV-3, BT-892 and BAUT1 were showed partial resistance reaction to sesame phyllody phytoplasma and powdery mildew disease (Gopal *et al*., 1998).

Among the four promising sesame cultivars tested for their field resistance against phyllody disease, lowest incidence of phyllody was observed in cv. TMV 4 while the highest incidence was detected in cv. TMV 3 followed by cv. SVPR 1 during various periods of observation (Selvanarayanan and Selvamuthukumaran, 2000).

Among 106 lines screened for phyllody disease in sesamum, the disease intensity was maximum in NS 3103(20 per cent) followed by NS 9203(16.66 per cent) and NS 6503(14.28 per cent) as compared to check variety TS-3 (3.80 per cent). No disease symptom was observed in variety Til-89 (Sarwar and Haq, 2006).

Out of 150 sesame germplasm evaluated under field conditions during *kharif*-2005, disease incidence of parental lines recorded on individual plant basis indicated that seven cultivars *viz*., RJS78, RJS147, KMR14, KMR79, Pragati, IC43063 and IC43236 and two wild spp. i.e. *Sesamum alatum* and *Sesamum mulayanum* were resistant to phytoplasma with mean incidence below 5 per cent in all the parental lines (Singh *et al*., 2007).

Susceptible reaction of Annigeri-1 and JG-11 to chickpea phyllody was observed on chickpea crop sown during April and May months in Southern parts of Karnataka (Ramappa *et al*., 2008).

Among thirty sesamum genotypes screened for phyllody, five genotypes *viz*., IVT-09-1, IVT-09-2, IVT-09-14, IVT-09-19 and Kanakapura-1(local variety) were resistant. Seventeen genotypes were moderately resistant and nine genotypes were moderately susceptible under field conditions at ZARS, GKVK (Manjunatha, 2010).

The resistance of 133 sesame genotypes belonging to different regions was evaluated in the field under high inoculum pressure for two consecutive years in Pakistan revealed that three genotypes namely NS 98002-04, NS 98003- 04 and NS 99005-01 were ranked as highly resistant as they remained symptomless till the harvest of crop while eleven others namely; NS97001-04, NS01004-04, Sumboonkkae, NS940051-04, NS20005-04, NS 11704, NS96019-04, Ahnsankkac, NS 11504, Hansumkkae and NS99006-04 were scored as resistant with percent disease infection (PDI) of 3.12, 3.33, 3.40, 3.45, 5.0, 5.30, 5.88, 7.14, 8.69, 8.70 and 10 per cent respectively. Other genotypes were ranked between moderately resistant to highly susceptible with PDI values ranging from 10.71per cent to 65.12 per cent. During second year all the tested genotypes were found to be infected with phyllody disease. Four genotypes *viz*., NS98002-04, NS98003-04, NS99005-01 and NS01004-04 were resistant with PDIs of 3.25, 3.25, 3.75 and 10.0 per cent respectively (Akhtar *et al*., 2013).

Among seven varieties of sesamum (E-8, DS-1, GT-1, TMV-3, DS-9, Navile-1 and local variety) evaluated for phyllody disease, GT-1 and DS-9 accounted minimum (10.67 per cent) incidence followed by DS-1 (11.34 per cent) and E-8 (14.00 per cent). Navile-1 recorded 16.00 per cent as against 29.34 per cent in local variety (Palanna *et al*., 2015).

Among 140 genotypes of grain amaranth screened for phyllody, 126 genotypes were found to be free from infection. Two genotypes *viz.*, RMA-7 and RMA-37 recorded <5 per cent disease incidence. Eight genotypes *viz.*, BGA-19; RGA-10; SKGPA-72, 105, 123; IC-035615, 081698-B and 095516 showed disease in the range of 6-20 per cent. The genotypes (SKGPA-83, 127 and IC-095430) recorded disease incidence in the range of 21-50 per cent whereas the genotypes IC095383, 095389 and 120621 were found to be highly susceptible showing >50 per cent disease incidence (Swathi Patil, 2015).

2.4 Management of sesamum phyllody

Information on the management of phyllody disease is very less. However, partial management of phyllody disease on fennel, black pepper and sesame are reviewed.

Eight insecticides were tested in 1978-80, three sprays of 0.01 % Fenvelarate gave the most effective control of *Orosius albicinctus* on sesame and increased average seed yields to 0.77 t/ha from 0.30 t in the untreated control (Sarnaik *et al*., 1986).

Sanjay Kumar and Goel (1993) reported that pyrethroid insecticide *viz*., Cypermethrin (60 g), Deltamethrin (12.5 g) and Fenpropathrin (100 g) a.i./ha were as effective as Fluvalinate (75 g), Fenvalerate (75 g) and Quinalphos (500 g) a.i./ha in maintaining the plant population and in regulating the phyllody disease in sesamum.

Jyothirmai *et al*. (2002) reported that imidacloprid 70 WS as seed treatment @ 5g/kg seed + imidacloprid (Confidor 200 SL) 0.01 % foliar spray drastically reduced leafhopper (*Empoasca kerri* Pruthi) population and increased the pod yield of groundnut.

Imidacloprid and thiomethoxam @ 25g a.i./ha were significantly superior over dimethoate @ 300 g a.i./ha and cypermethrin @ 100g a.i./ha in controlling aphids and jassids on okra. The plant product azadirachtin @ 3g a.i./ha was effective against aphids but not against jassids (Misra, 2002).

Confidor 350 SC @ 75 ml/ha was found to be superior over all the treatments in controlling aphid and jassid population on the cotton crop. Higher yield (1259.6 kg/ha) was recorded from the plot treated with confidor 350 SC @ 75 ml/ha, followed by confidor 350 SC @ 60 ml/ha (1188.8 kg/ha) (Choudhary *et al*., 2005).

Imidacloprid 70 WS @ 5-10g/kg seed and imidacloprid 20 SL @ 100-125 ml/ha were found highly effective and significantly superior to carbosulfan 25 DS @ 50g/kg in controlling the leafhopper (*Amrasca biguttula biguttula*) in okra (Dey *et al*., 2005).

Lal and Sinha (2005) reported that Imidacloprid seed treatment @ 5g/kg seed along with two foliar sprays of Betacyfluthrin or Lambda cyhalothrin and Endosulfan were the most effective treatments in managing leafhoppers (*Amrasca biguttula biguttula* Ishida) in okra.

Razaq *et al*. (2005) reported that Diafenthiuron, Acetamiprid, Imidacloprid and Thiamethoxam were found to be most effective in reducing jassid population below ETL (Economic threshold level) in cotton crop.

Seed treatment with Thiamethoxam @ 5 g a.i./kg followed by two foliar sprays alternated with Abamectin @ 15 g a.i./ha and Spinosad @ 75 g a.i./ha at fortnightly interval or the spray schedule of Thiamethoxam @ 20 g a.i./ha followed by Fipronil @ 50 g a.i./ha at fortnightly interval was found to be most effective strategy to manage leafhopper, shoot and fruit borer of okra (Sinha *et al*., 2007).

Solangi and Lohar (2007) reported that confidor proved to be more effective in controlling jassids and other insect pests in okra compared to sundaphos, polo and mospilan, where jassid mean population was 1.20 plant^{-1} as compared to pre-treatment population of 7.78 plant^{-1}, thrips 1.16 plant^{-1} as compared to pre-treatment population of 6.52 plant^{-1} , whitefly 1.18 plant^{-1}as compared to pre-treatment population of 8.31 plant^{-1}, mites controlled to the level of 2.42 plant^{-1} as compared to 8.56 plant^{-1} (control).

Four insecticides belonging to organophosphates (OPs) Fenitrothion, Chlorpyrifos ethyl, Malathion and the neonicotinoid Imidacloprid were tested for their capacity to limit the transmission of chrysanthemum yellows phytoplasma (CYP) by the leafhopper vector, *Macrosteles quadripunctulatus*. The OPs were applied to the foliage as sprays, while imidacloprid was applied to the soil as drench. The OP- treated plants were significantly less infected than water treated plants only at 1 and 4 days after treatment application, while those treated with imidacloprid were significantly protected at all times tested. The experiment confirmed that imidacloprid was much more effective than OPs in preventing the CYP transmission (Saracco *et al*., 2008).

Akhtar *et al*. (2009) reported that treatment of phyllody infected sesamum plants with tetracycline-Hcl (500 ppm) at weekly intervals, partially recovered the plants from the typical symptoms of the disease after 20-25 days of treatment.

Ahirwar *et al*. (2010) reported that incidence of nymph and adult population of sucking pests in sesamum *viz*., jassid, *Orosius albicinctus* (Distant), mirid bug, *Nesidiocoris tenuis* (Rent.) and whitefly, *Bemisia tabaci* (Gennadius) was decreased significantly by natural and indigenous products, *viz*., Neem oil (NO), Neem seed kernel extract (NSKE), Neem leaf extract (NLE), Garlic bud+ Red pepper extract (GB+RPE), Cow urine (CU) and Cow butter milk (CBM) as compared to untreated. Insecticide endosulfan was more effective than these products. The efficacy of all the above products were in the order of endosulfan> NSKE > NO > NLE > GB + RPE > CU > CBM. Grain yield was significantly higher in all the treatments as compared to untreated but was maximum with endosulfan 0.07 % (622 kg/ha) followed by NSKE- 30 ml/l (605 kg/ha).

VenkannaYasa (2010) reported that foliar application of imidacloprid @ 26.7 g a.i./ha at 25 and 40 days after sowing was found to be significantly effective in reducing leafhoppers (*Empoasca kerri* Pruthi) on groundnut and also superior among various neonicotinoid group *viz*., acetamiprid and thiamethoxam.

Three conventional insecticides *viz*., imidacloprid, endosulfan and profenophos were tested against potato leaf hopper on autumn potato crop. The order of effectiveness was found to be imidacloprid>endosulfan>profenophos with 88.59, 73.32 and 64.87 per cent control of the leaf hopper population respectively (Akbar *et al*., 2012).

Toxicity of nine insecticides *viz*., thiamethoxam 25 WDG @ 0.2 g/l, acetamiprid 20 SP @ 0.2 g/l, pyriproxyfen 10 EC @ 1.0 ml/l, acephate 75 SP @ 1.0 g/l, clothianidin 50 WDG @ 0.12 g/l, oxydemeton methyl 25 EC @ 1.5 ml/l, imidacloprid 17.8 SL @ 0.3 ml/l, dimethoate 30 EC @ 1.75 ml/l and lambda cyhalothrin 5 EC @ 0.5 ml/l was assessed against third nymphal instars of *A. biguttula biguttula* on *Bt* cotton under laboratory conditions at Department of Agricultural Entomology, College of Agriculture, Raichur. The per cent mortality of leafhopper was found to be maximum (50.67 %) in thiamethoxam 25 WDG with non-significant difference with imidacloprid 17.8 SL (46.67 %) at 25 days after spray. Clothianidin 50 WDG found to be next best treatment (Shreevani *et al*., 2012).

Treatments with imidacloprid and thiamethoxam as foliar applications were highly effective against aphids, up to 14 days in the case of jassids, while the effect was moderate on the whitefly population in cotton (mature and immature stages) (El-Naggar *et al*., 2013).

The application of insecticide (imidacloprid 20% SL, acetamiprid 20% SL, thiamethoxam 25 WG and acephate 75 SP) sprays immediately enhanced the mortality of the sucking insect pests on mungbean, *Vigna radiata* (L.). Whereas, seed treatment with imidacloprid and detergent did not show distinctive effect on the pest population. Imidaclopridand and thiamethoxam were found to be the most effective insecticides against sucking pests followed by acetamiprid (Iqbal *et al*., 2013).

The minimum incidence (9.80 per cent) of phyllody with highest fennel equivalent yield (3035.28 kg ha^{-1}) was observed in fennel intercropped with green gram (1:1) and the minimum incidence of phyllody (9.19 per cent) with highest yield (1947.17 kg ha^{-1}) was recorded in seedling root dip with 0.04 % Imidacloprid + one spray of 0.005 % imidacloprid after one month of transplanting, in addition to seedlings grown in 40 mesh nylon cloth net (Jaiman *et al*., 2013).

The incidence of phyllody was lower in methyl-o-demeton treated plants (1.2 and 1.6 %) than in the control (2.6 and 2.9 per cent) during *kharif* and summer respectively, and also increased seed yield (380 and 330 kg/ha) compared to check (210 and 180 kg/ha) (Pathak *et al*., 2013).

Among four newer insecticides (Fipronil, Imidacloprid, Buprofezin and Thiamethoxam + Emamectin benzoate) tested against two important sucking insects pests of brinjal, *Amrasca devastans* (jassids or leafhopper) and *Bemisia tabaci* (whitefly), Fipronil, Imidacloprid and Buprofezin were found to be most effective while Thiamethoxam + Emamectin benzoate was least effective. Imidacloprid, Fipronil and Buprofezin proved to be the superior against jassids and whiteflies while Thiamethoxam + Emamectin benzoate was moderately effective against whitefly but almost ineffective against jassids in their time-oriented mortality (Das and Islam, 2014).

Among different treatments tested, Imidacloprid 70 WS seed treatment @ 7.5 g/kg seed + Monocrotophos 36 SL (0.2 %) spray at the time of initiation of symptoms accounted for minimum phyllody incidence (18 per cent) followed by Imidacloprid 70 WS seed treatment @ 7.5 g/kg seed and Triazophos 40 EC (0.2 %) spray, which accounted for 18.34 and 19.00 per cent disease incidence respectively (Palanna *et al*., 2014).

Among the different treatments tested, against sucking insect pests *viz*., leafhopper, whitefly and aphids in okra, the cumulative effect of foliar spray of thiamethoxam 25 WG @ 0.006 % was found most effective against aphids, followed by lambda cyhalothrin 5 EC @ 0.004 %. While, thiamethoxam 25 WG @ 0.006 % was effective against leafhopper population followed by thiamethoxam 25 WG @ 0.008 %. Thiamethoxam 25 WG @ 0.006 % was effective against whitefly (Patil *et al*., 2014).

Insecticides *viz.*, Carbofuran, Confidor, Thiamethoxam and Acetamiprid were effective in reducing the incidence of aster phyllody when applied individually and in combination. Of the different treatments, lowest disease severity was recorded in Carbofuran + Confidor + Thiamethoxam + Acetamiprid and Carbofuran + Confidor + Thiamethoxam treatment. Carbofuran was least effective in controlling the phyllody disease incidence (Shweta Kumari, 2014).

Hosseini *et al*. (2015) reported that sowing date and spraying with insecticides has significant effect on infection of sesamum phyllody. Delayed sowing reduced sesame phyllody up to 31 %, spraying with Confidor reduced disease incidence at the first (June 10) and second sowing date (July 5) by 18.8 and 7.8 per cent respectively, but no differences were observed in yields. Seed treatment with Gaucho has no effect on disease incidence.

Nemade *et al*. (2015) reported that the minimum population of leafhoppers was recorded when sprayed with Fipronil 5 SC (0.075 %) which was on par with spraying with Diafenthiuron 50 WP (0.08 %) and Imidacloprid 30.5 SL (0.005 %). Next best treatment was Buprofezin 25 SC (0.05 %). Significantly highest seed cotton yield of 19.43 q/ha was harvested by application of Fipronil 5 SC (0.075 %) followed by Diafenthiuron 50 WP (0.08 %) and Imidacloprid 30.5 SL (0.005 %) with 18.66 and 18.19 q/ha respectively.

Imidacloprid was found most effective treatment for controlling jassids, followed by the microbial insecticide Spinosad. Extracts of *Polygonum* plant and *Pongamia* leaves at a concentration of 5 % and the microbial insecticide Spinosad gave higher jassid control, recording more than 50 % mortality. The extract of *Polygonum* at 5 % concentration was found very effective against jassids, achieving more than 60 % mortality at 3 and 7 days after treatment (DAT) (Sunil and Kaushik, 2015).

Imidacloprid 600 FS seed treatment + imidacloprid 17.8 SL spraying and imidacloprid 600 FS seed treatment + lambda-cyhalothrin 5 EC spraying were highly effective in reducing the phyllody incidence in sesamum by managing the vector leaf hopper, *Orosius albicinctus* Dist. and recorded maximum seed yields (4.47 and 4.41q/ha respectively). The highest benefit cost ratio was recorded in imidacloprid 600 FS seed treatment + spraying of lambda-cyhalothrin 5 EC (Thangjam and Vastrad, 2015).

III MATERIAL AND METHODS

The present investigations on sesamum phyllody were carried out during 2015-16 at Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, GKVK, Bengaluru and Krishi Vignan Kendra (KVK), Konehally, Tiptur. The details regarding the materials used and methodologies followed are presented in this chapter.

3.1 Survey for incidence of sesamum phyllody disease

Survey was conducted in Southern districts of Karnataka *viz.*, Ramanagar, Tumakuru and Hassan during *kharif* 2015 to know the incidence of sesamum phyllody in farmers field.

On the survey route the fields were selected randomly in each village. In each field an area of 10 m^2 was selected and the per cent disease incidence was calculated by recording the number of plants showing disease symptoms and the total number of plants observed by using the following formula.

$$\text{Disease incidence (\%)} = \frac{\text{Total number of infected plants}}{\text{Total number of plants observed}} \times 100$$

During survey data on stage of crop, acreage, type of symptoms produced and vector population was recorded from five randomly selected plants. Plants were vigorously shaken later carefully covering it with a net to disturb the hoppers. Counting was made after transferring the leaf hoppers from the nets into the transparent bottles.

3.2 Screening of genotypes entries to sesamum phyllody

Screening of sesamum genotypes against phyllody caused by phytoplasma was carried out to identify the source or sources of resistance (Plate 1).

Coordinated entries of sesamum IVT, AVT and 25 genotypes entries were screened under field conditions. Navile-1 was used as susceptible check.

The genotypes and coordinated entries were sown on 7th of May 2015 at Krishi Vignan Kendra (KVK), Konehally, Tiptur in two replications in single line of 4m length with spacing of 30cm between rows in a randomized complete block design (RCBD). All the recommended package of practices were followed in raising the crop under rainfed condition.

Coordinated entries were sown on 10th of June 2015 at Zonal Agricultural Research Station (ZARS), Bengaluru with three replications by maintaining spacing of 30cm between rows and 15cm between plants in a randomized complete block design (RCBD). Recommended package of practices were followed in raising the crop under irrigated condition.

Observations were made at 45, 60 and 75 DAS with respect to phyllody disease incidence by counting the number of infected plants out of total number of plants and the per cent disease incidence was calculated. The genotypes were further grouped into 6 categories based on reaction type as per the scale given by Mayee and Datar (1986) (Table 1) for chickpea stunt disease and the same was adopted for assessing the resistance of sesamum genotypes against phyllody disease.

Table 1: Key for scoring of incidence of sesamum phyllody

Rating	Per cent disease incidence (PDI)	Reaction
0	No symptoms on any plant	Immune
3	1-5	Resistant
5	6-20	Moderately resistant
7	21-50	Susceptible
9	50 or more	Highly susceptible

3.3 Disease management trial

A field trial was laid out during *kharif* 2015 at Zonal Agricultural Research Station (ZARS), University of Agricultural Sciences, Gandhi Krishi Vignan Kendra (GKVK), Bengaluru under rainfed conditions to know the effect of sowing (early and late sowing) and the efficacy of different insecticides (seven) against phyllody of sesamum.

Experiment was laid out in a split plot design with treatments replicated thrice with a plot size of 3 m × 5 m (Plate 2). The date of sowing was allotted for main plot and spray of different insecticides was allotted for the subplot. The variety Navile-1 was sown with a spacing of 30 cm × 15 cm. Standard agronomic practices were followed to raise the crop. The insecticides tested includes imidacloprid 70 WS (5 g/kg of seeds), imidacloprid 17.8 % SL (0.5 ml/L), acetamiprid 20 % SP (0.3 g/L), thiacloprid 21.7 % SC (1ml/L), thiamethoxam 25 WG (0.3 g/L), lambda-cyhalothrin 2.5 % EC (1ml/L) and azadirachtin 0.03 % EC (3 ml/L) (Table 2). Untreated check was maintained. Totally two sprays were given. First spray was given at 35 days after sowing and subsequently another spray was given at 55 days after sowing. Disease incidence was recorded at 45, 60 and 75 days after sowing (DAS) from each plot. Yield of each treatment was recorded in grams, extrapolated and expressed as kg/ha.

To identify the leaf hoppers associated with sesamum phyllody, yellow sticky traps were tied above the crop canopy to poles at three to four random sites in the field (Plate 3). The traps were removed five days after installation and the leaf hoppers were collected and identified at Department of Entomology, GKVK, University of Agricultural Sciences, Bengaluru.

Plate 1: Field screening of sesamum genotypes

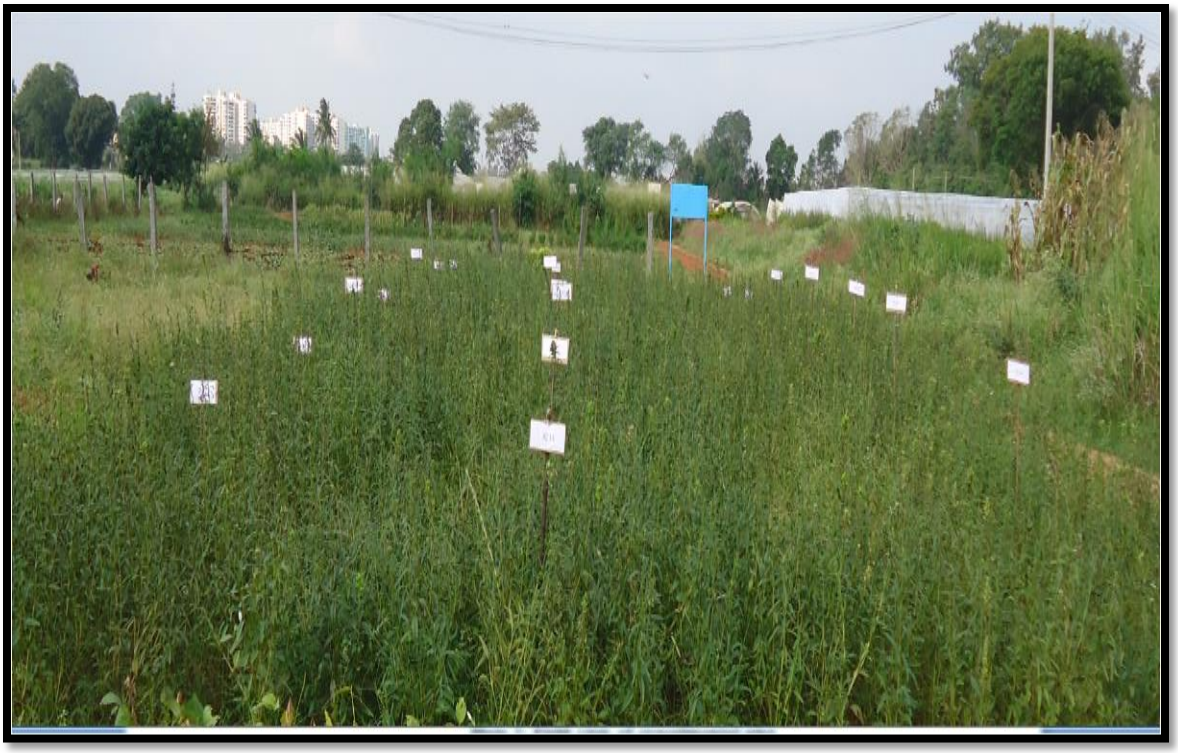


Plate 2: Field view of experimental plot

Plate 3: Yellow sticky trap installed in the field at ZARS, GKVK to collect leaf hoppers

$$\text{Disease incidence (\%)} = \frac{\text{Total number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Main treatments: Two different dates of sowing- early and late sowing

Sub treatments

T_1: Seed treatment with Imidacloprid 70 WS @ 5 g/kg of seeds

T_2: T_1 + Spray of Imidacloprid 17.8 % SL @ 0.5 ml/L

T_3: T_1 + Spray of Acetamiprid 20 % SP @ 0.3 g/L

T_4: T_1+ Spray of Thiacloprid 21.7 % SC @ 1 ml/L

T_5: T_1+ Spray of Thiamethoxam 25 WG @ 0.3 g/L

T_6: T_1+ Spray of Lambda-cyhalothrin 2.5 % EC @ 1 ml/L

T_7: T_1+ Spray of Azadirachtin 0.03 % EC (300 ppm) @ 3 ml/L

T_8: Untreated check

3.3.1 Analysis of variance

Results were analyzed using split plot design as per the requirement (Douglas Montgomery, 2012).

Table 2: Insecticides evaluated under field condition in the management of phyllody disease

Treatments	Concentrations	Method and timing of application
T_1: Imidacloprid 70 WS	5 g/kg	Seed treatment at the time of sowing
T_2: T_1+ Imidacloprid 17.8 % SL	0.5 ml/L	Foliar spray at 35 and 55 DAS
T_3: T_1+ Acetamiprid 20 % SP	0.3 g/L	Foliar spray at 35 and 55 DAS
T_4: T_1+ Thiacloprid 21.7 % SC	1 ml/L	Foliar spray at 35 and 55 DAS
T_5: T_1+ Thiamethoxam 25 WG	0.3 g/L	Foliar spray at 35 and 55 DAS
T_6: T_1+ Lambda cyhalothrin 2.5 % EC	1 ml/L	Foliar spray at 35 and 55 DAS
T_7: T_1+ Azadirachtin 0.03 % EC (300 ppm)	3 ml/L	Foliar spray at 35 and 55 DAS
T_8: Untreated check	-	-

IV EXPERIMENTAL RESULTS

Phyllody is one of the important and destructive disease of sesamum crop. The disease causes substantial yield loss by affecting growth, flowering and seed formation in the infected plants. Therefore, investigations were undertaken on management of phyllody caused by phytoplasma in sesamum. The findings of the investigation are as presented in this chapter.

4.1 SURVEY

4.1.1 Symptomatology

The most common symptoms produced were pale green leaves and bushy growth due to excessive stunting, severe reduction in leaf size, reduced internodal length, excessive axillary proliferation and floral malformation like abnormal green structures in place of normal flowers (Plate 4). The pods in disease infected plants after flowering were very small.

Affected plants were scattered in the field and could be more easily spotted at flowering and podding time. At the time of crop maturity when all the healthy plants were drying, the diseased plants in the field were conspicuously green. Occasionally, partial phyllody was also noticed, wherein, a few affected branches showed phylloid flowers, while the remaining branches produced normal flowers and pods.

4.1.2 Survey

Survey for the incidence of sesamum phyllody was carried out in three districts of Southern Karnataka *viz.,* Ramanagar, Tumakuru and Hassan during *kharif* 2015 to find out the incidence of sesamum phyllody as explained in the "Material and Methods". District wise disease incidence has been presented in plate 5 and Table 3.

The data revealed that phyllody incidence ranged from 13.6 to 31.21 per cent in the different districts surveyed and the leaf hopper vector population ranged from 1.33 to 3.53 per plant and identified as *Orosius albicinctus.* Minimum diseases incidence of 13.6 per cent was observed in Ramanagar district where the crop was 60 to 75 days old with a leaf hopper vector population of 1.33. Maximum disease incidence of 31.21 per cent was observed in Hassan district where the crop was 60 to 75 days old with a vector population of 3.53.

4.2. Screening of sesamum genotypes to phyllody

Nine IVT, nine AVT entries and twenty five genotypes were screened against phyllody under field condition at Krishi Vignan Kendra (KVK), Konehally, Tiptur. Navile-1 was used as susceptible check.

In the nine IVT entries screened, the incidence of phyllody ranged from 4.61 to 27.42 per cent. Entries KAU-05-2-12 and PC-14-2 with disease incidence of 4.61 and

Table 3: Incidence of sesamum phyllody disease in different districts of Southern Karnataka

District	Area (acre)	Disease Incidence (%)	Stage of the crop (Days after sowing)	Vector population (Mean/plant)	Symptoms observed
Ramanagar	25	13.60	60-75	1.33	Conversion of floral parts into leaf like structure, floral proliferation, shortening of internodes, virescence
Tumakuru	34	27.51	60-70	3.16	Conversion of floral parts into leaf like structure, cracking of capsule, yellowing of leaves, floral proliferation
Hassan	32	31.21	60-75	3.53	Conversion of floral parts into leaf like structure, shortening of internodes, cracking of capsule, virescence

Floral parts converted into leaf like structure

Floral proliferation

Virescence

Shotening of internodes

Plate 4: Different symptoms of phyllody disease on sesamum

Plate 5: Field view of sesamum crop infected with phyllody disease

5.39 per cent respectively were found resistant (Plate 6). Entry DS-28 with disease incidence of 8.78 per cent was found moderately resistant (Table 4).

In the nine AVT entries screened, the incidence of phyllody ranged from 15.57 to 24.74 per cent. In five entries *viz.*, RT-363, CUHY-57, AT-255, DS-23 and DS-10, the incidence of phyllody was less than 20 per cent and were found moderately resistant to phyllody.

The coordinated entries, nine IVT and nine AVT entries were screened under field condition at Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru to confirm the reaction of the entries (Table 4).

The incidence of phyllody in the nine IVT entries ranged from 5.58 to 28.49 per cent. Entries KAU-05-2-12, DS-28 and PC-14-2 with disease incidence of 8.62, 18.69 and 5.58 per cent respectively were found moderately resistant to phyllody.

In nine AVT entries screened, the incidence of phyllody ranged from 13.95 to 30.53 per cent. Five entries *viz.*, RT-363, CUHY-57, AT-255, DS-23 and DS-10 with disease incidence of less than 20 per cent were found moderately resistant to phyllody.

At both the locations IVT entry, DS-28 and AVT entries RT-363, CUHY-57, AT-255 and DS-10 showed moderately resistant reaction. Whereas, KAU-05-2-12 and PC-14-2 were resistant at KVK, Konehally, Tiptur but moderately resistant at Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru.

In the twenty five genotypes screened, the incidence of phyllody ranged from 4.60 to 28.19 per cent. Entry Kanakapura local showed resistant reaction and twenty one genotypes *viz*., NIC-16236, AKT 101, RT-54, K-15284, RT-11, EC303419, Amrit, AKT-64, RT-125, TMV-3, TKG-306, ST-9-2, ES-48, Chandana, ES- 8779-4, IS 294, E-8, DS-1, GT-1, DS-9 and Gulbarga with disease incidence of less than 20 per cent were found moderately resistant to phyllody. Three genotypes *viz.*, DS-5, Local variety (Black) and DSS-9 showed susceptible reaction (Table 5).

4.3 Management of sesamum phyllody

4.3.1 Effect of different treatments on the incidence of phyllody and seed yield of sesamum

Field experiment was conducted to know the effect of dates of sowing (early and late sowing) and the relative efficacy of different insecticides *viz.*, imidacloprid 70 WS, imidacloprid 17.8 % SL, acetamiprid 20 % SP, thiacloprid 21.7 % SC, thiamethoxam 25 WG, lambda-cyhalothrin 2.5 % EC and azadirachtin 0.03 % EC under field condition against phyllody disease incidence and seed yield during *kharif* 2015 at Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru as described in the "Material and Methods". The results obtained are presented in table 6.

Table 4: Reaction of IVT and AVT entries of sesamum to phyllody disease under field conditions

Sl. No.	Entries	Phyllody Disease incidence (%) /Reaction	
IVT entries		**Konehally**	**GKVK**
1	JCS-2464	22.78 (S)	23.03 (S)
2	KAU-05-2-12	4.61 (R)	8.62 (MR)
3	AT-249	22.10 (S)	25.13 (S)
4	DS-28	8.78 (MR)	18.69 (MR)
5	PC-14-1	22.45 (S)	26.53 (S)
6	TKG-22	26.70 (S)	26.75 (S)
7	AT-282	23.47 (S)	28.49 (S)
8	PC-14-2	5.39 (R)	5.58 (MR)
9	GT-10	27.42 (S)	26.97 (S)
AVT entries		**Konehally**	**GKVK**
1	RT-363	15.73 (MR)	18.47 (MR)
2	CUHY-57	15.57 (MR)	15.89 (MR)
3	DS-19	21.34 (S)	21.96 (S)
4	AT-255	17.49 (MR)	18.07 (MR)
5	CUMS-17	24.74 (S)	30.53 (S)
6	DS-23	19.52 (MR)	17.61 (MR)
7	JLS-301-24	21.43 (S)	23.64 (S)
8	DS-10	19.89 (MR)	13.95 (MR)
9	AT-231	21.02 (S)	21.33 (S)
10	Navile-1(Check)	32.55	31.60

*Note: R- resistant, MR- moderately resistant, S- susceptible

Plate 6: Sesamum genotypes found resistant to phyllody disease at KVK, Konehally

Table 5: Reaction of sesamum genotypes to phyllody disease under field conditions

Sl. No.	Genotypes	Phyllody % Disease incidence	Reaction
1	NIC-16236	13.09	MR
2	Kanakapura local	4.60	R
3	AKT 101	9.12	MR
4	RT-54	13.47	MR
5	K-15284	7.10	MR
6	RT-11	7.56	MR
7	EC303419	5.92	MR
8	Amrit	9.76	MR
9	AKT-64	10.73	MR
10	RT-125	9.41	MR
11	TMV-3	11.43	MR
12	TKG 306	16.58	MR
13	ST-9-2	14.34	MR
14	ES-48	14.52	MR
15	Chandana	13.22	MR
16	ES- 8779-4	14.47	MR
17	IS 294	18.40	MR
18	E-8	13.48	MR
19	DS-1	17.76	MR
20	GT-1	16.96	MR
21	DS-9	18.98	MR
22	DS-5	24.52	S
23	Local variety (Black)	25.22	S
24	DSS-9	28.19	S
25	Gulbarga	9.20	MR
26	Navile-1	32.55	S

*Note: R- resistant, MR- moderately resistant, S- susceptible

Table 6: Effect of sowing dates and insecticides on phyllody incidence and yield of sesamum

Treatment	Disease incidence (%)			Yield (kg/ha)
Dates of sowing (D)	**45 DAS**	**60 DAS**	**75 DAS**	
D_1 : Early sowing	15.23	22.07	25.43	249.15
D_2: Late sowing	8.97	19.53	22.90	266.24
S.E.m±	4.85	8.18	0.96	8.76
C.D (p=0.05)	NS	NS	NS	NS
Treatments (T)				
T_1: Imidacloprid 70 WS seed treatment @ 5 g/kg	8.70	15.69	17.23	150.78
T_2: T_1+ imidacloprid 17.8 % SL @ 0.5 ml/L spray	5.92	11.16	13.65	202.48
T_3: T_1+ acetamiprid 20 % SP @ 0.3 g/L spray	5.58	11.08	13.34	204.40
T_4: T_1+ thiacloprid 21.7 % SC @ 1 ml/L spray	6.62	12.54	14.96	175.25
T_5: T_1+ thiamethoxam 25 WG @ 0.3 g/L spray	6.97	12.53	15.10	173.35
T_6: T_1+ lambda-cyhalothrin 2.5 % EC @ 1 ml/L spray	7.04	13.32	15.49	165.92
T_7: T_1+ azadirachtin 300 ppm @ 3 ml/L spray	8.79	14.17	16.12	160.14
T_8: Untreated check	14.90	20.46	23.00	142.07
S.E.m±	0.45	0.60	0.58	5.67
C.D (p=0.05)	1.30	1.71	1.65	16.20
Interaction (D X T)				
D_1T_1	16.97	24.50	27.11	221.57
D_1T_2	10.37	16.72	21.18	302.85
D_1T_3	10.20	17.28	21.50	297.43
D_1T_4	11.94	20.09	23.10	254.44
D_1T_5	13.47	20.50	24.21	245.30
D_1T_6	13.60	21.01	24.40	239.73
D_1T_7	18.15	23.36	25.78	230.25
D_1T_8	27.14	33.14	36.17	200.67
D_2T_1	9.13	22.56	24.58	230.77
D_2T_2	7.38	16.75	19.78	303.61
D_2T_3	6.55	15.95	18.51	315.77
D_2T_4	7.93	17.54	21.78	271.32
D_2T_5	7.45	17.10	21.08	274.75
D_2T_6	7.52	18.94	22.06	258.02
D_2T_7	8.21	19.16	22.58	250.16
D_2T_8	17.57	28.24	32.84	225.54
S.E.m±	0.79	1.04	1.00	9.83
C.D (p=0.05)	2.25	2.96	2.86	28.07

NS: Non significant

Between two dates of sowing, the per cent disease incidence (PDI) was non significant. However, lower disease incidence (8.97 %) was observed in late sown crop compared to early sown crop at all stages.

The effect of different treatments on per cent disease incidence and yield was recorded. The results obtained revealed that all the treatments reduced the disease significantly compared to unsprayed control. T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded the least disease incidence (5.58 %) which was on par with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) and T_4 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiacloprid 21.7 % SC @ 1 ml/L) in which disease incidence of 5.92 % and 6.62 % was recorded respectively. In T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) and T_6 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of lambda-cyhalothrin 2.5 % EC @ 1 ml/L) disease incidence of 6.97 and 7.04 per cent respectively was observed, whereas in T_1 (seed treatment with imidacloprid 70 WS @ 5 g/kg) disease incidence of 8.70 per cent was recorded. T_7 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of azadirachtin 300 ppm @ 3ml/L) was least effective in which disease incidence of 8.79 per cent was recorded. The disease incidence in T_8 (untreated check) was 14.90 per cent at 45 DAS.

All the treatment combinations reduced the disease incidence significantly compared to untreated check. Among the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded lowest disease incidence (6.55 %) which was on par with the combinations late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8% SL @ 0.5 ml/L) (7.38 %), late sowing with T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) (7.45 %), late sowing with T_6 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of lambda-cyhalothrin 2.5 % EC @ 1 ml/L) (7.52 %) and late sowing with T_4 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiacloprid 21.7 % SC @ 1 ml/L) (7.93 %). Early sowing with no spray recorded significantly higher disease incidence (27.14 %) at 45 DAS.

The leaf hoppers submitted to the Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru were taxonomically identified as *Orosius albicinctus* and *Hishimonus phycitis* belongs to the family Cicadellidae (Plate 7).

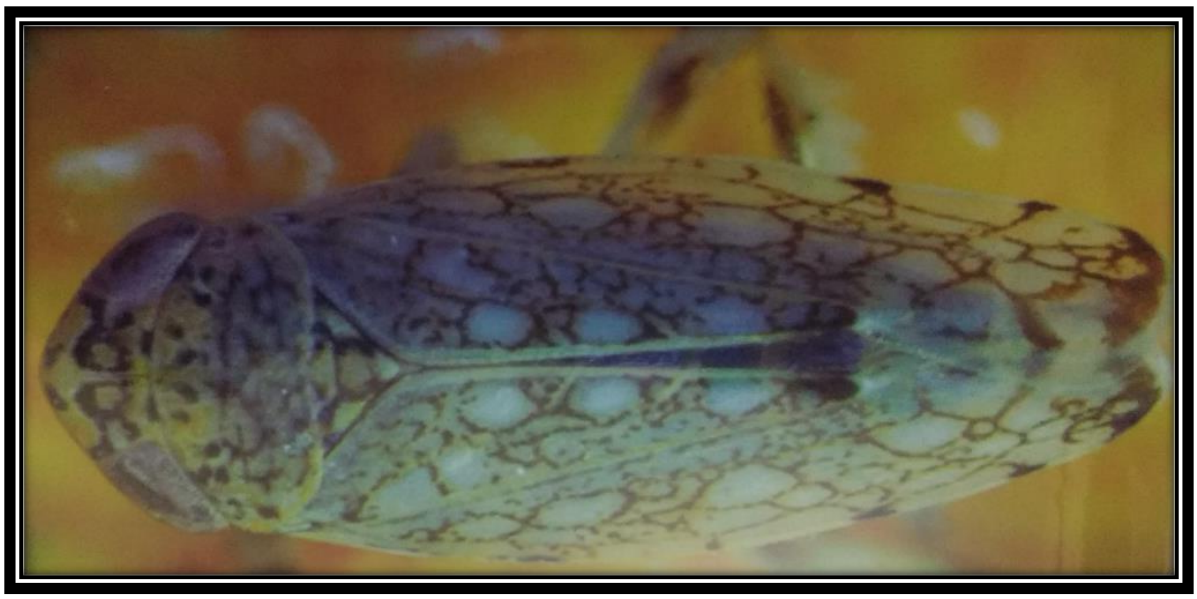
T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded the least disease incidence (11.08 %) which was on par with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L), T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) and T_4 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiacloprid 21.7 % SC @ 1 ml/L) in which disease incidence of 11.16 %, 12.53 % and 12.54 % was recorded respectively. In T_6 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of lambda-cyhalothrin 2.5 % EC @ 1 ml/L) and T_7 (seed

treatment with imidacloprid 70 WS @ 5 g/kg + spray of azadirachtin 300 ppm @ 3 ml/L) disease incidence of 13.32 and 14.17 per cent respectively was observed. T_1 (seed treatment with imidacloprid 70 WS @ 5 g/kg) was least effective in which disease incidence of 15.69 per cent was recorded. The disease incidence in T_8 (untreated check) was 20.46 per cent at 60 DAS.

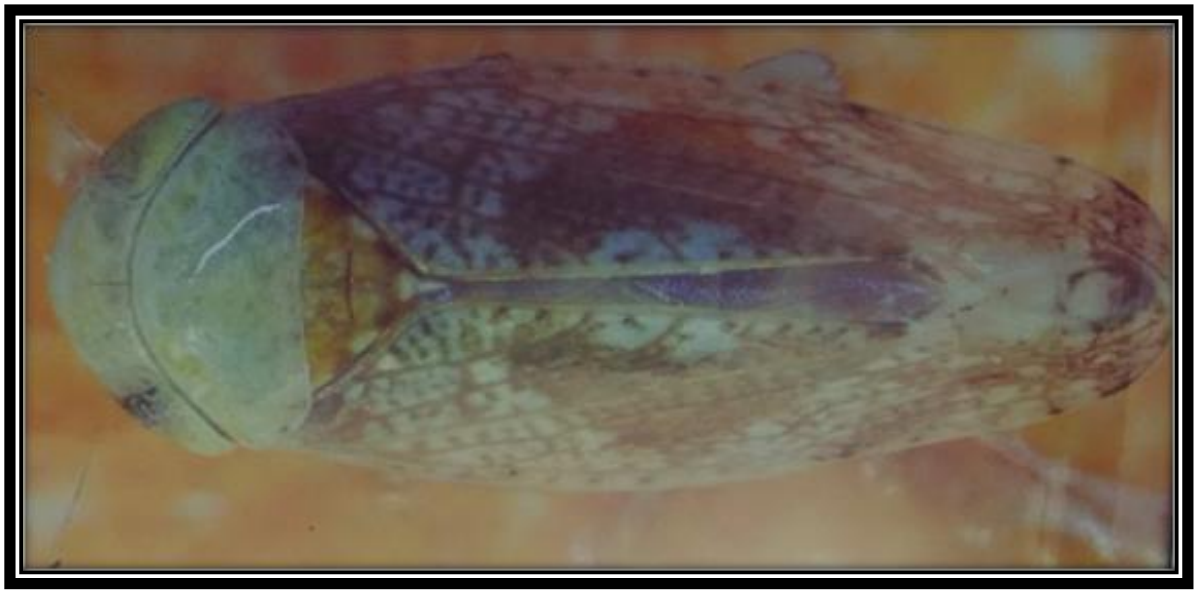
Among the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded lowest disease incidence (15.95 %) which was on par with the combinations early sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (16.72 %), late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (16.75 %), late sowing with T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) (17.10 %) and early sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) (17.28 %). Early sowing with no spray recorded significantly higher disease incidence (33.14 %) at 60 DAS.

The results obtained revealed that all the treatments reduced the disease significantly compared to unsprayed control. T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded the least disease incidence (13.34 %) which was on par with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) and T_4 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiacloprid 21.7 % SC @ 1 ml/L) in which disease incidence of 13.65 % and 14.96 % was recorded respectively. In T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) and T_6 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of lambda-cyhalothrin 2.5 % EC @ 1 ml/L) disease incidence of 15.10 and 15.49 per cent respectively was observed, whereas in T_7 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of azadirachtin 300 ppm @ 3 ml/L) disease incidence of 16.12 per cent was recorded. T_1 (seed treatment with imidacloprid 70 WS @ 5 g/kg) was least effective in which disease incidence of 17.23 per cent was recorded. The disease incidence in T_8 (untreated check) was 23.0 % at 75 DAS (Fig. 1).

All the treatment combinations reduced the disease incidence significantly compared to unsprayed control. Among the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded lowest disease incidence (18.51 %) which was on par with the combinations late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (19.78 %), late sowing with T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) (21.08 %) and early sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (21.18 %). Early sowing with no spray recorded significantly higher disease incidence (36.17 %).



Orosius albicinctus



Hishimonus phycitis

Plate 7: Leaf hopper species collected in yellow sticky traps at ZARS, GKVK, Bengaluru

Between two dates of sowing, the seed yield was non significant. However, maximum seed yield (266.24 kg/ha) was observed in D_2 (late sown crop) compared to D_1 (early sown crop) (249.15 kg/ha).

T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded highest seed yield of 204.40 kg/ha which was significantly higher compared to all other treatments, followed by T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) which recorded seed yield of 202.48 kg/ha and they were on par with each other. The lowest seed yield of 142.07 kg/ha was recorded in untreated check (Fig. 2).

Among the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded highest seed yield of 315.77 kg/ha which was on par with the combinations late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (303.61 kg/ha), early sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (302.85 kg/ha) and early sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) (297.43 kg/ha). Early sowing with no spray recorded significantly lowest seed yield of 200.67 kg/ha (Fig. 4).

Of the different treatment combinations, delayed sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L (T3) with least disease incidence (18.51 %) and higher seed yield (315.77 kg/ha) was found to be the best treatment for the management of sesamum phyllody followed by delayed sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L (T2) which recorded 19.78 % disease incidence and 303.61 kg/ha seed yield (Fig. 3 and 4).

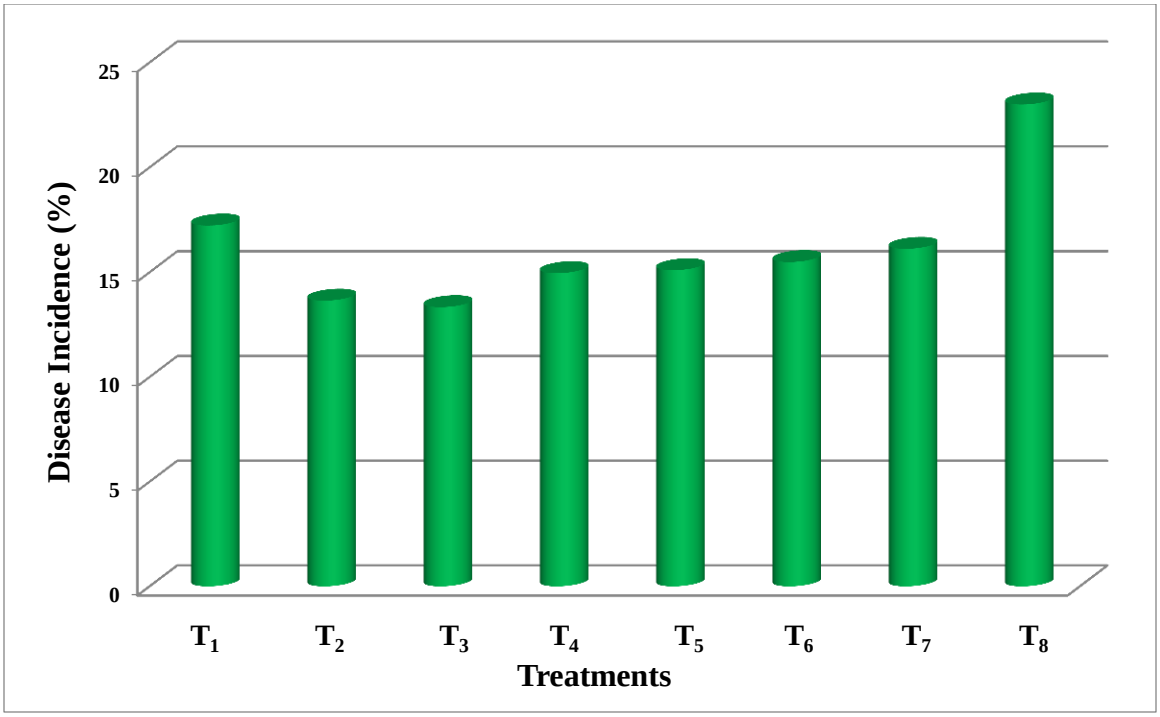


Fig 1: Effect of different insecticides treatments on disease incidence

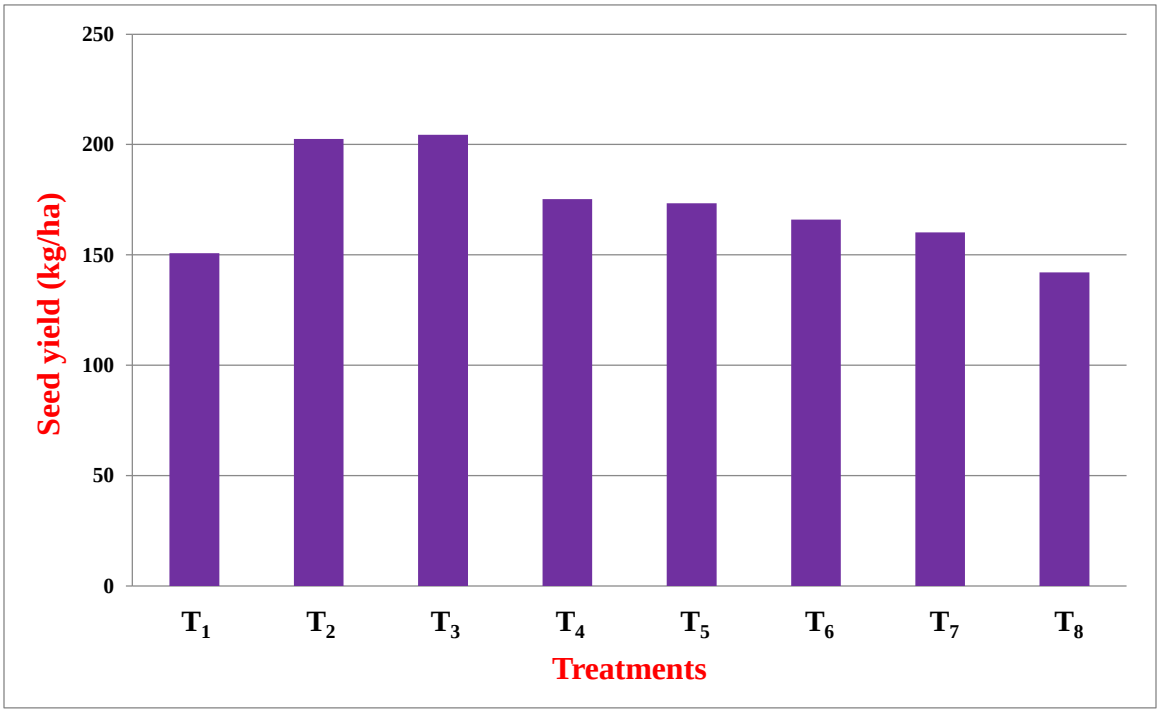


Fig. 2: Effect of different insecticides treatments on seed yield

T_1: Seed treatment with Imidacloprid 70 WS @ 5 g/Kg of seeds
T_2: T_1 + Spray of Imidacloprid 17.8 % SL @ 0.5 ml/L
T_3: T_1 + Spray of Acetamiprid 20 % SP @ 0.3 g/L
T_4: T_1+ Spray of Thiacloprid 21.7 % SC @ 1 ml/L
T_5: T_1+ Spray of Thiamethoxam 25 WG @ 0.3 g/L
T_6: T_1+ Spray of Lambda-cyhalothrin 2.5 % EC @ 1 ml/L
T_7: T_1+ Spray of Azadirachtin 0.03 % EC (300 ppm) @ 3 ml/L
T_8: Untreated check

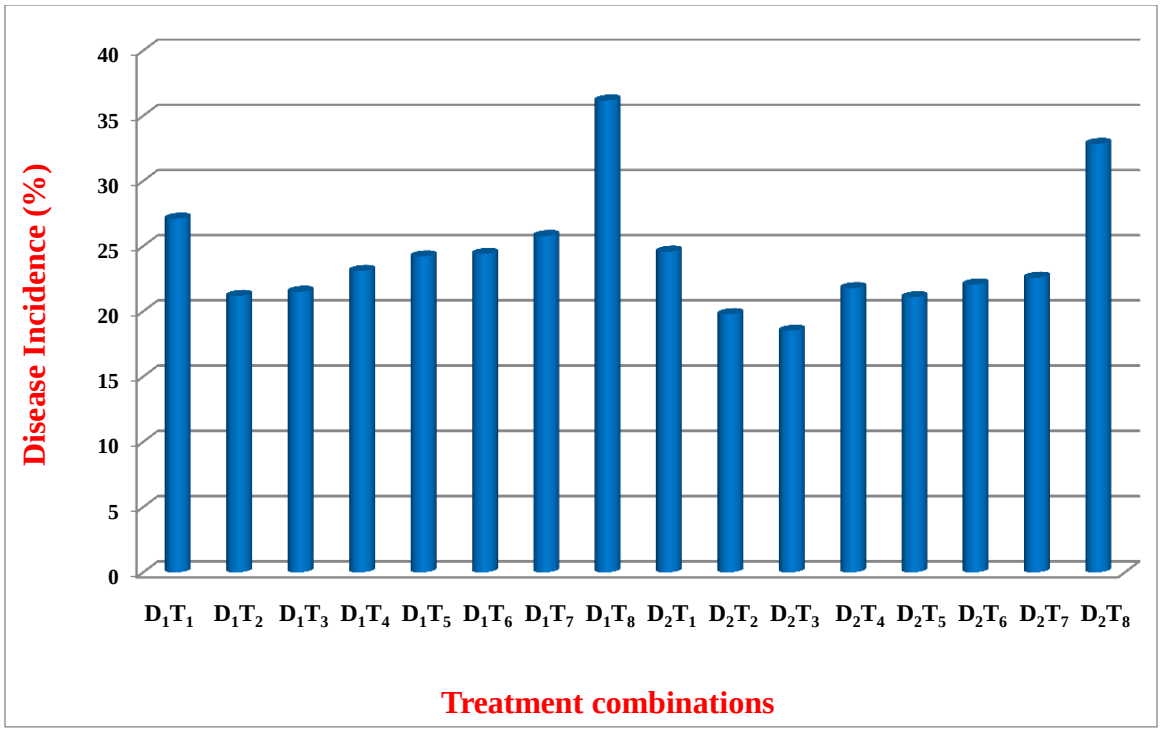


Fig 3: Effect of treatment combinations on disease incidence

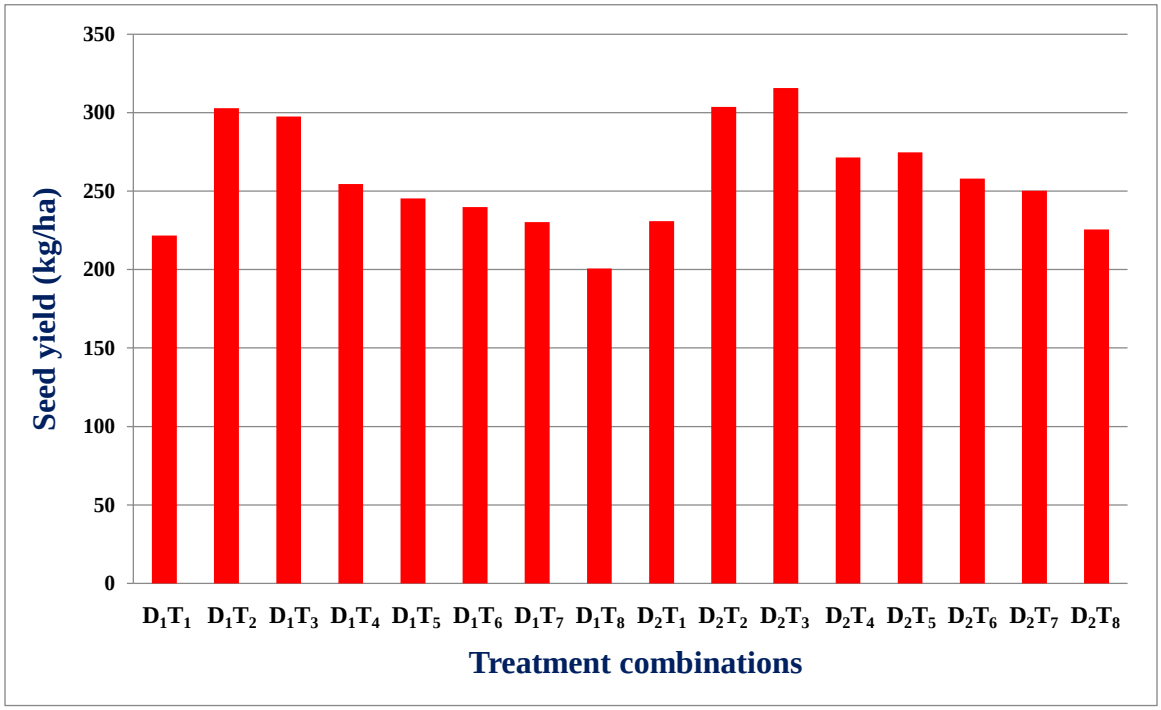


Fig 4: Effect of treatment combinations on seed yield

T_1: Seed treatment with Imidacloprid 70 WS @ 5 g/Kg of seeds
T_2: T_1 + Spray of Imidacloprid 17.8 % SL @ 0.5 ml/L
T_3: T_1 + Spray of Acetamiprid 20 % SP @ 0.3 g/L
T_4: T_1+ Spray of Thiacloprid 21.7 % SC @ 1 ml/L
T_5: T_1+ Spray of Thiamethoxam 25 WG @ 0.3 g/L
T_6: T_1+ Spray of Lambda-cyhalothrin 2.5 % EC @ 1 ml/L
T_7: T_1+ Spray of Azadirachtin 0.03 % EC (300 ppm) @ 3 ml/L
T_8: Untreated check

Imidacloprid 70 WS +
Acetamiprid 20 % SP (T_3)

Imidacloprid 70 WS +
Imidacloprid 17.8 % SL (T_2)

Seed treatment with
Imidacloprid 70 WS (T_1)

Untreated check (T_8)

Plate 8. Efficacy of different insecticides on incidence of sesamum phyllody and seed yield

V DISCUSSION

Phyllody disease is one of the major biotic constraints in the successful production of sesamum. Studies were undertaken on phyllody disease of sesamum and its management and results obtained are discussed in this chapter in the light of earlier reports.

The phyllody affected plants were found exhibiting symptoms such as stunting, yellowing, shortening of internodes and transformation of the floral organs partially or completely into leaf like structures. Such infected inflorescence did not produce any seeds. Symptoms of diseased plants may vary with the phytoplasma, host plant, stage of the disease, age of the plant at the time of infection and environmental conditions (Lee *et al*., 2000).

The most characteristic symptoms of the phytoplasmal infection on various crop plants has been reported by several workers (Suryanarayana, 1987; Rangaswamy *et al*., 1990; Win and Jung, 2012) which includes appearance of leafy flowers including a protruding ovary, absence of petals and green leaf like calyx called as phyllody, production of axillary shoots and stunting of the plants depending on stage of infection. Phytoplasmas are known to alter the growth and development of their host plants by producing effector proteins which deregulate the floral genes (MacLean *et al*., 2011).

Plants infected with phyllody were pale green, stunted with severe reduction in leaf size, reduced internodal length, excessive axillary proliferation and conversion of floral parts into abnormal green structures, developed in place of normal flowers. Similar symptoms were also reported by Abraham *et al*. (1977).

Survey for the incidence of sesamum phyllody was carried out in three districts of Southern Karnataka. It was found that the phyllody incidence ranged from 13.6 to 31.21 per cent in the different districts surveyed. Minimum diseases incidence of 13.6 per cent was observed in Ramanagar district and maximum disease incidence of 31.21 per cent was observed in Hassan district. Incidence of sesamum phyllody varied with locations but, there was no clear relationship between the vector population and disease incidence. This indicates the role of environment on the occurrence and incidence of the disease. Maximum disease incidence in Hassan district may be due to susceptibility of the cultivars grown and favourable environmental conditions like temperature and less amount of rainfall experienced in this district which falls under central dry zone. Similar observation were made by Palanna *et al.* (2014) who opined that sesamum phyllody is a major problem in central dry zone of Karnataka. Disease incidence in Tiptur and Arsikere taluks in *Kharif* 2009-10 ranged from 22 to 75 per cent (Manjunatha, 2010).

The disease incidence in the genotypes screened ranged from 4.61 to 30.53 percent. Among them three genotypes *viz.,* KAU-05-2-12, PC-14-2 and Kanakapura local showed resistant reaction. Twenty seven genotypes *viz.*, DS-28, RT-363, CUHY-57, AT-255, DS-23, DS-10, NIC-16236, AKT 101, RT-54, Amrit, AKT-64, RT-125, TMV-3,

TKG 306, ST-9-2, ES-48, Chandana, ES- 8779-4, IS 294, E-8, DS-1, GT-1, DS-9, K-15284, RT-11, EC-303419 and Gulbarga showed moderately resistant reaction.

Several workers had previously reported about the resistance sources against phyllody of sesamum. Palanna *et al*. (2015) reported GT-1 and DS-9 as resistant to phyllody and Manjunatha (2010) reported that IVT-09-1, IVT-09-2, IVT-09-14, IVT-09-19 and Kanakapura-1(local variety) showed resistant reaction. Similarly, forty two sesamum genotypes were categorised for their reaction to phyllody by Gopal *et al.*(1998) and reported that six genotypes showed resistance reaction *viz*., AT66, AT69, BT892, RT108, TC359 and TNAU12.

Field experiments were conducted during *kharif* 2015 in ZARS, GKVK, Bengaluru. Two dates of sowing and seven insecticides along with untreated check were evaluated for their efficacy in disease management under field condition. In two dates of sowing taken up, lowest disease incidence (22.90 %) was observed in late sown crop compared to early sown crop (25.43 %). The results agree with Hosseini *et al*. (2015) who reported that delayed sowing reduced sesamum phyllody up to 31 per cent.

The results revealed that among the different treatments, seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded the least disease incidence (13.34 %) which was on par with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L and seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiacloprid 21.7 % SC @ 1 ml/L in which disease incidence of 13.65 % and 14.96 % was recorded respectively. Seed treatment with imidacloprid 70 WS @ 5 g/kg was least effective in which disease incidence of 17.23 per cent was recorded. The disease incidence in untreated check was 23.0 %.

All the treatment combinations reduced the disease incidence significantly compared to unsprayed control. Among the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded lowest disease incidence (18.51 %) which was on par with the combinations late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (19.78 %), late sowing with T_5 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiamethoxam 25 WG @ 0.3 g/L) (21.08 %) and early sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (21.18 %). Early sowing with no spray recorded significantly higher disease incidence (36.17 %).

The maximum seed yield (266.24 kg/ha) was recorded in late sown crop compared to early sown crop (249.15 kg/ha). Of the different treatments, T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded highest seed yield of 204.40 kg/ha which was significantly higher compared to all other treatments, followed by T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) which recorded seed yield of 202.48 kg/ha. The lowest seed yield of 142.07 kg/ha was recorded in T_8 (untreated check).

Among the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) recorded highest seed yield of 315.77 kg/ha which was on par with the combinations late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (303.61 kg/ha), early sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) (302.85 kg/ha) and early sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) (297.43 kg/ha). Early sowing with no spray recorded significantly lowest seed yield of 200.67 kg/ha.

Of the different treatment combinations, late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) with lowest disease incidence (18.51 %) and highest seed yield (315.77 kg/ha) was found to be the best treatment for the management of sesamum phyllody followed by late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) which recorded 19.78 % disease incidence and 303.61 kg/ha seed yield.

The results agree with Palanna *et al*. (2015) who reported that, Imidacloprid 70 WS seed treatment @ 7.5 g/kg seed + Monocrotophos 36 SL (0.2 %) spray at the time of initiation of symptoms accounted for minimum phyllody incidence (18 %). Thangjam and Vastrad (2015) reported that Imidacloprid 600 FS seed treatment + imidacloprid 17.8 SL spraying and imidacloprid 600 FS seed treatment + lambda-cyhalothrin 5 EC spraying were highly effective in reducing the phyllody incidence in sesamum by managing the vector leaf hopper, *Orosius albicinctus* Dist. The present findings also supports the reports of Razaq *et al*. (2005) who reported that Diafenthiuron, acetamiprid, imidacloprid and thiamethoxam were found to be most effective in reducing jassid population below ETL (Economic threshold level) in cotton crop.

The results agree with Hosseini *et al.* (2015) who reported that delayed sowing reduced sesame phyllody up to 31 %. Spraying with Confidor reduced disease incidence at the first and second sowing date by 18.8 and 7.8 per cent respectively, but no differences were observed in yield. Seed treatment with Gaucho has no effect on disease incidence.

The research findings supports the results of Shweta Kumari (2014) who reported that insecticides *viz.,* Carbofuran, Confidor, Thiamethoxam and Acetamiprid which were effective and reduced the incidence of aster phyllody when applied individually and in combination over control. Of the different treatments, lowest disease severity was recorded in Carbofuran + Confidor + Thiamethoxam + Acetamiprid and Carbofuran + Confidor + Thiamethoxam treatment. Carbofuran was least effective in controlling the phyllody disease incidence.

The present findings conformity with Choudhary *et al*. (2005) who reported that confidor 350 SC @ 75 ml/ha was found to be superior over all other treatments in controlling aphid and jassid population on the cotton crop. Higher yield (1259.6 kg/ha)

was recorded from the plot treated with confidor 350 SC @ 75 ml/ha, followed by confidor 350 SC @ 60 ml/ha (1188.8 kg/ha).

In the present investigation, reduced phyllody incidence was observed in late sown crop compared to early sown crop. Among the treatments tested, seed treatment with imidacloprid 70 WS + spray of acetamiprid 20 % SP and seed treatment with imidacloprid 70 WS+ spray of imidacloprid 17.8 % SL were found effective in reducing the incidence of phyllody in sesamum. Late sowing with T_3 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L) and late sowing with T_2 (seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L) found better treatment combinations for reducing phyllody incidence and higher yield.

Future line of work

1. Host range of sesamum phyllody phytoplasma to find out the sources of infections
2. Diagnostic systems for early detection of phytoplasma strain
3. Breeding of phyllody resistant varieties of sesamum

VI SUMMARY

Investigations on sesamum phyllody caused by phytoplasma were carried out at Zonal Agricultural Research Station (ZARS), GKVK, Bengaluru and Krishi Vignan Kendra (KVK), Konehally, Tiptur during 2015-16. The salient findings of this investigation are summarized in this chapter.

The most common symptoms of sesamum phyllody disease was includes pale green leaves and bushy growth due to excessive stunting, severe reduction in leaf size, reduced internodal length, excessive axillary proliferation and floral malformation like abnormal green structures in place of normal flowers. The pods in disease infected plants after flowering were very small.

During survey in sesamum growing areas of Southern Karnataka, the incidence of sesamum phyllody ranged from 13.6 to 31.21 per cent. The disease incidence was lowest in Ramanagar district with incidence of 13.6 per cent. Hassan district recorded the highest incidence of 31.21 per cent.

In the IVT entries screened against sesamum phyllody the disease incidence ranged from 4.61 to 28.49 per cent, while in AVT entries it ranged from 13.95 to 30.53 per cent. In the genotypes (25) screened, the incidence of phyllody ranged from 4.60 to 28.19 per cent. Among forty three sesamum genotypes screened against the phyllody disease under field conditions, three genotypes *viz.*, KAU-05-2-12, PC-14-2 and Kanakapura local showed resistant reaction, twenty seven genotypes *viz.*, DS-28, RT-363, CUHY-57, AT-255, DS-23, DS-10, NIC-16236, AKT 101, RT-54, Amrit, AKT-64, RT-125, TMV-3, TKG 306, ST-9-2, ES-48, Chandana, ES- 8779-4, IS 294, E-8, DS-1, GT-1, DS-9, K-15284, RT-11, EC-303419 and Gulbarga showed moderately resistant reaction, thirteen genotypes *viz.*, JCS-2464, AT-249, PC-14-1, TKG-22, AT-282, GT-10, DS-19, CUMS-17, JLS-301-24, AT-231, DS-5, Local variety (black) and DSS-9 showed susceptible reaction.

In two dates of sowing taken up, lowest disease incidence (22.90 per cent) was observed in late sown crop compared to early sown crop (25.43 per cent). Seed yield was maximum (266.24 kg/ha) in late sown crop compared to early sown crop (249.15 kg/ha).

Seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L recorded the least disease incidence (13.34 per cent) which was on par with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L and seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of thiacloprid 21.7 % SC @ 1ml/L in which disease incidence of 13.65 and 14.96 per cent was recorded respectively.

The treatment combination, late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L recorded lowest disease incidence (18.51 per cent) which was on par with the combination late sowing with seed

treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L (19.78 per cent).

Seed yield was maximum (204.40 kg/ha) in seed treatment with imidacloprid 70 WS @ 5 g/kg+ spray of acetamiprid 20 % SP @ 0.3 g/L which was on par with seed treatment with imidacloprid 70 WS @ 5 g/kg+ spray of imidacloprid 17.8 % SL @ 0.5 ml/L (202.48 kg/ha).

The maximum seed yield (315.77 kg/ha) was recorded in treatment combination, late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L which was on par with late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L (303.61 kg/ha).

In management of the disease, late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of acetamiprid 20 % SP @ 0.3 g/L and late sowing with seed treatment with imidacloprid 70 WS @ 5 g/kg + spray of imidacloprid 17.8 % SL @ 0.5 ml/L were found effective.

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