THE VIRUS VECTOR RELATIONSHIP OF OKRA YELLOW VEIN MOSAIC (YVM) VIRUS WITH ITS VECTOR, *Bemisia tabaci* GEN. (HEMIPTERA: ALEYRODIDAE) AND ITS MANAGEMENT

A thesis submitted to the

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In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (AGRICULTURE)

In

AGRICULTURAL ENTOMOLOGY

By

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This is to certify that the thesis entitled, "**The virus vector relationship of okra yellow vein mosaic (YVM) virus with its vector, *Bemisia tabaci* Gen. (Hemiptera: Aleyrodidae) and its management"** submitted to the Faculty of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra State, in the partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE (Agriculture)* in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of bona-fide research carried out by **Patil Shivanjali Shashikant (Reg. No. ADPM/14/2336)** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma or published in other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

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ABSTRACT

The present investigation entitled "The virus vector relationship of okra yellow vein mosaic (YVM) virus with its vector, *Bemisia tabaci* Gen. (Hemiptera: Aleyrodidae) and its management" was carried out to study the virus vector relationship in okra YVM, its vector whitefly and its management. Okra is susceptible to attack of various insects from seedling to fruiting stage. Among these, okra whitefly not only causes direct damage by sucking the sap but also act as vector of yellow vein mosaic in okra which always has been a serious problem in okra. YVM is the most destructive viral disease in okra, has become a serious limiting factor in successful cultivation of this crop, which could reduce the yield by 30 to 70 per cent.

Vector management is one of the important remedy for control of this disease. Farmers are using insecticides frequently without recognizing vector incidence pattern, infection time, vector population,

etc. Understanding the critical growth stage for virus transmission and virus vector relationship and to identify the degree of okra yellow vein mosaic virus (YVM) at different growth stages of okra plantdue to number of whiteflies, so that appropriate control measures can be undertaken at proper stage of vector infestation and virus transmission.

The study was carried to determine the number of whiteflies required for transmission of okra YVM to test minimum number of viruliferous whiteflies required for successful transmission of okra YVM. In all the treatments, successful virus transmission has been observed even one number of viruliferous whitefly was sufficient to transfer the disease. One whitefly required significantly highest incubation period *i.e.* 15.33 days for development of disease symptoms. All the treatments *i.e.* number of whiteflies significantly cause different per cent disease incidence and also at different incubation period. As the number of whiteflies increased, the per cent disease incidence also increased and incubation period decreased.

The study was carried out to determine the effect of age of okra plant and its susceptibility to okra YVM. In all the treatments, successful per cent disease observed at different age of seedlings. Early age of okra seedlings were more susceptible to YVM incidence and showed more per cent disease incidence as compared to older plants. Incidence of whiteflies at early stage of crop i.e.up to 20 days after sowing, early development of disease symptoms were observed.

The study was carried out for the management of whiteflies with different treatments. Surviving average population of whiteflyper five plants at weekly interval after 1st, 2nd, 3rd and 4th fortnight of all treatments indicated that all treatments under test were found effective in reducing the population of whitefly as compared to untreated control. Mean efficacy of all treatments indicated that treatment T6 recorded lowest mean whitefly population (7.54 per five plants) which was significantly superior to rest of treatments. The next best treatments were T4 and T2 with whitefly population of 13.17 and 13.58 per five plants. Whereas, highest population among different treatments were observed in T1 (19.58), T3 (18.25) and T5 (17.92). Trend in efficacy of all the treatments noticed after first fortnight was more or less same even after next three fortnights with the tested treatments.

On the basis of overall findings it was observed that,

1. One viruliferous whitefly was sufficient to transmit the YVM in okra.
2. As number of viruliferous whiteflies increased per cent disease incidence increased and incubation period decreased.
3. Growth stage of seedlings was also a concerned factor in development of disease, as early stage was found most susceptible to development of disease symptoms.
4. Vector management at early stage (20-30 DAS) was reported as most important.
5. For management of whiteflies four spray (2 spray of acetamiprid 20% SP @ 0.005 per cent and 2 spray of diafenthiuron 50% WP @ 0.05 per cent) at an interval of 15 DAS or silver mulching + two sprays of insecticides *i.e.* (acetamiprid 20% SP @ 0.005 per cent and diafenthiuron 50% WP @ 0.05 per cent) or neem cake @ 10 t/ha + (50% N + recommended P + double K.) + two sprays of insecticides *i.e.* (acetamiprid 20% SP @ 0.005 per cent and diafenthiuron 50% WP @ 0.05 per cent) may adopted by the farmer.

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Place: *Dapoli*

Date: *May, 2016* ***(Patil Shivanjali Shashikant)***

APPENDIX - I

ABBREVIATIONS USED

%	:	Per cent
/	:	Per
@	:	At the rate
°C	:	Degree Celsius
C.D at 5%	:	Critical difference at 5 per cent
Cm	:	Centimeter (s)
T	:	Tonnes
Mt	:	Metric tones
Sq.m.	:	Square meter
et al.	:	And others
Fig.	:	Figure
Etc	:	et cetra
Ha	:	Hectare (s)
Tal.	:	Taluka
Dist.	:	District
Tr.	:	Treatment
No.	:	Number
DAS	:	Days After Sowing
YVMV	:	Yellow Vein Mosaic Virus
YVM	:	Yellow Vein Mosaic
OYVMV	:	Okra Yellow Vein Mosaic Virus
OELCV	:	Okra Enation Leaf Curl Virus
TYLCV	:	Tomato Yellow Leaf Curl Virus
TLCV	:	Tomato Leaf Curl Virus
IPM	:	Integrated Pest Management
MS	:	Maharashtra State
G	:	Gram
Mg	:	Milligram (s)
R. B. D.	:	Randomized Block Design
R. H.	:	Relative Humidity
S. D. ±	:	Standard Deviation
S.Em. ±	:	Standard error mean
temp.	:	Temperature
viz.,	:	Namely

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Research Title: "The virus vector relationship of okra yellow vein mosaic (YVM) with its vector, Bemisia tabaci Gen. (Hemiptera:Aleyrodidae) and its management"
Experiment Details
Statistical design : RBD
NO. Replications : 3
No. of Treatments : 7
Variety : Varsha Uphar
Spacing : 45 X 30 cm
Season : Rabi
Date of sowing : 2 Dec 2015
Location : Botany farm. College of Agri. Dapoli
Treatments Details
T1 Neem cake @10 t/ ha + (50% N + Recommended P + Double K.)
T2 [Neem cake @10 t/ ha + (50% N +Recommended P + Double K.)]+ two sprays of insecticides.
T3 Mulching with silver mulch
T4 Mulching + two sprays of insecticides
T5 Treatment T1 + T3
T6 Four sprays of insecticides.
T7 Control
Name of Student: Miss. Patil S. S.
Name of Research Guide: Dr. M. S. Karmarkar

Treatments	Number of whiteflies per plant
T1	1
T2	3
T3	5
T4	10
T5	15
T6	20
T7	25

Treatments	**Age of the plant**
T1	10 days
T2	15 days
T3	20 days
T4	25 days
T5	30 days
T6	35 days
T7	40 days

T1-Nutrient management	Neem cake @ 10 tonnes/ ha + (50% N + Recommended P + Double K.)
T2-Nutrient management + insecticides	[Neem cake @ 10 tonnes / ha + (50% N + Recommended P + Double K.)]+ Two sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent and 2nd spray- diafenthiuron 50% WP @ 0.05 per cent.
T3-Mulching	Mulching with silver plastic mulch
T4-Mulching + insecticides	Mulching with silver plastic mulch + two sprays of insecticides 1st spray – acetamiprid 20% SP @ 0.005 per cent and 2nd spray- diafenthiuron 50% WP @ 0.05 per cent
T5-Nutrient management + Mulching	Treatment T1 + T3 [Neem cake @ 10 tonnes / ha + (50% N + Recommended P + Double K.)] + Mulching with silver plastic mulch.
T6-Chemical control	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @ 0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @ 0.05 per cent.
T7-Control	Untreated control

Treatments	Number of whiteflies per plant
T1	1
T2	3
T3	5
T4	10
T5	15
T6	20
T7	25

Treatments	**Age of the plant**
T1	10 days
T2	15 days
T3	20 days
T4	25 days
T5	30 days
T6	35 days
T7	40 days

T1-Nutrient management	Neem cake @ 10 tonnes/ ha + (50% N + Recommended P + Double K.)
T2-Nutrient management + insecticides	[Neem cake @ 10 tonnes / ha + (50% N + Recommended P + Double K.)]+ Two sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent and 2nd spray- diafenthiuron 50% WP @ 0.05 per cent.
T3-Mulching	Mulching with silver plastic mulch
T4-Mulching + insecticides	Mulching with silver plastic mulch + two sprays of insecticides 1st spray – acetamiprid 20% SP @ 0.005 per cent and 2nd spray- diafenthiuron 50% WP @ 0.05 per cent
T5-Nutrient management + Mulching	Treatment T1 + T3 [Neem cake @ 10 tonnes / ha + (50% N + Recommended P + Double K.)] + Mulching with silver plastic mulch.
T6-Chemical control	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @ 0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @ 0.05 per cent.
T7-Control	Untreated control

CHAPTER I
INTRODUCTION

Vegetables form the most important component of our balanced diet. They are also considered as "Protective food" as they contain vitamins, minerals and dietary fibres apart from protein, lipids and carbohydrates of biological value. Okra [*Abelmoschus esculentus* (L) Moench] popularly known as 'bhendi' or 'lady's finger' is a favourite vegetable grown in tropical and subtropical parts of the world. In India, it is cultivated in almost all the states and consumed by the common people. Okra (*A. esculentus*) is the member of the family malvaceae and is said to be native of Africa, possibly Ethiopia (Singh and Bhagchandani, 1967). Okra is one of the most important fruit vegetable grown throughout the tropics and warm temperate zones. It is widely cultivated as summer season crop in North India and as *kharif* and summer season crop in Gujrat, Andhra Pradesh, Karnataka and Tamilnadu. Okra is cultivated at a commercial scale in the sub-himalayan region of Northeast India where insect pest damage limits production (Ghosh *et. al.,* 1999).

India ranks second in vegetable production in the world, producing about 162.187 million tonnes of vegetables from an area of around 9.205 million ha. In India okra is grown over an area of 0.231 million ha with production of 63.5 lakh metric tonnes and productivity is 27.5 metric tonnes ha $^{-1}$. It contributes 2.5 per cent of total vegetable area and contributes 3.9 per cent of total country production. In Maharashtra, area under this crop is 22 thousand ha with a production 3.28 lakh metric tonnes and productivity of 14.9 metric tonnes ha $^{-1}$ (Anonymous, 2013).

All over India, its immature tender fruits are used as vegetable. They are also used in soups and stews. It can also be sun-dried, pickled or canned for off season consumption. The roots and stems of okra are used for clearing the sugar cane juice while preparing jaggery and sugar. Its ripe black or brown white-eyed seeds are sometimes roasted, ground and used as a substitute for coffee in Turkey (Mehta 1959). According to Martin (1982) in addition to vegetable, okra has some attributes that could permit it to be used for other purposes. Leaves, buds and flowers are edible, dried seeds could provide oil, protein vegetable curd and dried stem could serve as source of paper pulp or fuel. Seeds after roasting are useful against genitourinary disorders and chronic dysentery.

Okra fruit is good source of vitamin A, B and C. The content of calcium in its fruit is very high (66 mg/ 100g of edible portion) as compared to that in other fruit vegetables. At the proper edible stage, okra pods are good source of protein, carbohydrates and minerals like Ca, Fe, and P *etc*. It is an excellent source of iodine. It is nutritionally rich as compared to tomato, egg plant and most of the cucurbits.

Okra is susceptible to the attack of various insects from seedling to fruiting stage. Whitefly, okra shoot and fruit borer, okra jassids, cut worm, leaf hopper, mealy bug, red spider mite, aphids, root knot nematode *etc*. are most serious causing substantial reduction in crop growth and yield. Among these pests, okra whitefly *Bemisia tabaci* Gen. (Hemiptera: Aleyrodidae) not only causes direct damage by sucking the sap but also acts as a vector of yellow vein mosaic in okra which always been a serious problem in okra.

Cent per cent infection of okra yellow vein mosaic virus (YVMV) plants in a field is very usual and yield losses ranges from 50 to 94 per cent (Sastry and Singh, 1974). Initial symptom of YVMV on young leaves is a diffuse, mottled appearance. Older leaves have irregular yellow areas which are interveinal. Clearing of small vein starts near the leaf margins, at various points, about 15-20 days after infection. Thereafter, the vein clearing develops into a vein chlorosis. The newly developed leaves exhibit an interwoven network of yellow vein, which enclose the green patches of the leaf. Fruits developing on infected plants have irregular yellow areas which follow a longitudinal alignment. The fruits are also malformed and reduced in size. The fruits are mostly yellow, small, tough and fibrous. (Brunt *et al.*, 1996). Yellow vein mosaic (YVM), the most destructive viral disease of okra, has become a serious limiting factor in the successful cultivation of this crop, which could reduce the yield by 30 to 70 per cent (Duzyaman, 1997).

The incidence of whitefly population had a significant and positive correlation with temperature and sunshine hours while a negative correlation with relative humidity and total rainfall (Ali *et. al.,* 2005). The disease incidence had a significant and positive correlation with white fly population (Pun *et. al.,* 2005). Different groups of insecticide have been recommended to control this whitefly (Suryawanshi *et. al.,* 2000, Satparthy *et. al.,* 2004). However the frequent use of synthetic insecticides during the fruit bearing stage leads to occurrence of toxic residues in fruits which could pose health hazard.

Vector management of YVMV is one of the most important remedy for control of this disease. Farmers are using insecticides frequently without recognizing vector incidence pattern, infection time, vector population, etc. Understanding the critical growth stage for virus transmission and virus vector relationship can help greatly to undertake appropriate control measures. Whitefly management includes the four cornerstones of Integrated Pest Management (IPM): host plant resistance, biological control, chemical control, and cultural practices. Like host plant resistance, cultural control ways are preventive in nature, but contrast with the first three tactics in being a heterogeneous group of practices, without well-defined boundaries or a coherent conceptual framework. The management by means of cultural practices consists of the manipulation of current or new components of the agroecosystem to reduce pest damage to non-economic levels. (Hilje, 2000).

Vectors usually attack the young okra plant at the vegetative stage for virus transmission. Frequent use of pesticides by the farmers, without recognizing the vector(s), its incidence pattern and the virus infection time, results in poisonous residues in the food chain. Understanding the growth stage critical for virus transmission can help greatly to undertake control measures to prevent virus transmission.

The objective of this study was to identify the degree of okra yellow vein mosaic virus (YVM) at different growth stages of okra plant and per cent transmission due to number of whitefly, so that appropriate control measures can be undertaken at the critical stages of vector infestation and virus transmission.

In view of reducing the losses due to okra YVMV, present research programme was conducted to study the virus vector relationship and its management with following objectives:

1. To determine the number of whiteflies required for transmission of okra yellow vein mosaic (YVM).
2. To determine the effect of age of okra plant and its susceptibility to okra YVM.
3. Management of whitefly (*B. tabaci*).

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CHAPTER III
MATERIAL AND METHODS

The present investigation entitled, "The virus vector relationship of okra yellow vein mosaic (YVM) virus with its vector, *Bemisia tabaci* Gen. (Hemiptera: Aleyrodidae) and its management" was carried out in the glass house of the Department of Agricultural Entomology, and Botany Farm of College of Agriculture, Dapoli during September 2015 to April 2016. The details of the materials used and methodology adopted during investigations are as given below,

3. Seed

The seed of okra variety Varsha uphar was obtained from Central Experimental Research Station, Wakawali for experimental purpose.

3.1. Experimental site

The glass house and Botany Farm, College of Agriculture, Dapoli, in Tahsil Dapoli of Ratnagiri district (Maharashtra) is situated in the subtropical region having high humidity, warm climate throughout the year with the fluctuation in daily temperatures. The place lies on $17^0 40$ to $17^0 45$ North Latitude and $73^0 16$ to $73^0 19$ East longitudes at elevation of 250 meters above mean sea level. The minimum annual precipitation is about 3500-4000 mm, which is generally from June to October.

3.2. Maintenance of culture of *B. tabaci*

To obtain initial culture, whiteflies were collected from naturally infected okra plants. The virus was maintained on okra (cultivar Varsha uphar) in insect proof cages by frequent transfers from diseased to healthy okra plants through whitefly. Healthy colonies of *B. tabaci* were maintained on okra plants in insect proof cages which were kept in glass house and used throughout transmission studies. A wooden cage of 150 × 60 cm was made and covered all over by muslin cloth which helped to protect whitefly inside the cage and this cage was used for whitefly transmission.

3.3. Determination of number of whiteflies required for transmission okra YVM.

Crop : Okra

Variety : Varsha uphar

Expt. Design : CRD

No. of treatments : Seven (7)

No. of replication : Three (3)

This study was carried out to determine the minimum number of viruliferous vector (whiteflies) required for successful transmission of the virus. Virus free whiteflies were first allowed to feed on diseased plant by giving 24 h acquisition feeding period and then allowed to feed on healthy okra seedlings of 20 days old for 24 h of inoculation feeding period. In case of acquisition feeding on diseased okra plants, a known number of whiteflies *viz.* 1, 3, 5, 10, 15, 20 and 25 whiteflies per seedling of test plant were allowed in the case. Afterward, the plants were sprayed with insecticide to kill the whiteflies. Five seedlings were used for each treatment and the experiment was repeated thrice.

Table 1. Treatment details of the number of whiteflies

Treatments	**Number of whiteflies per plant**
T1	1
T2	3
T3	5
T4	10
T5	15
T6	20
T7	25

3.4. Effect of age of the okra plant and its susceptibility to okra YVM transmission.

Crop : Okra

Variety : Varsha uphar

Expt. Design : CRD

No. of treatments : Seven (7)

No. of replication : Three (3)

To determine the age of okra plant and its susceptibility to okra YVM, the seedlings were grown in cages. Five viruliferous whiteflies were collected and allowed to feed on healthy okra plants for transmitting the virus to plants of 10, 15, 20, 25, 30, 35 and 40 days after transplanting. Thereafter, the plants were allowed to grow for two months for studying the symptoms. Five seedlings were used for each treatment and the experiment was repeated thrice.

Table 2. Treatment details of the age of seedlings

Treatments	Age of the plant
T1	10 days
T2	15 days
T3	20 days
T4	25 days
T5	30 days
T6	35 days
T7	40 days

3.5. Method of recording observations

Observations on number of virus infected plants on the basis of visual observations were recorded at weekly interval and per cent disease incidence was calculated. The per cent disease transmission and incubation period was recorded in each case.

3.6. Management of whitefly.

The field experiment was carried out on Botany Farm, College of Agriculture, Dapoli during summer 2016.

3.7.1. Table 3. Details of the field experiment.

Location	**Botany Farm**
Year and season of experiment	Summer-2016
Experimental Design	RBD
No. of treatments	7
No. of replications	3
Crop and variety	Varsha uphar
Seed rate	12 kg/ha
Plot size	Gross- 3.6 x 3.0 sq.m. Net- 2.7 x 2.4 sq.m.
Spacing	45 x 30 cm

3.7.2. Table 4. Details of the treatments

T1-Nutrient management	Neem cake @10 tonnes/ ha + (50% N + Recommended P + Double K.)
T2-Nutrient management + insecticides	[Neem cake @10 tonnes / ha + (50% N + Recommended P + Double K.)]+ Two sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent and 2nd spray- diafenthiuron 50% WP @ 0.05 per cent.
T3-Mulching	Mulching with silver plastic mulch
T4-Mulching + insecticides	Mulching with silver plastic mulch + two sprays of insecticides 1st spray – acetamiprid 20% SP @ 0.005 per cent and 2nd spray- diafenthiuron 50% WP @0.05 per cent
T5-Nutrient management + Mulching	Treatment T1 + T3 [Neem cake @10 tonnes / ha + (50% N + Recommended P + Double K.)] + Mulching with silver plastic mulch.
T6-Chemical control	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2ndspray- diafenthiuron 50% WP @0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4thspray- diafenthiuron 50% WP @0.05 per cent.
T7-Control	Untreated control

3.7.3. Time of application.

Neem cake and fertilizers were applied and well mixed with the soil of respective plots before sowing of seeds. Mulching with silver mulch was done immediately after germination. Insecticides were applied fifteen days after germination and subsequent sprays at an interval of fifteen days.

3.7.4. Method of recording observations.

Five plants per plot were selected randomly for recording observations. The number of adults of whiteflies were counted on three leaves representing top, middle and lower canopy of each selected plant. Observations were recorded at an interval of seven days. Observations on the incidence of yellow vein mosaic was also recorded and correlated with vector population.

3.8. Facilities required and their availability.

All the required facilities to conduct experiment were available at Department of Agricultural Entomology, College of Agriculture, Dapoli.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the experiment conducted for studying the virus vector relationship of okra yellow vein mosaic (YVM) virus with its vector whitefly and its management are presented and discussed under this chapter.

Results of the experiment conducted during *rabi* and summer season of 2015-16 at glass house, Department of Agricultural Entomology and Research Farm on the Department of Agricultural Botany, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli, Dist. Ratnagiri (Maharashtra) are presented separately under the subheads mentioned below.

4.1. To determine the number of whiteflies required for transmission for okra YVM.

4.2. To determine the effect of age of okra plant and its susceptibility to okra YVM.

4.3. Management of whiteflies.

4.1. To determine the number of whiteflies required for transmission for okra YVM.

The study was carried out to determine the minimum number of viruliferous whiteflies required for successful transmission of the okra YVM.

4.1.1a. Number of whiteflies required for transmission of disease.

This study was carried to determine the minimum number of viruliferous whiteflies required for successful transmission of YVM disease of okra.

Data on number of viruliferous whiteflies required and per cent disease incidence of okra yellow vein mosaic are presented in Table 5 and depicted in Fig. 1.

Table 5: Per cent disease incidence developed by number of whiteflies.

Tr. No.	Treatment (Number of whitefly)	Per cent disease incidence				
		R1	R2	R3	Total	Mean
T1	1	22 *(27.97)	18 (25.10)	20 (26.57)	79.64	26.55
T2	3	30 (33.21)	25 (30.00)	25 (30.00)	93.21	31.07
T3	5	35 (36.27)	30 (33.21)	35 (36.27)	105.75	35.25
T4	10	55 (47.87)	45 (42.13)	40 (39.23)	129.23	43.08
T5	15	60 (50.77)	70 (56.79)	70 (56.79)	164.35	54.78
T6	20	95 (77.08)	90 (71.57)	95 (77.08)	225.72	75.24
T7	25	100 (90.00)	100 (90.00)	100 (90.00)	270.00	90.00
SE (M±)						2.19
CD at 0.01%						6.51

*Figures in parentheses are arcsin transformed values.

Results revealed that in all the treatments successful virus transmission was observed indicating even one number of viruliferous whitefly was sufficient to transfer the disease. The mean per cent disease incidence successfully transferred by viruliferous whitefly ranged from 26.55 to 90 per cent. The treatment T7 with 25 viruliferous whitefly recorded highest per cent disease incidence (90 %) followed by T6 (20 whitefly), T5 (15 whitefly) and T4 (10 whitefly) with disease incidence of 75.24, 54.78 and 43.08 per cent, respectively. Whereas, treatment T1 with only one number of whitefly recorded the lowest per cent disease incidence (26.55 %) remaining at par with T2 (3 whiteflies). Treatment T3 (5 whiteflies) recorded 35.25 per cent disease incidence which remain at par with treatment T2 (3 whiteflies) 31.07 per cent.

4.1.1b. Incubation period required for transmission of okra YVM.

Data on incubation period required for development of disease when plants were exposed to different number of whiteflies are presented in Table 6 and depicted in Fig. 2.

Table 6: Incubation period required for development of okra YVM.

Treat No.	Treatment (number of whiteflies)	Incubation period in days				
		R1	R2	R3	Total	Mean
T1	1	15	16	15	46	15.33
T2	3	14	14	14	42	14.00
T3	5	11	12	11	34	11.33
T4	10	9	9	10	28	9.33
T5	15	8	8	9	25	8.33
T6	20	8	7	8	23	7.67
T7	25	7	7	7	21	7.00
SE (M±)						0.28
CD at 0.01%						1.19

The mean incubation period required for okra YVM transmission with different number of whiteflies ranged from 7.00 to 15.33 days. The treatment with one whitefly recorded significantly highest incubation period i.e. 15.33 days for development of disease symptoms remaining superior over rest of the treatments. This was followed by treatment T2 and T3 where, development of disease observed within a period of 14.00 and 11.33 days, respectively. Whereas, lowest time was required when plants were exposed to 25 viruliferous whiteflies. In this treatment, the development of disease recorded within 7 days. This treatment remain at par with treatment T6 (20 whiteflies per plants) with incubation period of 7.67 days.

Perusal of data on per cent disease incidence developed by different number of whiteflies revealed that it was observed immediately and indicated that even one whitefly can transfer up to 26.55 per cent disease incidence which matched to findings of Jayashree *et al.* (1999) who reported that one whitefly transmitted 21.67 per cent disease in pumpkin. Capoor and Ahmad (1975) noticed a maximum infection of 77.30 per cent with 20 whiteflies which matched with present findings. Sanwal *et al.* (2013) reported that minimum 10 number of whiteflies were required to induce 100 per cent infection, although a single whitefly could transmit the YVMV effectively. Incubation period required for development of okra YVM symptoms was 15.33 with one number of whitefly and 7.67 days with 20 whiteflies which, matched with findings of Jayashree *et al.* (1999) who demonstrated that required days for disease symptom development was 16.05 days when one whitefly was there and 7.40 days when 20 whiteflies.

4.2. To determine the effect of age of okra plant and its susceptibility to okra YVM.

The study was carried out to determine the age of okra plants and its susceptibility to yellow vein mosaic virus.

4.2.1a. Effect of age of okra seedlings on per cent disease incidence.

The study was carried to determine the effect of age of okra plant on per cent disease incidence.

Data on different age of okra plant seedlings susceptible to YVM virus and its per cent disease incidence are presented in table 7 and depicted in Fig. 3.

Table 7: Per cent disease incidence developed at different age of seedlings

Treat. No.	Treatment (Age of seedlings)	Per cent disease incidence				
		R1	R2	R3	Total	Mean
T1	10 day	85 *(67.21)	75 (60.00)	80 (63.43)	190.65	63.55
T2	15 day	90 (71.57)	95 (77.08)	95 (77.08)	225.72	75.24
T3	20 day	100 (90.00)	100 (90.00)	100 (90.00)	270.00	90.00
T4	25 day	90 (71.57)	85 (67.21)	85 (67.21)	205.99	68.66
T5	30 day	75 (60.00)	70 (56.79)	75 (60.00)	176.79	58.93
T6	35 day	65 (53.73)	60 (50.77)	55 (47.87)	152.37	50.79
T7	40 day	50 (45.00)	45 (42.13)	45 (42.13)	129.26	43.09
SE (M±)						1.45
CD at 0.01%						6.11

*Figures in parentheses are arcsin transformed values.

Results revealed that the early age of okra seedlings were more susceptible to YVM incidence and showed more per cent disease incidence as compared to older plants. Mean per cent disease incidence on different age of okra seedlings ranged from 43.09 to 63.55 per cent. The maximum mean per cent disease incidence was recorded in treatment T3 (90 %) when whiteflies were released 20 DAS followed by T2 (15 DAS) and T4 (25 days) with 75.24 and 68.66 per cent disease incidence, respectively. However in T1 (10 DAS) per cent disease incidence was comparatively low 63.55 per cent as compared to T2 and T3. This may be due to less canopy development up to the initial age of 10 DAS resulting in less initial inoculation of virus. Results also indicated that as the age advances per cent disease goes on decreasing.

4.2.1b. Incubation period required to age of seedlings for okra YVM virus transmission.

The data on viruliferous whiteflies transferred on different age of seedlings and incubation period or mean days required for successful transformation of okra YVM virus are presented in table 8 and depicted in Fig. 4.

Table 8: Incubation period require to age of the seedlings for transfer of okra YVM virus.

Tr. No.	Treatment (Age of seedlings)	Incubation period in days				
		R1	R2	R3	Total	Mean
T1	10	7	7	6	20	6.67
T2	15	7	7	7	21	7.00
T3	20	7	8	7	22	7.33
T4	25	8	8	8	24	8.00
T5	30	10	10	11	31	10.33
T6	35	12	13	13	38	12.67
T7	40	15	15	15	45	15.00
SE (M±)						0.25
CD at 0.01%						1.06

It was observed that the mean incubation period ranged between 6.67 to 15 days. The maximum incubation period was recorded in treatment T7 (15.00 days) where viruliferous whiteflies were released at 40 days old seedlings. Followed by T6 (35 days) and T5 (30 days) where incubation period was 12.67 and 10.33 days, respectively. The minimum number of incubation period was recorded in treatment T1 (6.67 days) in which whiteflies were released 10 DAS remaining at par with T2 and T3 (7.00 and 7.33 days), respectively. It indicates that incidence of whiteflies at early stage of crop *i.e* up to 20 DAS results in early development of disease.

Data on per cent disease incidence developed at different age of the seedlings indicated that when 10 days old plants were infected, per cent disease incidence was 63.35 per cent and at 15 to 20 days old, the per cent disease transmission was about 75.24 to 90 per cent which matched to findings of Sanwal *et al.* (2013). They reported that if plants when infected within 20 days after germination, their growth was retarded within few leaves and losses ranged from 94 to 100 per cent. Karri and Acharyya (2012) reported that when plants were infected within 20 days after germination the disease incidence was up to 98 per cent. The minimum incubation period required for successful transmission of okra YVM was about 6.67 days which was matched with the findings of Chatterjee *et al.* (2008) who reported that the minimum incubation period was 9 days in Mesta. However the young seedlings were recorded to be highly sensitive to tomato yellow leaf curl virus and thereafter, the susceptibility turn to reverse showing less susceptible to virus. This kind of virus was reported in tomato by Seetharama Reddy (1978).

4.3. Management of whitefly.

The study was carried out for the management of whiteflies with different treatments.

Observations on surviving population of okra whiteflies recorded at weekly interval after every spray of insecticides are given below separately.

4.3.1. Efficacy of the treatments against okra whiteflies recorded at different intervals (First fortnight).

Data on surviving population of okra whiteflies recorded at weekly interval (First fortnight) with different treatments are presented in Table 9 and depicted in Fig. 5.

Results revealed that all the treatments were significantly superior to control in suppressing the population of whiteflies. Observations recorded after 1st week indicated that treatment, T6 recorded lowest whitefly population (4.33 per five plants) which was significantly superior to rest of the treatments. The next best treatments were T2 and T4 with whitefly population of 8.67 per five plants and were at par with each other whereas highest population among the different treatments were observed in treatment T1 (17.33), T3 (15.00) and T5 (13.33).

Observations recorded after 2nd week showed more or less similar trend of whitefly population. The lowest pest population was recorded in treatment, T6 (9.67) which remained at par to T2 (12.33) and T4 (11.33). However, in control the population of whitefly was 24.00 per five plants.

Table 9: Whiteflies recorded at different intervals (First fortnight).

Tr. No.	Treatment	Average population of whiteflies/five plants		Mean population of whiteflies /five plants
		1st week	2nd week	
T1	Neem cake @10 t / ha + (50% N + Recommended P + Double K.)	17.33 *(4.16)	19.33 (4.39)	18.33 (4.28)
T2	T1 + two sprays of insecticides.	8.67 (2.94)	12.33 (3.51)	10.50 (3.22)
T3	Mulching with silver mulch	15.00 (3.87)	16.00 (4.00)	15.50 (3.94)
T4	Mulching + two sprays of insecticides	8.67 (2.92)	11.33 (3.36)	10.00 (3.14)
T5	Treatment T1 + T3	13.33 (3.65)	16.67 (4.07)	15.00 (3.86)
T6	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @0.05 per cent.	4.33 (2.06)	9.67 (3.10)	7.00 (2.58)
T7	Untreated control	27.00 (5.18)	24.00 (4.90)	25.50 (5.04)
SE (M±)		0.19	0.15	0.17
CD at 5 %		0.59	0.45	0.52

*Figures in parentheses are square root transformed values.

Data on mean population of whitefly per five plants (Table 9) also indicated more or less similar trend in efficacy of various treatments tested during present investigation. The mean whitefly population within treatment varied between 7.00 to 25.50. The maximum mean whitefly population of 25.50 was recorded in untreated control. The treatment T6 i.e. (acetamiprid 20% SP @ 0.005 per cent) recorded significantly lowest mean whitefly population (7.00) than rest of the treatments followed by T2 i.e. [Neem cake @10 t / ha + (50% N + Recommended P + Double K) + acetamiprid 20% SP @ 0.005 per cent] 10.50 and T4 i.e. [Silver mulch + acetamiprid 20% SP @ 0.005 per cent] 10.00. T3 i.e. [Silver mulch] 15.50, T5 i.e. [Neem cake @10 t / ha + (50% N + Recommended P + Double K) + Silver mulch] 15.00 and T1 i.e. [Neem cake @10 t / ha + (50% N + Recommended P + Double K)] 18.33 were nearly similar with each other.

4.3.2. Efficacy of the treatments against okra whiteflies recorded at different intervals (Second fortnight).

Data on surviving population of okra whitefly recorded at weekly interval (Second fortnight) with different treatments are presented in Table 10 and depicted in Fig. 6.

Results revealed that all the treatments were significantly superior to control in suppressing the population of whitefly. Observations recorded after 3rd week indicated that treatment, T6 recorded lowest whitefly population (5.67 per five plants) which was significantly superior to rest of the treatments. The next best treatments were T2 and T4 with whitefly population of 10.33 and 11.00 per five plants and were at par with each other whereas, highest population among the different treatments was observed in treatment T1 (17.67), T3 (17.33) and T5 (16.00).

Table 10: Whiteflies recorded at different intervals (Second fortnight).

Tr. No.	Treatment	Average population of whiteflies/five plants		Mean population of whiteflies /five plants
		3rd week	4th week	
T1	Neem cake @10 t / ha + (50% N + Recommended P + Double K.)	17.67 *(4.19)	20.00 (4.47)	18.83 (4.33)
T2	T1 + two sprays of insecticides.	10.33 (3.21)	13.67 (3.69)	12.00 (3.45)
T3	Mulching with silver mulch	17.33 (4.15)	19.33 (4.39)	18.33 (4.27)
T4	Mulching + two sprays of insecticides	11.00 (3.31)	12.67 (3.53)	11.83 (3.42)
T5	Treatment T1 + T3	16.00 (3.99)	18.33 (4.27)	17.17 (4.13)
T6	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @0.05 per cent.	5.67 (2.37)	10.67 (3.26)	8.17 (2.81)
T7	Untreated control	26.33 (5.12)	25.33 (5.02)	25.83 (5.07)
SE (M±)		0.19	0.19	0.19
CD at 5 %		0.58	0.58	0.58

*Figures in parentheses are square root transformed values.

Observations recorded after 4th week showed more or less similar trend of whitefly population. The lowest pest population was recorded in treatment T6 (10.67) which remained at par to T4 and T2 with 12.67 and 13.67 whitefly population per five plants, respectively. However in control the population of whitefly was 25.33 per five plants.

Data on mean population of whitefly per five plants (Table 10) also indicated more or less similar trend in efficacy of various treatments tested during present investigation. The mean whitefly population within treatment varied between 8.17 to 25.83. The maximum mean whitefly population of 25.83 was recorded in untreated control. The treatment T6 i.e. [diafenthiuron 50% WP @ 0.05 per cent] recorded significantly lowest mean whitefly population (8.17) than rest of the treatments followed by T4 i.e. [Silver mulch + diafenthiuron 50% WP @ 0.05 per cent] 11.83 and T2 i.e. [Neem cake @10 t / ha + (50% N + Recommended P + Double K) + diafenthiuron 50% WP @ 0.05 per cent] 12.00. T5, T3 and T1 were at par to each other with 17.17, 18.33 and 18.83 mean whitefly population per five plants.

4.3.3. Efficacy of the treatments against okra whiteflies recorded at different intervals (Third fortnight).

Data on surviving population of okra whitefly recorded at weekly interval (Third fortnight) with different treatments are presented in Table 11 and depicted in Fig. 7.

Results revealed that all the treatments were significantly superior to control in suppressing the population of whitefly.

Observations recorded after 5th week indicated that treatment T6 recorded lowest whitefly population (7.33 per five plants) which was significantly superior to rest of the treatments.

The next best treatments were T4 and T2 with whitefly population of 13.67 and 14.00 per five plants and remaining at par whereas, highest population among the different treatments were observed in T1 (24.33), T5 (19.00) and T3 (18.33).

Table 11: Whiteflies recorded at different intervals (Third fortnight).

Tr. No.	Treatment	Average population of whiteflies/five plants		Mean population of whiteflies /five plants
		5th Week	6th week	
T1	Neem cake @10 t / ha + (50% N + Recommended P + Double K.)	24.33 *(4.93)	19.67 (4.42)	22.00 (4.68)
T2	T1 + two sprays of insecticides.	14.00 (3.74)	15.00 (3.86)	14.50 (3.80)
T3	Mulching with silver mulch	18.33 (4.27)	19.00 (4.35)	18.67 (4.31)
T4	Mulching + two sprays of insecticides	13.67 (3.69)	14.67 (3.82)	14.17 (3.75)
T5	Treatment T1 + T3	19.00 (4.35)	20.00 (4.47)	19.50 (4.41)
T6	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @0.05 per cent.	7.33 (2.70)	7.67 (2.75)	7.50 (2.73)
T7	Untreated control	31.67 (5.62)	28.67 (5.34)	30.17 (5.48)
SE (M±)		0.16	0.20	0.18
CD at 5 %		0.52	0.62	0.57

*Figures in parentheses are square root transformed values.

Observations recorded after 6th week showed more or less similar trend of whitefly population. The lowest pest population was recorded in treatment T6 (7.67) followed by T4 and T2 with 14.67 and 15.00 whitefly population per five plants, respectively. However, in control the population of whitefly was 28.67 per five plants.

Data on mean population of whitefly per five plants (Table 11) also indicated more or less similar trend in efficacy of various treatments tested during present investigation. The mean whitefly population within treatment varied between 7.50 to 30.17. The maximum mean whitefly population of 30.17 was recorded in untreated control. The treatment T6 i.e. acetamiprid 20% SP @ 0.005 per cent recorded significantly lowest mean whitefly population (7.50) than rest of the treatments followed by T4 i.e. [Mulching + acetamiprid 20% SP @ 0.005 per cent] 14.17 and T2 i.e. [Neem cake @10 t / ha + (50% N + Recommended P + Double K) + acetamiprid 20% SP @ 0.005 per cent] 14.50.T3, T5 and T1 at par to each other with 18.67, 19.50 and 22.00 mean whitefly population per five plants.

4.3.4. Efficacy of the treatments against okra whiteflies recorded at different intervals (Fourth fortnight).

Data on surviving population of okra whitefly recorded at weekly interval(Fourth fortnight) with different treatments are presented in table 12 and depicted in Fig. 8.

Results revealed that all the treatments were significantly superior to control in suppressing the population of whitefly. Observations recorded after 7th week indicated that treatment T6 recorded lowest whitefly population (6.67 per five plants) which was significantly superior to rest of the treatments. Next best treatment T2 with 16.33 whitefly per five plants remain at par to T4, T1 and T3 and observed the values of 17.00, 20.00 and 20.33 whiteflies, respectively.

Table 12: Whiteflies recorded at different intervals (Fourth fortnight).

Tr. No.	Treatment	Average population of whiteflies/five plants		Mean population of whiteflies /five plants
		7th week	8th week	
T1	Neem cake @10 t / ha + (50% N + Recommended P + Double K.)	20.00 *(4.46)	18.33 (4.27)	19.17 (4.37)
T2	T1 + two sprays of insecticides.	16.33 (4.04)	18.33 (4.26)	17.33 (4.15)
T3	Mulching with silver mulch	20.33 (4.49)	20.67 (4.53)	20.50 (4.51)
T4	Mulching + two sprays of insecticides	17.00 (4.10)	16.33 (4.03)	16.67 (4.07)
T5	Treatment T1 + T3	20.67 (4.53)	19.33 (4.38)	20.00 (4.45)
T6	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @0.05 per cent.	6.67 (2.55)	8.33 (2.89)	7.50 (2.72)
T7	Untreated control	34.33 (5.85)	29.00 (5.38)	31.67 (5.61)
SE (M±)		0.25	0.24	0.25
CD at 5 %		0.76	0.74	0.75

*Figures in parentheses are square root transformed values.

Observations recorded after 8th week showed more or less similar trend of whitefly population. The lowest pest population was recorded in treatment T6 (8.33). T4 (16.33) was at par with T2, T1, T5 and T3 and observed the whiteflies as 18.33, 18.33, 19.33 and 20.67 per five plants, respectively. However, in control the population of whitefly was 29.00 whiteflies per five plants.

Data on mean population of whitefly per five plants (Table 12) also indicated more or less similar trend of efficacy of various treatments tested during present investigation. The mean whitefly population within treatment varied between 7.50 to 31.67. The maximum mean whitefly population of 31.67 was recorded in untreated control. The treatment T6 i.e. diafenthiuron 50% WP @ 0.05 per cent recorded significantly the lowest mean whitefly population (7.50) than rest of the treatments. Treatment T4 (16.67) was at par with T2, T1, T5 and T3 and observed the mean whitefly population of 17.33, 19.17, 20.00 and 20.50 per five plants, respectively. In untreated control, the mean whitefly population was 31.67 per five plants.

4.3.5. Mean efficacy of all the treatments against okra whiteflies recorded at different intervals.

Data on surviving population of okra whitefly recorded at different intervals with different treatments are given in Table 13 and depicted in Fig. 9.

Results revealed that all the treatments were significantly superior to control in suppressing the population of whitefly. Observations recorded on mean efficacy of all treatments indicated that treatment T6 recorded lowest mean whitefly population (7.54 per five plants) which was significantly superior to rest of treatments. The next best treatments were T4 and T2 with whitefly

Table 13: Mean whiteflies recorded at different (weekly) intervals.

Tr. No.	Treatment	Average population of whiteflies/five plants after every spray				Mean population of whiteflies/ five plants
		1st fort night	2nd fort night	3rd fort night	4th fort night	
T1	Neem cake @10 t / ha + (50% N + Recommended P + Double K.)	18.33 *(4.28)	18.83 (4.33)	22.00 (4.68)	19.17 (4.37)	19.58 (4.42)
T2	T1 + two sprays of insecticides.	10.50 (3.22)	12.00 (3.45)	14.50 (3.80)	17.33 (4.15)	13.58 (3.66)
T3	Mulching with silver mulch	15.50 (3.94)	18.33 (4.27)	18.67 (4.31)	20.50 (4.51)	18.25 (4.26)
T4	Mulching + two sprays of insecticides	10.00 (3.14)	11.83 (3.42)	14.17 (3.75)	16.67 (4.07)	13.17 (3.59)
T5	Treatment T1 + T3	15.00 (3.86)	17.17 (4.13)	19.50 (4.41)	20.00 (4.45)	17.92 (4.21)
T6	Four sprays of insecticides. 1st spray – acetamiprid 20% SP @ 0.005 per cent 2nd spray- diafenthiuron 50% WP @ 0.05 per cent 3rd spray – acetamiprid 20% SP @ 0.005 per cent 4th spray- diafenthiuron 50% WP @ 0.05 per cent.	7.00 (2.58)	8.17 (2.81)	7.50 (2.73)	7.50 (2.72)	7.54 (2.71)
T7	Untreated control	25.50 (5.04)	25.83 (5.07)	30.17 (5.48)	31.67 (5.61)	28.29 (5.3)
SE (M±)		0.17	0.19	0.18	0.25	0.20
CD at 5 %		0.52	0.58	0.57	0.75	0.60

*Figures in parentheses are square root transformed values.

population of 13.17 and 13.58 per five plants and remained at par. Whereas, highest population among different treatments were observed in T1 (19.58), T3 (18.25) and T5 (17.92) and remain at par to each other. However, in untreated control the population of whitefly was 28.29 per five plants.

Perusual of data on surviving mean population of whitefly recorded at weekly interval indicated that all the four foliar spray of acetamiprid and diafenthiuron afforded maximum protection to okra crop from ravaging of whitefly followed by mulching + two sprays of insecticide and nutrient management + two sprays of insecticide. Findings in respect of four sprays of acetamiprid and diafenthiuron observed 7.54 mean whiteflies per five plants which matched to findings of Ghosal and Chatterjee (2010 and 2011) who reported that 4.33 whiteflies per five plants observed at 50 DAS (Days After Sowing). The findings of present study showed that Diamond (acetamiprid) and polo (diafenthiuron) gave the best results among all the treatments used in the current study which are in accordance with that of Afzal *et al.* (2014) who found that 73.74 per cent mortality at 7 days after spraying when diafenthiuron was sprayed. Mean whitefly population of 18.25 observed in silver mulched plot per five plants which was similar to findings of Nyoike and Liburd (2008) who found the 15.22 whiteflies in cucurbits per five plants in silver mulched plot. Also Kelly *et al.* (1989) found in mulched poinsettia plots 16.56 whiteflies per five plants which were matched to our present research. Findings in respect of neem cake application for whitefly control could not be compared with research work of others for want of information on their efficacy against whiteflies.

CHAPTER II
REVIEW OF LITERATURE

A critical comprehensive review of literature is inevitable for any scientific investigation. A proper understanding of the problem requires a thorough review of the existing knowledge of the problem. A brief research work was carried on "The virus vector relationship of okra yellow vein mosaic (YVM) virus with its vector, *Bemisia tabaci* Gen. (Hemiptera: Aleyrodidae) and its management" are presented in this chapter.

2.1. Determination of number of whiteflies required for transmission of okra YVM

Verma (1952) observed that the single whitefly was able to transmit the virus in okra. However, minimum number of whiteflies required to produce the 100 per cent infection was about 10. The first visual symptom was the clearing of small veins, which usually started at various points near the leaf margins in about 15- 20 days after inoculation of plants. Whereas, Capoor and Ahamd (1975) noticed in pumpkin and reported that the maximum infection was 77.3 per cent with 20 whiteflies.

Subramanian (1979) reported that 15 whiteflies were required to cause 100 per cent transmission of yellow vein mosaic in lablab and niger.

Cohen *et al.* (1983) found that 5 whiteflies caused 100 per cent infection in squash leaf curl virus.

Salalrajan (1988) reported that 15-20 whiteflies were required to cause effective transmission of yellow vein mosaic virus disease of urdbean. Whereas same numbers of whiteflies were reported for effective transmission of yellow vein mosaic in soyabean by, Raghupathy (1989).

Monsour and Musa (1992) and Mehta *et al.* (1994) reported that the incidence and rate of spread of TYLCV was directly proportional to the whitefly population present in the environment in tomato field.

Raghupathy (1995) studied virus vector relationship in tomato and observed that the 3 whiteflies were sufficient to secure 100 per cent transmission of tomato leaf curl virus (TLCV).

Jayashree *et al.* (1999) studied and reported in pumpkin that though a single whitefly could transmit the virus to an extent of 21.67 per cent, the minimum number of whiteflies required for 100 per cent transmission were 15. It was also observed that the days required for symptom expression became progressively less as the number of whiteflies used for inoculating the test plants were gradually increased from one to twenty.

Muniyappa *et al.* (2000) conducted study on tomato leaf curl virus and reported that for successful transmission of the disease 5-15 adult viruliferous whiteflies were required to get 100 per cent transmission of leaf curl virus.

Muniyappa *et al.* (2003) studied pumpkin yellow vein mosaic virus and recorded 100 per cent transmission of virus when plants were exposed to 5-15 adult viruliferous whiteflies.

Chatterjee *et al.* (2008) studied the disease transmission efficiency of the whiteflies in mesta by allowing different numbers of insects to feed. They reported that the disease was transmitted by whitefly at transmission efficiency of 85 per cent for *H. sabdariffa* and 79 per cent for *H. cannabinus*. A minimum of three whiteflies per plant was found to be effective for disease transmission. It was also observed that the 3, 5, 10 and 20 number of whiteflies transmit 22.22, 52.94, 64.71 and 78.94 per cent disease, respectively.

Rashid *et al.* (2008) conducted experiment to record number of whiteflies required for transmission of tomato yellow leaf curl virus. It has been observed that even one individual whitefly was capable of transmitting the virus. When 3, 5 and 10 viruliferous whiteflies per plant were released the disease transmission was 20, 30 and 70 per cent, respectively. It was also found that the 15 whiteflies could transmit the tomato yellow leaf curl virus to a range of 100 per cent.

Dastoogeer *et al.* (2011) conducted study to determine the minimum number of the viruliferous vector required for successful transmission of the jute leaf mosaic virus. It has been observed that even a single whitefly was capable of transmitting the disease although 15 whiteflies could transmit the jute leaf mosaic virus to extent of 100per cent and showed that the maximum 15 viruliferous whiteflies required for effective transmission of jute leaf mosaic virus. There found the positive correlation between number of whitefly and transmission of causal agent.

Sanwal *et al.* (2013) reported a single whitefly can transmit the yellow vein mosaic virus effectively however, the minimum number of whiteflies required to induce 100 per cent infection was 10 per plant.

2.2. Effect of age of okra plant and its susceptibility to okra YVM transmission

Kulkarni (1924) reported losses to the extent of 98 per cent in okra when plants were infected by whiteflies within 20 days after germination. Whereas, Khan and Mukhopadhyay (1986) and

Bhagabati and Goswami (1992) reported that the infection of yellow vein mosaic virus under natural field condition depends on the environmental parameters, crop characteristics and efficient vector population.

Verma (1952) studied the relationship of yellow vein mosaic virus and its vector whitefly and reported the first visual symptom was the clearing of small veins, which usually started at various points near the leaf margins in about 15 – 20 days after inoculation of plants. Affected plants early come to flower and chemical control of this disease is difficult.

Sastry and Singh (1973) reported that spraying at initial stage of okra just after germination was most important. If the crop was not sprayed within 20 days after germination disease incidence goes up high.

Sastry and Singh (1974) studied the stage of crop growth at which infection and loss in yield occurred. The disease transmitted by the whitefly (*B. tabaci*) and the losses depend upon the age of plant at the time of infection. The overall loss recorded was in the range of 50 to 90 per cent. They also observed that the extent of damage declines with delay in infection of the plants and reported with a loss of 49 to 84 per cent, when infection occurred after 50 to 65 days of germination.

Sastry and Singh (1975) Studied and reported in okra that when plants were infected at 35 and 50 days after germination, the loss in yield was 83 and 49 per cent, respectively. They noticed that mosaic disease retarded the plant growth and few leaves were produced when infection occurred within 35 days after germination.

Reddy (1978) conducted study on the age of the tomato plants and its susceptibility to the virus. Results revealed that tomato plants could be infected at all growth stages. However, the young seedlings were recorded to be highly sensitive to tomato leaf curl virus and thereafter, the susceptibility turned to reverse showing less susceptibility to virus.

Brunt *et al.* (1996) reported that the initial symptoms were developed on young leaves. Older leaves had irregular yellow interveinal areas. Clearing of the small veins started near the leaf margins, at various points, about 15-20 days after infection. Thereafter a vein clearing developed into a vein chlorosis. Newly developed leaves exhibited an interwoven network of yellow vein, which enclosed the green patches of leaf. Fruits developing on infected plants have irregular yellow areas which followed a longitudinal alignment. Due to heavy infestation the fruits became malformed and reduced in size. Fruits were mostly yellow, small, tough and fibrous.

Narula *et al.* (1999) studied and reported in cotton that the cotton leaf curl virus resulted in increased vector populations and also more reservoirs of the virus for the infection of the young crop.

Pun and Doraiswamy (1999) observed that if plants infected within 20 days after germination, their growth was retarded with few leaves and malformed fruits resulting in loss ranging from 94 to 100 per cent.

Ali *et al.* (2000) observed that as plant's age increased the rate of yield loss decreased due to pathogen. They recorded loss of 84 and 49 per cent when disease observed on plants at the age of 50 and 65 days old, respectively.

Bhagat (2000) reported losses due to yellow vein mosaic virus infection depend upon the age of the plant at infection.

Arora *et al.* (2008) reported infection of OYVM virus in all stages of the crop and severely reduced plant growth and yield of okra. The infected plants were stunted and produced small-sized pale yellow fruits.

Rashid *et al.* (2008) Studied effect of age of the tomato plant and its susceptibility to tomato yellow leaf curl virus and reported that the young seedlings up to age of 20 days were highly vulnerable to the virus. When 30, 45, 60 and 75 days old plants were inoculated; the percentage of transmission was 75.00, 59.38, 43.75 and 18.75, respectively. This indicated that as the age of the seedlings increased, their susceptibility to virus infection decreased accordingly.

The degree of okra mosaic virus at different growth stages of okra plants was studied by Fajinmi and Fajinmi (2010). It was observed that the plants protected from vector up to 28 days after emergence were less infected by virus (17.1 to 22.1 %) as compared to control (30. 8 to 38.2 %). As a result there was a significant increase in okra fruit yields (7.5t/ha) as compared to control (3.6t/ha).

Shroff *et al.* (2010) reported the association of OYVM disease with whitefly population. Results revealed that whitefly population was positively correlated at 25 and 50 DAS. The crop stage during this period could be the most vulnerable for attack by whitefly vector to cause OYVM disease.

Dastogeer *et al.* (2011) studied the effect of age of the jute plant and its susceptibility to jute leaf mosaic virus. The jute plants artificially inoculated at different growth stages showed different virus reaction. The young seedlings up to the age of 20 days were found to be highly vulnerable to virus. When 30, 45, 60 and 75 days old plants were inoculated; the percentage of transmission was 85, 60, 35, and 20, respectively. This indicated that the age of seedlings increased, their susceptibility to virus infection decreased accordingly.

Karri and Acharya (2012) studied the effect of stage of infection and incidence of yellow vein mosaic in different varieties of okra. It was observed that when plants were infected within twenty days after germination, the losses recorded were up to 90 per cent. The varieties which showed more incidence of YVMV at thirty and sixty days after sowing was found to have greater loss in yield rather than those varieties which having the same intensity of the disease at later stage of the growth.

Sindhumole and Manju (2013) studied association of okra yellow vein mosaic incidence with vector population. They indicated that whitefly population at 30 DAS (Days after sowing) had positive correlation with disease incidence at 50 DAS to final harvest. This demonstrated the fact that feeding by the vectors during the initial stage of crop growth, especially at 30 DAS, leads to the incidence and development of YVM disease throughout the crop phase. Moreover, whitefly count during 50 DAS also influenced the disease expression during the final phase of the crop.

Sanwal *et al.* (2013) recorded loss to the extent of 94 to 100 per cent in plants infected within 20 days after germination. They also reported loss of 49 to 84 per cent when infection occurred after 50 to 65 days of germination indicating extent of damage declines with delay in infection of plants.

2.3. Management of whitefly (*B. tabaci*)

Kelly *et al.* (1989) conducted study in poinsettia and reported that the transparent polythene mulch had a repellent effect on pest and vector insect such as aphid, whitefly and thrips.

Dahal *et al.* (1992) checked the effect of planting and chemicals on the incidence and spread of yellow vein mosaic of okra. They found that the disease incidence reached comparable levels in both the treated and untreated plots after 45-60 days of sowing and rates of disease increase were similar. They observed that systemic insecticide delayed or reduced the incidence of okra yellow vein mosaic disease.

Incidence of tomato mottle virus in Florida and tomato yellow leaf curl virus in Jordan in tomato were studied by Csizinszky *et al.* (1995) and Suwwan *et al.* (1988) The reduced population of whitefly using aluminum or silver reflective mulches. Colored or reflective mulches were most effective early in the crop cycle, before the developing plant canopy.

Sprays of neem products like neem oil and neem seed kernel extract (NSKE) had also shown promising results in okra in reducing whitefly vector and OYVM disease as reported by Ambekar *et al.* (2000), Srivastava, (2001) and Schumutterer, (2002).

Gupta *et al.* (2000) studied role of neem cake in control of whitefly in mung bean. They reported that application of neem cake suppressed the whitefly population in mung bean.

Mustafa (2000) reported that Confidor (imidacloprid) and Polo (diafenthiuron) gave almost 72.6 per cent mortality of whitefly. He also recorded mortality of whitefly with the application of acetamiprid.

Bi *et al.* (2001) found in cotton that peak populations of whitefly adults and nymphs as well as honeydew production increased in response to increasing nitrogen levels in large plots of cotton. Therefore there may be some potential to manipulate whitefly populations through fertilization practices.

Parrish and Assail (2001) and Aslam *et al.* (2003) observed in cotton that there was significant mortality of whitefly with the application of acetamiprid.

Ali *et al.* (2003) reported in cotton that buprofezin, fenpropathrin, endosulfan, imidacloprid, acetamiprid and diafenthiuron reduced the whitefly nymphal population significantly. But the adult of whitefly population with the treatment of acetamiprid, diafenthiuron, imidacloprid and endisulfan was 56, 58.34, 61.67 and 64, respectively.

Bhaskaran *et al.* (2003) reported that the dose of diafenthiuron (300 g. a.i. /ha) was sufficient for effective management of spiraling whitefly on guava.

Reitz *et al.* (2003) conducted study on pepper and observed that reflective mulch alone successfully delayed and decreased spread of virus transmitted by various insect pest.

Saradha and Nachiappan (2003) evaluated the field efficacy of diafenthiuron 50% WP against whitefly (*B. tabaci)* on brinjal. They observed that diafenthiuron at 800 g.a.i. /ha had maximally reduced the whitefly population.

Khattak *et al.* (2004) showed significant reduction in the whitefly population at 24, 72 and even 120 hours after spray by using Confidor (imidacloprid) and Polo (diafenthiuron) in cotton.

Sundararaj and Dubey (2005) revealed that by basal application of neem cake and foliar spray of neem seed oil the incidence of *Acaudaleyrodes rachipora* (Singh) on the seedlings of important tree species of Indian arid zone can be managed.

Gowdar *et al.* (2007) reported in okra that acetamiprid, imidacloprid, triazophos and monocrotophos significantly reduced YMV incidence and mean whitefly population.

Veenila *et al.* (2007) studied and reported in okra that neem seed kernel extract (NSKE) 5 per cent gave effective control of whitefly and acetamiprid 20 SP @ 30 – 40 g/ha were effective against whiteflies.

Asi *et al.* (2008) concluded that Confidor (imidacloprid) and Polo (diafenthiuron) were highly effective against sucking insect pest of cotton.

Nyoike and Liburd (2008) studied use of living or reflective mulch in cucurbits. The use of reflective mulch proved more effective in management of whitefly and disease management.

Afzal *et al.* (2009) studied in cotton and reported that Polo (diafenthiuron) gave 73.74 per cent mortality of whitefly.

Naik *et al.* (2009) and Patel *et al.* (2010) concluded that all the neonicotinoids, buprofezin, diafenthiuron were quite effective in managing yellow vein mosaic virus disease indirectly by exerting direct effect on whitefly population.

Ghosal and Chatterjee (2010 and 2011) studied and reported in okra that the whitefly population was minimum (2.67/5plants) in diafenthiuron when sprayed at 35 DAS and when sprayed at 50 DAS it was 4.33/5plants. The disease incidence at 60 DAS was significantly less in diafenthiuron treatment (3.50%), as compared to 38.30 per cent in untreated control. The incidence was arrested even at 80 DAS, in diafenthiuron treatment recording least incidence (10.0%) of YMD.

Nath and Sinha (2011) reported in okra that various neonicotinoids were used effectively to control the sucking pests of okra. Abbas *et al.* (2012) reported in cotton that Confidor (imidacloprid), Actara (thiamethoxam) and Diamond (acetamiprid) proved to be highly effective against whitefly.

Mali *et al.* (2012) reported in okra that two sprays of imidacloprid @ 1ml/3 l water followed by two sprays of 0.5 per cent azadirachtin resulted in maximum control of the disease.

Moses Mutetwa and Tuarira Mtaita (2014) reported fewer thrips, aphids and whiteflies were on plants on silvery grey colored mulch compared to other colored mulch in cucumber.

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CHAPTER V

SUMMARY AND CONCLUSION

Amongst the several pests attacking on okra, whitefly *Bemisia tabaci* Genn. is considered to be the most destructive pest causing enormous yield loss and susceptible to attack from seedling to fruiting stage. The losses caused by sucking pest complex in okra in the tune of 54.40 per cent. Whitefly not only causes direct damage by sucking the sap but also it is a vector of Yellow Vein Mosaic which is a serious problem in okra. Yield losses due to YVM in okra ranges from 50 to 94 per cent. YVM is most destructive viral disease of okra and has become a serious limiting factor in successful cultivation of this crop.

The disease incidence had a positive correlation with whitefly population. Different group of insecticides have been recommended to control this whitefly. Farmers are using insecticides frequently without recognizing vector incidence pattern, infection time and vector population. Understanding the critical growth stages for virus transmission and virus vector relationship, can help greatly to undertake appropriate control measures and to prevent virus transmission. Therefore, it is necessary to identify the degree of okra yellow vein mosaic virus at different growth stages and per cent transmission due to number of whiteflies so that appropriate control measures can be undertaken at critical stages of vector infestation and virus transmission.

In view of this, statistically designed field experiment was conducted during *rabi* and summer season of 2015–16 at glass house, Department of Agricultural Entomology and Research Farm of Department of Agricultural Botany, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli, Dist. Ratnagiri (Maharashtra) to test the virus vector relationship of okra yellow vein mosaic virus with its vector whitefly and its management. The results obtained are summarized below,

Results of the laboratory experiment conducted to determine the number of whiteflies required for transmission of okra YVM revealed that all the treatments *i.e.* number of whiteflies significantly cause different per cent disease incidence and also at different incubation period. The mean per cent disease incidence successfully transfers by viruliferous whitefly ranged between 26.55 to 90 per cent. 25 viruliferous whiteflies recorded highest per cent disease incidence *i.e.* 90 per cent followed by 20 whitefly record 75.24 per cent while one number of whitefly transmitted up to only 26.55 per cent disease incidence. The mean incubation period required for successful YVM transmission is different with different number of whiteflies and ranged between 7.00 to 15.33 days. One whitefly required significantly highest incubation period *i.e.* 15.33 days for development of disease symptoms and superior over rest of the treatments. When plants were exposed to 25 viruliferous whiteflies, lowest incubation period of 7.00 days were required for development of disease symptoms. Hence, the number of whiteflies increases, the per cent disease incidence goes on increasing and incubation period goes decreasing.

Results of the laboratory experiment conducted to determine the effect of age of okra plant and its susceptibility to okra YVM revealed that all the treatments *i.e.* age of seedlings significantly caused different per cent disease incidence and also at different incubation period. Mean per cent disease incidence on different age of okra seedlings ranged from 43.09 to 90.00 per cent. 20 days old okra seedlings recorded highest per cent disease incidence *i.e.* 90 per cent followed by 15 days seedlings recorded 75.24 per cent while 40 days old okra seedlings developed only 43.09 per cent disease incidence. Early age of okra seedlings were more susceptible to YVM incidence and showed more per cent disease incidence as compared to older plants. The mean incubation period required for successful YVM transmission was different with different age of seedlings and ranged between 6.67 to 15 days. At 10 days, okra seedlings required significantly low incubation period *i.e.* 6.67 days for development of disease symptoms and superior over rest of the treatments. When plants were exposed to whiteflies at 40 days, highest incubation period of 15.00 days were required for development of disease symptoms. Incidence of whiteflies at early stage of crop was up to 20 days results in early development of disease. As the age advances the per cent disease incidence goes on decreasing and incubation period goes on increasing.

Data on effect of various treatments including insecticides against okra whitefly, *B. tabaci* recorded after 1st, 2nd, 3rd and 4th fortnights of all treatments indicated that all treatments under test were found effective in reducing the population of whitefly as compared to untreated control. Overall results indicated that, the mean population of whitefly per five plants recorded after 1st, 2nd, 3rd and 4th fortnight of four spray of insecticides *i.e.* T6 (2 spray of acetamiprid 20% SP @ 0.005 per cent and 2 spray of diafenthiuron 50% WP @0.05 per cent) was 7.00, 8.17, 7.50 and 7.50 as against 25.50, 25.83, 30.17 and 31.67, respectively in untreated control. The treatments with silver mulching + two sprays of insecticides *i.e.* (acetamiprid 20% SP @ 0.005 per cent and diafenthiuron 50% WP @ 0.05 per cent) and treatment with neem cake @ 10 t/ha + (50% N + recommended P + double K.) + two sprays of insecticides *i.e.* (acetamiprid 20% SP @ 0.005 per cent and diafenthiuron 50% WP @ 0.05 per cent) were found equally effective and significantly superior over rest of the treatments in reducing the population of whiteflies per five plants. During entire period of experimentation, treatment of neem cake @ 10 t/ha + (50% N + recommended P + double K.) was found consistently least effective in checking whitefly population as compared with all other treatments. Trend in efficacy of all the treatments noticed after first fortnight was more or less same even after next three fortnights with the tested treatments.

Based on the overall results of laboratory and field experiments following conclusion can be made.

1. One viruliferous whitefly was sufficient to transmit YVM in okra.
2. As number of viruliferous whiteflies increased, per cent disease incidence increased and incubation period decreased.
3. Growth stage was also a concerned factor in development of disease as early stage was found most susceptible stage to development of disease symptoms.
4. Vector management at early stage (20-30 DAS) was reported as most important.
5. For management of whiteflies, four spray (2 spray of acetamiprid 20% SP @ 0.005 per cent and 2 spray of diafenthiuron 50% WP @ 0.05 per cent) at an interval of 15 DAS or silver mulching + two sprays of insecticides *i.e.* (acetamiprid 20% SP @ 0.005 per cent and diafenthiuron 50% WP @ 0.05 per cent) or neem cake @ 10 t/ha + (50% N + recommended P + double K.) + two sprays of insecticides *i.e.* (acetamiprid 20% SP @ 0.005 per cent and diafenthiuron 50% WP @ 0.05 per cent) may be adopted by the farmer.