"SEASONAL INCIDENCE AND BIORATIONAL MANAGEMENT OF GRAPE THRIPS [*Rhipiphorothrips cruentatus* Hood.]"

by

Ankireddy Jawahar Reddy
(Reg. No.017/164)

MASTER OF SCIENCE (AGRICULTURE)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413722, DIST-AHMEDNAGAR
MAHARASHTRA, INDIA

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APPROVED BY

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MAHARASHTRA, INDIA

2019

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or other person to any
other University or Institute
for a Degree or Diploma

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CERTIFICATE

This is to certify that the thesis entitled **"SEASONAL INCIDENCE AND BIORATIONAL MANAGEMENT OF GRAPE THRIPS [*Rhipiphorothrips cruentatus* Hood.]"**submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **Mr. Ankireddy Jawahar Reddy**under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	-	Per cent
&	-	and
@	-	At the rate of
/	-	Per
A	-	Intercept
a.i	-	Active ingredient
B	-	Slope
ICBR	-	Incremental Cost Benefit Ratio
CD	-	Critical Difference
CV	-	Coefficient of Variance
DBS	-	Days Before Spraying
DAS	-	Days After Spraying
PTC	-	Pre Treatment Count
et al.,	-	Co-workers
etc.	-	et cetera
ETL	-	Economic Threshold Level
Fig.	-	Figure
G	-	Gram
Ha	-	Hectare
Hrs	-	Hours
i.e.	-	that is
Kg	-	Kilo gram
Ltd.,	-	Limited
L	-	Litre
M	-	Metre
M ha	-	million hectares
M t	-	million tones
m^2	-	square metre
Max	-	Maximum

Mg	-	Milligram
Min	-	Minimum
Ml	-	Millilitre
Mm	-	Millimetre
SMW	-	Standard Meteorological Week
NS	-	Non Significant
^{o}C	-	Degree centigrade
RH	-	Relative Humidity
SE	-	Standard Error
SG	-	Soluble Granules
Sig.	-	Significant
T	-	tonnes
Viz	-	Namely
w/v	-	Weight in volume

ABSTRACT

SEASONAL INCIDENCE AND BIORATIONAL MANAGEMENT OF GRAPE THRIPS [*Rhipiphorothrips cruentatus* H.]

by

Mr. Ankireddy Jawahar Reddy

A candidate for the degree

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MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI – 413722

2019

Research Guide	**:**	**Dr. Y. S. Saindane**
Department	**:**	**Agricultural Entomology**

The studies on seasonal incidence and biorational management of grape thrips, *Rhipiphorothrips cruentatus* Hood (Thripidae: Thysonoptera) were carried out at All India Co-ordinated Research Project (AICRP) on Fruits, Department of Horticulture, MPKV., Rahuri, during 2017-18.

Commercial viticulture has made a considerable progress in Maharashtra during past decade. The per hectare yield obtained in the well maintained vineyards of Thompson seedless in Maharashtra is about 40 tonnes and is reported to be perhaps the highest in the world. Its cultivation was initially confined mainly to Pune, Nasik, Sangli, Solapur and Ahmednagar districts. Now, it has been extended to Aurangabad, Satara, Beed, Osmanabad, Lathur and Nanded districts of the state.

The studies on seasonal incidence revealed that the incidence of active stages both nymphs and adults started appearing from November 1st week (7.88/shoot) when new flush started after fruit or forward pruning in October, 2017. The population gradually increased and peak incidence was observed from second week of December (50th standard meteorological week) *i.e.,* (8.28/shoot) to second week of January (2nd standard meteorological week) *i.e.,* (8.53/shoot). The higher incidence of thrips was coincided with the flowering stage of grape vine.

The linear correlation studies revealed that the weather parameters *viz.,* maximum (r = -0.558) and minimum temperatures (r = -0.419) are significantly negative correlated with thrips incidence. Whereas, it had significant positive correlation with both morning (r = 0.474) and evening relative humidity (r = 0.233). While all other weather parameters such as rainfall (r = 0.092^{NS}), sunshine (r = -0.094^{NS}) and wind velocity (r = -0.130^{NS}) have not shown any significant relationship with population of thrips.

In bioefficacy studies, results revealed that standard check emamectin benzoate 5 SG consistently proved to be the most promising by recording the least population (3.10/shoot). Among biorational insecticides neem oil 2% (4.09/shoot) proved as best treatment followed by, karanj oil (4.51/shoot) and neemazol (5.08/shoot). While entomopathogenic fungi *Lecanicillium lecanii* recorded less population (4.24/shoot) and emerged as best treatment as compared to the *Metarhizium anisopliae* (4.87/shoot) and *Beauveria bassiana* (5.34/shoot). While chlli methanolic extract (6.29/shoot), garlic methanolic extract (6.78/shoot), chilli water extract (6.85/shoot) and garlic water extract (7.08/shoot) are the least effective treatments.

As regards, Incremental Cost Benefit Ratio (ICBR) in respect of different treatments ranged between 1.30 to 7.92. The highest ICBR of 1:7.92 was recorded in the treatment with emamectin benzoate 5 SG, and it was followed by entomopathogenic fungi like *Lecanicillium lecanii* (1:6.34) and *Metarhizium anisopliae* (1:5.32). Although neem oil and karanj oil has great reduction of thrips population, but has less incremental cost benefit ratio *i.e.* 2.81 and 3.04, respectively, due to high dose and its cost.

The mycosis test of three entomopathogenic fungi *viz. Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii* were studied on grape thrips. Mycosis by *Beauveria bassiana* confirmed the pathogenicity of entomopathogenic fungi on grape thrips. Highly pronounced mycosis was observed by *Metarhizium anisopliae* on the dead bodies of thrips. Mycosis test of *Lecanicillium lecanii* was also proved on grape thrips.

1. INTRODUCTION

Grapes (*Vitis vinifera* L.) is one of the important and widely grown fruit crops in the world. It is temperate by origin however, it has been successfully cultivated in tropical and subtropical climatic condition of India by modifying the required horticultural practices. Grapes are said to have originated from Asia Minor and then spread to Greece, Germany, the United States of America and the Philippines. Grapes seems to have been introduced to India from Iran and Afghanistan in 1300 AD (Bose *et al*., 1999).

It is widely grown in France, Spain, Italy, America, Australia, Algeria, Africa and India. In India grapes are mostly cultivated in the states of Maharashtra, Himachal Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Haryana, Punjab etc.

In recent years considerable interest has been aroused in India about grape cultivation due to prolific yield, export potential and good returns. Therefore, the area under grape is constantly increasing. In India, grapes are grown over an area of 1,38,000 ha with the production of 30 lakh MT (Annual Report NRCG, 2017-2018). Maharashtra is the leading grape growing state covering an area of about 78000 ha with the production of 1.80 lakh MT (Annual Report NRCG, 2017-2018).

Commercial viticulture has made a considerable progress in Maharashtra during past decade. The per hectare yield obtained in the well maintained vineyards of Thompson seedless in Maharashtra is about 40 tonnes and is reported to be perhaps the highest in the world. Its cultivation was initially confined mainly to Pune, Nasik, Sangli, Solapur and Ahmednagar districts. Now, it has been extended to Aurangabad, Satara, Beed, Osmanabad, Lathur and Nanded districts of the state.

Extensive and intensive cultivation of grapes (*Vitis vinifera* L.) attract diverse pests in different countries. Introduction of grape varieties from one country to another also aid the distribution pests. A total of 40 vertebrates (Birds-27, bat-2, snails and slugs-5, rodents-6) was recorded as pests of grapes in different countries. Among them birds and bats are known to cause significant damage. Mites numbering 41 and nematodes numbering 113 were recorded as pests of grapes. A total of 459 insects (Dermaptera-2, Orthoptera-17, Isopteran-12, Hemiptera-116, Thysanoptera-34, Lepidoptera-106, Diptera-12, Hymenoptera-26, Coleoptra-134) are known to attack different parts of grapevine. Overall 653 pests are known to damage the crop in different grape growing regions of the world (Mani, 2014).

In India, as many as 94 species of insects and mites have been reported (Tandon and Verghese, 1994). Common pests so far reported are flea beetle *Scelodonta strigicolis* (Motschulsky), mealy bugs *Maconellicoccus hirsutus* (Green), thrips *Ripiphorothrips cruentatus* (Hood) and *Scirtothrips dorsalis* (Hood) and Shot hole borer *Xyleborus crassiusculus* (Motschulsky).

The insect pest would cause as much as 80 per cent yield losses, if these are not controlled at appropriate time (Azam, 1983). Among various pests infecting grape crop most important are mealy bugs, mites, stem borer, flea beetle, thrips and chaffer beetle. Among sucking pests, thrips are considered as serious on grapes. Recently, this pest has assumed major pest status on grapes as the scab caused on berries reduces quality, yield and marketability.

Thrips, once considered to be the insect pests of minor importance in horticultural crops, but have gained the paramount importance due to their ability to cause economic losses, to subsist on new hosts and by being polyphagous in nature (Dahiya *et al*., 1995). *Ripiphorothrips cruentatus* (H.) and *Scirtothrips dorsalis* (H.) are the species recorded infesting the leaves and berries (Butani., 1979).

Thrips ***(****Rhipiphoprothrips cruentatus* H.) both nymphs and adults cause damage by rasping the lower surface of the leaf with their stylets and sucking the oozing cell sap. The injured surface is marked by the number of minute spots thereby producing a speckled silvery effect, which can be detected from a distance. They feed in groups, generally on the undersurface of the leaves. Curling of the leaves is observed in case of severe incidence (Kulakarni *et al*., 2007).

Females lay eggs in rachis, pedicels and on newly developed berries. Nymphs feed on pollen and internal tissues of calyptra. Thrips also attack blossoms and developing berries. Fruit setting is poor and yield is considerably reduced. Some feeding also occurs on the surface of berries causing scarring and hallow spots at the feeding site. Thrips are also responsible for the scab formation on the berries. The affected berries develop a corky layer and become brown. Fruits obtained from seriously attacked plants are of poor quality and fetch low price in the market.

Farmers in Ahmednagar and Nashik and adjacent districts complain that they have difficulty in managing thrips infestation on grapes and very little information is available on the seasonal occurence and control of thrips on grapes.

Hence the research work on seasonal occurrence of the grape thrips has done in order to provide proper information about the incidence of thrips on grape vine orchard to the farmers in and around the Ahmednagar and Nashik district. With quick control of insects by chemical insecticides all the insect suppression traits other than chemical control have lagged behind. Today number of chemicals are often used on large scale regardless of their side effects. Also some of the results concluded that 27 chemical pesticides out of 171 chemical pesticides can be found usually in grape samples which indicates that the stability of these pesticides is very high or they retain in the grape fruit for a long time after use of them which affect the export value of grapes (Raikwar *et al*., 2011).

The side effects of chemical control, also which effects the export value of grapes due to pesticide residues, hence a research programme on biorational pesticide management of thrips has conducted which has no residual effects and are ecofriendly. There are number of new bio pesticides available in the market for the control of various insects. These biopesticides are relatively safer, requires in low doses and doesn't leave residual problems. It is imperative to evaluate such biorational pesticides against thrips, so as to use these biorational insecticides in effective manner or can fit in integrated pest management strategy.

Therefore, considering the importance of the grape and the problem posed by insect pests, an in depth study on the nature of damage, seasonal incidence in correlation with weather parameters, and biorational management of thrips on grapes was initiated.

The present investigations were undertaken to study *Rhipiphoprothrips cruentatus* Hood a major species of thrips on grapes with following objectives:

Objectives:-

1. To study the seasonal incidence of grape thrips and their correlation with weather parameters.

2. To study the bioefficacy of biorational insecticides against grape thrips.

2. REVIEW OF LITERATURE

A review pertaining to seasonal incidence of thrips and efficacy of different biorational insecticides against thrips on grape vine is presented in this chapter. Since the available information is scanty, the relevant information on other horticultural crops is also reviewed.

2.1 Seasonal incidence of grape thrips and their correlation with weather parameters

Ananthakrishnan (1971) reported that *Scirtothrips dorsalis* and *Rhipiphorothrips cruentatus* Hood affecting grapes in Tamil Nadu, Andhra Pradesh, Maharashtra and Karnataka. These two species were also recorded by Butani (1979). This study has recorded four additional species of thrips representing two families on grapes from India for the first time. The families and species recorded are Aeolothripidae (*Sterothrips arorai*) and Phlaeothripidae (*Karnyothrips flavipes*, *Haplothrips tenuipennis* and *Xylaplothrips sp*.).An in depth knowledge regarding the influence of crop growth parameters (tender leaves, half matured leaves, fully matured leaves, flowers, pea, marble and large sized berries) on the thrips is essential to know the critical growth stage that is susceptible to thrips damage. A perusal of the literature on the incidence of thrips revealed that it intensively feeds on tender leaves, flower bunches and young fruits, and the population starts building up with the initiation of new flush.

Nagaraj *et al.* (2017) conducted survey of *Scirtothrips dorsalis* Hood at progressive farmer field for grape, Bijapur during 2013-14 at weekly intervals, revealed that thrips population was observed immediately after both April and October pruning. Highest population of 14.60 thrips/shoot was observed during third week of May after April pruning, which coincided with inflorescence period. Similarly thrips population was observed with highest of 16.25 thrips/inflorescence during first week of December after October pruning. Also correlation studies with weather parameters and insect incidence revealed that thrips population was negatively correlated with minimum temperature (-0.35), wind speed (-0.39) and rainfall after October pruning.

Kulakarni *et al.* (2007) carried out a survey between April, 2004 –March, 2005 at National Research Centre for Grape, Pune. They observed the thrips population at weekly intervals throughout the year and found that the population has reached peak of 8-10/shoot of vine in November and December months which coincided with the flowering period. Correlation studies with weather parameters revealed significant negative correlation between population of thrips and rainfall.

Dahiya and Lakra (2001) studied the seasonal occurrence and succession thrips *Rhiphophorothrips cruentatus* on grapevine, mango, guava and jamun in Hissar, Haryana for four years.Thrips were remained active on reproductive and vegetative parts of one (or) the other host plants round the year. On grapevine thrips activity was reduced from March to December peaking 8.5 thrips/leaf.

Murugan (2000) reported that thrips population gradually increased during the observation period and reached its peak during first fortnight of April. He found severe infestations during April – May and decline in population from June with the onset of rains. The fortnight average maximum temperatures and sunshine hours had a significantly positive correlation with the population of thrips, correlation coefficient values being r = 0.8039 and r = 0.530, respectively. Besides, minimum temperature also showed positive correlation with the population of thrips, the 'r' value being 0.1908. However, relative humidity, total rainfall and wind velocity were negatively correlated with the thrips population, correlation coefficients values being r = -0.7366, r = -0.2375 and r = -0.2602, respectively.

Harish (2002) studied species complex, biology and management of thrips on grapes cv. Bangalore blue, and revealed that the incidence of *S. dorsalis*, accordingly the incidence prevailed throughout the cropping period, except during fruiting season on grapes. The pest number attained peak during the first week of November and third week of May in winter and summer season, respectively.

Moleas and Addante (1993) studied western flower thrips on table grapes in Southern Italy: Thrips biology and management and found that western flower thrips (*Frankliniella occidentalis*) appears on grapes soon after sprouting. Female population was in peak during fruit setting and larvae peaked three weeks later.

Aliakbarpour and Che Salmah (2010) conducted a research on evaluation of yellow sticky traps for monitoring the population of thrips (Thysanoptera) in a Mango Orchard and revealed that the abundance of thrips was high during the flowering period of the dry season and decreased during the flowering period of the rainy season. The latter period coincided with decreased temperature and increased relative humidity. Percentage of adult emergence from the soil was lower in the rainy season than recorded in the dry season in both orchards

Shibao (1990) studied seasonal changes and infestation of chilli thrips *Scirtothrips dorsalis* (Thysonoptera: Thripidae) on grapeand noticed the infestation of *Scirtothrips dorsalis* from June to September during 1988 and identified the population peaks in July and August on two cultivars of grapes namely Neo Muscat and Muscat bailey A, respectively.

Schwartz (1988) studied the infestation of *Thrips tabaci* on three table grape varieties during 1984-85 in South Africa. He observed that the infestation was maximum during the blossom stage and shoots.

Kulkarni *et al.* (2008) reported that thrips population was noticed throughout the year with an average peak of 8-10/ shoot of vine in November and December months, which coincided the flowering period. He also conducted correlation studies with weather parameters and insect incidence revealed that rainfall was significantly negatively correlated with population of sucking insects like thrips and jassids (-0.52 and -0.42, respectively).

Duraimurugan and Jagadish (2002) studied the seasonal incidence of *Scirtothrips dorsalis* on local red rose during 1999-2000.They stated that the incidence prevailed throughout the flowering period and reached its peak during first fortnight of April (42.81 thrips per flower). Severe infestation occurred between April and May. The incidence was significantly positively correlated with maximum temperature and sunshine hours but significantly negatively correlated with mean relative humidity and positively correlated with minimum temperature and negatively correlated with rain fall and wind velocity, respectively.

Shibao *et al.* (2004) conducted experiment on seasonal fluctuation in population density of phytoseiid mite and yellow tea thrips on grape and predation of the thrips by *E.sojaensis*. Results indicated that *S. dorsalis* was found in high densities from late June to July. The number of *S. dorsalis* larvae consumed per hour and day by *E. sojaensis* were 1.4 and 5.4, respectively.

Populations of *S. dorsalis* were observed on the new shoots of pomegranate in Gujarat from June to December. The thrips population were abundant during June to August. Prolonged dry spell after rains favoured increase in population of thrips. The weekly average minimum and maximum temperatures had a highly significant positive correlation with the population of thrips, correlation coefficient values being r= 06519 and r = 0.527 respectively. Besides, relative humidity also showed positive correlation with the population of thrips, the ‘r’ value being 0.409. However, rainfall did not show any association with the population of thrips on pomegranate (Bagle, 1993).

Lopes *et al.* (2002)studied occurence of thrips on niagara table grape and its control with the insecticides thiacloprid and methiocarb associated with Metarhizium anisopliae, also reportedthrips are important pests on table grapes in United States and several countries of Europe. Damage caused by thrips, particulary *Frankliniella occidentalis*, was observed on niagara table grape crop in Limeira-SP, Brazil. During the blooming period, high thrips densities were observed feeding on pollen and small berries.

Kumar *et al.* (1994) conducted research on population dynamics and insecticidal management of mango thrips *Scirtothrips dorsalis* Hood (Thysanoptera :Thripidae) in south Gujarath, and reported that higher incidence of *Scirtothrips dorsalis* on mango was observed during March to April and September to October coinciding with new flush. Leaf infestation was highest (30.5 to 31.5 per cent) during October and remained at low level during remaining months of the year.

Varadarajan and Veeravel (1995) studied the seasonal dynamics of *Scirtothrips dorsalis* on chillies by monitoring the pest with yellow sticky traps and confirmed that the pest incidence was minimum during the last week of July when maximum temperature was 35^{o}C and rain fall was 44 mm while peak occurrence was recorded during 1st week of September when maximum temperature was 35^{o}C and when there was no rainfall. They also observed that the pest population positively correlated with maximum temperature but negatively correlated with rainfall.

In the year 1998 Lingeri *et al*., studied seasonal occurrence of chilli mites (*Polyphagotarsonemus latus* Banks) and thrips (*Scirtothrips dorsalis* Hood) and reported that incidence of *Scirtothrips dorsalis* in chillies were more pronounced during December and January. Population was tended to increase during dry periods and lower minimum temperature and lower intensity of rainfall.

Bindu and Patel, (2001) studied population dynamics of thrips on chilli cotton and pigeon pea, and revealed that a significant negative relationship was found between population of *Scirtothripsdorsalis* and minimum temperature infesting chillies.

Murai (2000) studied effect of temperature on development and reproduction of the onion thrips, *Thrips tabaci*, and reported the hatchability was more than 80% at temperatures between 15 and 25^{o}C, it was low at 30^{o}C. Mean adult longevity decreased with increasing temperature, from a maximum of 86.6 days at 15^{o}C to a minimum of 12.8 days at 30^{o}C.

Duraimurugan and Jagadish (2004) evaluated seasonal incidence of *Scirtothrips dorsalis* on rose cv.local red from September 1999 to June 2000. Severe infestation occurred from February to May. The increase in temperature favoured the multiplication of the pest. Population declined from June with the onset of rains. Their study revealed that incidence was significantly positively correlated with maximum temperature and negatively correlated with rainfall and relative humidity.

2.2 The bioefficacy of biorational insecticides against grape thrips

2.2.1 *Beauveria bassiana*

Maina *et al.* (2017) conducted a review on the use of entomopathogenic fungi in the management of insect pests of field crops. It was reported that, more than 171 mycoinseticides have been produced with at least 12 species from the over 800 fungi species identified as pathogenic to insects. Most of these products were developed based on *Beauveria bassiana*, *Metarhizium anisopliae* and *Isaria fumosoroseus* propagules. They are currently available in countries of North and South America, Europe and Asia, with few in Africa and Middle East. Often they reported mycoinsecticides have the potentials to play a key role in integrated pest management (IPM) programme for effective and relatively safe insect pest management in field and horticultural crops.

Jacobson *et al.* (2001) studied compatibility of *Beauveria bassiana* (Balsamo) Vuillemin with *Amblyseius cucumeris* Oudemans (Acarina: Phytoseiidae) to Control *Frankliniella occidentalis* Pergande (Thysanoptera:Thripidae) on Cucumber Plants and concluded that when two high volume sprays of *B. bassiana* (Naturalis-L), applied with a six day interval to glasshouse-grown cucumber crops reduced numbers of immature *F. occidentalis* by 75% compared to an untreated control during the three weeks following the first application.

Ludwig and Oetting (2002) conducted a research on efficacy of *Beauveria bassiana* plus insect attractants for enhanced control of *Frankliniella occidentalis* (Thysanoptera: Thripidae) and concluded that when attractants were used in combination with *B. bassiana* against western flower thrips (*F. occidentalis*) on greenhouse grown chrysanthemums the treatments containing *B. bassiana* reduced thrips populations, treatments containing *B. bassiana* plus attractants did not reduce thrips population compared to the *B. bassiana* treatment without attractants.

2.2.2 *Metarhizium anisopliae*

Arthurs *et al.* (2013) compared with controls, three applications of mycoinsecticides and other biorational insecticides at 7 to 14 day intervals reduced overall *S. dorsalis* populations on pepper plants *Capsicum annuum* cv. California Wonder. Spinosad reduced populations by 94–99%, *M. brunneum* F52 by 84–93%, *B. bassiana* GHA by 81–94%, *I. fumosorosea* PFR-97 by 62–66%, and different horticultural oils by 58–85%. The proportion of marketable fruit was significantly increased by *M. brunneum* F52, *B. bassiana* GHA, and 2% Suffoil-X treatments.

Heyler *et al.* (1995) conducted a research on control of westren flower thrips (*Frankliniella occidentalis* Pergande) pupae in compostand reported that the fungal pathogen *Metarhizium anisopliae* proved better when applied as a prepupation rather than post pupation treatment against thrips *Frakliniella occidentalis*.

Vestegaard *et al.* (1996) assessed the efficacy of *M. anisopliae* against western flower thrips, *F. occidentalis* by mixing spores into peat containing gerbera plants. Two or three monitorings showed a reduction in thrips population 4 to 6 days after treatment with *M. anisopliae*.

Lopes *et al.* (1990) evaluated the efficiency of applications of *M. anisopliae* (strain 1104) $5x10^6$ and $1x10^8$ conidia ml^{-1} for the control of thrips in areas of hydroponic lettuce production. The number of adults per plant was observed, in comparison to initial infestation. The application of the fungus, at both concentrations, caused a 60% reduction of the thrips population, 6 days after the first application.

Lopes *et al.* (2002) conducted an experiment on occurence of thrips on niagara table grape and its control with the insecticides thiacloprid and methiocarb associated with Metarhizium anisopliae, andreported that application of *M. anisopliae* in combination with methiocarb was the best strategy for thrips control.

2.2.3 *Lecanicillium lecanii*

Ravi *et al.* (2017) concludedefficacy of entomopathogenic fungi against thrips on Okraand revealed that the combination of *V. lecanii* 1.15% WP + *M. anisopliae* 1.15% WP was the most effective treatment as compared to standard check dimethoate for suppression of thrips population on okra.

Sithanantham *et al.* (2007) conducted research status and scope for biological control of sucking pests in India: Case study of thrips. He suggested that entomopathogens (like *Verticillium lecanii*) have shown promise for augmentative biological control of (*Scirtothrips dorsalis*), there is scope for identifying more adapted and virulent strains of the entomopathogens, besides developing improved formulations for extending their shelf and field life.

Hanamant *et al.* (2014) evaluated some biopesticides and biorationals against thrips and leafminer in Rabi/Summer groundnut. Results revealed that spinosad 45 EC @ 0.20 ml/l, *L. lecanii* @ 6 g/l and *L. lecanii* @ 4 g/l found effective in reducing thrips population.

Visalakshy *et al*. (2004) showed results of a survey on potential microbial agents against thrips as a natural epizootic or fungal infection on *T. palmi* infesting cucumbers during February 2004. The fungi was identified as *Verticillium lecanii* and this caused approximately 20% mortality on thrips.

Latha (2010) conducted a pathogenicity test against onion thrips and among 16 isolates tested for pathogenicity, seven isolates were pathogenic causing more than 50 per cent mortality of second instar thrips. The LC_{50} values for second instar nymphal stage of *T. tabaci* to different entomofungal pathogens viz., *V. lecanii* (Vl3, Vl4), *B. bassiana* (Bb1, Bb2, Bb11), *M. anisopliae* (Ma2) and *Fusarium sp*. (GM14) determined were 2.27×10^6, 6.65×10^7, 3.28×10^7, 5.94×10^8, 1.59×10^9, 1.379×10^7 and 2.546×10^8 spores/ml, respectively and LT_{50} values were 3.69, 5.02, 5.07, 6.36, 5.92, 4.61 and 6.01 days, respectively when treated @ 1×10^9 spores/ml. *V. lecanii* Vl3 recorded lower median lethal concentration and median lethal time than the other entomofungal pathogens.

Cuthbertson *et al.* (2005) conducted a research on effect of temperature and host plant leaf morphology on the efficacy of two entomopathogenic biocontrol agents of *Thrips palmi* (Thysanoptera: Thripidae) and revealed the results regarding assessments of the effect of temperature on the efficacy of *S. feltiae* indicated that higher mortality of *T. palmi* was recorded at 20°C compared to either 15 or 25°C, whereas significantly higher *T. palmi* mortality followed application of *L. muscarium* at 25°C.

Krishnamoorthy *et al.* (2007) conducted in vitro interaction study and concluded pongamia oil alone was found to be safe to the *L. lecanii* in nature and iprodan + carbendazim and carbendazim were found to be highly toxic.

2.2.4 Neem based formulations

Kulkarni *et al*. (2008) tested the chemical based, bio intensive based and neem based modules for their bio-efficacy on insect pest management of grapes. Chemical based module was found most effective treatment in reducing insect population followed by biointensive based modules (combination of neem formulation + bio-pesticides + chemical pesticides) consisting of azadiractin 1 and 5 % formulation along with chemical insecticides and bio-pesticides was better alternative for minimizing pesticide residue in grape.

Chandrasekaran and Veeravel (1998) evaluated the bio efficacy of plant products, viz., achook (0.05%, 1.0%, 1.5%), neem oil (1%, 3%, 5%), neem cake (1%, 3%, 5%), tobacco leaf extract (1%, 3%, 5%) along with an insecticide monocrotophos (0.05%) against *S. dorsalis* on chilli. The results revealed that monocrotophos was the most effective treatment. Among the plant products tested achook (1.5%) significantly reduced the thrips population, followed by neem oil (5% and 3%). Neem cake extract was the least effective in reducing thrips population.

Narvaria (2003) conducted evaluation of botanical products against pest complex of chilli. Results on thrips shown that neem oil (5%) showed best control over the neem oil (2%) with mean percent reduction of 64.33 and 57.33, respectively.

Keisa *et al.* (1995) conducted a field test against chilli thrips by using neem derivatives namely achook and nimin along with monocrotophos 0.05%. Results indicated that average percentage control of thrips was higher in monocrotophos treated plots (79%), followed by the treatment of alternate sprays of achook- monocrotophos (65%). But the mean percentage control of thrips in achook and nimin treated plots was only 33% and 45%, respectively.

2.2.5 Karanj oil

Rakesh (2017) conducted an experiment on field efficacy of certain bio-pesticides against chilli thrips *Scirtothrips dorsalis* (Hood) on Chilli (Capsicum annuum L.) and reported that among various insecticides and bio pesticides for control of *S.dorsalis*, spinosad (73.21%) proved to be most effective treatment followed by imidacloprid (67.58%), pongamia oil (55.78%), neem oil (55.64%), NSKE (53.03%) and garlic sap extract (50.03%), whereas, *B. bassiana* (33.36%) was found to be least effective against this pest.

Narvaria (2003) conducted evaluation of botanical products against pest complex of chilli. Results on thrips shown that karanj oil (5%) showed good control over the karanj oil (2%) with mean per cent reduction of 60.33 and 63.00, respectively.

2.2.6 Chemical insecticides

Kulkarni *et al.* (2007) studied the bio-efficacy of emamectin benzoate (proclaim) with a standard check lambda cyhalothrin (karate) and dichlorovos against grape thrips. They observed that proclaim 5% SG @ 11 g a.i./ha was found to be the most effective dose in reducing thrips and it was superior over lower dose of 9.5 g a.i./ha but both the treatment were superior to standard chemicals lambda cyhalothrin 5% EC @ 12.5 g a.i./ha and dichlorovos 76% WSC @ 1.2 ml/L in reducing thrips. None of the dose of proclaim was found phytotoxic to the crop.

Muthukrishnan *et al.* (2012) studied effect of emamectin benzoate 5% SG against thrips and fruit borer complex on grapevine. Results indicated that emamectin benzoate 5% SG was significantly effective at 11.0 and 22.0 g a.i./ha when sprayed twice at 15 days interval and minimized the incidence of thrips, *Rhipiphorothrips cruentatus* and fruit borers *Helicoverpa armigera* and *Spodoptera litura* on plants and fruits. Among all treatments, emamectin benzoate most effectively reduced pest population and increased fruit yield. The insecticide did not register any adverse effects on coccinellid predators.

Mori *et al.* (2001) conducted experiment on effects of pesticides on the spider mite predators, *S. takahashii* and *S. japonicus*. Results found that thrips were mildly susceptible to ememectin benzoate, while the lady bird beetle was tolerant, although it suffered some reduced survival and its LC_{50} (10.95 ppm) was similar to the recommended concentration (10 ppm).

Abdu-Allah *et al.* (2002) conducted experiment on efficacy of certain insecticides against the black vine thrips under laboratory and field conditions. Results showed that emamectin benzoate was the most toxic against nymphs and teflubenzuron was the least one.

APEDA (2017) recommended emamectin benzoate 5% SG @ 0.22 g/L against thrips on grape vine with a pre harvest interval of 25 days having MRL of 0.05 mg/kg for the export of grapes to European union.

2.2.7 Garlic and chilli extracts

Iqbal *et al.* (2015) evaluated various indigenous plant extracts against sucking insect pests of okra crop, it was revealed that, neem followed by garlic significantly reduce the mean population of jassid (6.31, 6.86), whitefly (7.41, 8.21) and thrips (11.99, 12.43), respectively. Neem also showed minimum fruit damage percentage (3.38%) followed by garlic (6.67%).

Sandeep *et al.*(2017) conducted experiment on bio-efficacy of various insecticides and botanicals against chilli thrips (*S. dorsalis* Hood) and their comparative cost: benefit analysis in chilli crop. Results showed that among all botanicals, the highest percent increase in yield over control was recorded by application of *A. sativum* extract (34.46%), followed by *A. cepa* extract (22.33%).

Abtew *et al.* (2017) conducted a research on repellency of plant extracts against the legume flower thrips *Megalurothrips sjostedti* (Thysanoptera: Thripidae)and the results revealed that the repellency of some plant extracts against the legume flower thrips *Megalurothrips sjostedti* (Thysanoptera: Thripidae), results revealed that *Piper nigrum*, *Cinnamomum zeylanicum*, *Cinnamomum cassia* as strong repellents. Whereas garlic and neem oil shows moderate repellency.

3. MATERIALS AND METHODS

The studies on seasonal incidence and bio-efficacy of some biorational insecticides against grape thrips, *Rhipiphorothrips cruentatus* Hood (Thripidae: Thysonoptera) were carried out at All India Co-ordinated Research Project (AICRP) on Fruits, Department of Horticulture, MPKV., Rahuri, during 2017-18.

The materials used and method followed for different aspects of experiment are presented in this chapter. The studies were carried out in two parts.

i. Seasonal incidence of grape thrips and correlation with weather parameters
ii. Bioefficacy of some biorational insecticides against grape thrips

3.1 Seasonal incidence of grape thrips and correlation with weather parameters

Occurrence and seasonal incidence studies of thrips, *Rhipiphorothrips cruentatus* Hood (Thripidae: Thysonoptera) were carried out at AICRP on Fruits, commencing after October, 2017 pruning to November, 2018. Observations were recorded from 5 unprotected grape vines in the field on 5 shoots per vine. The thrips population was correlated with weather parameters viz., maximum temperature, minimum temperature, relative humidity and rainfall to quantify the impact of abiotic factors on the incidence levels of thrips. The thrips, *R. cruentatus* Hood was found in field observations (Plate 3.1).

3.1.1 Climatic condition

Geographically, the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between 19.3491°N, 74.6461°E varied from 495 to 569 meters above the sea level. Climatically, this area falls in semi arid tropics with annual rainfall varying from 307 to 619 mm. The average rainfall being 520 mm, distributed over 15 to 45 days in different months. Nearly 80 per cent of the rainfall is received from South-West monsoon from June to September.

The annual average maximum temperature is 30^{0}C with a range of 33 to 41^{0}C and mean minimum temperature 17.2^{0}C with the range between 9.5 to 17^{0}C and average maximum and minimum humidity ranged from 59 to 35 per cent, respectively.

3.1.2 Materials

The materials usedin seasonal incidence experiment are black paper, magnifying lens, camel hair brush were used. The details about the materials are given below.

a) Thrips nymph

c) Berry scars

Plate 3.1: Thrips and damage symptoms in grapes

3.1.2.1. Black paper

As thrips are very minute in size and are light yellowish in colour which are difficult to observe on coloured background hence a black paper is used on which a tapping of shoots is done and the thrips which fall on this black paper are easily visible to naked eye and their numbers are counted and noted in data sheet.

3.1.2.2 Magnifying lens

In some cases magnifying lens (3X) is used for keen observation of the 1st instar nymphs which are very small and are white in colour during their immediate eclosion.

3.1.2.3 Hair brush

A black hair brush is used in order to remove the thrips which fall on the black paper during tapping, to avoid confusion about the population count of thrips for next tapping.

3.1.3 Methodology

Five vines were selected for this study. From each vine five shoots are randomly selected. The counts were made by tapping shoots gently on a black paper sheet, for counting population of both nymphs and adults a magnifying lens is used and their numbers are noted in data sheet (Duraimurugan and Jagadish, 2004).

3.1.4 Method of observation

Occurrence, seasonal incidence and peak periods of infestation were documented by collecting the absolute counts of the thrips at weekly intervals round the year.

3.1.5 Meteorological data

The data on weather parameters viz., maximum temperature, minimum temperature, relative humidity and rainfall was obtained from AICRP on Water Management, MPKV., Rahuri for statistical analysis.

3.1.6 Statistical analysis

The procedures adopted were Pearson's correlation, multiple linear regression technique as given by Glaton and step-down regression analysis considering the percentage of correlation (Goutham, 2009).

3.2 Efficacy of certain bio-rational insecticides against thrips on grapevine

To evaluate the bioefficacy of certain bio-rational insecticides against thrips on grapevine a field experiment was carried out in a vineyard at All India Co-ordinated Research Project on Fruits, Department of Horticulture, MPKV., Rahuri, after October, 2017 pruning.

3.2.1 Experimental details

1.	Design	:	Randomized Block Design
2.	Treatments	:	12
3.	Replications	:	3
4.	Crop	:	Grape
5.	Variety	:	Flame Seedless
6.	Spacing	:	3.0 × 1.5 m
7.	Plot size	:	16.5× 3.0 m
8.	Orchard established	:	2002

3.2.1.1 Experimental lay out

The experiment field was laid in a Randomized Block Design (RBD) with 12 treatments including an untreated control with three replications. Two vines were taken for each treatment, hence for the whole experiment 72 vines are selected. Details of layout given in (Fig.3, Plate 3.2).

3.2.2 Insecticides used

The details of insecticides used in study are given in Table 3.1.

3.2.2.1 Preparation of chilli and garlic extracts

Using two different solvents *i.e* methanol and water, chilli and garlic extracts were prepared (Plate 3.3).

3.2.2.1.1 Chilli and garlic methanolic extracts (1%)(W/V)

Five hundred grams of green chilli and garlic Purchased from local market. Both are blended separately with help of blender. Blended chilli and garlic paste is taken separately in one litre conical flask. Then 500 ml of methanol is added in each conical flask and mouth of the flask is closed in order to prevent the chances of evaporation of methanol as it is highly volatile compound. The extract issoaked overnight. The solution is filtered through muslin cloth in the next day morning. The filterate material is collected and the residues which remain in muslin cloth are discarded.

Plate 3.3: Chilli and garlic methanolic extract

Chilli and garlic water extracts are prepared separately by the above same procedure, where methanol is replaced with water, both these extracts are prepared just before one day of spraying (Anonymus).

3.2.3 Insecticidal application

3.2.3.1 Preparation of spray fluid

The amount of spray volume required was estimated at each time by spraying water on control treatment. The amount of insecticide required for preparing spray solution was calculated for each insecticide. At each time of preparing spray emulsion, the measured quantity of insecticide was mixed with little quantity of water and then the solution was poured in bucket containing the desired quantity of water and adjuvant, it was thoroughly stirred with the help of wooden stick.

3.2.3.2 Method of spraying

The insecticides were applied as foliar sprays. A total of three sprays were applied at an interval of ten days after October pruning.

Spray schedule:

I Spray - 2nd December, 2017

II Spray - 12th December, 2017

III Spray - 22nd December, 2017

The insecticides were applied by using battery powered Knapsack pneumatic sprayer and the sprayings were administered during the early hours of the day and the necessary precautions were taken to prevent drift of spray fluid from reaching to adjacent vine. The sprayer and container used for spray were thoroughly cleaned with water before switching over to the other test insecticide and rinsed with spray fluid to be applied next. Information about insecticides of which efficacy was tested against thrips was presented in results and discussion chapter.

RI	RII	RIII
T_2	T_{11}	T_{10}
T_4	T_{12}	T_6
T_8	T_7	T_9
T_6	T_5	T_8
T_7	T_1	T_{11}
T_5	T_{10}	T_1
T_3	T_9	T_{12}
T_{10}	T_4	T_7
T_1	T_6	T_2
T_9	T_8	T_5
T_{12}	T_2	T_3
T_{11}	T_3	T_4

N ↑

T_1 : *Beauveria bassiana* (5g/l)
T_2 : *Metarhizium anisopliae* (5g/l)
T_3 : *Lecanicillium lecanii* (5g/l)
T_4 : Neem oil (2%)
T_5 : Karanj oil (2%)
T_6 : Neemazol (3 ml/l)
T_7 : Chilli methanolic extract (2%)
T_8 : Garlic methanolic extract (2%)
T_9 : Emamectin benzoate (0.22 g/l)
T_{10} : Chilli water extract (2%)
T_{11} : Garlic water extract (2%)
T_{12} : Untreated Control

Fig.3.1 Plan and layout of the experimental field

b) Grape orchard after pruning

Plate 3.2: Experimental field

Table 3.1. Particulars of biorational insecticides evaluated against grape thrips

Sr. No.	Technical name	Chemical toxins	Formulation	Trade name	Source of product
1	*Beauveria bassiana*	Beauvericin, Bassianolide	1.15% WP (1×10^8 cfu/g)	Phule Beauveria	Biocontrol laboratory, Department of Agril. Entomology, MPKV, Rahuri
2	*Metarhizium anisopliae*	Dextrucin A and B	1.15% WP (1×10^8 cfu/g)	Phule Metarhizium	Biocontrol laboratory, Department of Agril. Entomology, MPKV, Rahuri
3	*Lecanicillium lecanii*	Dipicolinic acid	1.15% WP (1×10^8 cfu/g)	Phule Bugicide	Biocontrol laboratory, Department of Agril. Entomology, MPKV, Rahuri
4	Neem oil	Azadirachtin	---	---	Mangal Products, Ahmednagar (M.S)
5	Karanj oil	Karanjin	---	---	Mangal Products, Ahmednagar (M.S)
6	Neemazol	Azadirachtin	10000 ppm	Neemazol	E.I.D – Parry Ltd, Thyangavalli (v), Cuddalore, T.N
7	Chilli methanolic extract	Capsaicin	1: 1 (W/V) (Cilli : Methanol)	---	An extract prepared in laboratory for experimental purpose
8	Garlic methanolic extract	Diallyl disulfide	1: 1 (W/V) (Garlic : Methanol)	---	An extract prepared in laboratory prepared for experimental purpose
9	Emamectin benzoate	4’’-deoxy-4’’-methylamino derivative of abamectin.	5% SG	Proclaim	Syngenta India Ltd, Mumbai
10	Chilli water extract (2%)	Capsaicin	1: 1 (W/V) (Chilli :Water)	---	An extract prepared in laboratory prepared for experimental purpose
11	Garlic water extract (2%)	Diallyl disulfide	1: 1 (W/V) (Garlic : Water)	---	An extract prepared in laboratory prepared for experimental purpose

3.2.4 Method of recording field observations

For each treatment two vines were selected. The data was recorded on population of thrips by tapping five shoots from each treated vines. Pre-treatment count was taken prior to the insecticidal application and post counts were taken at 3, 5, 7 and 10 days after spray (DAS), (Duraimurugan and Jagadish, 2004).

3.2.5 Assessment of effectiveness of insecticides

On the basis of the absolute counts of the thrips recorded, the population reduction in different treatments over control was calculated by using Modified Abbot's formula given by Fleming and Retnakaran (1985).

$$\text{Per cent reduction over control} = \frac{\text{Population in control - population in treatment}}{\text{Population in control}} \times 100$$

Pre count (1 DBS) and post count (mean of 3, 5, 7 and 10 DAS) population and per cent reduction over control were calculated after each spray. Cumulative mean of three sprays with pooled mean are presented and discussed in chapter 4.

3.2.6 Yield data

Grape bunches were harvested from each treatment separately and yield was recorded. Total yield was calculated by adding the yield from different treatments. The per treatment yield was then converted to tonnes per ha.

$$\text{Yield (kg ha}^{-1}\text{)} = \frac{\text{Yield per treatment (Kg)}}{\text{Net area of plot (ha)}} \times 10{,}000$$

3.2.7 Incremental cost benefit ratio

The incremental cost benefit ratio of each insecticide was calculated by taking into account of the prevailing market price of input, produce and labour charges.

3.2.8 Statistical Analysis

The observations recorded from the different treatments about studied insects were subjected to statistical analysis (RBD) to know the significance of difference among different treatments at 0.05 level of significance. The values in number were transformed into square root values ($\sqrt{x+0.5}$) (Gomez and Gomez, 1984).

3.2.9 Mycosis test of mycoinsecticides on grape thrips

In this test, growth of different mycoinsecticides (*Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii*) on grape thrips observed under compound microscope.

3.2.9.1 Materials

In mycosis test a compound microscope, camel hair brush, petri plates and glass beakers, were used. The details about the materials are given below.

3.2.9.1.1 Compound microscope

As thrips are very minute in size we can't observe the fungal infection on thrips with our naked eye. Hence a compound microscope with various objective lens (10X and 40X) are used to observe presence of fungal infection on various body parts of dead thrips.

3.2.9.1.2 Camel hair brush

As thrips are very minute insects we can't easily handle them with our hands which leads to crusing of their few body parts, so a camel hair brush was used to transfer the infected thrips from petri plates to the stage of compound microscope.

3.2.9.1.3 Petriplates

For conducting the mycosis test on thrips, treatment is done by using petri plates which are easy to handle and support the growth mycoinsecticides on the body of thrips, also these plates acts as a stage for placement of treated grape leaves and release of thrips.

3.2.9.2 Methodology

The method used for mycosis test on thrips was described here. Three mycoinsecticides like *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii* were studied for mycosis test on grape thrips.

The fungal suspension of three mycoinsecticides are prepared separately in beakers by mixing 5 g of each mycoinsecticide in 100 ml of water in beaker. All the three mycoinsecticides suspensions are prepared in three separate beakers. The young grape leaves are collected from field and their surface is cleaned with mercuric chloride by using cotton, in order to remove fungal spores present on the leaves. Later on the leaves are rinsed with the distilled water to remove the chemical on leaves.

These grape leaves are smeared with the fungal suspension prepared and placed in the petri plates. For each mycoinsecticide three petri plates were prepared for mycosis test. Thrips nymphs were collected from the field and released into each petri plates in numbers of 10. These petri plates were packed with the polythene stripe in order to avoid the escape of thrips from petri plates.These petri plates were incubated in cool place for seven days to promote the infection of fungus on the thrips (Plate 3.4) (Latha *et. al.* 2010)

3.2.9.3 Method of observation

Detailed microscopic examination of thrips samples collected from the petri plates of different treatments were observed after seven days and ten days of treatment under the microscope with various resolutions like 10 and 40X for the growth of different fungus on various body parts of the thrips. These microscopic photographs are clearly mentioned in the results.

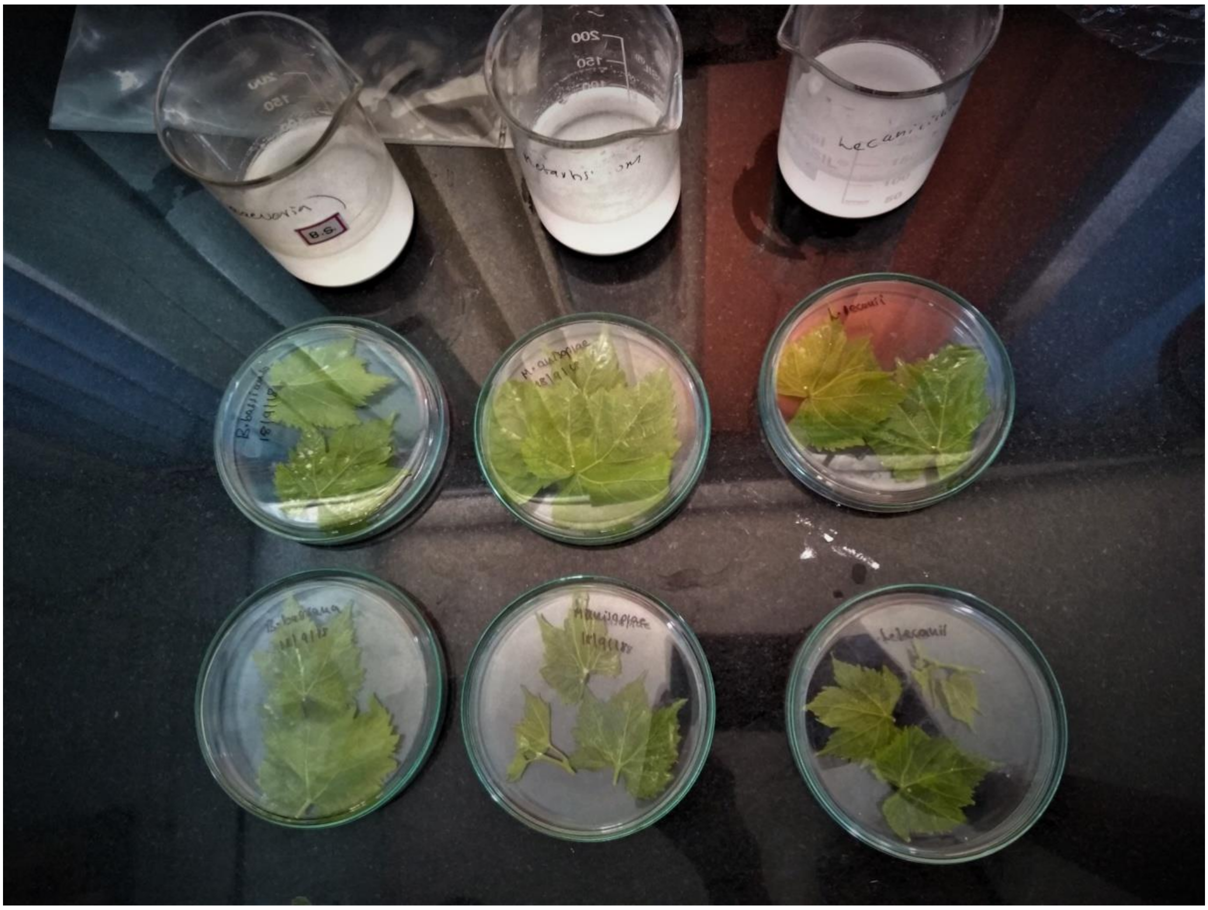


Plate 3.4: Mycosis test of mycoinsecticides on grape thrips

4. RESULTS AND DISCUSSION

The present investigation was intended to study the seasonal incidence and biorational management of grape thrips [*Rhipiphorothrips cruentatus* H.]. The research trail on bioefficacy of biorational insecticides and seasonal incidence were undertaken at AICRP on Fruits, Department of Horticulture, MPKV, Rahuri, during 2017-18. The results obtained during the studies have been presented and discussed with following titles:

4.1 Seasonal incidence of grape thrips and their correlation with weather parameters

Studies on seasonal incidence of thrips, *Rhipiphorothrips cruentatus* Hood on grape vine (Flame Seedless) were conducted during November, 2017 to October, 2018. Thrips population attained peak numbers at various growth stages of crop.

4.1.1 Seasonal incidence of thrips on grapevine

The population counts of thrips were recorded at weekly intervals commencing from October pruning 2017 to october, 2018.

The results revealed that the incidence of active stages both nymphs and adults started appearing from November 1st week (7.88/shoot) when new flush started after fruit or forward pruning in October, 2017 (Table 4.1, Fig. 4.2). The population gradually increased and peak incidence was observed from second week of December, (50th standard meteorological week) *i.e.*, (8.28/shoot) to second week of January, (2nd standard meteorological week) *i.e.*, (8.53/shoot). The higher incidence of thrips was coincided with the flowering stage of grape vine.

Thus there was increase in the population when new flush started and highest population was observed at the flowering stage while there was decrease in the population level when leaves get older and after fruit setting.

The incidence of thrips started when maximum and minimum temperature was 31.3^{0}C and 13.7^{0}C where morning and evening humidity was 58.4 per cent and 29.6 per cent, respectively. The thrips population increased gradually and reached to its peak (8.53/shoot) at 28.1^{0}C maximum and 12.2^{0}C minimum temperature.

The present results are in agreement with Kulkarni *et al.* (2008) who reported that the thrips population was observed throughout the year with an average peak of 8-10 thrips/shoot of vine in November and December months, which coincide the flowering period.

4.1.2 Correlation studies

The effect of different weather factors like rainfall, sunshine, wind velocity, relative humidity, maximum temperature and minimum temperature, on the incidence of thrips on grape vine were correlated and presented below (Table 4.2 and Fig 4.1). Multiple linear regression models were also carried out for collected data (Table 4.3).

Table 4.2: Correlation studies between incidence of grape thrips and weather parameters during 2017-2018.

Sr. No.	Weather parameters	Correlation coefficient (r)
1.	Rainfall (mm)	0.092^{NS}
2.	Sunshine (Hr)	-0.094^{NS}
3.	Wind velocity (Kmph)	-0.130^{NS}
4.	Evening relative humidity	0.233*
5.	Morning relative humidity	0.474**
6.	Minimum Temperature	-0.419**
7.	Maximum Temperature	-0.558**

**Correlation is significant at the 0.01 level.

*Correlation is significant at the 0.05 level

NS - Non Significant.

The linear correlation studies revealed that the weather factors maximum (r = -0.558) and minimum temperatures (r = -0.419) are significantly negatively correlated with thrips incidence. Whereas, it had significant positive correlation with both morning (r = 0.474) and evening relative humidity (r = 0.233).

The present correlation studies of weather parameters influence on the incidence of grape vine thrips are in accordance with the Gowtham *et. al*. (2009) who reported a significant negative correlation between population of thrips and maximum and minimum temperature and remaining other weather factors does not have much influence on thrips population

While all other factors such as rainfall ($r = 0.092^{NS}$), sunshine ($r = -0.094^{NS}$) and wind velocity ($r = -0.130^{NS}$) have not shown any significant relationship with the population of thrips. Even though rainfall was positively correlated with the population of thrips but it was not found to be statistically significant.

Table 4.1: Seasonal incidence of grape thrips (Nov 2017 - Oct 2018)

SMW	Date	No of thrips per shoot	Temperature (^{0}C)		Humidity (%)		Wind Velocity (Kmph)	Sunshine (hrs)	Rainfall (mm)
			Max	Min	Morn (I)	Even (II)			
44	(2017) Oct 29-4	7.64	31.3	13.7	58.4	29.6	1.2	9.7	0
45	Nov 5-11	7.88	30.2	13.2	63.2	36.1	1.6	9.8	0
46	12-18	8.04	29.9	12.2	65.8	34	0.6	8.9	0
47	19-25	8.08	30.1	16.6	71.1	47.2	0.4	6.2	0
48	26-2	8.12	29.8	11.3	66.4	33.8	0.6	8.3	0
49	Dec 3-9	8.24	28.5	17.5	71.4	49.4	1.6	4.5	0
50	10-16	8.28	25.4	16.7	63.2	34.0	0.7	6.6	0
51	17-23	8.16	28.3	13.9	64.1	35.1	0.6	6.8	0
52	24-31	8.44	29.3	12.8	68.2	36.2	0.7	7.1	0
1	(2018) Jan 1-7	8.52	28.4	10.6	67	36	0.2	7.9	0
2	8-14	8.53	28.1	12.2	63	35	0.3	7.5	0
3	15-24	6.33	29.9	12.8	70	32	0.5	8.6	0
4	22-28	4.32	28.4	9.5	55	27	0.5	9.4	0
5	29-4	3.21	30.3	10.6	59	21	0.7	9.5	0
6	Feb 5-11	2.61	31.2	13.8	53	23	1.3	7.4	0
7	12-18	1.64	30.4	13.5	66	34	0.8	9.0	0
8	19-25	1.52	33.7	15.0	53	24	0.7	8.8	0
9	26-04	1.00	34.6	17.0	49	20	1.1	8.5	0
10	Mar 5-11	1.04	34.6	18.2	44	20	1.4	7.4	0
11	12-18	0.88	33.1	18.9	48	25	1.4	5.9	0
12	19-25	0.96	35.0	16.4	44	19	1.9	8.8	0
13	26-01	1.04	37.6	18.0	40	15	1.9	9.2	0
14	Apr 2-8	0.96	37.5	19.8	40	19	1.8	7.9	0
15	9-15	0.80	37.2	20.0	44	19	1.6	8.8	0
16	16-22	0.68	39.3	22.3	41	21	3.6	10.0	1.0
17	23-29	0.56	39.4	19.7	30	13	2.2	10.8	0
18	30-06	0.60	40.6	21.0	36	17	3.9	10.6	0
19	May 7-13	0.00	40.2	24.2	32	18	4.1	10.3	0
20	14-20	0.00	39.8	24.3	36	19	4.8	9.8	0
21	21-27	0.00	38.8	25.2	40	20	4.5	7.1	0

SMW	Date	No of thrips per shoot	Temperature (^0C)		Humidity (%)		Wind Velocity (Kmph)	Sunshine (hrs)	Rainfall (mm)
			Max	Min	Morn (I)	Even (II)			
22	28-03	2.12	38.8	24.7	64	34	4.4	7.8	34.6
23	Jun 4-10	6.12	34.2	24.6	72	47	3.7	3.8	11.0
24	11-17	7.24	35.3	25.0	62	42	11.6	7.8	0
25	18-24	7.44	34.1	23.4	72	54	4.9	4.8	43.0
26	25-01	6.92	32.1	23.0	73	53	7.7	4.8	63.8
27	Jul 2-8	5.92	31.7	23.3	76	59	8.0	3.9	26.2
28	9-15	4.80	28.2	22.8	80	70	5.0	0.3	13.8
29	16-22	3.08	29.4	23.0	77	65	8.7	1.8	4.4
30	23-29	2.00	28.6	22.7	75	62	7.5	1.3	0
31	30-05	1.28	31.3	23.3	72	53	7.9	4.0	0
32	Aug 6-12	1.12	30.0	23.0	75	62	6.8	1.5	0
33	13-19	0.88	27.8	22.5	81	73	4.8	0.6	58.4
34	20-26	0.72	27.9	21.5	80	70	5.0	3.0	24.2
35	27-02	2.04	29.6	21.1	75	61	3.5	5.0	6.4
36	Sept 3-9	3.72	30.1	19.6	70	53	4.1	5.8	0
37	10-16	3.60	32.4	19.5	69	49	0.8	7.6	0
38	17-23	3.32	31.9	22.1	71	45	2.7	6.i	3.8
39	24-30	2.92	33.8	22.3	71	44	1.3	8.1	0
40	Oct 1-7	1.68	34.0	25.5	67	43	1.3	7.8	0
41	8-14	1.48	34.0	18.4	55	30	1.6	8.8	0
42	15-21	1.20	33.5	18.6	50	30	1.3	8.2	0
43	22-28	2.24	34.4	16.8	46	30	1.0	8.5	0
44	29-04	2.84	31.7	14.4	58	39	1.9	9.4	2.0
	Mean	3.49	32.56	18.72	60.24	37.37	2.88	7.02	5.52
	Max.	8.53	40.60	25.50	81.00	73.00	11.60	10.80	63.80
	Min.	0.00	25.40	9.50	30.00	13.00	0.20	0.30	0.00

N=53; SMW- Standard Meteorological Week; Max- Maximum ; Min- Minimum; Morn-Morning; Evn-Evening; Kmph- kilometer per hour

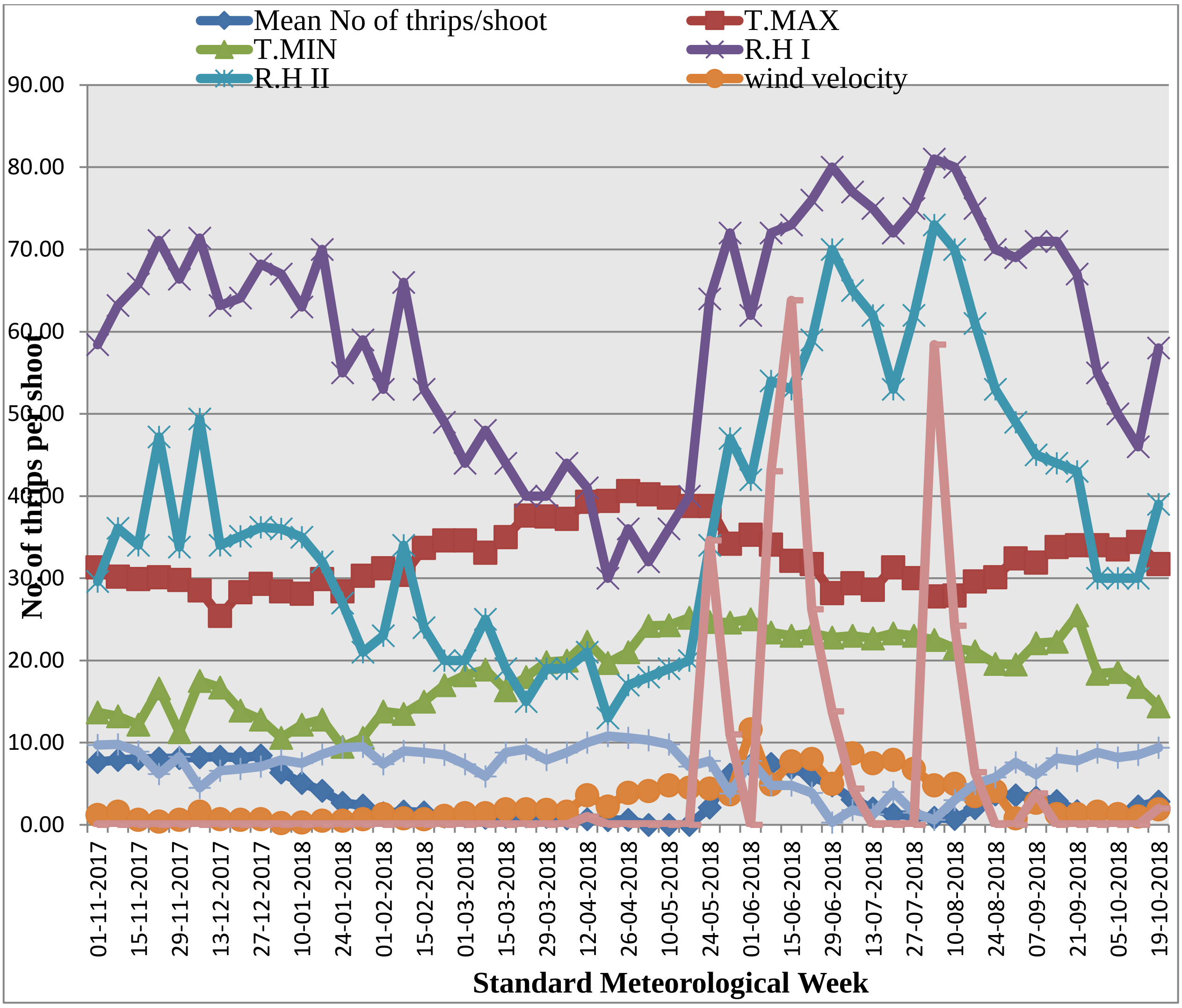


Fig 4.1: Impact of weather parameters on population of grape thrips

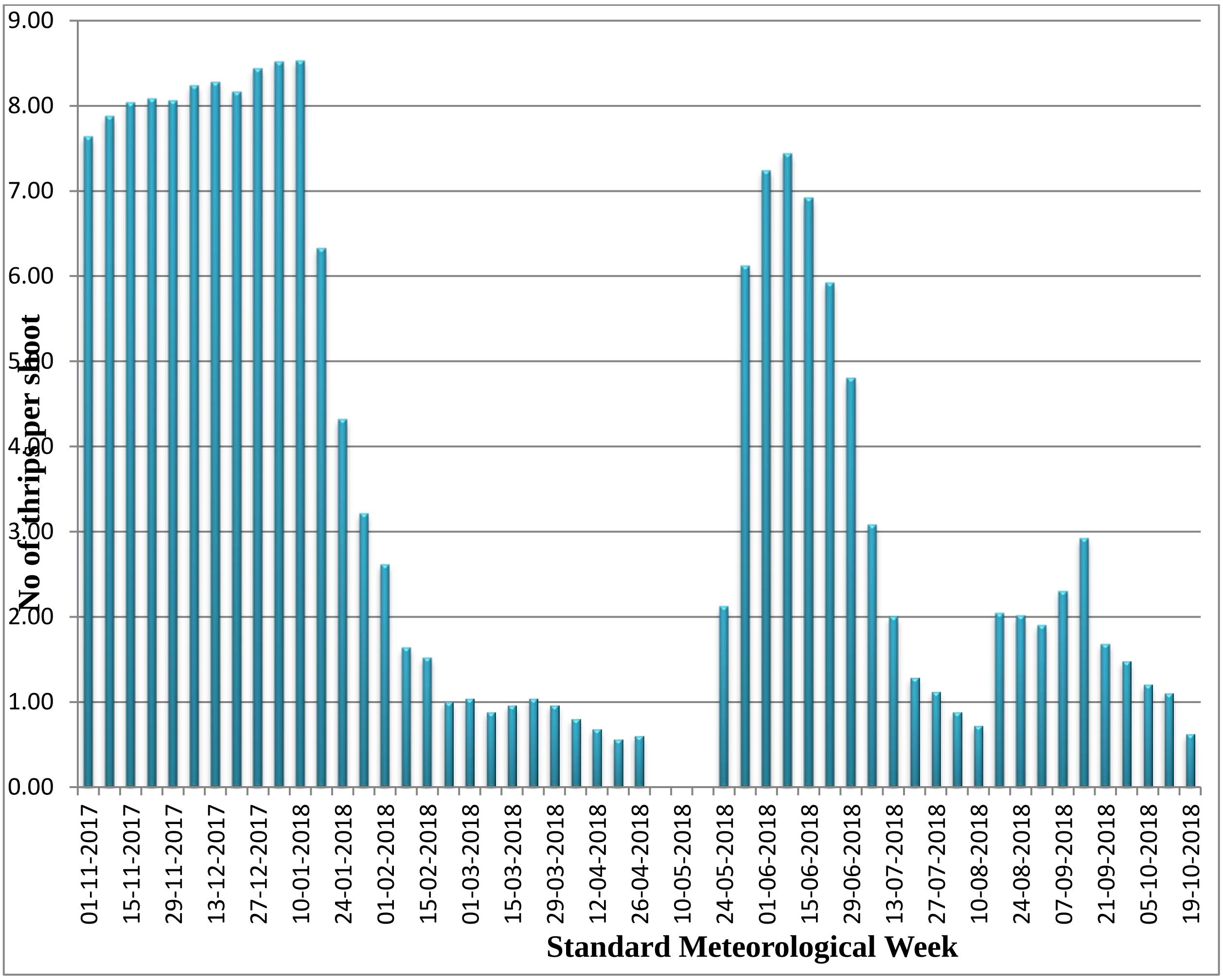


Fig 4.2: Incidence of thrips on grapes (November 2017 to October 2018)

The similar results are in accordance with results of Nagaraj *et. al*. (2017) who found that rainfall has non significant effect on the incidence of thrips population whereas, sunshine and wind speed although negatively correlated but are non significant in relation with incidence of thrips population.

Harish et al. (2002) also observed the non significant relation with the wind speed (r = -0.108) which is in agreement with the present investigation.

Over all, the occurrence and seasonal incidence of thrips was influenced negatively by maximum and minimum temperature while positively correlated with morning and evening relative humidity other weather parameters such as sunshine, wind velocity and rainfall have not shown any significant impact on the incidence levels of thrips population.

The present results are in confirmation with the findings of Kulkarni and Harish works.

4.1.3 Multiple linear regression analysis

Multiple linear regression models were also carried out for collected data (Table 4.3)

Weather parameters **Y = a + bx**

Y= Incidence of thrips

a= intercept

x= weather factor

b = Slope

Results indicated that rainfall (X_1) was contributed 0.6 per cent (R^2 = 0.006) towards the thrips incidence only. With addition of sunshine (X_2), wind velocity (X_3), morning relative humidity (X_4), evening relative humidity (X_5), minimum temperature(X_6) and maximum temperature (X_7) values of R^2 increased up to 0.90, 6.90, 20.00, 46.40, 52.10 and 53.10 per cent, respectively. Thus, it was clearly evident that morning relative humidity, minimum and maximum temperature was the major contributing weather parameters with 46.40, 52.10 and 53.10 per cent respectively for incidence of thrips. The total weather parameters influence on the incidence of thrips to the extent of 53.10 percent (R^2 = 0.531).

The present regression results are in agreement with Nagaraj *et al.* (2017), who reported that total influence of weather parameters on the thrips incidence during October pruning in grape vine is 65.80 per cent with $R^2 = 0.658$.

Table 4.3: Multiple linear regression analysis between incidence of grape thrips and weather parameters during 2017-2018

Sr. No	Variable	Regression model	R^2
1.	Rainfall (X_1)	$Y = 3.546 + 0.016X_1$	0.006
2.	Sun shine (X_2)	$Y = 4.005 + 0.010 X_1 - 0.067X_2$	0.009
3.	Wind velocity (X_3)	$Y = 6.054 + 0.023X_1 - 0.221X_2 - 0.343X_3$	0.069
4.	Relative Humidity (M) (X_4)	$Y = -3.564 + 0.007X_1 + 0.443X_2 - 0.368X_3 + 0.136X_4$	0.200
5.	Relative Humidity (E) (X_5)	$Y = -10.701 + 0.004X_1 + 0.262X_2 + 0.022X_3 - 0.152X_4 + 0.300X_5$	0.464
6.	Minimum temperature (X_6)	$Y = -3.780 + 0.013X_1 + 0.209X_2 +0.242X_3 - 0.102X_4 + 0.230X_5 - 0.259X_6$	0.521
7.	Maximum temperature (X_7)	$Y = 3.151 + 0.021X_1 + 0.356X_2 + 0.254X_3 - 0.123X_4 + 0.208X_5 - 0.105X_6 - 0.270X_7$	0.531

*M = Morning

*E = Evening

4.2. Bioefficacy of somebiorational insecticides against grape thrips

Thrips, once considered to be the insect pests of minor importance in horticultural crops, but have gained the paramount importance due to their ability to cause economic losses, to subsist on new hosts and by being polyphagous in nature (Dahiya *et al*., 1995). Thrips were observed as a serious pest of grape. It is mainly responsible for leaf curl symptoms and scars on berries due to rasping on the leaves and flower buds. *Ripiphorothrips cruentatus* (H.) and *Scirtothrips dorsalis* (H.) are the species recorded infestion on leaves and berries (Butani., 1979).

In the present investigation, insecticides like emamectin benzoate 5 SG @11 g a.i.ha^{-1}, biorational insecticides such as neem oil, karanj oil, neemazol, chilli methonolic extract, garlic methonolic extract and three biopesticides (*Metarhizium anisopliae* @ 5 g/l, *Lecanicillium lecanii* @ 5 g/l,and *Beauveria bassiana* @ 5 g/l) were tested for their efficacy against thrips with untreated control (water spray). Three sprays were given, first spray was given at ETL (3 thrips per shoot), next two sprays were given at 10 days interval. The pre-count was recorded 1 DBS and the surviving pest population was recorded at 3, 5, 7 and 10 DAS. The mean survival population was worked out to determine effectiveness of each spray treatment and also the overall mean of surviving pest population and per cent reduction over control was computed to study performance of different insecticides. The data pertaining to effect of different insecticides on population of thrips are presented in (Table 4.7) and described here under.

4.2.1 First spray

The data pertaining to efficacy of insecticides against thrips after first spray presented in (Table 4.4). The thrips population recorded, a day before spraying (PTC) varied from 8.10 to 8.73 thrips per shoot, which showed non significant difference among treatments indicating homogenous distribution of thrips population in the experimental area. Post treatment population counts were taken at 3 DAS, 5 DAS, 7 DAS and 10 DAS.

4.2.1.1 3 DAS

It could be seen that all the insecticidal treatments were significantly superior over untreated control (8.83/shoot) at 3 DAS. The observations recorded three days after first spray indicated that standard check emamectin benzoate 5 SG @ 11 g a.i.ha^{-1} was proved to be significantly superior treatment with minimum thrips population (5.17/shoot). Whereas, in case of biorational insecticides neemazol (6.93/shoot) was effective however it was on par with neem oil 2% (7.03/shoot), karanj oil 2% (7.10/shoot) and *Lecanicillium lecanii* (7.10/shoot) The treatments with chilli and garlic water extracts 2% was found to be the least effective in reducing the thrips population (8.07 and 8.00 per shoot).

4.2.1.2 5 DAS

A significant reduction in thrips population was observed with all biorational insecticides during 5DAS. Among biorational insecticides neem oil treated plants recorded least population (3.63/shoot) which was on par with neemazol (3.70/shoot) and karanj oil (3.93/shoot) followed by *Lecanicillium lecanii* (4.43/shoot) shows on par relation with *Metarhizium anisopliae* (4.93/shoot). However, untreated plants recorded highest thrips population (8.83/shoot).

4.2.1.3 7 DAS

The results after ten days of first spray showed that biorationals, neem oil treated plants recorded least population (2.20/shoot) which was on par with neemazol (2.87/shoot) and *Lecanicillium lecanii* (2.30/shoot). Karanj oil (3.07/shoot) is next effective treatment. *Metarhizium anisopliae* (3.00/shoot) is on par with *Beauveria bassiana* (3.37/shoot). Chilli and garlic extracts 2% continued to be the least effective treatment with 4.30 to 5.93 thrips per shoot, respectively.

TABLE 4.4: Bio-efficacy of some biorational insecticides against thrips on grapes (1^{st} spray)

Treatment details		Dose	Number of thrips per shoot					Mean	Per cent reduction of thrips over contol
			Pre-count	3 DAS	5 DAS	7 DAS	10 DAS		
T_1	***Beauveria bassiana***	5g/l ($1x10^8$ cfu/g)	8.70 (3.03)	8.13 (2.94)	5.70 (2.49)	3.37 (1.97)	4.47 (2.23)	5.42 (2.43)	38.10
T_2	***Metarhizium anisopliae***	5g/l ($1x10^8$ cfu/g)	8.27 (2.96)	7.43 (2.82)	4.93 (2.33)	3.00 (1.87)	4.20 (2.17)	4.89 (2.32)	44.10
T_3	***Lecanicillium lecanii***	5g/l ($1x10^8$ cfu/g)	8.10 (2.93)	7.10 (2.76)	4.43 (2.22)	2.30 (1.67)	3.90 (2.10)	4.43 (2.22)	49.33
T_4	**Neem oil (2%)**	20 ml/l	8.60 (3.02)	7.03 (2.74)	3.63 (2.03)	2.20 (1.64)	3.97 (2.11)	4.21 (2.17)	51.90
T_5	**Karanj oil (2%)**	20 ml/l	8.50 (3.00)	7.10 (2.76)	3.93 (2.11)	3.07 (1.89)	4.53 (2.24)	4.66 (2.27)	46.76
T_6	**Neemazol (10000 ppm)**	3 ml/l	8.10 (2.93)	6.93 (2.73)	3.70 (2.05)	2.87 (1.83)	4.23 (2.18)	4.43 (2.22)	49.33
T_7	**Chilli methanolic extract (2%)**	20 ml/l	8.17 (2.94)	7.17 (2.77)	5.37 (2.42)	4.30 (2.19)	8.20 (2.95)	6.26 (2.60)	28.48
T_8	**Garlic methanolic extract (2%)**	20 ml/l	8.27 (2.96)	7.53 (2.83)	5.73 (2.50)	4.90 (2.32)	8.43 (2.99)	6.65 (2.67)	24.00
T_9	**Emamectin benzoate**	0.22 g/l	8.30 (2.97)	5.17 (2.38)	2.10 (1.61)	1.73 (1.49)	3.50 (2.00)	3.13 (1.90)	64.29
T_{10}	**Chilli water extract (2%)**	20 ml/l	8.73 (3.04)	8.07 (2.93)	6.47 (2.64)	5.47 (2.44)	8.67 (3.03)	7.17 (2.77)	18.10
T_{12}	**Garlic water extract (2%)**	20 ml/l	8.63 (3.02)	8.00 (2.92)	6.60 (2.66)	5.93 (2.54)	8.60 (3.02)	7.28 (2.79)	16.76
T_{12}	**Untreated Control**	---	8.67 (3.03)	8.83 (3.06)	8.83 (3.06)	8.60 (3.02)	8.73 (3.04)	8.75 (3.04)	0.00
S. E. m. ±		---	0.117	0.088	0.075	0.065	0.097	0.061	----
CD at 5%		---	NS	0.260	0.220	0.193	0.286	0.181	----

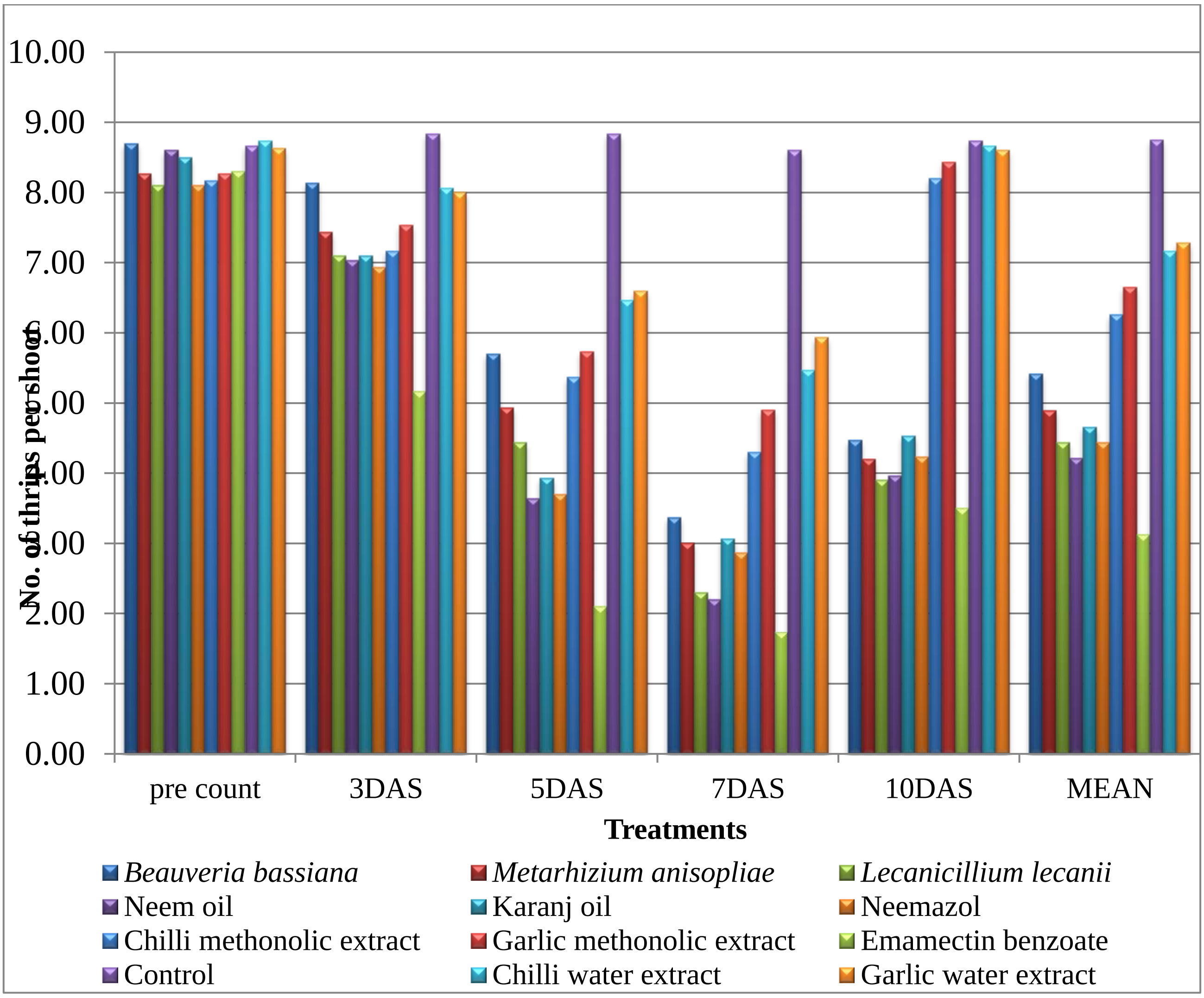


Fig 4.3: Effect of biorational insecticides against grape thrips after first spray

4.2.1.4 10 DAS

The results after ten days of first spray showed that standard check emamectin benzoate 5 SG @ 11 g a.i.ha^{-1} proved to be significantly superior recording minimum thrips population (3.50/shoot). Biorational insecticides entomopathogenic fungi *Lecanicillium lecanii* and neem oil with 3.90 and 3.97 thrips per shoot respectively on par with each other statistically.

Considering the mean population of thrips after first spray, it was found that biorational insecticides neem oil (4.21/shoot) and *Lecanicillium lecanii* (4.43/shoot) was the most effective treatment with least population of thrips. Whereas, chilli water extract and garlic water extract was least effective with 7.17 and 7.28 thrips per shoot, respectively.

The data also indicated that higher reduction of population over control was observed in plots treated with standard check emamectin benzoate (64.29%). Among biorational insecticides neem oil (51.90%).*Lecanicillium lecanii* and neemazol had same per cent reduction over control *i.e* 49.33%. Next in order of effectiveness were karanj oil (46.76%), *Metarhizium anisopliae* (44.10%) and *Beauveria bassiana* (38.10%).

4.2.2 Effect of biorational insecticides on thrips after second spray

The results on efficacy of insecticides on population of thrips after second spray were presented in (Table 4.5).The data on thrips population collected at 10 DAS after I spray was considered as pre count for second spray. In post treatment observations of second spray, all insecticides showed significant difference over untreated control.

4.2.2.1 3 DAS

Among the treatments standard check emamectin benzoate 5 SG @ 11 g a.i.ha^{-1} reduced the thrips population to an extent of 4.30/shoot and was significantly superior to remaining other treatments. The treatments that followed in the descending order of efficacy were karanj oil 2% and neem oil 2% which caused a population reduction to 5.93 and 6.70 thrips per shoot, respectively. This was followed by *Lecanicillium lecanii* (7.20/shoot), neemazol (7.23/shoot), chilli methanolic extract (7.40/shoot) and garlic water extract (7.40/shoot) which were on par with each other.

4.2.2.2 5 DAS

Among biorational insecticides neem oil recorded least population (4.67/shoot). They were followed by entomopathogenic fungi *Lecanicillium lecanii* (4.83/shoot) and karanj oil (4.87/shoot) found to be on par with each other. The next effective treatments was *Metarhizium anisopliae* (5.47/shoot). Neemazol (6.00/shoot) and *Beauveria bassiana* (6.00/shoot) were on par with each other.

4.2.2.3 7 DAS

The observations recorded after seven days of second spray showed that neem oil was most effective and significantly superior over all the other treatments with 1.77 thrips per shoot, however on par with *Lecanicillium lecanii* (1.97/shoot). This was followed by *Metarhizium anisopliae* (2.80/shoot), karanj oil (3.27/shoot) and *Beauveria bassiana* (3.27/shoot) which were on par with each other statistically. The remaining treatments in the descending order of efficacy were neemazol (5.00/shoot) and chilli methanolic extract (5.03/shoot) being on par with each other. Among all the insecticides tested, garlic water extract 2% was the least effective treatment with thrips population of 6.33/shoot.

4.2.2.4 10 DAS

The observations recorded after ten days of second spraying revealed that *Lecanicillium. lecanii* are most effective and significantly superior over all other treatments with thrips population of 2.63 per shoot. It was followed by neem oil (3.13/shoot) and *Metarhizium anisopliae* (3.50/shoot) which were on par with each other. The least effective treatments were garlic methanolic extract (6.97/shoot), chilli water extract (7.20/shoot) and garlic water extract (7.60/shoot), by being on par with each other.

Considering the mean population of thrips after second spray, it was found that standard check emamectin benzoate was the most effective treatment with least population of thrips (3.06/shoot). Among biorational insecticides neem oil (4.07/shoot) and *Lecanicillium*

Table: Effect of biorational insecticides against grape thrips after second spray

Treatment details		Dose	Number of thrips per shoot				Mean	Per cent reduction of thrips over control
			3 DAS	5 DAS	7 DAS	10 DAS		
T_1	***Beauveria bassiana***	5g/l ($1x10^8$ cfu/g)	8.06 (3.02)	6.00 (2.55)	3.27 (1.94)	4.07 (2.14)	5.48 (2.45)	37.45
T_2	***Metarhizium anisopliae***	5g/l ($1x10^8$ cfu/g)	8.03 (2.92)	5.47 (2.44)	2.80 (1.82)	3.50 (2.00)	4.95 (2.33)	43.54
T_3	***Lecanicillium lecanii***	5g/l ($1x10^8$ cfu/g)	7.20 (2.77)	4.83 (2.31)	1.97 (1.57)	2.63 (1.77)	4.16 (2.16)	52.57
T_4	**Neem oil (2%)**	20 ml/l	6.70 (2.68)	4.67 (2.27)	1.77 (1.51)	3.13 (1.91)	4.07 (2.14)	53.61
T_5	**Karanj oil (2%)**	20 ml/l	5.93 (2.54)	4.87 (2.32)	3.27 (1.94)	3.80 (2.07)	4.47 (2.23)	49.05
T_6	**Neemazol (10000 ppm)**	3ml/l	7.23 (2.78)	6.00 (2.55)	5.00 (2.35)	4.80 (2.30)	5.76 (2.50)	34.32
T_7	**Chilli methanolic extract (2%)**	20 ml/l	7.40 (2.81)	6.53 (2.65)	5.03 (2.35)	6.27 (2.60)	6.31 (2.61)	28.04
T_8	**Garlic methanolic extract (2%)**	20 ml/l	8.10 (2.93)	7.07 (2.75)	6.07 (2.56)	6.97 (2.73)	7.05 (2.75)	19.58
T_9	**Emamectin benzoate**	0.22g/l	4.30 (2.19)	3.67 (2.04)	1.63 (1.46)	2.63 (1.77)	3.06 (1.89)	65.11
T_{10}	**Chilli water extract (2%)**	20 ml/l	7.80 (2.88)	6.73 (2.69)	5.67 (2.48)	7.20 (2.77)	6.85 (2.71)	21.86
T_{11}	**Garlic water extract (2%)**	20 ml/l	7.40 (2.81)	7.07 (2.75)	6.33 (2.61)	7.60 (2.85)	7.10 (2.76)	19.01
T_{12}	**Untreated Control**	---	8.63 (3.02)	8.67 (3.03)	8.87 (3.06)	8.90 (3.07)	8.77 (3.04)	0.00
S. E. m. ±		---	0.100	0.082	0.067	0.074	0.060	
CD at 5%		---	0.295	0.241	0.197	0.217	0.176	

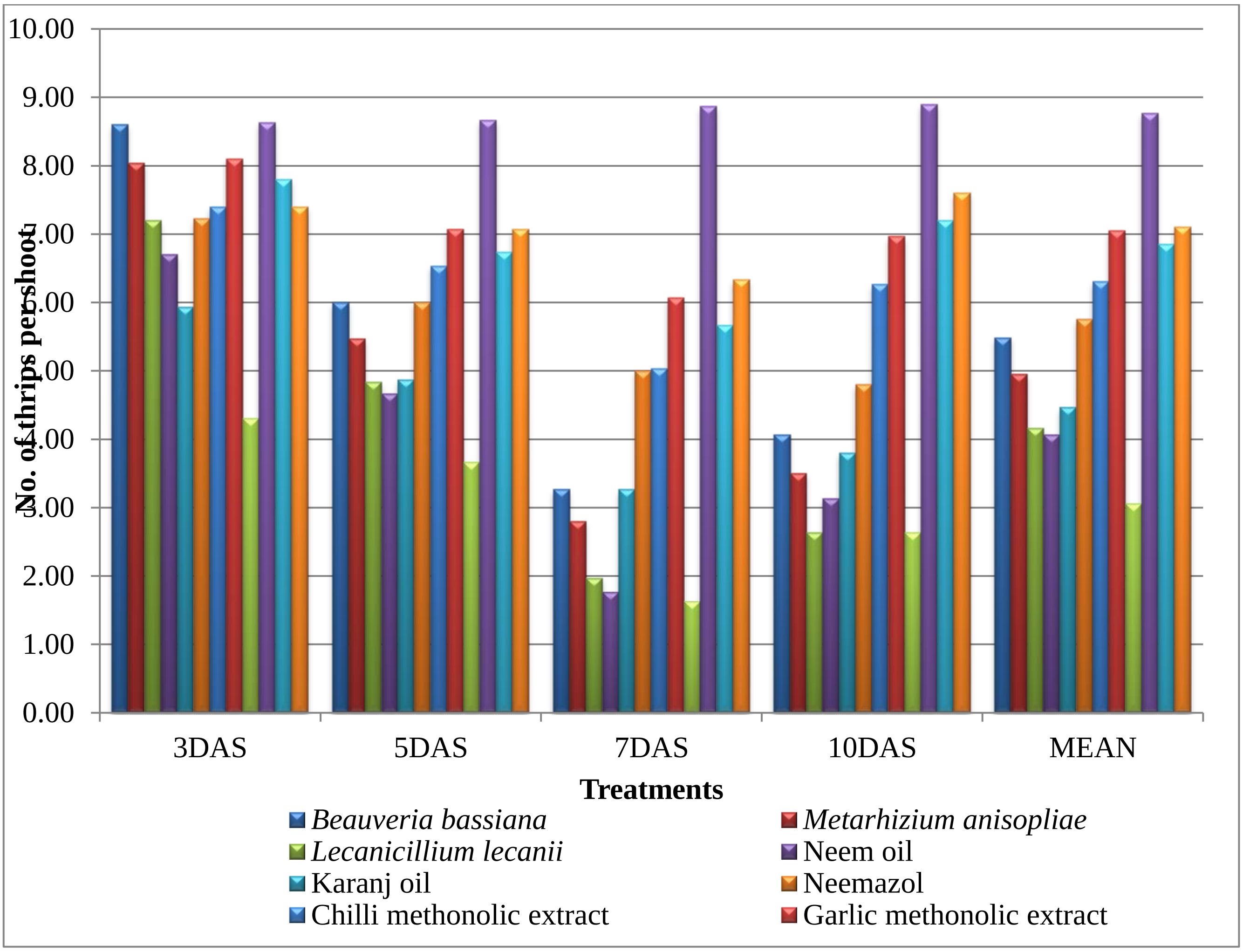


Fig 4.4: Effect of biorational insecticides against grape thrips after second spray

lecanii (4.16/shoot) proved as effective treatments. Whereas, chilli water extract and garlic water extract was least effective with 6.85 and 7.10 thrips per shoot, respectively.

The cumulative effect of treatments indicated that higher reduction of population over control was observed in plots treated with standard check emamectin benzoate (65.11%). Among biorational insecticides neem oil (53.61%) emerged as best treatment over control. Next in order of effectiveness were *Lecanicillium lecanii* (52.57%), karanj oil (49.05%), *Metarhizium anisopliae* (43.54%) and *Beauveria bassiana* (37.45%).

4.2.3 Effect of different insecticides on thrips population after third spray

The results with regard to the efficacy of treatments after third spray were presented in (Table 4.6). The population recorded, a day before spraying (DBS) varied from 8.10 to 8.57 thrips per shoot.

4.2.3.1 3 DAS

The data recorded at three days after spray, showed that among all treatments, standard check emamectin benzoate 5 SG @ 11 g a.i.ha^{-1} registered least thrips population (4.40/shoot) and proved to be significantly superior over other treatments. Among biorational insecticides best treatment is karanj oil (6.13/shoot), followed by neem oil (6.40/shoot). Whereas, *Metarhizium anisopliae* (7.63/shoot), neemazol (7.23/shoot) and *Beauveria bassiana* (8.20/shoot) are on par among themselves. The least effective treatment continued to be chilli methanolic extract (8.10/shoot), garlic methanolic extract (8.27/shoot) and was also on par among themselves statistically.

4.2.3.2 5 DAS

At 5 DAS, the number of thrips ranged from 3.77 to 6.73 thrips per shoot. The lowest thrips population was observed in the standard check treatment emamectin benzoate 5 SG @ 11 g a.i.ha^{-1} which proved to be significantly superior recording minimum of 3.77 thrips per shoot. Among biorational insecticides, neem oil treated plots recorded least population (4.73/shoot). This was followed by karanj oil (4.80/shoot) and neemazol (4.80/shoot) which were on par with each other. The least effective treatments garlic methonolic extract 2% (6.23/shoot) and chilli water extract 2% (6.23/shoot) were on par with each other statistically.

4.2.3.3 7 DAS

At 7 DAS, neem oil (1.97/shoot) emerged as the best treatment. This was followed by *Lecanicillium lecanii* (2.10/shoot) and *Metarhizium anisopliae* (2.80/shoot). Karanj oil 2% (2.93/shoot), neemazol (3.10/shoot) and *Beauveria bassiana* (3.13/shoot) were on par among themselves. Among all insecticides tested chilli methanolic extract (4.80/shoot), garlic methanolic extract (5.10/shoot), chilli water extract (5.20/shoot) and garlic water extract (5.67/shoot) showed the least efficacy in controlling the thrips population which were on par among themselves statistically.

4.2.3.4 10 DAS

The observations recorded after ten days of third spray showed that *Lecanicillium lecanii* (2.30/shoot) significantly superior over other treatments. The other effective treatments were neem oil (2.90/shoot) and *Metarhizium anisopliae* (3.40/shoot). Garlic methanolic extract (6.97/shoot), chilli water extract (7.10/shoot) and garlic water extract (7.20/shoot) showed the least efficacy in controlling the thrips population which were on par among themselves statistically.

Considering the mean population of thrips after third spray, it was found that standard check emamectin benzoate was the most effective treatment with least population of thrips (3.11/shoot). Among birational insecticides neem oil (4.00/shoot), *Lecanicillium lecanii* (4.12/shoot) and karanj oil (4.42/shoot) were the best treatments. Whereas, garlic methanolic extract and garlic water extract was least effective with 6.64 and 6.85 thrips per shoot respectively.

The cumulative effect of treatments indicated that higher reduction of population over control was observed in plots treated with standard check emamectin benzoate (63.18%). Among birational insecticides neem oil is the best treatment with 52.62% reduction over control. Next in order of effectiveness were *Lecanicillium lecanii* (51.23%), karanj oil (47.68%), *Metarhizium anisopilae* (43.63%), neemazol (40.08%) and *Beauveria bassiana* (39.19%).

4.2.4 Pooled data

The data pertaining to efficacy of insecticides against thrips during first, second and third spray are pooled and presented in (Table 4.7). It could be seen that all the insecticidal treatments were significantly superior over untreated control.

The pooled data of three sprays revealed that standard check emamectin benzoate 5 SG consistently proved to be the most promising by recording the least population (3.10/shoot). Among biorational insecticides neem oil 2% (4.09/shoot), karanj oil (4.51/shoot) and neemazol (5.08/shoot). While entomopathogenic fungi *Lecanicillium lecanii* recorded less population (4.24/shoot) as compared to the *Metarhizium anisopliae* (4.87/shoot) and *Beauveria bassiana* (5.34/shoot).

Table: bioefficacy of biorational insecticides in 3rd spray

Treatment details		Dose	Number of thrips per shoot				Mean	Per cent reduction of thrips over control
			3 DAS	5 DAS	7 DAS	10 DAS		
T_1	***Beauveria bassiana***	5g/l ($1x10^8$ cfu/g)	8.20 (2.95)	5.17 (2.38)	3.13 (1.91)	4.03 (2.13)	5.13 (2.37)	39.19
T_2	***Metarhizium anisopliae***	5g/l ($1x10^8$ cfu/g)	7.63 (2.85)	5.20 (2.39)	2.80 (1.82)	3.40 (1.97)	4.76 (2.29)	43.63
T_3	***Lecanicillium lecanii***	5g/l ($1x10^8$ cfu/g)	7.17 (2.77)	4.90 (2.32)	2.10 (1.61)	2.30 (1.67)	4.12 (2.15)	51.23
T_4	**Neem oil (2%)**	20 ml/l	6.40 (2.63)	4.73 (2.29)	1.97 (1.57)	2.90 (1.84)	4.00 (2.12)	52.62
T_5	**Karanj oil (2%)**	20 ml/l	6.13 (2.58)	4.80 (2.30)	2.93 (1.85)	3.80 (2.07)	4.42 (2.22)	47.68
T_6	**Neemazol (10000 ppm)**	3ml/l	7.23 (2.78)	4.80 (2.30)	3.10 (1.90)	5.10 (2.37)	5.06 (2.36)	40.08
T_7	**Chilli methanolic extract (2%)**	20 ml/l	8.10 (2.93)	6.00 (2.55)	4.80 (2.30)	6.27 (2.60)	6.29 (2.61)	25.47
T_8	**Garlic methanolic extract (2%)**	20 ml/l	8.27 (2.96)	6.23 (2.59)	5.10 (2.37)	6.97 (2.73)	6.64 (2.67)	21.32
T_9	**Emamectin benzoate**	0.22g/l	4.40 (2.21)	3.77 (2.07)	1.73 (1.49)	2.53 (1.74)	3.11 (1.90)	63.18
T_{10}	**Chilli water extract (2%)**	20 ml/l	7.60 (2.85)	6.23 (2.59)	5.20 (2.39)	7.10 (2.76)	6.53 (2.65)	22.61
T_{11}	**Garlic water extract (2%)**	20 ml/l	7.80 (2.98)	6.73 (2.99)	5.67 (2.99)	7.20 (3.00)	6.85 (2.99)	18.85
T_{12}	**Untreated Control**	---	8.37 (2.88)	8.43 (2.69)	8.47 (2.48)	8.50 (2.77)	8.44 (2.71)	0.00
S. E. m. ±		---	0.097	0.084	0.072	0.093	0.063	---
CD at 5%		---	0.286	0.249	0.214	0.274	0.186	---

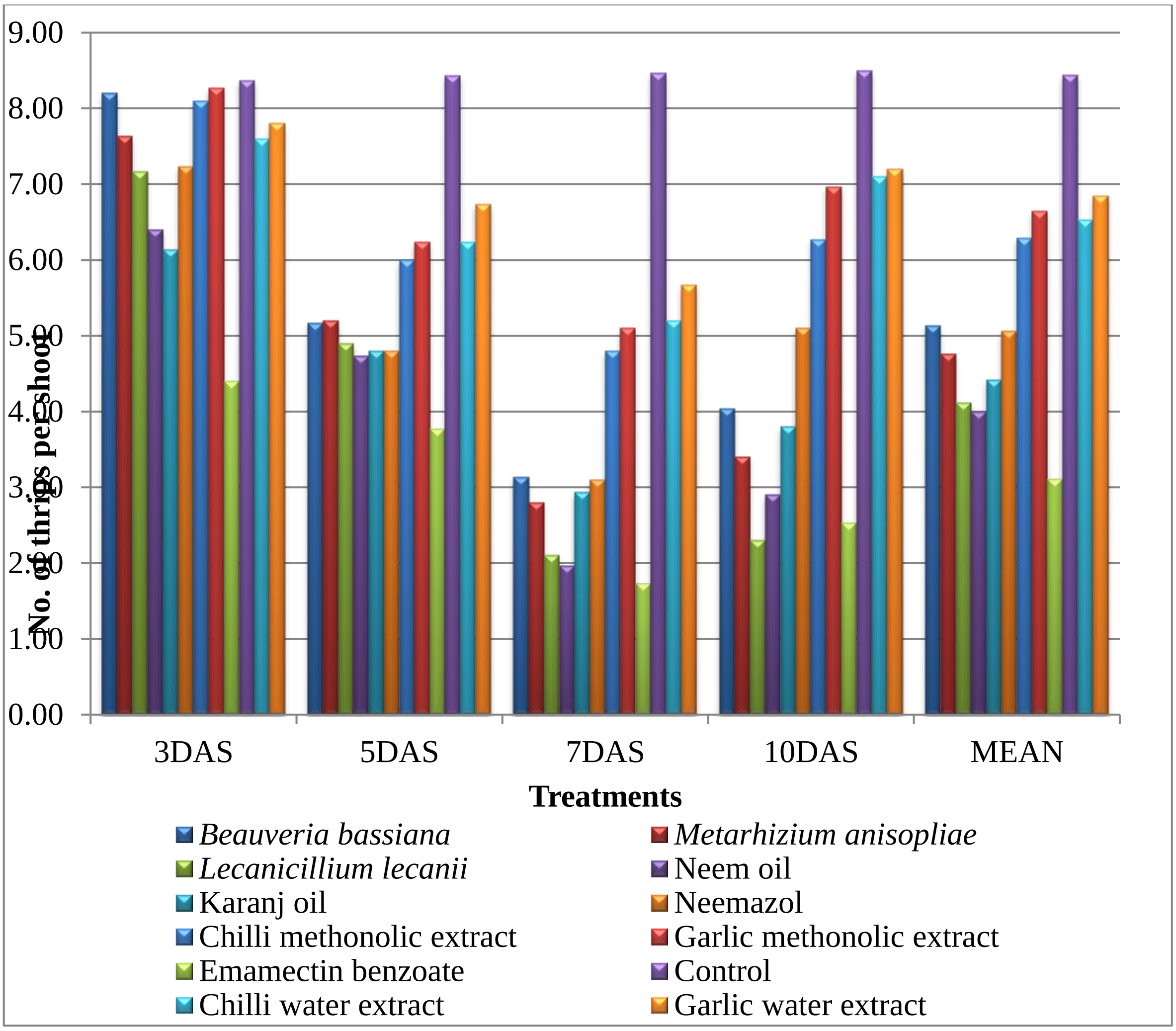


Fig 4.5: Effect of biorational insecticides against grape thrips after third spray

The data also indicated that higher per cent reduction over control of population was observed in plots treated with standard check emamectin benzoate 5 SG (64.21%). Among biorational insecticides neem oil (52.71%) and *Lecanicillium lecanii* (51.04%). Next in order of effectiveness were karanj oil (47.83%), *Metarhizium anisopliae* (43.76%), neemazol (41.26%), *Beauveria bassiana* (38.23%), chlli methanolic extract (27.35%), garlic methanolic extract (21.63%), chilli water extract (20.83%) and garlic water extract (18.20%).

Abdu-Allah *et al.* (2017) reported emamectin benzoate was the highest in reduction ratio of nymphs thrips in both laboratory and field conditions. Emamectin benzoate has translaminar movement which helps in control of thrips population present under the leaf surface. Muthukrishnan *et al.* (2012) revealed that emamectin benzoate most effectively reduced population of grape thrips and borers at 11 g and 22 g a.i.ha^{-1} and increased fruit yield simultaneously. He also reported the insecticide did not register any adverse effects on coccinellid predators. The bioefficacy of emamectin benzoate @ 0.20 g/L in reducing thrips population was also reported by kulkarni *et al.* (2017).

Kesai *et al.* (1995) reported that neem derivatives like achook and nimin derivative showed good control of chilli thrips population reduction. Meena *et al.* (2017) reported neem oil and karanj oil was the most effective treatments compared to the garlic sap extract and *B. bassiana* during an experiment on field efficacy of certain biopesticides against chilli thrips.

Sandeep kumar *et al.* (2017) showed that NSKE 5% caused maximum mortality of 64.50%, while garlic and onion extract showed comparatively less performance with 55.98% and 51.53% respectively.

Ravi *et al.* (2017) reported combination of *L. lecanii* 1.15% WP + *M. anisoplae* 1.15% WP was the most effective treatment as compared to standard check dimethoate for suppression of thrips population on okra.

These earlier findings support the present investigations.

4.2.5 Cost economics of grapes

The cost effectiveness of the different insecticides used during study was assessed and presented in the (Table 4.8). The ICBR in respect of different treatments ranged between 1.30 to 7.92. The highest ICBR was observed among entomopathogenic fungi like *L. lecanii* (1:6.34) and *M. anisopliae* (1:5.32). Although neem oil and karanj oil has great reduction of thrips population, but has less cost benefit ratio *i.e* 2.81 and 3.04, respectively due to high cost of the insecticide.

4.2.6 Mycosis test of mycoinsecticides on grape vine thrips

The fungal suspension of three mycoinsecticides *viz., Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii* were studied for mycosis test on grape thrips. Detailed microscopic examination of the thrips samples collected from the petri plates showed that all the test entomopathogenic fungi found growing in the body of the thrips.

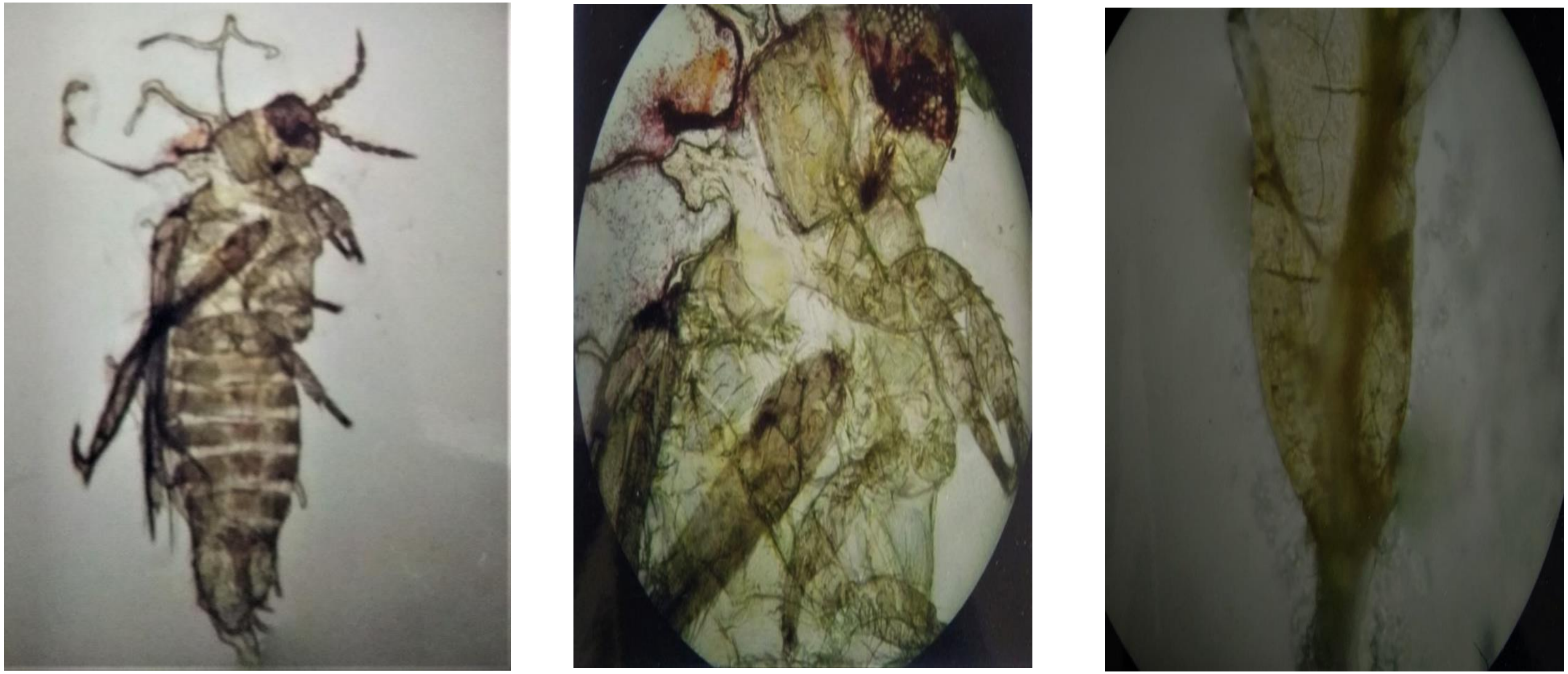
The moribund adult thrips showed profuse fungal growth in the body cavity, (Plates 4.1, 4.2 and 4.3). The microscopic photographs in the plates clearly indicated the mycosis by *Beauveria bassiana* was predominant behind compound eyes, prothorax, near fore coxa, stomach portion and between inter segmental spaces (Plate 4.1 – a). Close up view showed clear growth of fungus in thorax and abdominal portion (Plate 4.1 – c). In advanced stages after tight filling the body cavity the fungus outgrowth was observed on head, legs and posterior part of abdomen, (Plate 4.1 – b). Highly pronounced mycosis by *Metarhizium anisopliae* was observed in the thrips which shrunken and hardened its body (Plate 4.2 – a, b, c and d). The growth was observed in almost all body parts. The growth was observed along intersegmental joints around genital parts (Plate 4.2 – c and d), tergo- sternum joint (Plate 4.2 – b), head and prothorax and inter wings (Plate 4.2 – a and c). *Lecanicillium lecanii* soften the body of the thrips and growth was observed on antennary tips, around compound eyes, legs and tissues in different part of the body and alimentary canal in mid infestation (Plate 4.3 – a), in advanced stages whole body was captured by the fungus and growth was also vivid on surface of the body (Plate 4.3 – b and c).

Similar results are observed by Ravi *et al.* (2017) reported mycosis on thrips by *B. bassiana* and *L. lecanii* during an experiment on efficacy of entomopathogenic fungi against thrips on okra and Latha *et al.* (2010) who proved mycosis on thrips by *B. bassiana*, *M. anisopliae* and *L. lecanii* during an investigation on the evaluation of fungal pathogens against onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae).

Tabe 4.8: Cost economics of grape production influenced by treatment of biorational insecticides for thrips management.

Sr. No.	Treatment details	Quantity of insecticide required (kg or L/ha)	Yield (t/ha) **A**	Additional yield over control (t/ha) **B**	Additional profit (Rs/ha) **C**	Cost of treatment & labour for three sprays (Rs/ha) **D**	Net profit (Rs/ha) **E = C-D**	ICBR **F= C/D**
1	*Beauveria bassiana*	5 kg/ha	16.81	1.11	33300	6480	26820	5.13
2	*Metarhizium anisopliae*	5 kg/ha	16.85	1.15	34500	6480	28020	5.32
3	*Lecanicillium lecanii*	5 kg/ha	17.07	1.37	41100	6480	34620	6.34
4	Neem oil	15 L/ha	18.34	2.64	79200	28185	51015	2.81
5	Karanj oil	15 L/ha	17.88	2.18	65400	21480	43920	3.04
6	Neemazol	3 L/ha	17.00	1.30	39000	19680	19320	1.98
7	Chilli methanolic extract	20 L/ha	16.79	1.09	32700	14880	17820	2.19
8	Garlic methanolic extract	20 L/ha	16.42	0.72	21600	16560	5040	1.30
9	Emamectin benzoate	220 g/ha	17.88	2.18	65400	8250	57150	7.92
10	Chilli water extract	20 L/ha	16.13	0.43	12900	5880	7020	2.19
11	Garlic water extract	20 L/ha	16.05	0.35	10500	7080	3420	1.48
12	Untreated control	-	15.70	-	-	-	-	-

B bassiana – Rs. 200 per 1 kg	*M. anisoplae* – Rs. 200 per 1 kg	cost of labour - Rs. 3480/ha	Chilli methanolic extract – Rs. 190/1 ltr
Neem oil – Rs. 549 per 1 ltr	*L. lecanii* – Rs. 200 per 1 kg	Garlic water extract – Rs. 60/1 ltr	Chilli water extract – Rs. 40 per 1 ltr
Emamectin benzoate – Rs. 795/100 g	Karanj oil – Rs. 400 per 1 ltr	Garlic methanolic extract – Rs. 218/1 ltr	
grapes – Rs. 30,000/- per tonne	Neemazol – Rs. 1800 per 1 ltr	ICBR – Incremental Cost Benefit Ratio	



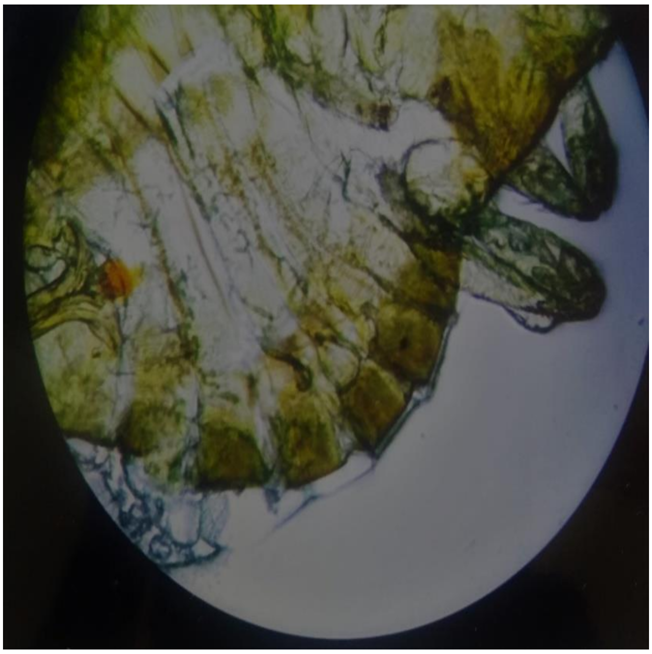
a) Fungal growth on insect body

b) Mycelium growth on thorax and head

c) Fungal growth near abdomen

Plate 4.1: Mycosis of *B.eauveria bassiana* on grape thrips

a) Fungus outgrowth on head



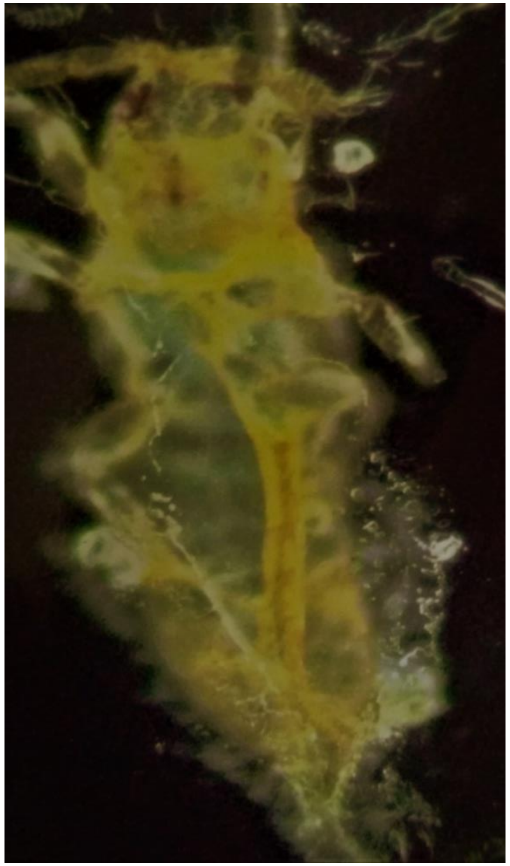
b) Fungal growth on tergo-sternum joint

c) Spore formation on thorax

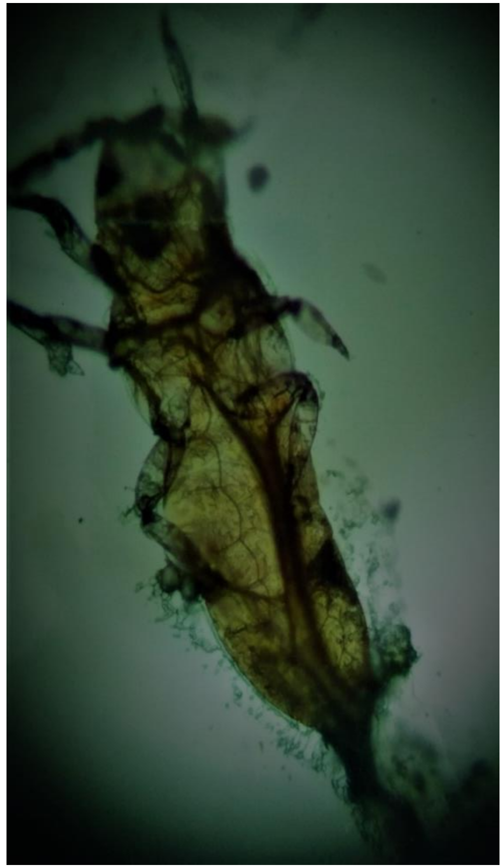
d) Mycelium accumulation near ovipositor

Plate 4.2: Mycosis of *Metarhizium anisopliae* on grape thrips

a) Fungal spores in gut



b) Mycelium growth on body



c) Fungal growth on dead insect

Plate 4.3: Mycosis of *Lecanicillium lecanii* on grape thrips

5. SUMMARY AND CONCLUSION

The present investigation were undertaken to study the seasonal incidence and biorational management of grape thrips, *Rhipiphorothrips cruentatus* Hood (Thripidae: Thysonoptera) under field conditions. The field experiment was carried out at All India Co-ordinated Research Project on Fruits, Department of Horticulture, MPKV., Rahuri, during 2017-18 and results obtained are summarized below.

5.1 Summary

5.1.1 Seasonal incidence of grape thrips and their correlation with weather parameters

Thrips were observed causing damage at various growth stages of crop, majority of population were observed during new flush to fruit setting stage of crop. The observations on seasonal incidence of thrips were recorded on number of thrips per shoot on randomly selected five plants, starting from the October (2017) pruning to November 2018.

Incidence of active stages both nymphs and adults started appearing from November 1st week when new flush started after fruit or forward pruning in October, 2017. The population gradually increased, and peak incidence was observed from second week of December (50th Standard Meteorological week) to second week of January (2nd Standard Meteorological week). The higher incidence of thrips was coincided with the flowering stage of grape vine.

The incidence of thrips started when maximum and minimum temperature was 31.3^{0}C and 13.7^{0}C where morning and evening humidity was 58.4 and 29.6 per cent, respectively. The thrips population increased gradually and reached to its peak at 28.1^{0}C maximum and 12.2^{0}C minimum temperature.

The linear correlation studies revealed that the weather parameters *viz.*, maximum and minimum temperatures are significantly negative correlated with thrips incidence. Whereas, it had significant positive correlation with both morning and evening relative humidity. While all other weather parameters *viz.*, rainfall, sunshine and wind velocity have not shown any significant relationship with population of thrips.

5.1.2 Bioefficacy of some biorational insecticides against grape thrips

The results pertaining to the overall cumulative mean efficacy of the treatments revealed that among all the insecticidal treatments, standard check emamectin benzoate 5% SG @ 11 g a.i.ha^{-1} has emerged as the best treatment to reduce the thrips population in grapes as compared to all other insecticidal treatments. Among biorational insecticides neem oil 2% showed good control followed by karanj oil 2% and neemazol. Among entomopathogenic fungi *Lecanicillium lecanii* recorded less population as compared to the *Metarhizium anisopliae* and

Beauveria bassiana. chlli methanolic extract, garlic methanolic extract, chilli water extract and garlic water extract are the least effective treatments.

The cost effectiveness of the different insecticides used during study was assessed. The ICBR ratio in respect of different treatments ranged between 1.30 to 7.92. The highest ICBR ratio of 1: 7.92 was recorded in the treatment of emamectin benzoate 5 SG. It was followed by *Lecanicillium lecanii* (1:6.34) and *Metarhizium anisopliae* (1:5.32). Although neem oil and karanj oil has great reduction of thrips population, but has less incremental cost benefit ratio *i.e* 2.81 and 3.04, respectively due to high cost of the insecticide.

5.2 Conclusion

- The infestation of thrips [*Rhipiphorothrips cruentatus* H.] was found maximum in second week of January, 2018 (1^{st}SMW), higher incidence of thrips coincided with the flowering stage of grape vine and revealed negatively correlation with maximum and minimum temperatures. Whereas, it had significant positive correlation with both morning and evening relative humidity. While all other factors such as rainfall, sunshine and wind velocity have not shown any significant influence on the population of thrips.
- Biorational insecticides neem oil 2% proved to be significantly superior over all other treatments, it was followed by entomopathogenic fungi like *Lecanicillium lecanii*, karanj oil 2%, *Metarhizium anisopliae* and *Beauveria bassiana* proved as best treatment in reduction of thrips population. Standard check emamectin benzoate 5% SG @ 11 g a.i.ha^{-1} proved to be significantly superior over all other treatments.
- The ICBR ratio in respect of different treatments ranged between 1.30 to 7.92. The highest ICBR ratio was observed among entomopathogenic fungi like *Lecanicilliumlecanii* (1:6.34) and was followed by *Metarhiziumanisopliae* (1:5.32), respectively. The cost benefit ratio of neem oil is (1:2.81).
- The mycosis test of three entomopathogenic fungi *viz,. Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii* were studied on grape thrips. Mycosis by *Beauveria bassiana* was confirmed the pathogenicity of entomopathogenic fungi on grape thrips. Highly pronounced mycosis was observed by *Metarhizium anisopliae* on the dead bodies of thrips. Mycosis test of *Lecanicillium lecanii* was also proved on grape thrips.

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7. APPENDIX

Details of meteorological data during investigation period (2017 - 2018)

SMW	Date	Temperature (^{0}C)		Humidity (%)		Wind Velocity (Kmph)	Sunshine (hrs)	Rainfall (mm)
		Max	Min	Morn (I)	Even (II)			
	2017							
44	Oct 29-4	31.3	13.7	58.4	29.6	1.2	9.7	0
45	Nov 5-11	30.2	13.2	63.2	36.1	1.6	9.8	0
46	12-18	29.9	12.2	65.8	34	0.6	8.9	0
47	19-25	30.1	16.6	71.1	47.2	0.4	6.2	0
48	26-2	29.8	11.3	66.4	33.8	0.6	8.3	0
49	Dec 3-9	28.5	17.5	71.4	49.4	1.6	4.5	0
50	10-16	25.4	16.7	63.2	34.0	0.7	6.6	0
51	17-23	28.3	13.9	64.1	35.1	0.6	6.8	0
52	24-31	29.3	12.8	68.2	36.2	0.7	7.1	0
	2018							
1	Jan 1-7	28.4	10.6	67	36	0.2	7.9	0
2	8-14	28.1	12.2	63	35	0.3	7.5	0
3	15-24	29.9	12.8	70	32	0.5	8.6	0
4	22-28	28.4	9.5	55	27	0.5	9.4	0
5	29-4	30.3	10.6	59	21	0.7	9.5	0
6	Feb 5-11	31.2	13.8	53	23	1.3	7.4	0
7	12-18	30.4	13.5	66	34	0.8	9.0	0
8	19-25	33.7	15.0	53	24	0.7	8.8	0
9	26-04	34.6	17.0	49	20	1.1	8.5	0
10	Mar 5-11	34.6	18.2	44	20	1.4	7.4	0
11	12-18	33.1	18.9	48	25	1.4	5.9	0
12	19-25	35.0	16.4	44	19	1.9	8.8	0
13	26-01	37.6	18.0	40	15	1.9	9.2	0
14	Apr 2-8	37.5	19.8	40	19	1.8	7.9	0
15	9-15	37.2	20.0	44	19	1.6	8.8	0
16	16-22	39.3	22.3	41	21	3.6	10.0	1.0
17	23-29	39.4	19.7	30	13	2.2	10.8	0
18	30-06	40.6	21.0	36	17	3.9	10.6	0
19	May 7-13	40.2	24.2	32	18	4.1	10.3	0
20	14-20	39.8	24.3	36	19	4.8	9.8	0
21	21-27	38.8	25.2	40	20	4.5	7.1	0

SMW	Date	Temperature (^0C)		Humidity (%)		Wind Velocity (Kmph)	Sunshine (hrs)	Rainfall (mm)
		Max	Min	Morn (I)	Even (II)			
22	28-03	38.8	24.7	64	34	4.4	7.8	34.6
23	Jun 4-10	34.2	24.6	72	47	3.7	3.8	11.0
24	11-17	35.3	25.0	62	42	11.6	7.8	0
25	18-24	34.1	23.4	72	54	4.9	4.8	43.0
26	25-01	32.1	23.0	73	53	7.7	4.8	63.8
27	Jul 2-8	31.7	23.3	76	59	8.0	3.9	26.2
28	9-15	28.2	22.8	80	70	5.0	0.3	13.8
29	16-22	29.4	23.0	77	65	8.7	1.8	4.4
30	23-29	28.6	22.7	75	62	7.5	1.3	0
31	30-05	31.3	23.3	72	53	7.9	4.0	0
32	Aug 6-12	30.0	23.0	75	62	6.8	1.5	0
33	13-19	27.8	22.5	81	73	4.8	0.6	58.4
34	20-26	27.9	21.5	80	70	5.0	3.0	24.2
35	27-02	29.6	21.1	75	61	3.5	5.0	6.4
36	Sept 3-9	30.1	19.6	70	53	4.1	5.8	0
37	10-16	32.4	19.5	69	49	0.8	7.6	0
38	17-23	31.9	22.1	71	45	2.7	6.i	3.8
39	24-30	33.8	22.3	71	44	1.3	8.1	0
40	Oct 1-7	34.0	25.5	67	43	1.3	7.8	0
41	8-14	34.0	18.4	55	30	1.6	8.8	0
42	15-21	33.5	18.6	50	30	1.3	8.2	0
43	22-28	34.4	16.8	46	30	1.0	8.5	0
44	29-04	31.7	14.4	58	39	1.9	9.4	2.0
	Mean	32.56	18.72	60.24	37.37	2.88	7.02	5.52
	Max.	40.60	25.50	81.00	73.00	11.60	10.80	63.80
	Min.	25.40	9.50	30.00	13.00	0.20	0.30	0.00

N=53; SMW- Standard Meteorological Week; Max- Maximum ; Min- Minimum; Morn-Morning; Evn-Evening; Kmph- kilometer per hour

8. VITAE

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of

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in

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