BIO-RATIONAL MANAGEMENT OF THRIPS (*Thrips tabaci* Lindeman) INFESTING CUCUMBER UNDER POLYHOUSE CONDITION

By

Mr. Bhojane Parag Dilip

(Reg. No. P/017/166)

AGRICULTURAL ENTOMOLOGY SECTION

COLLEGE OF AGRICULTURE, PUNE-411 005

MAHATMA PHULE KRISHI VIDYAPEETH

RAHURI - 413 722, DIST.-AHMEDNAGAR

MAHARASHTRA STATE (INDIA)

2019

BIO-RATIONAL MANAGEMENT OF THRIPS (*Thrips tabaci* Lindeman) INFESTING CUCUMBER UNDER POLYHOUSE CONDITION

By

Mr. Bhojane Parag Dilip
(Reg. No. P/017/166)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.-AHMEDNAGAR,
MAHARASHTRA, INDIA

In partial fulfilment of the requirement for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

In

AGRICULTURAL ENTOMOLOGY

AGRICULTURAL ENTOMOLOGY SECTION
COLLEGE OF AGRICULTURE, PUNE-411 005

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.-AHMEDNAGAR
MAHARASHTRA STATE (INDIA)
2019

BIO-RATIONAL MANAGEMENT OF THRIPS (*Thrips tabaci* Lindeman) INFESTING CUCUMBER UNDER POLYHOUSE CONDITION

By

Mr. Bhojane Parag Dilip

(Reg. No. P/017/166)

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.-AHMEDNAGAR,
MAHARASHTRA, INDIA

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

In

AGRICULTURAL ENTOMOLOGY

APPROVED BY

Dr. C. S. Chaudhari
(Chairman and Research Guide)

Dr. U. B. Hole
(Committee member)

Dr. S. A. More
(Committee member)

Dr. S. K. Chavan
(Committee member)

AGRICULTURAL ENTOMOLOGY SECTION
COLLEGE OF AGRICULTURE, PUNE-411 005

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.-AHMEDNAGAR
MAHARASHTRA STATE (INDIA)
2019

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part

there of has not been submitted

by me or other person to any

other University or Institute

for a Degree or

Diploma.

Place : Pune

Date : / / 2019

(P. D. Bhojane)

Dr. C. S. Chaudhari

Asst. Professor,
Agricultural Entomology Section,
College of Horticulture, Pune-411 005
Maharashtra State (India)

CERTIFICATE

This is to certify that the thesis entitled, "Bio-rational Management of Thrips (*Thrips tabaci* Lindeman) Infesting Cucumber under Polyhouse Condition", 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. BHOJANE PARAG DILIP**, 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 the investigation have been duly acknowledged.

Place : Pune **(C. S. Chaudhari)**
Date : / /2019 Research Guide

Dr. S. R. Kulkarni

Professor,
Agricultural Entomology Section,
College of Agriculture, Pune-411 005
Maharashtra State (India)

CERTIFICATE

This is to certify that the thesis entitled, **"**Bio-rational Management of Thrips (*Thrips tabaci* Lindeman) Infesting Cucumber under Polyhouse Condition", 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. BHOJANE PARAG DILIP**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

Place : Pune
Date : / /2019

(S. R. Kulkarni)
Head of the Section

Dr. P. N. Rasal

Associate Dean,
College of Agriculture, Pune- 411 005,
Mahatma Phule Krishi Vidyapeeth,
Rahuri - 413 722, Dist. Ahmednagar,
Maharashtra State (India)

CERTIFICATE

This is to certify that the thesis entitled, "Bio-rational Management of Thrips (*Thrips tabaci* Lindeman) Infesting Cucumber under Polyhouse Condition", 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. BHOJANE PARAG DILIP**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

Place : Pune **(P. N. Rasal)**
Date: / /2019 Associate Dean

ACKNOWLEDGEMENT

I avail this golden opportunity to express sense of gratitude and indebtedness towards the man of golden heart and chairman of advisory committee ***Dr. C. S. Chaudhari****, Asst. Professor of Entomology, Agricultural Entomology Section, College of Horticulture, Pune. I owe to him for his constant inspiration and well versed advice and keen criticism, prompt suggestions regarding research problems, constant encouragement and sympathetic attitude throughout the course of investigation and the completion of thesis.*

I give my special thanks with great respect to the advisory committee members ***Dr. U. B. Hole****, Professor and Head, Agril. Entomology, College of Agriculture, Pune,* ***Dr. S. A. More****, Assistant Professor, Agril. Entomology, College of Agriculture, Pune,* ***Dr. S. K. Chavan****, Asst. Professor, College of Horticulture, Pune, for their valuable suggestions and kind co-operation in the conduct of this research.*

I sincerely thank to ***Dr. P. N. Rasal****, Associate Dean, College of Agriculture, Pune, for providing necessary facilities for successful completion of my research work.*

I am very thankful to ***Dr. R. L. Naik****, Assistant Professor of Entomology,* ***Dr. R. V. Nakat****, Associate Professor,* ***Dr. G. R. Lolge****, Professor of Entomology,* ***Dr. S. M. Galande,*** *Associate Professor of Entomology,* ***Dr. I. A. Ghonmode****, Assistant Professor of Entomology and other staff members of Agril. Entomology Section, for their generous treatment, advises, affection and co-operation that have received.*

I wish to express my sincere thanks to ***Dr. D. P. Kaledhonkar,*** *professor of statisics,* ***Dr. A. A. Bhagat,*** *Asst. Professor of statistics,* ***Mr. Ravindra Sawant,*** *Rizwan Seeds,* ***Walse sir****, Agril. assistant,* ***Dr. Uday Shende,*** *Sr. Scientist, IMD,* ***Dr. Umesh Kulkarni,*** *Jr. Scientist, IMD,* ***Amit Pawar****, Agril. Asst.,* ***Shri Kadam sir****,* ***Bhalekar sir*** *for valuable help and guidance during the research work.*

I am extremely thankful to my seniors ***Sachin Wankhedkar, Suraj Jadhav, Sushmita Tawate, Akshay Lalge*** *for their kind co-operation and suggestions during this investigation.*

I have no words to express my feelings towards my family but I make a mention of my philosopher father ***Mr. Dilip Anant Bhojane,*** *loving mother* ***Mrs. Surekha Dilip Bhojane*** *and great hearted brother* ***Aniruddha Dilip Bhojane****. I express my deep sense of appreciation towards my uncle, aunt for their never* *ending love, constant encouragement, blessing and eternal moral support which have brought my educational carrier to this stage.*

I also remember my late grandmother ***Anusaya Anant Bhojane,*** *you were a real and true inspirational person. You may not be with us but your sweet memories will stay with us forever.*

I cannot express my sincere thanks to my beloved friends ***Mayur, Akshay Marbhal, Sandesh, Aakash, Khandu, Shubham, Shriprasad, Akshay Dhamdhere, Rushikesh, Krupal, Manyagol, Smitesh, Ankit*** *and* ***Waykar*** *for supporting me and providing valuable help.*

It gives me immense pleasure to all my batchmates ***Chandrashekhar, Avinash, Yogesh, Satkulal, Supriya*** *and juniors* ***Keshav, Mohiniraj, Mangesh, Tejashri*** *and* ***Anuradha,*** *for their excellent company and valuable help.*

While travelling on this path of education, many hands pushed me forth, learned hearts put me on the right track enlighted by their knowledge and experience. I ever rest thanks to all of them.

*Above all I bow my head before the God of wisdom, success and good luck "**Lord Ganesha**" without whose blessings, it would have not been possible for me at this stage of my life.*

Place : Pune

Date : / /2019 **(P. D. Bhojane)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

@	:	at the rate of
/	:	Per
%	:	Per cent
^{o}C	:	Degree Celsius
<	:	Less than
a.i.	:	Active ingredient
Avg.	:	Average
B:C	:	Benefit cost ratio
Bt	:	*Bacillus thuringiensis*
CD	:	Critical difference
CS	:	Capsule suspensions
CV	:	Coefficient of variance
cfu	:	Colony-forming unit
cm	:	Centimetre
DAS	:	Days after spraying
DC	:	Dispersible concentrate
EC	:	Emulsifiable concentrate
et al.	:	et alli (and others)
etc.	:	*et cetera* (and so on)
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram
ha	:	Hectare
i.e.	:	id est (that is)
J.	:	Journal
kg	:	Kilogram(s)
l	:	Liter
m	:	Meter
ml	:	Milliliter
NS	:	Non-significant
RH	:	Relative humidity
Rs	:	Rupee
SC	:	Suspension concentrate
S.E.	:	Standard error
Sci.	:	Sciences
SMW	:	Standard Meteorological week

SP	:	Soluble powder
Tmax	:	Maximum temperature
Tmin	:	Minimum temperature
t	:	Tones
viz.,	:	Videlicet (namely)
v/v	:	Volume concentration
WG	:	Wettable granule
w/w	:	Weight concentration

ABSTRACT

"Bio-rational Management of Thrips (*Thrips tabaci* Lindeman) Infesting Cucumber under Polyhouse Condition"

by

Mr. Bhojane Parag Dilip

A candidate for the degree
of
MASTER OF SCIENCE (AGRICULTURE)
in

AGRICULTURAL ENTOMOLOGY
Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722
2019

Research Guide	**:**	**Dr. C. S. Chaudhari**
Department	**:**	**Agricultural Entomology**

The present experiment "Bio-rational Management of Thrips (*Thrips tabaci* Lindeman) Infesting Cucumber under Polyhouse Condition" was conducted to study the seasonal incidence of thrips, biointensive approaches against thrips and the effect of selective pesticides on yield of cucumber under polyhouse condition. The experiment was carried out at the Hi-tech floriculture and vegetable project, College of Agriculture, Pune under Mahatma Phule Krishi Vidyapeeth, Rahuri during *rabi* 2018.

The seasonal incidence study revealed that incidence of thrips was the highest in the cucumber under polyhouse condition during the 43rd standard meteorological week (50.06 thrips/3 leaves/plant), whereas it was minimum in 1st standard meteorological week (25.86 thrips/3 leaves/plant). There was a significant positive correlation between temperature and thrips population. Whereas humidity was negatively correlated. Out of Linear and non-linear regression equations work out from the data revealed that cubic non-linear equation could give 90 per cent precision which can help farmers in early prediction of thrips incidence in polyhouse.

The treatments, Neem oil @ 1 ml/l, Karanj oil @ 1 ml/l, *Metarhizium anisopliae* @ 4 gm/l, *Lecanicillium lecanii* @ 4 gm/l, Mineral oil hortimin @ 0.5 ml/l, Polyether Modified Trisiloxane @ 0.25 ml/l, were evaluated along with the standard check of lamda cyhalothrin @ 0.5 ml/l. Among the bio-rational components of pest management entomopathogenic fungi, *Lecanicillium lecanii and Metarhizium anisopliae* proved to be effective, having gradual cumulative reduction after the application of consecutive sprays. Among the oils, neem oil (botanical) @ 1 ml/l and Hortimin (mineral oil) @ 0.5 ml/l were the second best bio rational components. The treatment with lambda cyhalothrin @ 0.5 ml/l (standard check) was significantly superior in suppressing the pest and recording the yield (23.81 t/ha) as well. However the highest yield of 20.33 t/ha was recorded in neem oil followed by *Lecanicillium lecanii* (18.67 t/ha) among the non-chemical treatments.

Pages 1 to 61

INTRODUCTION

Cucurbits are grown in all tropical and subtropical countries of the world. Cucurbits include 118 genera and 825 species (Laila *et al*., 2015). Cucumber (*Cucumis sativus* L.) belongs to family Cucurbitaceae which is one of the most important vegetable crop while its fruits are used as pickle or salad in India. It is thought to be one of the oldest vegetable crops and has been found in cultivation for over 3000 years in India. It is a warm season crop, has little or no tolerance to frost. Growth and development are favoured by temperature above 20°C. The optimum temperature for growing is between 20°C and 30°C (Dhillon *et al.*, 2017). Locally cucumber is known as *kakadi* and grown throughout the Maharashtra. The major cucumber growing districts in Maharashtra are Nashik, Ahmednagar, Pune, Gadchiroli, Raigad, Osmanabad, Kolhapur (Anonymous, 2017a). Cucumber provides daily fiber (3%), carbohydrates (1%), potassium (4%), vitamin C (4%) and small amount of iron, calcium, magnesium and vitamin A (Szalay, 2017).

Today, India is the second largest producer of vegetables in the world, next to China, with a production level of more than 175 million tonnes annually (Anonymous, 2017b). Maharashtra produced vegetables with an annual production of 103.60 lakh tonnes from 6.93 lakh ha. Cucumber has been reported as a commercial cash crop in tropical and sub-tropical parts of India with an annual production of 1.14 million tonnes from 78 thousand hectares and productivity is 15 tonnes per hectare (Anonymous, 2017c).

Thrips are considered as one of the most destructive insect pest of greenhouse crop due to direct feeding damage to plant parts such as foliage and flower and indirect damage arises from feeding on parenchyma of leaves and subsequent reduction in photosynthetic ability of the plant and eventually can result in significant yield loss. While direct damage causing the fruit to curl and rendering it unmarketable. Disease transmission is another form of thrips indirect damage. Furthermore, it is difficult to manage in greenhouse production system due to high female reproductive capacity, rapid life cycle, residence in cryptic habitats such unopened terminal buds that protect them from exposure to contact insecticides and resistance to various insecticides chemical classes (Cloyd 2009), (Rajabpour *et al.*, 2011). Impacts due to thrips include yield and quality losses, additional research, plant health certification costs and loss of exports (Macleod *et al.,* 2004).

Thrips are major pest of greenhouse causes white or brown spot on leaves where the plant cells have been destroyed. On vegetable flowers, thrips feeding creates silvery streaks on the petals. In cucumber, thrips damage is noticed on the lower leaves. In cucumber fruit, feeding creates severe distoration and curling as well as white streaks. Ghost-spotting can also occur with cucumber (Murphy *et al.,* 2014). Both adults and larvae of thrips usually fed on plant sap. Feeding usually caused yellowing and dropping of leaves. High infestations resulted in stunted growth, white leaf blotches and low yields (Lall and Singh, 1968). Failure to control this pest by timely and effective means causes considerable damage and results in immense economic losses by remarkably reducing yield.

Effect of thrips on growth, photosynthesis, yield and quality of greenhouse cucumber showed that high density of thrips for short time period significantly increased number of fruits downgraded from grade 1 to 2. Thrips also increased fruit curvature and reduced plant growth, photosynthesis and marketable fruit yield. It is very difficult for cucumber plant to recover from thrips damage once yield loss had taken place (Hao *et al.,* 2002).

Although, protective cultivation (in soil or soilless media) offers a favorable environment for crop growth, development and consequently, results in higher productivity. However, numerous factors *viz.* temperature, relative humidity, radiation, evapotranspiration (crop water requirement) vapour pressure deficit, plant stomatal conductance, irrigation, fertigation, disease incidence affect the greenhouse cucumber production to a significant degree. Water vapor pressure deficit (WPD) between greenhouse air and crop may affect the transpiration and consequently absolute air humidity (Singh *et al.,* 2017). Besides, the microclimate with high temperature and humidity inside polyhouse also provides a congenial environment for faster multiplication of pests like thrips (Kaur *et al.,* 2010; Sood, 2011).

Insect pests are the prime threats to production and productivity of greenhouse crops worldwide. Presence of warm, humid conditions and abundant food under protected structures provide a stable environment and habitat for pest development. Often, the natural enemies that keep pests under control outside are lacking under protected environment. For these reasons, pest situations often become alarming in the indoor environment than outdoors (Rathee *et al*., 2018). Producers of vegetable crops generally can accept a higher level of damage than those of ornamental crops that are produced for their aesthetic value (Sood, 2011).

Population of thrips increased with increasing temperatures and decreasing relative humidity (Maklad *et al.,* 2012). There is little understanding of the population dynamics of thrips on cucumber. It is likely that the thrips population growth rate changes with the season. It is suggested that better understanding of the early phase of population growth may enable better estimates of pest incidence when the exponential phase of increase begins and thrips control should be applied (Jarosik *et al.,* 1997).

Since, sucking pests like plant and leaf hoppers, aphids, whiteflies, scale insects, thrips and mites to have developed resistance to insecticides (Rabindra and Ramanujam, 2007). The bio intensive approaches devastate the pest population with no hazardous effects on human health and the environment. The entomopathogenic fungi has an important position among all the biocontrol agents because of its route of pathogenicity, broad host range and its ability to control both sap sucking and chewing pests (Khan *et al*., 2012).

Biological control for insect-pest management in greenhouses has proved effective and its use is steadily increasing, worldwide (Perdikis *et al.*, 2008). Botanicals like neem seed powder extract and neem soap can be effectively used as alternative to synthetic insecticides (Krishnamoorthy *et al.*, 2013). Green pesticides can also prove effective in agricultural situations and semi synthetic products in pest management has been considered to constitute the umbrella of green pesticides (Koul *et al.*, 2008). Plant essential oils in general have been recognized as an important natural source of pesticides and favours beneficial insects (Tripathi *et al.*, 2009). Biological control is one of the alternatives to chemical pesticides and it can be described as the limitation of the abundance of living organisms and their products by other living organisms. Entomopathogenic fungi, specifically the anamorphic taxa *Metarhizium anisopliae*, Hypocreales (Ascomycota), is among the natural enemies of pests in agroecosystems (Meyling and Eilenberg, 2007). The fungus *Verticillium lecanii* is one of the members of *Deuteromycetes* and it can be used for crop protection (Alavo, 2015).

Synthetic agricultural chemicals namely plant growth regulators, commercial fertilizers and pesticides are widely used to minimize crop losses in conventional greenhouses. These applications are used to obtain higher yield but it damages structure of soil, causes environmental pollution, threatens human health and decreases crop quality. Organic agriculture under greenhouse conditions has gained importance because of increasing sensitivity to human and environmental health, consumer pressure on producers and demand to organically grown crops from other countries. However, organic agriculture under greenhouse conditions is more difficult (Guncan *et al.*, 2006).

Farmers are extensively and successfully using contact, systemic insecticides and synthetic pyrethroid for controlling the pests. However, repeated application of same group of chemicals is not a desirable practice, as this could lead to undesirable problems like resistance, resurgence and residues. The entire reliance on chemical insecticides has always been to minimize the losses due to insect pests. To mitigate the hazards of chemical insecticides, the present investigation has been conducted to evaluate eco-friendly options of pest management against thrips on cucumber under polyhouse condition. The objectives of the investigation are as follows:

- To study the seasonal incidence of thrips in cucumber.
- To evaluate bio-rational component against thrips under polyhouse condition.
- To study the impact of treatments on yield.

2. REVIEW OF LITERATURE

2.1 Seasonal Incidence of Cucumber Thrips (*Thrips tabaci* Lindeman) Under Polyhouse Condition:

Lall and Singh (1968) found that both adults and larvae of thrips usually fed on plant sap. Feeding usually caused yellowing and dropping of leaves. High infestations resulted in stunted growth, white leaf blotches and low yields. Thrips were active on various host plants throughout the year and were most active on onion from October to May.

Rosenheim *et al.* (1990) studied that distribution of *Thrips palmi* Karny and *Frankliniella occidentalis* (Pergande) within plant and relative contributions of each species to fruit scarring were investigated in field planting of cucumber, *Cucumis sativus* (L.). Densities of *T. palmi* were greatest on foliage, whereas *F. occidentalis* were the maximum on flowers. There was incidence of fruit scarring, within and between field plantings. The high densities of *F. occidentalis* in flowers may create opportunities for them to incidentally feed upon and scar young fruit.

Jarosik *et al.* (1997) determined developmental rate of *Frankliniella occidentalis* (Pergande) on cucumber *Cucumis sativus* under commercial greenhouse conditions and stated that the lower developmental threshold (LDT) and the sum of effective temperatures (SET) for the pre-imaginal development were 10.7°C and 23.1°C, respectively. He also revealed that throughout the exponential phase, the rate of population growth increased with time/age of plant. As significant damage to cucumber may occur during the exponential phase of population increase, the sum of effective temperatures of 23.1°C can be used to predict when damage is likely to start to occur.

Murai (2000) studied effects of five constant temperatures (15, 20, 23, 25 and 30°C) under 16L:8D photoperiod on development, reproduction and population growth of *Thrips tabaci* reared on diet of pollen and honey solution and revealed that mean adult longevity decreased with increasing temperature, from maximum of 86.6 days at 15°C to minimum of 12.8 days at 30°C. Intrinsic rate of natural increase (r_m) was the highest at 25°C.

Bergant *et al.* (2005) stated that abundant precipitation affect mortality of insects. Because of the higher temperatures, the development of onion thrips in late spring and early summer was more rapid. High precipitation influenced the survival of onion thrips (*Thrips tabaci*) and reduced the population. The dry year offer favorable conditions for onion thrips development.

Rueda *et al.* (2007) studied seasonal abundance for onion thrips, *Thrips tabaci* Lindeman, for two consecutive seasons (dry and rainy) to develop economic thresholds (ET) revealed that thrips populations were the highest during the dry season, with average thrips per leaf per day 5.2 times higher than during the rainy season and also found that during the rainy season thrips populations were always below economic injury level. However, during the dry season data indicated that farmers should use an AT (Action Threshold) between 0.5 and 1.6 thrips per leaf, depending on the particular agronomic, climatic and market conditions.

Patel *et al.* (2009) studied population dynamics of chilli thrips, *Scirtothrips dorsalis* Hood in relation to abiotic factors and revealed that the incidence of S. *dorsalis* on chilli crop commenced from first week of September and continued up to harvest of the crops being peak activity was recorded in November (4.99 to 5.54 thrips/leaf) and February– March (5.29 to 7.38 thrips/leaf). Correlation coefficient values worked out for thrips incidence and weather parameters revealed that significant positive relationship existed with maximum temperature whereas significant negative correlation was found with morning, afternoon and mean relative humidity. Among the different abiotic factors studied, decrease in afternoon relative humidity (between the range of 20 to 40 %) helped in build-up of the pest population.

Ibrahim and Adesiyun (2010) observed in the onion crop that November transplant had a peak population of onion thrips in late February (176 thrips per plant). Water traps indicated that the peak population of adult thrips was at the time of harvest in April, similar to November transplant.

Ullah *et al.* (2010) recorded that incidence of onion thrips (*T. tabaci*) in onion crop was 1.20 thrips per plant in first week of February and reached to its peak (100 thrips per plant) during the last week of April. Later, the population declined to 3.85 thrips per plant towards the end of May as the crop started to mature.

Barot *et al.* (2012) studied population dynamics of thrips, *Scirtothrips dorsalis* Hood infesting chilli in relation to weather parameters during the *Rabi* season and found that thrips attained first (8.80 thrips/twig), second (5.66 thrips/twig) and third as well as the highest peak (10.54 thrips/twig) during 2^{nd} week of November, 3^{rd} week of December and 3^{rd} week of February, respectively. Correlation coefficient values worked out for thrips incidence and weather parameters revealed that significant positive relationship existed with Bright Sun Shine Hours, Maximum Temperature and Vapour Pressure Deficit (morning, afternoon and mean), whereas significant negative correlation was found with Minimum Temperature, Relative Humidity (morning, afternoon and mean), Vapour Pressure (morning, afternoon and mean) and rainfall.

Maklad *et al.* (2012) studied the impact of different colour polythene of greenhouse and its ultimate effect on the development thrips and whitefly in Egypt. Application of black and white nets and polyethylene sheet affect on environmental factors under greenhouse conditions whereas environmental factors (temperature and relative humidity) were higher with application of polyethylene sheet comparing with application of black and white nets. There was positive relationship between environmental (temperature and relative humidity) factors and population of aphids, spider mites, thrips and whitefly using black and white nets and polyethylene sheet.

Population of different pests increased with increasing temperatures and decreasing relative humidity. Maximum population of spider mites and thrips were recorded during June. Population of aphid was most frequent with using different shading nets, while population of spider mites and thrips were more frequent, While whitefly pests was less frequent. Populations of insects were more high when using polyethylene sheet than black and white nets.

Dharmatti and Beeraganni (2013) conducted experiment to find out seasonal incidence of thrips attacking onion by transplanting seedling at monthly interval for three years period. The seedlings transplanted in *rabi* season had peak thrips populationas compared to *kharif* season transplanting dates. They revealed that onion thrips mainly breeds from November 1st to January 1st with a peak in December on onion crop. Whereas, Chandra and Rana (2014) observed the highest population of onion thrips in second half of March 2013 and the lowest in first half of February 2013 at Uttar Pradesh.

Neergude *et al.* (2014) studied seasonal incidence and indicated prevalence of high population of thrips in the *kharif* season especially during August to October. Generally, the population of thrips occurrence on onion crop was low during seedling and it gradually increased during vegetative stage of the crop and reached a peak occurrence during physiological maturity.

Bukero *et al.* (2015) conducted experiment to study the activity of thrips on rose and result indicated that the maximum population of thrips was recorded on 2nd April (15.78 ± 0.79/leaf) and (18.32 ± 0.86/flower). Whereas the minimum population was observed on May, 28th (0.96 ± 0.20/leaf) and (2.28 ± 0.30/flower). It was found that the population of the pest was negatively correlated with temperature (r = -0.36) and relative humidity (r = - 0.75).

Gundappa *et al.* (2016) assessed the dynamics of mango thrips population across 20 mango orchards based on thermal indices under subtropical conditions revealed that the mean thrips population across standard weeks was the highest (6.18 ± 0.14) during 15th SMW followed by 3.13 ± 0.15 in 16th and 1.87 ± 0.06 in 17th SMW during 2013. In the next year, the highest values were 4.67 ± 0.09 followed by 4.19 ± 0.10 and 4.07 ± 0.15 in 16th, 17th and 18th SMW respectively. The best fit polynomial regression analysis indicated that thrips population could be predicted up to 95 per cent using these thermal indices.

Subba and Ghosh (2016) studied population dynamics of thrips (*Thrips tabaci* L.) in relation to abiotic factors in tomato and revealed that minimum number of thrips (0.42-53/leaf) population was recorded during 38th to 44th standard week and maximum level of population was observed during 45th to 2nd (1.05-1.89/leaf) and again during 6th to 20th (1.00-2.22/leaf) standard week. Correlation coefficient values revealed that temperature difference had significant positive influence on thrips while significant negative correlation with temperature (minimum and average), relative humidity (minimum, average) and weekly total rainfall.

Syed *et al.* (2016) studied population dynamics of sucking insect pests; thrips, *Thrips tabaci* found that population of thrips were very low (3.69±0.45) in 3rd week of December 2010, and the highest was recorded (100.62+0.51) in 3rd week of March, respectively. They concluded that temperature and humidity varied during different dates and time, and played an important role in increasing thrips.

Birhade *et al.* (2017) evaluated seasonal incidence of thrips on onion and revealed that the infestation of thrips was first observed at 2nd week after transplanting in 38th SMW, with population of 1.6 thrips/plant. The peak incidence of 19.1 thrips/plant was recorded in 46th SMW *i.e.* second week of November. The correlation of thrips with morning humidity (0.73), evening humidity (-0.71) and rainfall (-0.58) are negatively significant. This indicated that increase in rainfall and humidity (evening and morning) decreased the thrips population on onion.

Kaur *et al.* (2017) studied the effect of temperature on growth and development of *Thrips tabaci* Lindeman on *Bt* cotton at different constant temperature (25, 30 and 35°C) and 60 per cent relative humidity. Which concluded that with an increase in temperature from 25 to 35°C there was significant decrease in the duration of developmental parameters, adult life parameters, total life cycle and per cent survival of *T. tabaci*. Optimum temperature for the growth of *T. tabaci* is 30°C as growth index was maximum at this temperature.

Vijayalaxmi *et al.* (2017) studied seasonal incidence of thrips and *Groundnut bud necrosis virus* (GBNV) in groundnut (*Arachis hypogaea* L.) and revealed that the incidence of thrips and GBNV started in 2nd week of August and population of thrips, reached the peak in the fourth week of September with a mean of 3.40 to 6.4 thrips/3 leaves in (*kharif*) and 3.20 to 7.1 thrips/3 leaves (*rabi*) reached the peak at the end of March. In *kharif* and *rabi*, thrips population showed negative correlation with morning and evening RH and positive correlation with (Tmax) and (Tmin), rainfall and sunshine hours respectively.

Alasady and Al-ghadban (2018) carried out Studies in the field which was cultivated by cucumber crop *(Cucumis sativus)* found that melon thrips, *Thrips pamli* Karny was the dominant species recorded 76%, the highest number of it was noticed in the first week of October recorded 42.1 individual species. Second highest number of thrips was shown by onion thrips *Thrips tabaci* recorded 23% of all pest thrips species, highest number of it was recorded at second week of October 2016 with an average of 9.1 individuals per leaf, whereas tomato thrips *Frankliniella schultzie* recorded 0.4%, *Haplothrips* sp., *Eremiothrips* sp. *recorded* 0.21% each, *Anaphothrips sudanensis* recorded the lowest percent (0.1%).

Kumawat *et al.* (2018) studied the seasonal incidence of thrips, *Thrips tabaci* on onion during December to May (*Rabi*) and found that the incidence of thrips on onion was commenced in the third week of February (3.66 thrips / plant) and reached to it’s peak in the last week of March (40.32 thrips/ plant). The correlation studies revealed that the thrips population had non-significant positive correlation with the temperature and non-significant negative with the relative humidity.

Vinuthan *et al.* (2018) studied on the seasonal incidence of *Thrips tabaci* during *kharif-rabi* and *rabi-summer* revealed that thrips population was high during *rabi-summer* in the onion crop. The correlation studies between thrips population and weather factors indicated that the maximum temperature was significantly positive correlated with thrips population in both the seasons, while maximum and minimum relative humidity was significantly negatively correlated. In *kharif*, rainfall was significantly negative correlated with thrips population.

2.2 Bio-efficacy of Bio-rational Components Against Thrips (*Thrips tabaci* Lindeman) on Cucumber Under Polyhouse Condition:

Azaizeh *et al.* (2002) studied biological control of the western flower thrips (WFT), using the entomopathogenic *Metarhizium anisopliae-7 (M. a-7)* in cucumber crop found that with a low initial WFT population of three or four insects per leaf, the spray treatment was effective in reducing the population growth to a lower level than in the other treatments or control. The *M. a-7* strain was found to be effective in reducing the population growth of WFT under greenhouse conditions, particularly when the initial thrips population was low to moderate.

Tipping *et al.* (2003) reported that Silwet L-77, an organosilicone surfactant, was applied to several arthropod pests of California table grapes. Eggs of pacific spider mite, *Tetranychus pacificus* were highly susceptible with mortality more than 99.4% (0.1% Silwet L-77). Mortality of immature and adult stages of cotton aphid, western flower thrips and pacific spider mite was (>93.8%, >98.5% and >99.4%) for 0.1 per cent, 0.25 per cent and 0.5 per cent Silwet L-77, respectively. Grape mealybug crawlers had 100% mortality when treated with 0.5 per cent and 1.0 per cent Silwet L-77 solutions; however, mortality was only 6.7 per cent when (0.1% Silwet L-77) was applied.

Alavo and Accodji (2004) studied the principal group of aphid pathogenic fungi, the most prevalent and widely encountered species belong to the order Entomophtorales (Zygomycetes). In particular environments (greenhouses or tropical regions), some Deuteromycetes species may also significantly reduce aphid numbers; the most important species is *Verticillium lecanii* (Zimm.) *viegas.*

Mandal *et al.* (2006) conducted an experiment during two successive summer seasons of 2000 and 2001 to assess the effectiveness of some neem based integrated management approaches against the okra jassid, *Amrasca biguttula.* The treatments comprised soil application of neem cake @ 200 kg per ha with 3 foliar application of neem seed kernel extract (5%), neem oil (3%) Amrutguard (0.5%) and neem leaf decoction @ 0.5 kg. Neem cake treatments with inclusion of endosulfan and chlorpyrifos performed better than those with other integrated treatments in reducing the pest incidence and producing more marketable fruit yield. Integrated treatments proved profitable.

Thungrabeab *et al.* (2006a) conducted study to investigate the pathogenicity of different entomopathogenic fungi against *T. tabaci* larvae under controlled climatic conditions in the laboratory and also found that in laboratory studies, *T. tabaci* was susceptible to *Verticillium lecanii* (Zimmermann) Viegas, *Beauveria bassiana* (Balsamo) Vuillemin, *Metarhizium anisopliae* (Metsch.) Sorokin and further revealed that in the glasshouse, *V. lecanii* has been used successfully to control *T. tabaci* on cucumber and under greenhouse conditions, *M. anisopliae* was found to be effective in reducing the population growth of *F. occidentalis* on cucumber.

Thungrabeab *et al.* (2006b) studied the efficacy of different entomopathogenic fungi against western flower thrips, *Frankliniella occidentalis* (Pergande) and onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae). Results revealed that *B. bassiana* Bb. 5335 and *M. anisopliae* Ma. 7965 were superior in efficacy against both thrips species within a broader range of temperature. They found that both thrips species reared on bean, cucumber, leek and swan river daisy were highly susceptible to fungal infection.

Chavan *et al.* (2008) studied on liquid formulation of *Verticillium lecanii* (Zimmermann) Viegas under laboratory conditions and revealed that both the liquid formulation of *V. lecanii* irrespective of dosage tested had showed significantly higher efficacy in controlling red spider mite. Formulation A caused 67.66 to 82.78 per cent mortality and its 1.00 per cent concentration showed highest (82.78 %) kill. The reduction in the mite caused by formulation B was 70.08 to 85.23 per cent. The 1 per cent concentration of formulation B showed highest (85.23%) mortality of the pest.

Perdikis *et al.* (2008) reported that solanaceous greenhouse crops are susceptible to infestation by a high number of insect and mite pests that can cause serious yield losses. The most important of these pests are whiteflies, aphids, leafminers, thrips and spider mites. He further revealed that the use of entomopathogenic fungi is a major alternative for whitefly control. Various fungi, *Beauveria bassiana* (Balsamo) Vuillemin, *Paecilomyces fumosoroseus* (Wize) Brown and Smith, and *Lecanicillium lecanii* (Zimmermann) have been shown a high potential for whitefly control.

Mandi and Senapati (2009) evaluated the effectiveness of four insecticides - acetamiprid 0.004% (Dhanpreet – 20% SP), thiamethoxam 0.005% (Avant-25% WG), neem pesticide 0.4% (ultineem 1% W/W) and *Bacillus thuringiensis,* subsp. kurstaki (*Bt*) at gL^{-1} against thrips (*Scirtothrips dorsalis* Hood) infesting chilli (*Capsicum frutescens)* and revealed that Neem pesticide (54.2%) and microbial pesticide BT (43.43%) were found moderately effective.

Pinheiro *et al.* (2009) studied the most susceptible nymphal stage of *Bemisia tabaci* biotype B to neem (*Azadirachta indica* A. Juss.) oil applied to dry bean (*Phaseolus vulgaris* L.)

in a screenhouse. A solution of commercial oil (Dalneem) extracted from neem seeds was sprayed directly on each nymphal instar at 0, 0.1, 0.25, 0.5, 1 and 2% concentrations for lethal concentration (LC) determination, and at 0, 0.5 and 1% concentrations for lethal time (LT) determination.and revealed that a mortality rate of over 80% was observed on the 6^{th} day for the first to third instars at 1% concentration and finally concluded that the first three nymphal stages were more susceptible to neem oil when compared to the fourth nymphal stage.

Egho and Emosairue (2010) successfully used mineral oils to control insect pests on cowpea. The study assayed the effectiveness of three mineral oils- premium motor spirit (PMS), dual purpose kerosene (DPK) and automotive gas oil (AGO) at 4 per cent concentration in the management of legume bud thrips, *Megalurothrips sjosstedti.* The results indicated that all the tested mineral oil effectively controlled *Megalurothrips sjosstedti* damage in the early season.

Patil *et al.* (2010) conducted experiments to determine the effective and economical control measure for the management of onion thrips, in onion for which 10 new insecticides and bio-insecticides were tested, i.e. *Beaveria bassiana* 1×10^8 cfu at 4g per litre, 5 per cent NSKE, *Verticilium lecanni* 2×10^8 cfu at 5g per litre, methyl demeton 25 EC at 0.025 per cent, carbosulfan 25 EC at 0.025 per cent, spinosad 45 SC at 0.0135 per cent, deltamethrin 1 EC + triazophos 35 EC at 0.072 per cent, indoxacarb 14.5 SC at 0.0145 per cent, flufenoxuron 10 DC at 0.005 per cent and novaluron 10 EC at 0.01 per cent. The pooled data for the consecutive 3 years showed that all these treatments were effective and economical against onion thrips.

Ahmed and El-mogy (2011) used two biological formulations, neem (Nimbicidine) and *Beauveria bassiana* (Bio-power) and jojoba oil for control of onion thrips, *T. tabaci* in onion field. Results showed that all tested products revealed significant reduction in thrips populations on both growing and flowering periods. Maximum per cent reduction in thrips population *Dichromothrips nakahari* treated with neem oil was 82.1 per cent under field experiment.

Aliakbarpour *et al.* (2011) determined the efficacy of neem oil in a mango (*Mangifera indica* L.) orchard at 1, 2 and 3 per cent concentrations and imidacloprid, a commonly used synthetic insecticide, on populations of thrips and their toxicities to mango pollinators. After two consecutive applications at 7-day interval, both neem oil and imidacloprid effectively reduced thrips populations compared to an untreated plot. Neem oil at 2 per cent was effective against adult thrips 96 hours after the second application (59.8% reduction) and caused only 24.9 per cent mortality of pollinators.

Sabir *et al.* (2011) studied on comparative IPM including the contribution of individual IPM components was conducted for two seasons and revealed that combination of azadirachtin and agrospray (0.5%) was the most effective component of IPM for controlling the sucking pests of cucumber under protected cultivation**.**

Faiz *et al.* (2012) tested five plant derivatives such as lemon oil, bittergourd extract, bakain leaf extract, neem oil and neem leaf extract each at 5 percent concentration for their repellency and phagodeterrent effects against jassid and thrips in the cotton crop and results revealed in case on thrips that all plant derivatives controlled thrips population significantly. Among the used botanicals bakain leaf extract, neem oil and neem leaf extract showed comparatively higher mortality of thrips compared to other plant derivatives.

Khan *et al.* (2012) studied six entomopathogenic fungal isolates, three each of *Beauveria bassiana* and *Verticillium lecanii*, were screened for pathogenicity test against the green peach aphids, *M. persicae* to select high virulent isolate with the most suitable application and to determine the role of individual enzyme in its virulence. *V. lecanii* 3 showed highest virulence or toxicity against the target pest treated either with conidial (80.70%) or filtrate (88.36%) application while *B. bassiana* 70 and *B. bassiana* 76 showed high toxicity (77.14 and 80.86%, respectively) in filtrate application at 6th day of incubation.

Annamalai *et al.* (2013) studied the pathogenicity of *Beauveria bassiana* (Balsamo) Vuillemin and *Lecanicillium lecanii* Zimmerman against onion thrips, *Thrips tabaci* Lindeman and found that highest concentration of *B. bassiana* (1×10^{12} spores/ml) caused maximum cumulative corrected mortality (CCM) of (90.63%) at 7 days after treatment (DAT) and lowest of (43.75%) at 1×10^{6} spores/ml level and in case of *L. lecanii* 86.57 per cent and (31.34%) mortality was recorded at similar treatments, respectively. Thus, further revealed that both the organisms were significantly effective against thrips.

Arthurs *et al.* (2013) evaluated commercial strains of entomopathogenic fungi for control of chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) and revealed that in greenhouse cages, 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 per cent, *Metarhizium brunneum* F52 by 84–93 per cent, *Beauveria bassiana* GHA by 81–94 per cent, *I. fumosorosea* PFR-97 by 62–66 per cent, and different horticultural oils by 58–85 per cent.

Bernardi *et al.* (2013) revealed that Azadirachtin was efficient against *Tetranychus urticae* Koch in strawberry with a mortality rate similar to that of abamectin and also stated that the azadirachtin showed lower biological persistence (7 days) than abamectin (21 days).

Krishnamoorthy *et al.* (2013) conducted field experiments to study the bio-efficacy of neem seed powder extract (NSPE) (4%), neem soap (NS) (1%), essential oils of Basil or Tulsi *(Ocimum tenuiflorum* syn. *O. sanctum*), (0.2%) and scented *Geranium,* (*Pelargonium graveolens*), (0.2%) along with commonly used synthetic insecticides *viz.*, dimethoate (0.06%), acephate (0.075%) and fipronil (0.05%) against onion thrips, *Thrips tabaci* Lind. during summer

2011 and 2012. All botanicals, essential oils and insecticides significantly reduced thrips incidence during both the seasons. This study clearly illustrated that neem products and essential oils can be used as components of thrips IPM.

Sayed (2013) studied the efficiency of the bioinsecticides, Mycotal (*Verticillium lecanii*), Biosect (*Beauveria bassiana*) and their mixture as well as Capel 2 EC against the second instar nymphs of the whitefly, *B. tabaci* on cucumber varieties in the field trials cleared that the mixture of Micotal and biosect was the superior compound after 3 days of application, since it gave 94.7 per cent reduction in *B. tabaci* population infesting cucumber and revealed that biosect came next in this respect followed by micotal and Caple 2 which showed inferior efficacy among the tested bio-insecticides.

Mascarin *et al.* (2014) studied the toxicity of four commercial non-ionic surfactants against immature *Bemisia tabaci* (Gennadius) biotype B whiteflies with spreading ability. Results revealed that trisiloxane-based surfactants (Break-thru and Silwet l-77) exhibited the highest toxicity to 1st, 2nd (early) and 3rd, 4th (late) instar nymphs as well as the greatest wetting performance. The combinations of both fungi with trisiloxane carriers significantly increased nymphal mortality with mostly additive and synergistic effects on early and late nymphs, respectively. Their findings underline the compatibility and enhanced activity of silicon-based surfactants with *B. bassiana* and *I. fumosorosea* for use in integrated whitefly management program.

Singh *et al.* (2014) evaluated the efficacy of certain biopesticides against *Thrips tabaci* on garlic. Among the biopesticides, kalmegh (*Andrographis paniculata*) decoction was more effective against thrips (3.73–5.01 thrips per leaf) and the efficacy was similar to 0.03 per cent dimethoate followed by lantana (*Lantana camara*), neem (*Azadirachta indica*), sickle senna (*Cassia tora*), sadaphuli (*Catharanthus roseus*), karanj (*Pongamia pinnata*) and arka (*Calotropis gigantea*).

Fitiwy *et al.* (2015) tested two chemical insecticides including *dimethoate* 40 per cent E.C and Lambda-cyhalothrin (Karate 5 EC), and five botanical extracts obtained from neem (*Azadirachta indica* A. Juss), Mexican marigold (*Tagetus minuta L.),* tree tobacco (*Nicotiana glauca* Graham) and Jimson weed (*Datura stramonium L.)* for their controlling effect on onion thrips and revealed that Karate has had the highest effect (0.55) compared to control (11.88) in reducing thrips pest population. Application of neem seed reduced thrips population (2.57) as compared to control (25.5).

Patra *et al.* (2015) tested Lambda cyhalothrin 4.9 CS at four dose levels (12.5, 15, 20 and 25 g a.i/ha) with standard check fipronil 5 per cent SC @ 50g a.i/ha and spinosad 48 SC @ 80 g a.i/ha against the chilli thrips and it was found that lowest average score of thrips (0.75 and 1.19 in two years) were recorded in lambda cyhalothrin 4.9 CS @ 25 g a.i./ha treated plots.

Annamalai *et al.* (2016) tested bio efficacy of *B. bassiana* and *V. lecanii* in comparison with their commertial formulations along with standard check of Fenvalerate 20 EC. It was found that Fenvalerate @ 0.0075 per cent recorded highest mortality of *Thrips tabaci* (90.10%) followed by commertial formulation of *V. lecanii* (Phule Bugicide @ 2 x 10^8 cfu/g) with 74.90 per cent mortality.

Subba and Ghosh (2016) assessed the efficacy of botanicals extract and synthetic insecticides viz., tobacco (7.5%) (75ml/l), garlic (5%) (50ml/l), Polygonum (5%) (50ml/l), Spilanthes (5%) (50ml/l), neem+spilanthes (1.5ml+40ml/l), neem pesticide (2.5ml/l), acetamiprid (1g/3l) were evaluated in tomato for the control of thrips. Results showed that individual mean per cent suppression of neem pesticides, extract of Spilanthes, Polygonum, tobacco, garlic were 60.73, 53.21, 50.70, 42.10, and 41.52 per cent respectively and neem+Spilanthes gave satisfactory result provoding 72.27 per cent suppression.

Chaudhari *et al.* (2017) conducted the trial in cucumber under shade net conditions against *Thrips tabaci* (Lindeman) using six biorational components with standard check of spinosad @ 1.2 ml/l. They found that *Verticillium lecanii* @ 4 g/l (avg. 59.50%) and trisiloxane @ 0.25 ml/l (avg. 57.84%) was found to be most significant among the eco-friendly options for suppression of thrips followed by *Metarhizium anisopliae* @ 4 g/l (avg. 57.20%) and neem oil @ 1 ml/l (avg. 56.47%). Mineral oil @ 0.5 ml/l (avg. 54.84%) and fish oil rosin soap @ 1 ml/l (avg. 54.11%) were next best amongst the bio-rational components.

Khoso *et al.* (2017) assessed the efficacy of different bio-extract such as tobacco, neem oil, Datura leaves extracts against onion thrips and carbosulfan was used as control treatment and results revealed that the highest mean population of the pest was at untreated (control) plot which was 71.85$\pm$0.21 followed by Datura (14.50$\pm$0.23), Tobacco (7.10$\pm$0.21), Carbosulfan (6.17$\pm$0.23) and Neem (5.83$\pm$0.18). In plots treated with different bio pesticides, the highest mortality of the pest was recorded on the 7^{th} day of second spray. Whereas 94.26, 96.48 and 85.63 per cent mortality was recorded on tobacco, neem and datura treated plot, respectively.

El-Sheikh (2017) studied the population density of onion thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae) under onion field conditions and used two entomopathogenic fungi *Beauveria bassiana* (Bals.) Vuill. and *Metarhizium anisopliae* (Metsch.) (Deuteromycotina: Hyphomycetes) isolates revealed that the reduction in insect numbers were 74, 62.87 and 87.08 per cent for *B. Bassiana*, *M. anisopliae* isolates and Actellic 50 per cent, respectively. In *B. bassiana* isolate corrected mortality ranged 35.90–93.59 per cent while in *M. anisopliae* isolate was ranged 8.97–84.62 per cent. Thus found that the two isolates may be effective against *T. tabaci.*

Zahid *et al.* (2017) studied the effect of different synthetic chemicals (Lambda-cyhalothrin and Bestox) and botanicals (Neem extract and Parthenium extract) pesticides against the Red pumpkin beetle (*Aulacophora foveicollis*) on three varieties of Cucumber (*Cucumis sativus*) and results revealed that after the second spray damage of the Red Pumpkin Beetle reduced to 8.2 per cent and 10.7 per cent in the Lambda-cyhalothrin and Bestox treated plots respectively.

Ganchev and Atanasova (2018) studied insecticidal action of Silwet L-77, a common organosilicone surfactant and wetting agent for plant protection products, on the base of trisiloxane ethoxylate, was observed at concentrations 0.011 – 0.012 per cent (v/v), towards three aphid species: *Aphis nerii* Boyer de Fonscolombe, *Macrosiphum rosae* (L.) and *Aphis pomi* (de Geer) and results indicated that Silwet L-77 has good potential for controlling tested aphid species alone.

2.3 Impact of Biopesticides on Yield of Cucumber:

Rosenheim *et al.* (1990) studied distribution of *T. palmi* and *Frankliniella occidentalis* within plant and relative contributions of each species to fruit scarring were investigated in field planting of cucumber, *Cucumis sativus* (L.). Densities of *T. palmi* were greatest on foliage, whereas *F. occidentalis* were greatest on flowers. There is incidence of fruit scarring, within and between field plantings. The high densities of *F. occidentalis* in flowers may create opportunities for them to incidentally feed upon and scar young fruit (45.5 ± 3.0% fruit scarred).

Welter *et al.* (1990) studied mixed infestations of thrips, composed of 94 per cent *Thrips palmi* Karny and 6 per cent *Frankliniella occidentalis* (Pergande), resulted in significant reductions in total cucumber yield, mean fruit size, and total fruit. Reductions of 54.2 per cent in total fruit weight at final harvest were observed and also total yield for the season were reduced 10 per cent by the highest level of fruit damage, possibly because 70 per cent of all yield was harvested before significant build-up of thrips populations.

Shipp *et al.* (1998) investigated the effects of thrips on growth, photosynthesis and productivity of greenhouse sweet pepper revealed that damage by western flower thrips (WFT) on the fruit was direct and instant. Short periods of high thrips densities resulted in cosmetic damage to the fruit. The major period for fruit damage occurred in the 3rd to 5th weeks before harvest. Therefore, thrips abundance should be maintained below 1200 larval-days per plant to prevent the negative impact of WFT on plant physiology and yield.

Hao *et al.* (2002) investigated effects of thrips (*Frankliniella occidentalis*) on growth, photosynthesis, yield and quality of greenhouse cucumber and revealed that most vulnerable stage to cosmetic damage was 4-10 days before fruit harvest, when the fruit were growing rapidly therefore it is recommended to control thrips abundance below 700 accumulated thrips-days per sticky card to prevent a negative thrips impact on plant physiology or yield.

Kadri and Goud (2005) among the insect pest, onion thrips, *T. tabaci* is most serious inflicting 34- 43 per cent loss in yield. Even 90 per cent loss in yield has also been reported on onion when thrips attack the crop in early stages of crop growth. Both nymph and adults rasp the leaf surface and feed. The bulb yield on weight basis in kg per plot was on oozing sap resulting in lightening of whole plants. Due to injury, leaves become twisted and dry from apex developing into white patches. A maximum of 71.22 per cent loss in bulb yield was noticed in unprotected crop.

Mandal *et al*. (2006) conducted an experiment to assess the effectiveness of some neem based integrated management approaches against the okra jassid, *Amrasca biguttula*. The treatments comprised soil application of neem cake @ 200 kg per ha with 3 foliar application of neem seed kernel extract (5%), neem oil (3%) Amrutguard (0.5%) and neem leaf decoction @ 0.5 kg. Neem cake treatments with inclusion of endosulfan and chlorpyriphos performed better than those with other integrated treatments in reducing pest incidence and producing more marketable fruit yield. Integrated treatments proved profitable with the maximum cost benefit ratio.

Sithanantham *et al*. (2007) found that thrips are an important group of sucking insects causing substantial yield losses in several tropical crops, as direct pest or as virus vectors. In onion, thrips, *Thrips tabaci* caused yield loss in the range of 47-87 per cent.

Patil *et al*. (2010) determined effective control measure for the management of onion thrips. The pooled data for the consecutive 3 years showed that all these treatments were effective and economical against onion thrips. Deltamethrin 1 EC + Triazophos 35 EC @ 0.072 per cent recorded significantly higher yield of 24.32 t/ha over rest of the treatments and 11.08 t/ha in control. This treatment was at par with the treatments of spinosad 45 SC @ 0.0135 per cent and carbosulfan 25 EC 0.025 per cent. The highest gross monetary returns (Rs.1,35,853/ha), net income (Rs. 68,549/ha) and C:B ratio (1: 2.02) were observed in the treatment with Deltamethrin 1 EC + Triazophos 35 EC @ 0.072 per cent.

Ahmed and El-mogy (2011) used two biological formulations, neem (Nimbicidine) and *Beauveria bassiana* (Bio-power) and jojoba oil for control of onion thrips, *T. tabaci* in onion field. They also considered vegetative characteristics, yield and germination of onion seeds and revealed that on the flowering period, Nimbicidine and Malathione were more effective on thrips population as well as they gave the highest significant seed yield.

Arthurs *et al.* (2013) evaluated commercial strains of entomopathogenic fungi for control of chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) and revealed that the proportion of marketable fruit was significantly increased by *Metarhizium brunneum* F52, *Beauveria bassiana* GHA, and 2 per cent SuffOil-X treatments.

Shiberu and Mahammed (2014) reported that thrips attack a number of vegetable crops particularly onion thrips causing considerable economic damage on onion crops. Usually young leaves are preferred, but buds and flowers also get infested. Under severe infested conditions the leaves shed and hence plant growth is affected and their control is vital to the production and profitability of onion crop. If onion thrips are not controlled, damage can routinely reduce bulb yields. In addition to use integrated pest management, use of selective insecticides in rotation to be the most important tools for thrips control.

Patra *et al.* (2015) tested Lambda cyhalothrin 4.9 CS at four dose levels (12.5, 15, 20 and 25 g a.i/ha) with standard check fipronil 5 per cent SC @ 50g a.i/ha and spinosad 48 SC @ 80 g a.i/ha against the chilli thrips found that the highest yield was recorded from lambda cyhalothrin 4.9 CS @ 25 g a.i./ha treated plots (62.33 and 61.06 q/ha).

Subba and Ghosh (2016) assessed the population dynamics of thrips (*Thrips tabaci*) in relation to abiotic factors and its botanical management in tomato and revealed that the lowest yield was recorded from control plots i.e. 18.32 t/ha and highest yield, 30.15 t/ha were recorded from acetamiprid treated plot followed by neem+Spilanthes (27.55 t/ha), Spilanthes (26.67 t/ha) and Polygonum (26.32 t/ha) which are significantly different from yield of other treated plots but in spite of using toxic acetmiprid, application of neem+*spilanthes* mixture is best as it is cost effective and environment friendly.

Bemisile *et al.* (2018) stated that ability of fungal pathogens such as *Beauveria bassiana* and *Metarhizium anisopliae* to exist as endophytes in plants and protect their colonized host plants against the primary herbivore pests has widely been reported. Aside from the role of pest management that has been traditionally ascribed to fungal endophytes, recent findings provided evidence of other possible functions as plant yield promoter, soil nutrient distributor, abiotic stress and drought tolerance enhancer in plants.

3. MATERIAL AND METHODS

The present experiment "Bio-rational management of thrips (*Thrips tabaci* Lindeman) infesting cucumber under polyhouse condition" was conducted to study the seasonal incidence of thrips on cucumber under polyhouse condition, biointensive approaches against thrips and the effect of treatments on yield of cucumber under polyhouse condition.

The experiment was carried out at the Hi-tech floriculture and vegetable project, College of Agriculture, Pune under Mahatma Phule Krishi Vidyapeeth, Rahuri during *Rabi* 2018. The materials and methods employed to study above aspects are described below.

3.1 Materials:

The cucumber seeds of the cultivar falconstar were sown in the experimental plot in the polyhouse. Mixed fertilizers were used for the development after sowing of cucumber seeds. Neem oil, Karanj oil, *Metarhizium anisopliae*, *Lecanicillium lecanii*, Mineral oil (Hortimin) and Polyether Modified Trisiloxane are used as bio-intensive treatments along with Lamba cyhalothrin 5 EC spray as a standard check and untreated control. Rope, tape, bags, labels, marker, bucket, jug, knapsack sprayer, measuring cylinder etc. were supplied by the Department of Agricultural Entomology and Hi-tech floriculture and vegetable project, College of Agriculture, Pune. The detail information regarding chemicals and myco-insecticides is given below in Table 3.1. Treatments details along with formulations and doses are given in Table 3.2.

3.2 Methodology

The present study was undertaken in Hi-tech floriculture and vegetable project, College of Agriculture, Pune during *Rabi*-2018. The details of experiment are given below.

3.2.1 Details of the Experiment

Crop	- Cucumber
Variety	- Falconstar
Design	- Completely Randomized Design
Polyhouse structure	- Round type
Replication	- Three
Treatments	- Eight
Plot size	- 4 m x 1 m
Spacing	- 60 cm x 30 cm
Season	- *Rabi*
Date of sowing	- 10th September 2018
Date of Ist spraying	- 9th November 2018

Date of IInd spraying - 24th November 2018

Date of IIInd spraying - 9th December 2018

Table 3.1 Details of Biopesticides, Botanicals and Chemicals Used in Experimentation

No.	Technical Name	Formulation	Trade Name	Dose	Source/ Manufacturer
1	Neem oil	100% oil	Nimbin 5000 ppm	1 ml/l	M/s Multimol Micro Fertilizer Industries, Sinnar, Nasik.
2	Karanj oil	100% oil	Agrilabh-K oil	1 ml/l	M/s Agrilabh Beej Ltd., Indore
3	*Metarhizium anisopliae*	1.5% WP	Phule *Metarhizium*	4 g/l	Agril. Entomology Section, College of Agriculture, Pune.
4	*Lecanicillium lecanii*	1.5% WP	Phule Bugicide	4 g/l	Agril. Entomology Section, College of Agriculture, Pune.
5	Mineral oil	100% oil	Hortimin	0.5 ml/l	M/s Indian Oil Corp. Ltd., Haryana
6	Polyether modified trisiloxane	S 280	Break-Thru	0.25 ml/l	M/s Evonic Industries, Mumbai
7	Lambda cyhalothrin	5% EC	Mustang	0.5 ml/l	M/s Sumil Chemical Industries Pvt. Ltd., Samba (J & K)

3.2.2 Seedlings:

Cucumber seeds were sown in the plots of size 4 m x 1 m i.e One rack containing 20 pots. Seeds of variety “Falconstar” were sown in the pot with the spacing 60 cm x 30 cm with FYM and cocopit mixture. The recommended fertigation was made through automatic fertigation machine every day at morning. The interculture operations were carried out as per the recommendations.

3.2.3 Seasonal Incidence of Thrips

3.2.3.1 Observations

For studies on seasonal incidence of thrips population *T. tabaci* Lindeman 10 plants were selected and tagged per plot. The population count was taken at weekly interval in accordance with the meteorological weeks of the year during the experimental period. The population of nymphs and adults were recorded early in the morning from apical, middle and bottom leaves i.e. three leaves each from ten selected plant. Three tappings were given to leaves on black paper sheet and counted for the record.

3.2.3.2 Meteorological Data

The required meteorological data for studying seasonal incidence of thrips were recorded from dry and wet bulb thermometer installed in polyhouse. To study the influence of meteorological parameters T_{max}, T_{min} and morning relative humidity (RH_1), evening relative humidity (RH_2) were recorded at both morning and evening hours of the day. The mean data of the week was taken into account for further analysis. Finally, the co-relation and regression analysis between occurrence of pests and weather parameters worked out.

3.2.4 Bioefficacy of Biopesticides

3.2.4.1 Preparation of Solutions

As per the concentrations the solution dosages were calculated for one liter water. The mixture of insecticide and water was prepared in bucket. The clean irrigation water sourced from well used for preparing insecticide and botanicals solutions.

3.2.4.2 Spraying

Aspee make manually operated knapsack sprayer of fifteen liter capacity was used for application of treatments. Three sprayings were conducted at 15 days of interval during experiment. Spraying was conducted in the morning hours.

3.2.4.3 Observations

For recording observations on thrips, ten plants were selected randomly from each plot. Pretreatment count was recorded one day before spraying and observations on post treatment count was taken on 3, 7, 10 and 14 days after spraying. The observations were taken in morning hours, by three tappings on upper, middle and lower leaf i.e. 3 leaves each from 10 selected plants per plot on black paper sheet. Nymphs and adults were counted with magnifying lens (10x). Healthy marketable fruit yield was recorded at each harvesting.

3.2.5 Statistical Analysis:

The meteorological data of $T_{max,}$ T_{min} and humidity was subjected to correlation analysis. The similar data were used to calculate linear and non-linear regression and linear, quadratic, inter-relation and cubic equations were formulated to achieve maximum accuracy in prediction of incidence of thrips under polyhouse condition in cucumber. The data on thrips population per plant was used to calculate percent reduction in population in each treatment using the formula given by Henderson and Tilton (1955). Data on percent reduction was transformed into Arc Sin values and subjected to CRD analysis (Panse and Sukhatme 1978) to draw valid conclusion. The yield data kg/plot was converted in to t/ha and it was subjected to analysis of variance to draw the inference.

3.2.5.1 Formula Given by Henderson and Tilton, 1955:

$$\text{Per cent reduction} = 1 - \left(\frac{T_a}{C_a} \times \frac{C_b}{T_b} \right)$$

Where,

T_a = Infestation in treated plot after application

T_b = Infestation in treated plot before application

C_a = Infestation in control plot after application

C_b = Infestation in control plot before application

Table 3.2 Treatment Details:

Treatment	Chemical Name	Dose
T_1	Neem oil formulation	1 ml/l
T_2	Karanj oil formulation	1 ml/l
T_3	*Metarhizium anisopliae*	4 g/l
T_4	*Lecanicillium lecanii*	4 g/l
T_5	Mineral oil (Hortimin)	0.5 ml/l
T_6	Polyether Modified Trisiloxane	0.25 ml/l
T_7	Lambda Cyhalothrin	0.5 ml/l
T_8	Untreated control	---

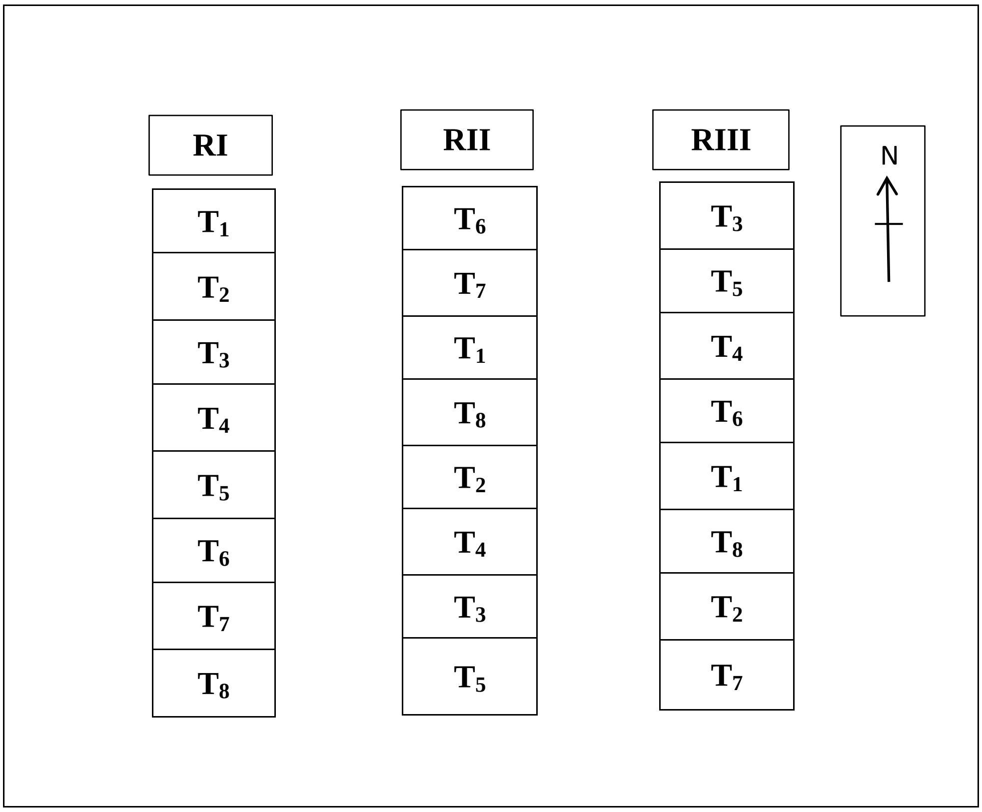

Fig. 3.1 Plan of Layout

4. RESULTS AND DISCUSSION

Experiment was conducted during *Rabi* 2018 in cucumber under polyhouse condition. During the experimentation on evaluation of bio-rational approaches against *Thrips tabaci* in cucumber under polyhouse condition the observations on thrips population, seasonal incidence of thrips and effect of treatments on the yield was recorded. After the statistical analysis of data, the interpretation of the results in as under.

4.1 Seasonal Incidence of Thrips (*Thrips tabaci* L.) on Cucumber under Polyhouse Condition:

4.1.1 Seasonal Incidence of Thrips:

Seasonal incidence of *Thrips tabaci* was studied by taking count of thrips from selected plants. The data is presented in Table 4.1 and graphically represented in Fig. 4.1. From depicted data, it is observed that population of thrips started building up from 37th standard meteorological week i.e. 2nd week of September 2018 (32.10 thrips/3 leaves/ plant). Then it abruptly increased from 39th standard meteorological week i.e. 4th week of September 2018 (41.90 thrips/3 leaves/plant) to 43rd standard meteorological week i.e. 4th week of October 2018 (50.06 thrips/3 leaves/plant).

The maximum thrips population range was found throughout the experiment from 25.86 thrips/3 leaves/plant to 50.06 thrips/3 leaves/plant. The thrips population was observed the highest on 43rd standard meteorological week i.e. 4th week of October 2018 (50.06 thrips/3 leaves/plant). After which population started declining from 44th standard meteorological week i.e. 5th week of October 2018 (40.26 thrips/3 leaves/plant) till 1st standard meteorological week i.e. 1st week of January 2019 (25.86 thrips/3 leaves/plant) in which the lowest thrips population was recorded. There was a slight increasing trend of thrips population in last week of observation i.e. 2nd week of January 2019 (26.66 thrips/3 leaves/plant).

Thus, present study indicated that hot and dry atmospheric conditions with temperature range between 19.5 to 35.1°C and humidity 27 to 89 per cent favoured the multiplication of thrips under polyhouse conditions. Present findings are in conformity with Jarosik *et al.* (1997) who recorded the relationship between the rate of development and temperature was linear from 18 to 33°C for eggs, and from 18 to 31°C for the first instar of thrips, *Frankliniella occidentalis* Pergande under greenhouse conditions on cucumber.

Table 4.1 Seasonal Incidence of Thrips (*Thrips tabaci* L.) on Cucumber under Polyhouse Condition:

Month	Meteorological Week	Temperature (°C)		Relative Humidity (%)		Mean Thrips Population/3 Leaves/ Plant
		Tmax	Tmin	RH-I (Morning)	RH-II (Evening)	
September	37	31.7	19.5	88	54	32.10
	38	32.2	22.1	88	57	34.33
	39	34	22	94	55	41.90
October	40	34.2	23.2	88	47	45.93
	41	34.4	22.2	90	37	45.20
	42	35.1	23.3	89	31	49.66
	43	35	23.1	89	27	50.06
	44	33.7	20.2	83	35	40.26
November	45	34.9	19.4	93	36	41.00
	46	34	15.1	93	28	40.43
	47	33	18.3	87	42	37.46
	48	31.3	16.4	92	43	32.03
December	49	31.2	13.3	95	31	30.86
	50	30.4	14.2	91	37	28.33
	51	28.4	12.2	95	40	27.63
	52	27.8	12.1	93	32	27.36
January	1	26.3	10.7	93	24	25.86
	2	26	10.8	94	24	26.66

4.1.2 Correlation of Incidence of Thrips (*Thrips tabaci* L.) on Cucumber with Weather Parameters under Polyhouse Condition:

Correlation coefficient of meteorological parameters against incidence of thrips on cucumber under polyhouse condition is represented in Table 4.2. The meteorological parameters viz., minimum temperature, maximum temperature, morning and evening relative humidity respectively during experimental period i.e. from September 2018 to January 2019 are presented in Appendix-I.

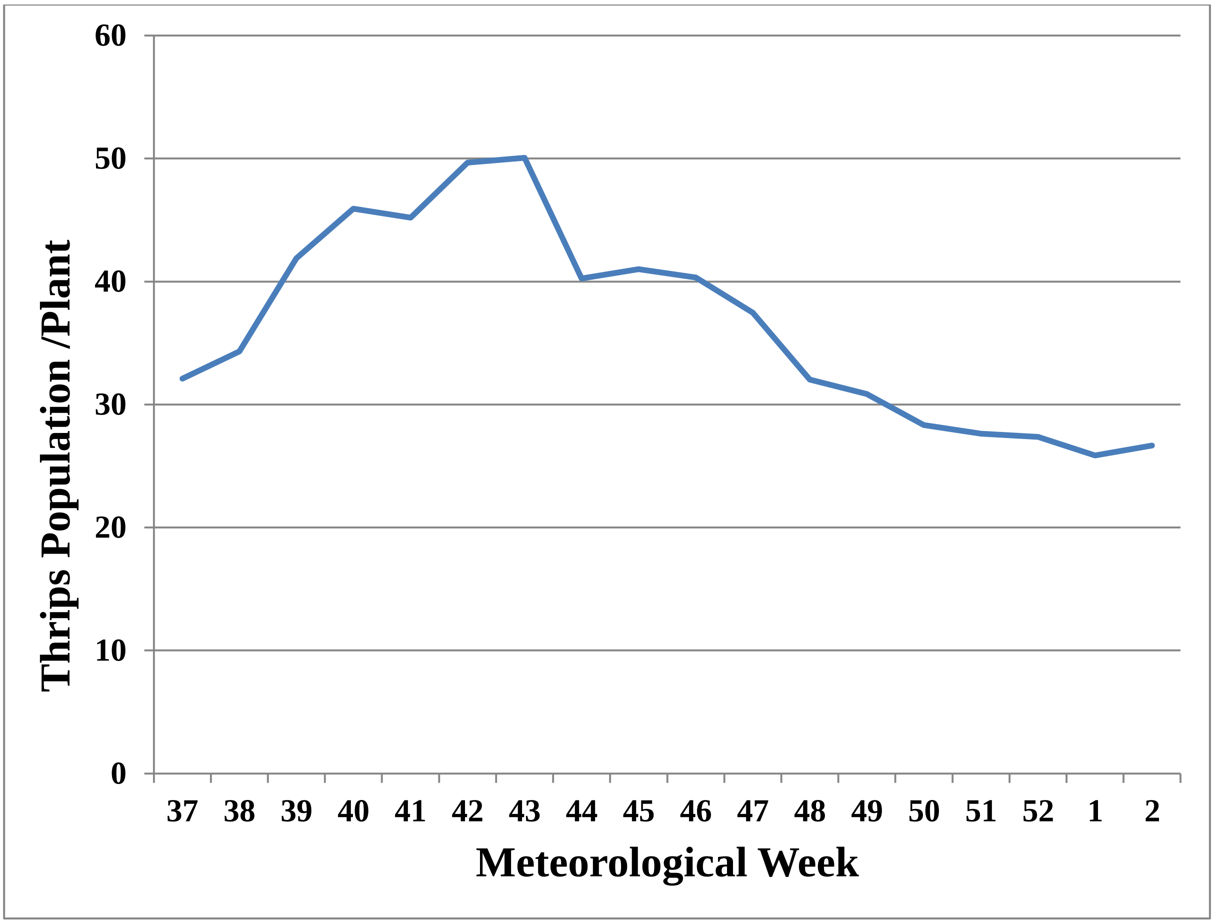

Fig. 4.1 Seasonal Incidence of Thrips, *Thrips tabaci* on Cucumber under Polyhouse Condition:

Tabel 4.2 Correlation Coefficient (r) of Seasonal Incidence of Thrips with Meteorological Parameters:

Meteorological Parameters		*Thrips tabaci*
Temperature (°C)	Maximum Tmax	0.8930**
	Minimum Tmin	0.6547**
Relative Humidity (%)	Morning (RH-I)	-0.1730*
	Evening (RH-II)	-0.1365 (NS)

*significant at 5% level, **significant at 1% level, NS = non-significant

Correlation analysis of incidence of *T. tabaci* with meteorological parameters revealed positive and significant correlation (0.8930) between incidence and maximum temperature. It was also positive and significant correlation (0.6547) between incidence and minimum temperature. But it was negative and significant between incidence and morning relative humidity (RH_1) (-0.1730) and there was negative and non-significant relation between incidence and evening relative humidity (RH_2) (-0.1365).

Similar results were reported by Maklad *et al.* (2012) in cucumber under greenhouse conditions. They recorded that population of thrips increased as well as increasing temperatures and decreasing relative humidity. Also, similar results were recorded in onion ecosystem on the incidence of thrips by Bergant *et al.* (2005) and Kumawat *et al.* (2018) who recorded that there is positive correlation with temperature and negative in case of humidity on the development of thrips population. However, the present findings are in contradiction to the results of Barot *et al.* (2012) recorded negative correlation of thrips with minimum temperature in onion under field condition. In the present finding there is positive correlation of minimum temperature with thrips population which may be the result of less difference in the range of minimum and maximum temperature under polyhouse conditions compared to field condition.

Table 4.3 Discriptive Weather Data:

	Tmax	Tmin	RH1	RH2	Thrips Population
Mean	32.46	17.96	90.83	37.77	38.22
Standard Error	0.27	0.79	0.43	1.37	0.99
Median	32.60	17.75	91.50	36.5	36.3
Mode	34.00	19.50	93	37	34.3
Standard Deviation	2.01	5.81	3.21	10.07	7.33
Sample Variance	4.07	33.85	10.33	101.49	53.84
Kurtosis	-1.06	2.15	-0.15	-0.70	-1.10
Skewness	-0.33	1.21	-0.65	0.53	0.33
Range	6.70	24.40	12	33	25.80
Minimum	26.30	10.70	83	24	25.86
Maximum	35.10	23.30	95	57	50.06
Count	54	54	54	54	54

4.1.3 Regression Analysis of Thrips Incidence:

The regression analysis of thrips incidence is represented in Table 4.4. The data showed that linear relation equation between thrips and weather parameters (Tmax, Tmin, $RH_{1,}$ RH_2) showed 84.9 per cent precision. While non-linear equation such as quadratic equation, inter-relation and cubic equation showed better precision than linear relation equation. In non-linear equation quadratic equation showed 88.3 per cent precision, while inter-relation equation showed 89.3 per cent precision between thrips and weather parameters (Tmax, Tmin, $RH_{1,}$ RH_2). Among all equations cubic equation was non-linear, showing the highest i.e. 90.8 per cent precision between thrips and weather parameters (Tmax, Tmin, RH_1, RH_2). The regression equations (models) derived in the present study based on abiotic parameters and thrips incidence will be helpful to the farmers in the prediction of thrips incidence under polyhouse condition with maximum accuracy. These results are in line with the results of Boll *et al.* (2007), they stated that regression models using infestation variables with and without climatic variables significantly increased calibration precision and made possible the accurate description of population dynamics.

Table 4.4 Regression Analysis of Thrips Incidence:

Equation	R^2	Equation
Linear relation	0.85	Y= -57.175 + 2.950 Tmax** + 0.199 Tmin (NS) + 0.035 RH_1 (NS) – 0.188 RH_2**
Quadratic equation	0.88	Y= 366.918 – 22.308 Tmax (NS) + 0.321 Tmin (NS) – 0.408 RH_1 (NS) – 0.719 RH_2 (NS) + 0.396 $Tmax^2$** -0.005 $Tmin^2$ (NS) + 0.003 RH_1^2 (NS) +0.007 RH_2^2 (NS)
Inter relation	0.89	Y= -238.15 + 9.914 Tmax (NS) – 16.928 Tmin (NS) + 2.585 RH_1 (NS) + 3.450 RH_2 (NS) – 0.530 $Tmax^2$ (NS) -0.051 $Tmin^2$ (NS) – 0.049 RH_1^2 (NS) – 0.010 RH_2^2 (NS) + 0.971 Tmax. Tmin (NS) + 0.241 Tmax. RH_1 (NS) – 0.216 Tmax. RH_2 (NS) – 0.182 Tmin. RH_1 (NS) + 0.061 Tmin. RH_2 (NS) + 0.039 RH_1. RH_2 (NS)
Cubic equation	0.91	Y= -145.39 + 319.09 Tmax* – 170.06 Tmin* – 237.06 RH_1* + 42.134 RH_2* – 0.377 $Tmin^2$ (NS) + 4.122 RH_1^2* + 0.009 RH_2^2 (NS) + 0.026 Tmax. Tmin (NS) – 3.416 Tmax. RH_1* – 0.052 Tmax. RH_2 (NS) + 1.895 Tmin. RH_1* + 0.036 Tmin. RH_2 (NS) – 0.457 RH_1. RH_2* + 0.008 $Tmin^3$(NS) – 0.016 RH_1^3*

Y = no. of thrips, Tmax = maximum temperature, Tmin = minimum temperature,
RH_1 = morning relative humidity, RH_2 = evening relative humidity

4.2 Evaluation of Bio-rational Components for Management of Thrips:

4.2.1 After First Spray:

The data on per cent reduction of thrips at 3, 7, 10 and 14 DAS after first spray is presented in Table 4.5 and depicted in Fig. 4.2 and live count of thrips after first spray is depicted in Fig. 4.3. Non significance of precount of thrips population one day before initiation of spraying indicated that there was homogenous distribution of thrips in the crop. All the treatments were found significant over untreated control at all interval of observations.

At 3 DAS, lamda cyhalothrin @ 0.5 ml/l recorded highest reduction of thrips population with 74.04 per cent and found to be significantly superior over all treatments. The next best treatment was mineral oil hortimin @ 0.5 ml/l with 59.76 per cent reduction of thrips population which is at par with treatment polyether modified trisiloxane @ 0.25 ml/l with 58.64 per cent reduction of thrips. Neem oil @ 1 ml/l (54.01%) and karanj oil @ 1 ml/l (52.31%) were statistically equal in redcing thrips population. *Metarhizium anisopliae* @ 4 g/l with 12.36 per cent reduction of thrips population was found to be least effective which was at par with *Lecanicillium lecanii* @ 4 g/l with 13.98 per cent thrips reduction.

At 7 DAS, the suppression of thrips varied from 19.45 to 79.80 per cent. Lamda cyhalothrin @ 0.5 ml/l was found significant with 79.80 per cent over all treatments. The next best treatment was neem oil formulation @ 1 ml/l with 62.30 per cent reduction of thrips population. The treatment *Metarhizium anisopliae* @ 4 g/l recorded 19.45 per cent reduction of thrips population was found the least effective, at par with *Lecanicillium lecanii* @ 4 g/l (21.87%). The treatments with Hortimin @ 0.5 ml/l (58.00%) and karanj oil (55.72%) were on par with each other at 7 DAS in thrips reduction followed by trisiloxane @ 0.25 ml/l (52.70%).

At 10 DAS, lamda cyhalothrin @ 0.5 ml/l was found superior over all treatments with 76.46 per cent reduction in thrips population. The next best treatment was neem oil formulation @ 1 ml/l with 58.21 per cent reduction of thrips population. The next best treatments were Hortimin @ 0.5 ml/l (50.80%), trisiloxane @ 0.25 ml/l (50.10%) and karanj oil @ 1 ml/l (46.30%) were on par with each other at 10 DAS in thrips reduction. However, *Lecanicillium lecanii* @ 4 g/l (40.27%) and *Metarhizium anisopliae* @ 4 g/l (38.72%) were least effective and at par with each other.

At 14 DAS, lamda cyhalothrin @ 0.5 ml/l was found to be the most effective treatment with 68.54 per cent reduction in thrips population followed *Lecanicillium lecanii* @ 4 g/l, neem oil formulation @ 1 ml/l and *Metarhizium anisopliae* @ 4 g/l were second best and equally effective in reducing thrips with 53.05, 51.06 and 50.81 per cent respectively. The least effective treatment was karanj oil formulation @ 1 ml/l with 40.07 per cent thrips reduction. While Hortimin @ 0.5 ml/l (44.41%) and trisiloxane @ 0.25 ml/l (43.96%) were on par to each other at the end of first spray.

Table 4.5 Per cent Reduction of Thrips (*Thrips tabaci* L.) in Cucumber after First Spray:

Treatment No.	Treatment details	Dose	Pre-Count thrips/ 3 leaves/ Plant $	Per cent reduction of thrips at				
				3 DAS #	7 DAS #	10 DAS #	14 DAS #	Avg.
T1	Neem oil formulation	1 ml/l	**36.63 (6.13)**	**54.01 (47.28)**	**62.30 (52.10)**	**58.21 (49.71)**	**51.06 (45.58)**	**56.39**
T2	Karanj oil formulation	1 ml/l	**31.03 (5.65)**	**52.31 (46.30)**	**55.72 (48.26)**	**46.30 (42.85)**	**40.07 (39.25)**	**48.60**
T3	*Metarhizium anisopliae*	4 g/l	**34.13 (5.92)**	**12.36 (20.55)**	**19.45 (26.13)**	**38.72 (38.46)**	**50.81 (45.44)**	**30.33**
T4	*Lecanicillium lecanii*	4 g/l	**33.56 (5.87)**	**13.98 (21.94)**	**21.87 (27.85)**	**40.27 (39.37)**	**53.05 (46.73)**	**32.29**
T5	Mineral oil (Hortimin)	0.5 ml/l	**32.20 (5.76)**	**59.76 (50.60)**	**58.00 (49.58)**	**50.80 (45.44)**	**44.41 (41.77)**	**53.24**
T6	Polyether Modified Trisiloxane (Break-Thru)	0.25ml/l	**34.66 (5.97)**	**58.64 (49.95)**	**52.70 (46.53)**	**50.10 (45.03)**	**43.96 (41.51)**	**51.35**
T7	Lambda cyhalothrin	0.5 ml/l	**35.83 (6.06)**	**74.04 (59.35)**	**79.80 (63.28)**	**76.46 (60.97)**	**68.54 (55.86)**	**74.71**
T8	Untreated control	---	**32.63 (5.79)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	
	SE ±		**0.100**	**0.63**	**0.78**	**0.86**	**0.59**	
	CD @ 5%		**NS**	**1.92**	**2.40**	**2.6**	**1.82**	
	CV %		**2.92**	**2.56**	**3.02**	**3.21**	**2.27**	

$ indicates figures in parentheses from this column are √n+1 transformed values

# indicates figures in parentheses from these columns are arc sin transformed values

DAS- Days After Spraying

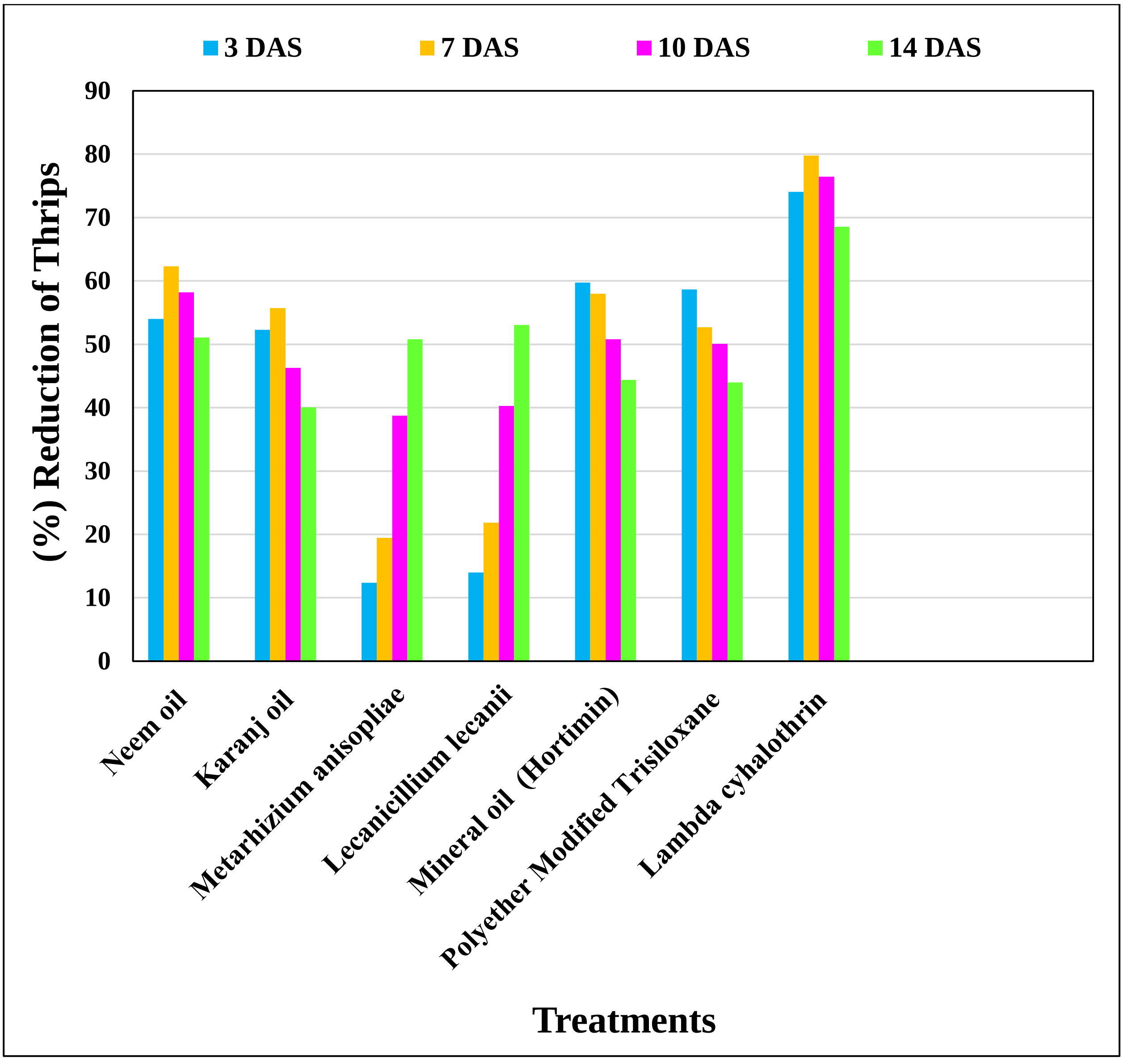

Fig. 4.2 Per cent Reduction of Thrips after First Spray

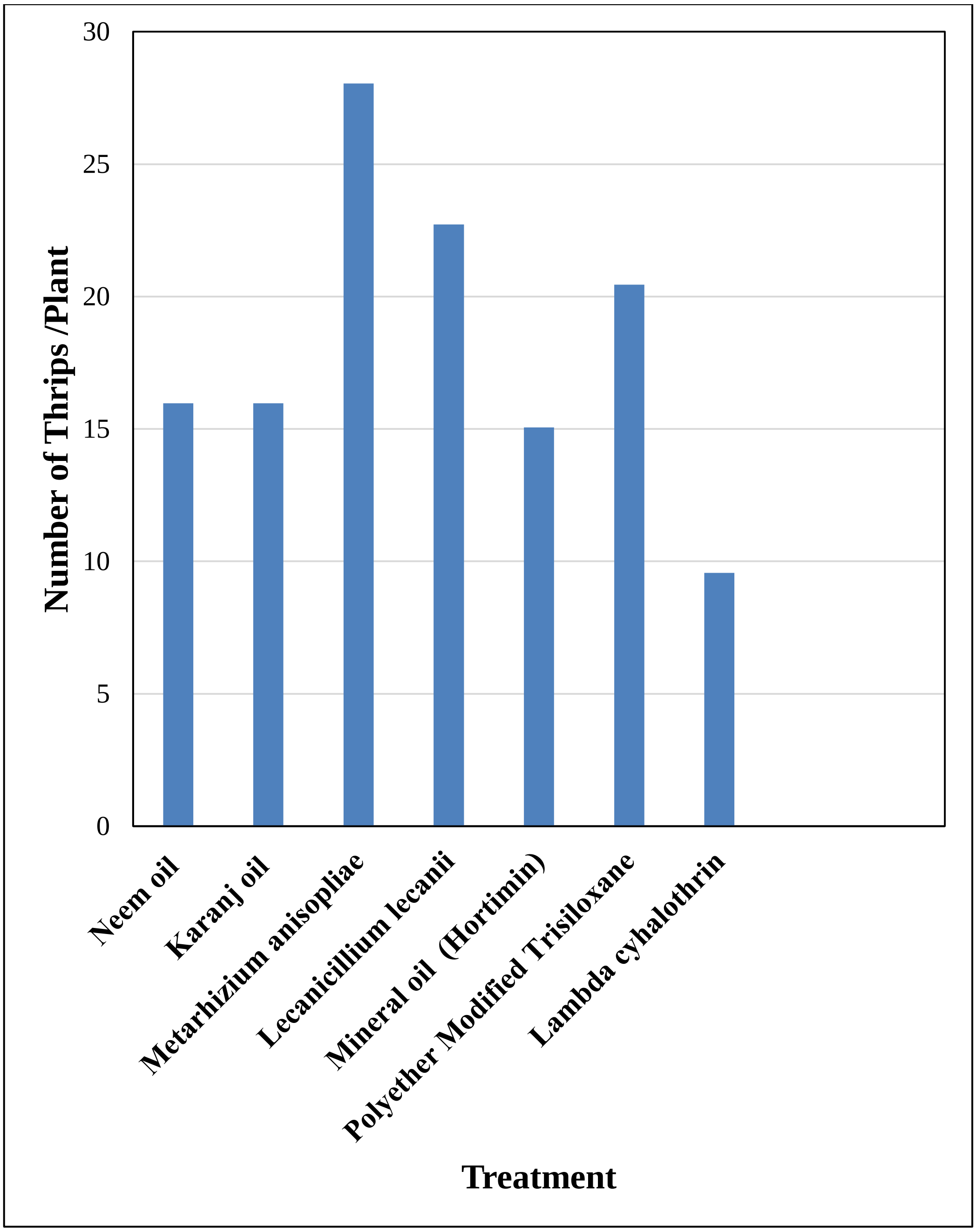

Fig. 4.3 Live Count of Thrips (*Thrips tabaci* L.) in Cucumber after First Spray

4.2.2 After Second Spray:

The data on per cent reduction of thrips after second spray is presented in Table 4.6 and depicted in Fig. 4.4 and live count of thrips after second spray was depicted in Fig 4.5. The precount of thrips population was recorded 14 DAS after first spray and spraying was carried on the next day. At precount, there was significant variation in reduction of pest population among the treatments at all intervals of post spraying observation. All the treatments were found significant over control on all observations.

At 3 DAS, lamda cyhalothrin @ 0.5 ml/l was recorded the highest reduction of thrips population with 76.55 per cent and found significantly superior over all treatments. The next best treatment was mineral oil hortimin @ 0.5 ml/l with 63.59 per cent thrips reduction at par with polyether modified trisiloxane @ 0.25 ml/l with 61.83 per cent thrips reduction. The least effective treatment was *Metarhizium anisopliae* @ 4 g/l with 55.51 per cent reduction of thrips population. *Lecanicillium lecanii* @ 4 g/l, karanj oil formulation @ 1 ml/l and neem oil formulation @ 1 ml/l shown the trend of 57.12 < 57.33 < 58.13 per cent thrips reduction which are statistically similar and significantly superior over least effective *Metarhizium anisopliae* @ 4 g/l (55.51%).

At 7 DAS, lamda cyhalothrin @ 0.5 ml/l was recorded highest reduction of thrips population with 84.64 per cent and found to be significantly superior over all treatments. The next best treatment was neem oil formulation @ 1 ml/l with 63.85 per cent reduction of thrips population which was at par with hortimin @ 0.5 ml/l (61.38%) and *Lecanicillium lecanii* @ 4 g/l (60.51%). The least effective was polyether modified trisiloxane @ 0.25 ml/l) with 55.44 per cent reduction of thrips population which was at par with remaining treatments *Metarhizium anisopliae* @ 4 g/l (57.08%) and karanj oil formulation @ 1 ml/l (58.53%).

At 10 DAS, lamda cyhalothrin @ 0.5 ml/l was found to be the most effective treatment with 82.06 per cent reduction in thrips population followed *Lecanicillium lecanii* @ 4 g/l, *Metarhizium anisopliae* @ 4 g/l and neem oil formulation @ 1 ml/l were second best and equally effective in reducing thrips with 62.80, 61.10 and 60.32 per cent respectively. The least effective treatment was karanj oil formulation @ 1 ml/l with 50.25 per cent thrips reduction which was at par with polyether modified trisiloxane @ 0.25 ml/l (51.24%). Hortimin @ 0.5 ml/l was found superior over karanj oil formulation and polyether modified trisiloxane.

At 14 DAS, lamda cyhalothrin @ 0.5 ml/l was recorded the highest reduction of thrips population with 73.52 per cent and found to be significantly superior over all treatments.

Table 4.6 Per cent Reduction of Thrips (*Thrips tabaci* L.) in Cucumber after Second Spray:

Treatment No.	Treatment Details	Dose	Pre-Count Thrips/ 3 Leaves/ Plant $	Per Cent Reduction of Thrips at				
				3 DAS #	7 DAS #	10 DAS #	14 DAS #	Avg.
T1	Neem oil formulation	1 ml/l	**17.92 (4.35)**	**58.13 (49.66)**	**63.85 (53.03)**	**60.32 (50.94)**	**52.22 (46.25)**	**58.63**
T2	Karanj oil formulation	1 ml/l	**18.59 (4.42)**	**57.33 (49.19)**	**58.53 (49.89)**	**50.25 (45.12)**	**45.32 (42.29)**	**52.85**
T3	*Metarhizium anisopliae*	4 g/l	**19.80 (4.56)**	**55.51 (48.14)**	**57.08 (49.05)**	**61.10 (51.40)**	**61.89 (51.85)**	**58.89**
T4	*Lecanicillium lecanii*	4 g/l	**15.75 (4.09)**	**57.12 (49.07)**	**60.51 (51.04)**	**62.80 (52.39)**	**64.03 (53.13)**	**61.11**
T5	Mineral oil (Hortimin)	0.5 ml/l	**17.90 (4.34)**	**63.59 (52.86)**	**61.38 (51.57)**	**57.03 (49.02)**	**50.31 (45.15)**	**58.07**
T6	Polyether Modified Trisiloxane (Break-Thru)	0.25ml/l	**23.55 (4.95)**	**61.83 (51.82)**	**55.44 (48.10)**	**51.24 (45.69)**	**47.09 (43.31)**	**53.90**
T7	Lambda cyhalothrin	0.5 ml/l	**11.90 (3.59)**	**76.55 (61.01)**	**84.64 (66.92)**	**82.06 (64.92)**	**73.52 (59.00)**	**79.19**
T8	Untreated control	---	**47.02 (6.92)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	
	SE ±		**0.038**	**0.45**	**0.99**	**0.66**	**0.69**	
	CD @ 5%		**0.116**	**1.39**	**3.04**	**2.01**	**2.12**	
	CV %		**1.52**	**1.52**	**3.26**	**2.21**	**2.45**	

$ indicates figures in parentheses from this column are √n+1 transformed values

# indicates figures in parentheses from these columns are arc sin transformed values

DAS- Days After Spraying

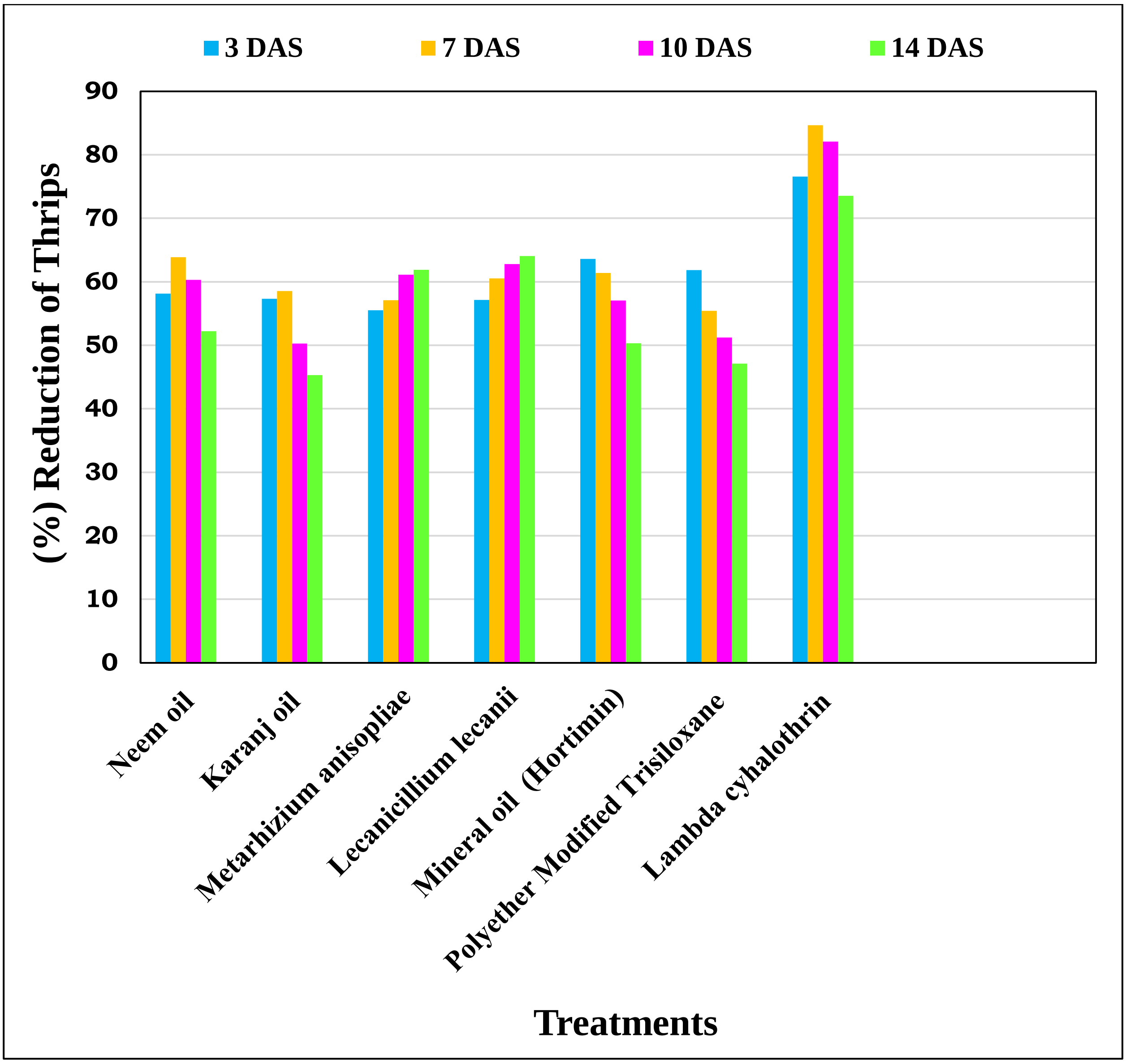

Fig. 4.4 Per cent Reduction of Thrips after Second Spray

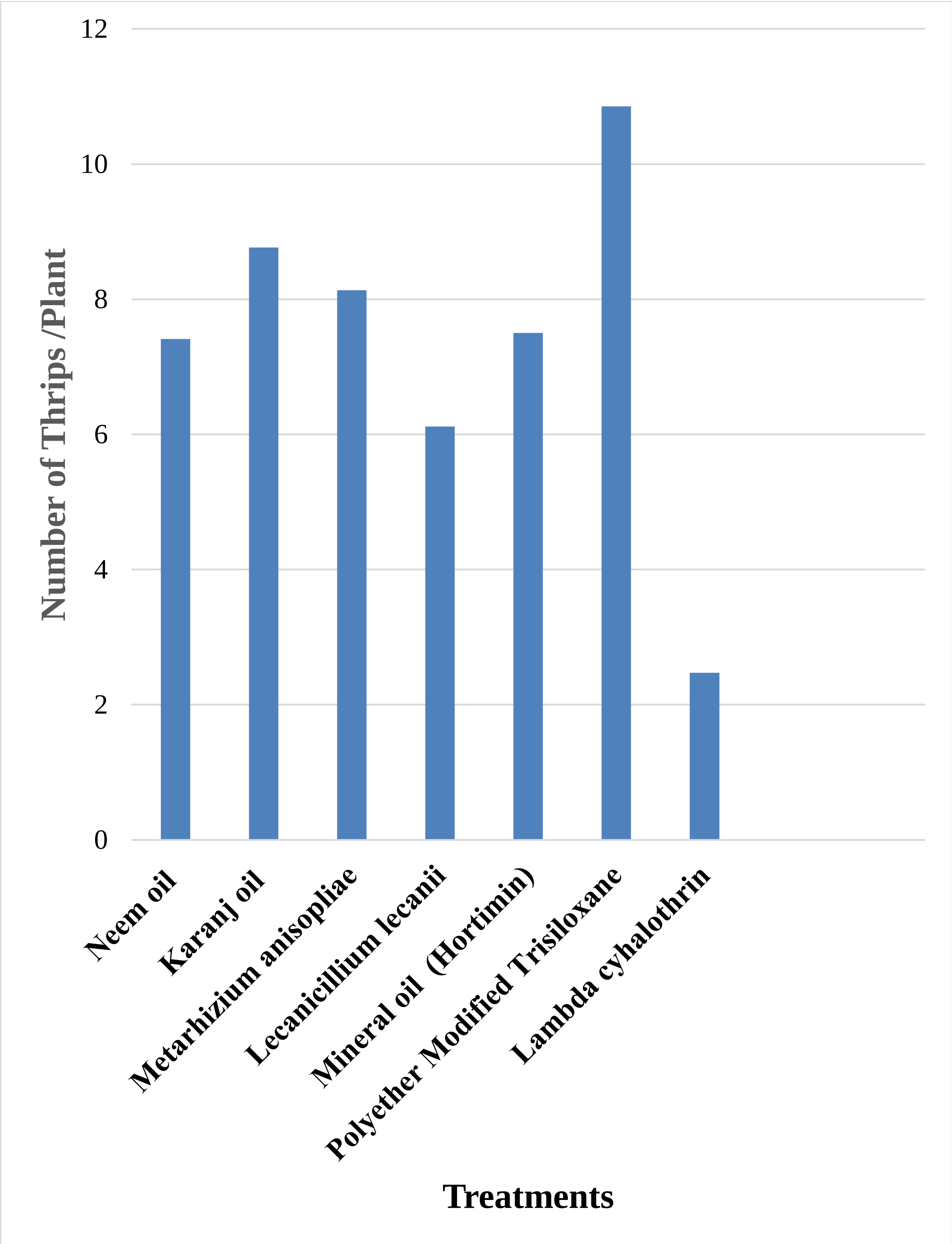

Fig. 4.5 Live Count of Thrips (*Thrips tabaci* L.) in Cucumber after Second Spray

Lecanicillium lecanii @ 4 g/l and *Metarhizium anisopliae* @ 4 g/l were second best treatment with per cent thrips reduction 64.03 and 61.89 percent respectively and were on par with each other. The least effective was karanj oil formulation @ 1 ml/l with (45.32%) per cent thrips reduction which was at par with polyether modified trisiloxane @ 0.25 ml/l (47.09%). There is 52.22 and 50.31 per cent reduction in thrips population with treatment neem oil formulation @ 1 ml/l and hortimin @ 0.5 ml/l respectively, which were superior than least effective treatments i.e. karanj oil formulation and polyether modified trisiloxane.

4.2.3 After Third Spray:

The data on per cent reduction of thrips after third spray is presented in Table 4.7 and depicted in Fig. 4.6 and live count of thrips after third spray is depicted in Fig. 4.7. The precount of thrips population was recorded 14 DAS after second spray and spraying was carried on next day. At precount, there was significant variation in reduction of pest population among the treatments at all intervals of post spraying observation. All the treatments were found significant over untreated control at all interval of observations.

At 3 DAS, lamda cyhalothrin @ 0.5 ml/l was found to be the most effective treatment with 80.20 per cent reduction in thrips population followed *Lecanicillium lecanii* @ 4 g/l, polyether modified trisiloxane @ 0.25 ml/l and *Metarhizium anisopliae* @ 4 g/l were second best and equally effective in reducing thrips with 66.51, 64.58 and 63.73 per cent respectively. The least effective was hortimin @ 0.5 ml/l (57.34%) which was at par with karanj oil formulation @ 1 ml/l (58.45%) and neem oil formulation @ 1 ml/l (60.19%).

At 7 DAS, lamda cyhalothrin @ 0.5 ml/l was recorded the highest reduction of thrips population with 94.08 per cent and found to be significantly superior over all treatments. The second best was neem oil formulation @ 1 ml/l (67.98%) which was at par with *Lecanicillium lecanii* @ 4 g/l, *Metarhizium anisopliae* @ 4 g/l and hortimin @ 0.5 ml/l, which shown per cent thrips reduction trend as 67.77, 66.01 and 61.81 per cent respectively. karanj oil formulation @ 1 ml/l (56.13%) was least effective and at par with polyether modified trisiloxane @ 0.25 ml/l with 58.74 per cent thrips reduction.

At 10 DAS, lamda cyhalothrin @ 0.5 ml/l (89.16%) was significantly superior over all treatments. *Lecanicillium lecanii* @ 4 g/l (68.86%) was second best and at par with *Metarhizium anisopliae* @ 4 g/l (67.13%) and neem oil formulation @ 1 ml/l (65.81%). karanj oil formulation @ 1 ml/l (53.84%) was the least effective and at par with polyether modified trisiloxane @ 0.25 ml/l (54.61%),

Table 4.7 Per cent Reduction of Thrips (*Thrips tabaci* L.) in Cucumber after Third Spray:

Treatment No.	Treatment Details	Dose	Pre-Count Thrips/ 3 Leaves/ Plant $	Per cent reduction of thrips at				
				3 DAS #	7 DAS #	10 DAS #	14 DAS #	Avg.
T1	Neem oil formulation	1 ml/l	**8.56 (3.09)**	**60.19 (50.86)**	**67.98 (55.51)**	**65.81 (54.19)**	**59.94 (50.71)**	**63.48**
T2	Karanj oil formulation	1 ml/l	**10.17 (3.34)**	**58.45 (49.84)**	**56.13 (48.50)**	**53.84 (47.18)**	**47.02 (43.27)**	**53.86**
T3	*Metarhizium anisopliae*	4 g/l	**7.54 (2.92)**	**63.73 (52.95)**	**66.01 (54.32)**	**67.13 (55.00)**	**68.45 (55.80)**	**66.33**
T4	*Lecanicillium lecanii*	4 g/l	**5.66 (2.58)**	**66.51 (54.62)**	**67.77 (55.38)**	**68.86 (56.05)**	**70.01 (56.77)**	**68.28**
T5	Mineral oil (Hortimin)	0.5 ml/l	**8.89 (3.14)**	**57.34 (49.20)**	**61.81 (51.81)**	**60.39 (50.97)**	**58.94 (50.13)**	**59.62**
T6	Polyether Modified Trisiloxane (Break-Thru)	0.25ml/l	**12.46 (3.66)**	**64.58 (53.46)**	**58.74 (50.01)**	**54.61 (47.62)**	**49.35 (44.61)**	**56.82**
T7	Lambda cyhalothrin	0.5 ml/l	**3.15 (2.03)**	**80.20 (63.59)**	**94.08 (76.45)**	**89.16 (70.78)**	**81.21 (64.31)**	**86.16**
T8	Untreated control	---	**37.24 (6.18)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	
	SE ±		**0.034**	**0.78**	**1.21**	**0.61**	**0.69**	
	CD @ 5%		**0.104**	**2.39**	**3.72**	**1.86**	**2.10**	
	CV %		**1.91**	**2.52**	**3.75**	**1.92**	**2.27**	

$ indicates figures in parentheses from this column are √n+1 transformed values

# indicates figures in parentheses from these columns are arc sin transformed values

DAS- Days After Spraying

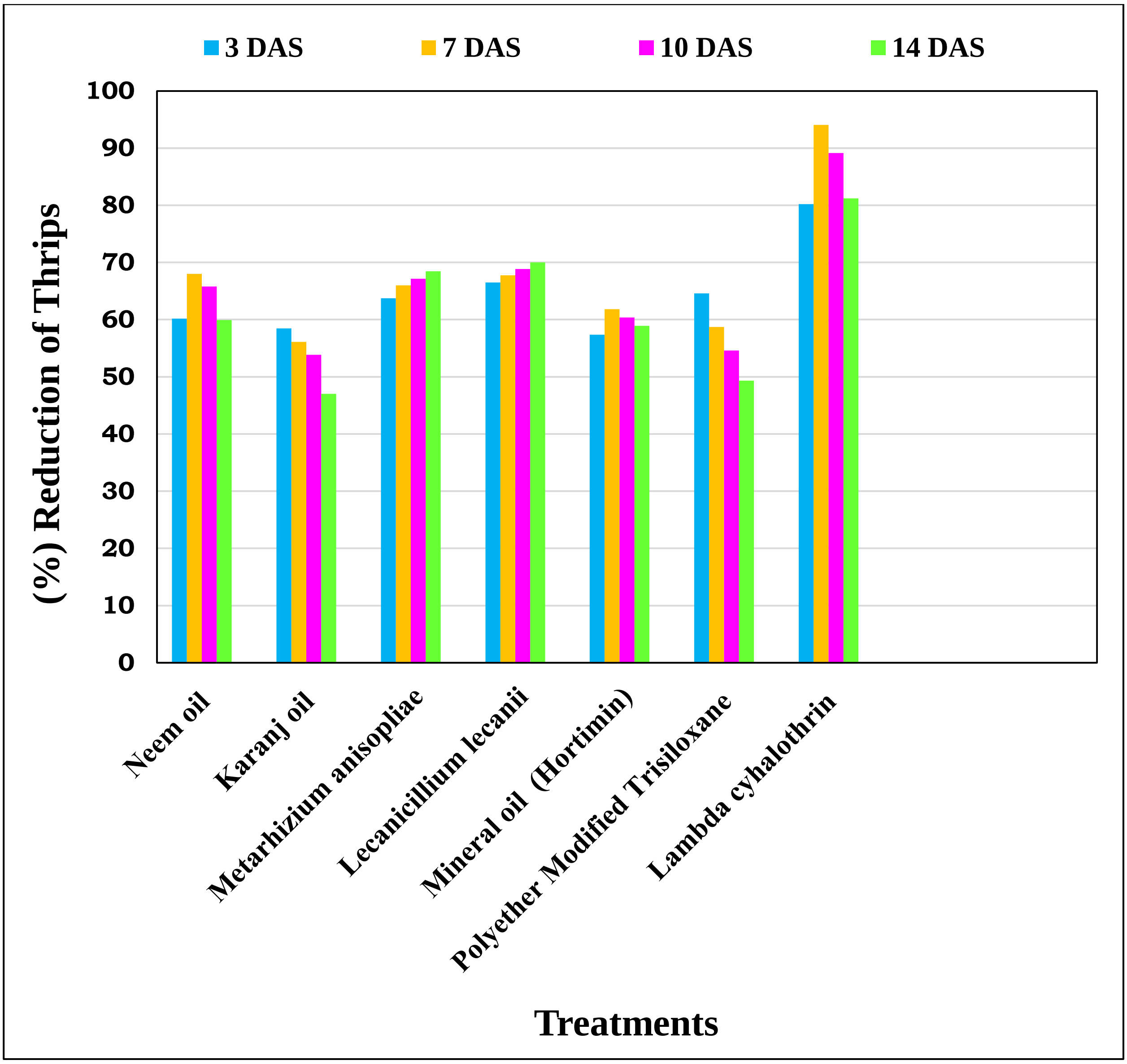

Fig. 4.6 Per cent Reduction of Thrips after Third Spray

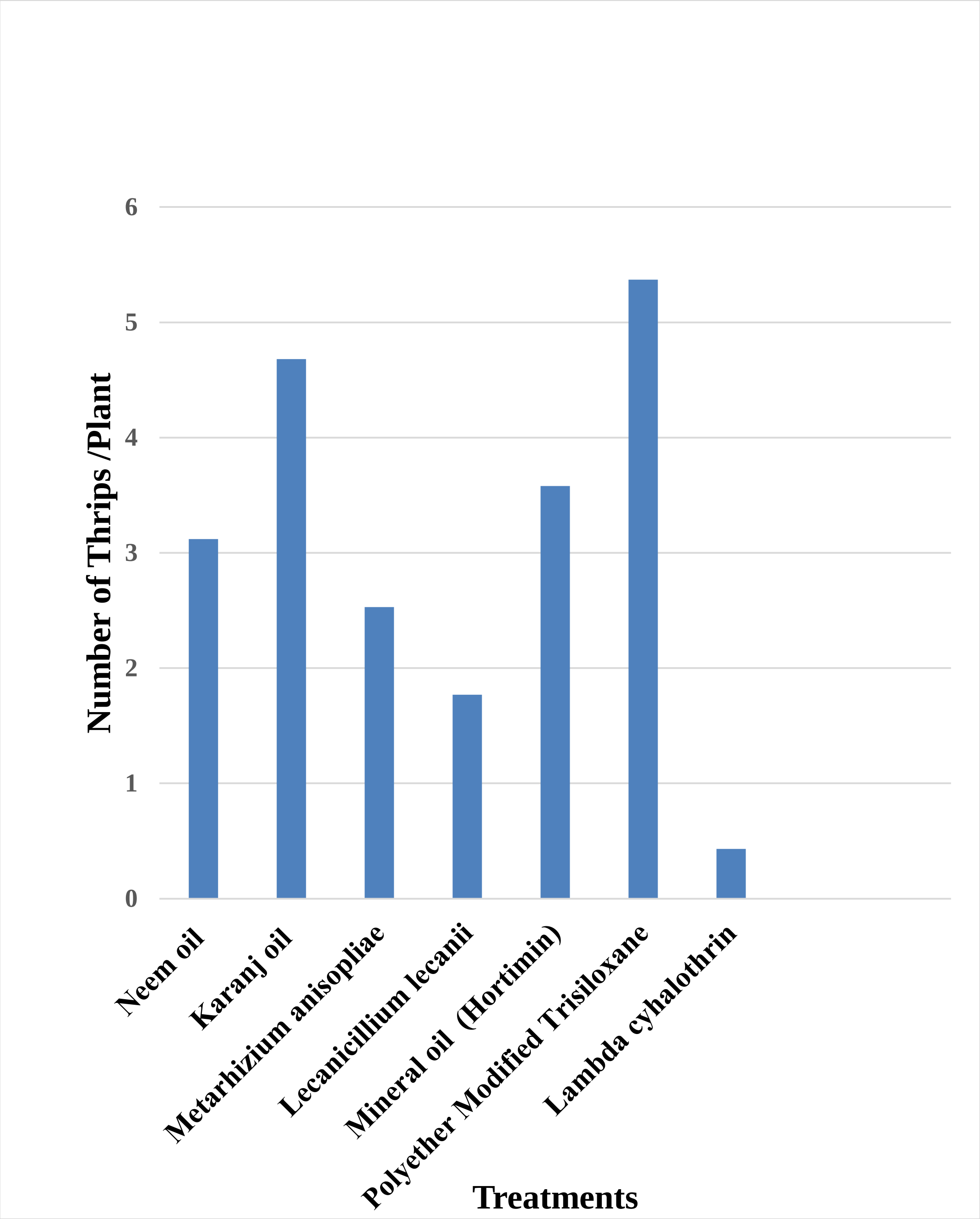

Fig. 4.7 Live Count of Thrips (*Thrips tabaci* L.) in Cucumber after Third Spray

however with 60.39 per cent reduction of thrips population hortimin @ 0.5 ml/l was superior over least effective treatments i.e. karanj oil formulation and polyether modified trisiloxane.

At 14 DAS, lamda cyhalothrin @ 0.5 ml/l was found to be the most effective with 81.21 per cent reduction in thrips population followed by *Lecanicillium lecanii* @ 4 g/l and *Metarhizium anisopliae* @ 4 g/l were second best and equally effective in reducing thrips with 70.01 and 68.45 per cent respectively. Neem oil formulation @ 1 ml/l (59.94%) and mineral oil hortimin @ 0.5 ml/l (58.94%) were on par with each other and third best treatment. karanj oil formulation @ 1 ml/l (47.02%) and polyether modified trisiloxane @ 0.25 ml/l (49.35%) were on par with each other and were the least effective.

Lambda cyhalothrin @ 0.5 ml/l was used as a standard check was found to be effective in suppression *Thrips tabaci* on cucumber which is in line with results noticed by Zahid *et al.* (2017) who tested lambda cyhalothrin against red pumpkin beetle in cucumber. Moreover, similar results of lambda cyhalothrin against thrips were reported by Patra *et al.* (2015) and Fitiwy *et al*. (2015) in chilli and onion, respectively which conforms the present results.

The myco-insecticides *Lecanicillium lecanii and Metarhizium anisopliae* @ 4 g/l were the best bio-intensive option for the suppression of thrips in cucumber under polyhouse conditions. Thungrabeab *et al.* (2006a) successfully controlled thrips population in cucumber by using *L. lecanii* and *M. anisopliae* which is in conformity of the current results. In addition, the results of mycoinsecticides in the present experiment were in conformity with the results of Azaizeh *et al.* (2003), Chaudhari *et al.* (2017) and Sayed (2013) in cucumber under polyhouse, shade net and field condition, respectively. Arthurs *et al.* (2013) and Annamalai *et al.* (2013) reported the successful suppression of thrips with *Lecanicillium lecanii and Metarhizium anisopliae* formulation in chilli and onion, respectively. It was observed in the present research that there was increase in reduction percentage of the pest through improved pathogenicity at successive sprays which may be due to the cumulative effect of fungal pathogen.

The botanical oil such as neem oil @ 1 ml/l also found similar effect as like myco-insecticides and superior than mineral oils. Sabir *et al.*, (2011) and Chaudhari *et al.*, (2017) found neem oil as essential component of IPM against thrips in cucumber under protected conditions which is in accordance with the present results of neem oil aganist thrips in cucumber. Further, Mandi and Senapati (2009), Mandal *et al.* (2006), Faiz *et al.* (2012) achieved successful management of thrips and okra jassid by the application of neem oil in the field condition are in conformity with present findings. Also, Patil *et al.* (2010), Ahmed and El-mogy (2011) and Krishnamoorthy *et al.* (2013) were reported the neem oil as a economical option in onion crop against thrips. The mineral oil (Hortimin) @ 0.5 ml/l was found successful in reduction of thrips. These findings are in line with the results of the experiments conducted by

Table 4.8 Bioefficacy Pooled data of three sprays:

Treatment No.	Treatment details	Dose	Pre-Count thrips/3 leaves/ Plant $	Per cent reduction of thrips at			
				3 DAS #	7 DAS #	10 DAS #	14 DAS #
T1	Neem oil formulation	1 ml/l	**21.03 (4.69)**	**57.44 (49.25)**	**64.70 (53.53)**	**61.44 (51.59)**	**54.40 (47.50)**
T2	Karanj oil formulation	1 ml/l	**19.92 (4.57**	**56.03 (48.44)**	**56.79 (48.88)**	**50.12 (45.05)**	**44.13 (41.61)**
T3	*Metarhizium anisopliae*	4 g/l	**20.49 (4.63)**	**43.86 (41.45)**	**47.51 (43.55)**	**55.65 (48.22)**	**60.38 (50.97)**
T4	*Lecanicillium lecanii*	4 g/l	**18.32 (4.39)**	**45.86 (42.61)**	**50.04 (45.00)**	**57.30 (49.18)**	**62.36 (52.13)**
T5	Mineral oil (Hortimin)	0.5 ml/l	**19.65 (4.54)**	**60.23 (50.88)**	**60.39 (50.98)**	**56.07 (48.46)**	**51.22 (45.67)**
T6	Polyether Modified Trisiloxane (Break-Thru)	0.25ml/l	**23.55 (4.95)**	**61.68 (51.73)**	**55.62 (48.21)**	**51.98 (46.11)**	**46.80 (43.14)**
T7	Lambda cyhalothrin	0.5 ml/l	**16.96 (4.23)**	**76.92 (61.26)**	**86.17 (68.14)**	**82.55 (65.28)**	**74.42 (59.59)**
T8	Untreated control	---	**22.87 (4.88)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**	**0.00 (0.57)**
	SE ±		**0.04**	**0.29**	**0.48**	**0.26**	**0.42**
	CD @ 5%		**0.13**	**0.90**	**1.47**	**0.80**	**1.30**
	CV %		**1.63**	**1.03**	**1.63**	**0.90**	**1.51**

$ indicates figures in parentheses from this column are √n+1 transformed values

# indicates figures in parentheses from these columns are arc sin transformed values

DAS- Days After Spraying

Egho and Emosairue (2010) where they found mineral oil as a effective eco-friendly option for the control of legume bud thrips. whereas, it was less effective option than neem oil in controlling thrips in cucumber which is in line with the results of Chaudhari *et al.* (2017). The least effective treatment among the bio-rationales was karanj oil in the present research, which is confirmed by the results of Singh *et al.* (2014) who reported the karanj oil as a least effective in reducing thrips population among all botanicals. In Neem oil treatment, thrips reduction was increasing up to 7 days after that it was started decreasing which may be out of decreasing repellency due to degradation on the plant more or less similar trend was there in mineral oil.

Use of surfactant polyether modified trisiloxane @ 0.25 ml/l also found one of the ecofriendly option for the thrips control which is more or less equal in efficacy percentage with mineral oil (Hortimin). Surfactants mainly act as a physical poison as well as they might be affecting physiological activity of the insect pests. These methylated silicones are considered inert ingredients, but their superior surfactant properties allow them to wet, and either suffocate or disrupt important physiological processes in mites and insects. These results are in support of current results. The mortality due to the use of silicon based surfactant in the present study is confirmed by the work carried out by Mascarin *et al.* (2014), Tipping *et al.* (2003) and Ganchev and Atanasova (2018). They reported mortality of thrips (98.5%), whitefly (72-74%), aphid (93.8%) and 100 per cent mortality of crawlers of mealy bug. Chaudhari *et al.* (2017) reported 57.84 per cent average reduction of thrips in cucumber under shade net condition which also in conformity with the current findings.

4.2.4 Cumulative result after three sprays:

The treatment with lamda cyhalothrin @ 0.5 ml/l was found to be superior at all interval of observations in controlling the thrips in cucumber under polyhouse condition. The trisiloxane @ 0.25 ml/l was found to be unconventional option in controlling thrips equal in its efficacy to Hortimin @ 0.5ml/l at first interval of observation but reduction in Trisiloxne start declining 7 days after spraying (DAS) whereas Hortimin @ 0,5ml/l and Neem oil 1 ml/l were effecting till 10 DAS. However, Karanj oil @ 1 ml/ l was least effective in reducing thrips amongst all ecofriendly options under test.

The bio-intensive treatments with by *Lecanicillium lecanii* and *Metarhizium anisopliae* @ 4 g/l were next best to standard check of lamda cyhalothrin at 14 DAS with 62.36 and 60.38 per cent reduction of thrips which indicates that myco-insecticides have taken their time for mycosis in first 7 to 10 days and actual reduction was observed in last interval of observation. It was also noticed that the per cent reduction was gradually increase as the number of sprays progressed it is due to the cumulative effect of fungal pathogen in plot. Thus, both myco-insecticides *Lecanicillium lecanii and Metarhizium anisopliae* @ 4 g/l were proved the best bio-intensive option for the suppression of thrips in cucumber under polyhouse conditions. Thungrabeab *et al.,* (2006) successfully controlled thrips population in cucumber by using *L. lecanii* and *M. anisopliae.* Azaizeh *et al.,* (2002), Chaudhari *et al.,* (2017) and Sayed (2013) in cucumber under polyhouse, shade net and field condition, respectively.

Use of surfactant polyether modified trisiloxane @ 0.25 ml/l also found one of the ecofriendly option for the thrips control which is more or less equal in efficacy percentage with mineral oil (Hortimin). Surfactants mainly act as a physical poison as well as they might be affecting physiological activity of the insect pests. These methylated silicones are considered inert ingredients, but their superior surfactant properties allow them to wet, and either suffocate or disrupt important physiological processes in mites and insects. These results are in support of current results. The mortality due to the use of silicon based surfactant in the present study is confirmed by the work carried out by Mascarin *et al.,* (2014), and Ganchev and Atanasova (2018)

The botanical oil such as neem oil @ 1 ml/l also found to be more or less similar effect as like myco-insecticides and superior than mineral oils. Sabir *et al.,* (2011) and Chaudhari *et al.,* (2017) found neem oil as essential component of IPM against thrips in cucumber under protected conditions which is in accordance with the present results of neem oil aganist thrips in cucumber. The mineral oil (Hortimin) @ 0.5 ml/l found to be successful in reduction of thrips. Egho and Emosairue (2010) found mineral oil as a effective eco-friendly option for the control of legume bud thrips. Whereas, it was less effective option than neem oil in controlling thrips in cucumber which conforms the present results. However, the least effective treatment among the bio-rationales was karanj oil in the present research, which is confirmed by the results of Singh *et al.,* (2014) who reported the karanj oil as a least effective in reducing thrips population among all botanicals.

4.3 Study of Impact of Treatments on Yield of Cucumber:

The data on the yield (t/ha) with respect to treatments is presented in Table 4.8 and depicted in Fig. 4.8. The yield of twelve pickings in cucumber were recorded from each plot in kg/plot and converted to tone/ha. Lamda cyhalothrin @ 0.5 ml/l recorded significantly highest yield of cucumber (23.81 t/ha) followed by neem oil formulation @ 1 ml/l (20.33 t/ha) which is at par with *Lecanicillium lecanii* @ 4 g/l (18.67 t/ha). Remaining treatments were statistically similar in recording yield which was in range of 18.00 to 17.33 t/ha except treatment with karanj oil formulation @ 1 ml/l and untreated control. Thus *Metarhizium anisopliae* @ 4 g/l (18.00 t/ha) was third best yield obtained, which was at par with, polyether modified trisiloxane @ 0.25 ml/l and mineral oil hortimin @ 0.5 ml/l with yield trend 17.66 and 17.33 t/ha respectively. Untreated control recorded inferior yield (13.40 t/ha) among all treatments followed by karanj oil formulation @ 1 ml/l (16.10 t/ha).

Patra *et al.* (2015) reported lambda cyhalothrin as effective in controlling option for thrips in chilli and recorded highest yield while the high gross monitory returns in onion were achieved through controlling thrips with *L. lecanii* by Patil *et al.* (2010). Similarly, Arthurs *et al.* (2013) revealed that proportion of marketable fruit yield was significantly increased by *M. brunneum* in chilli by controlling thrips. Bemisile *et al.* (2018) also reported that *M. anisopliae* can be good plant yield promoter aside from the pest management and Mandal *et al.* (2006) and Ahmed and El-mogy (2011) found higher yield and maximum cost benefit ratio from neem oil treatment in okra and onion respectively. These reports are in support of present results.

Table 4.9 Yield of Cucumber With Respect to Treatments

Treatment No.	**Treatment**	**Dose**	**Yield (t/ ha)**
T_1	Neem oil formulation	1 ml/l	20.33
T_2	Karanj oil formulation	1 ml/l	16.10
T_3	*Metarhizium anisopliae*	4 g/l	18.00
T_4	*Lecanicillium lecanii*	4 g/l	18.67
T_5	Mineral oil (Hortimin)	0.5 ml/l	17.33
T_6	Polyether Modified Trisiloxane (Break-Thru)	0.25 ml/l	17.66
T_7	Lambda cyhalothrin	0.5 ml/l	23.81
T_8	Untreated control	---	13.40
	SE ±		0.62
	CD @ 5%		1.86
	CV %		5.87

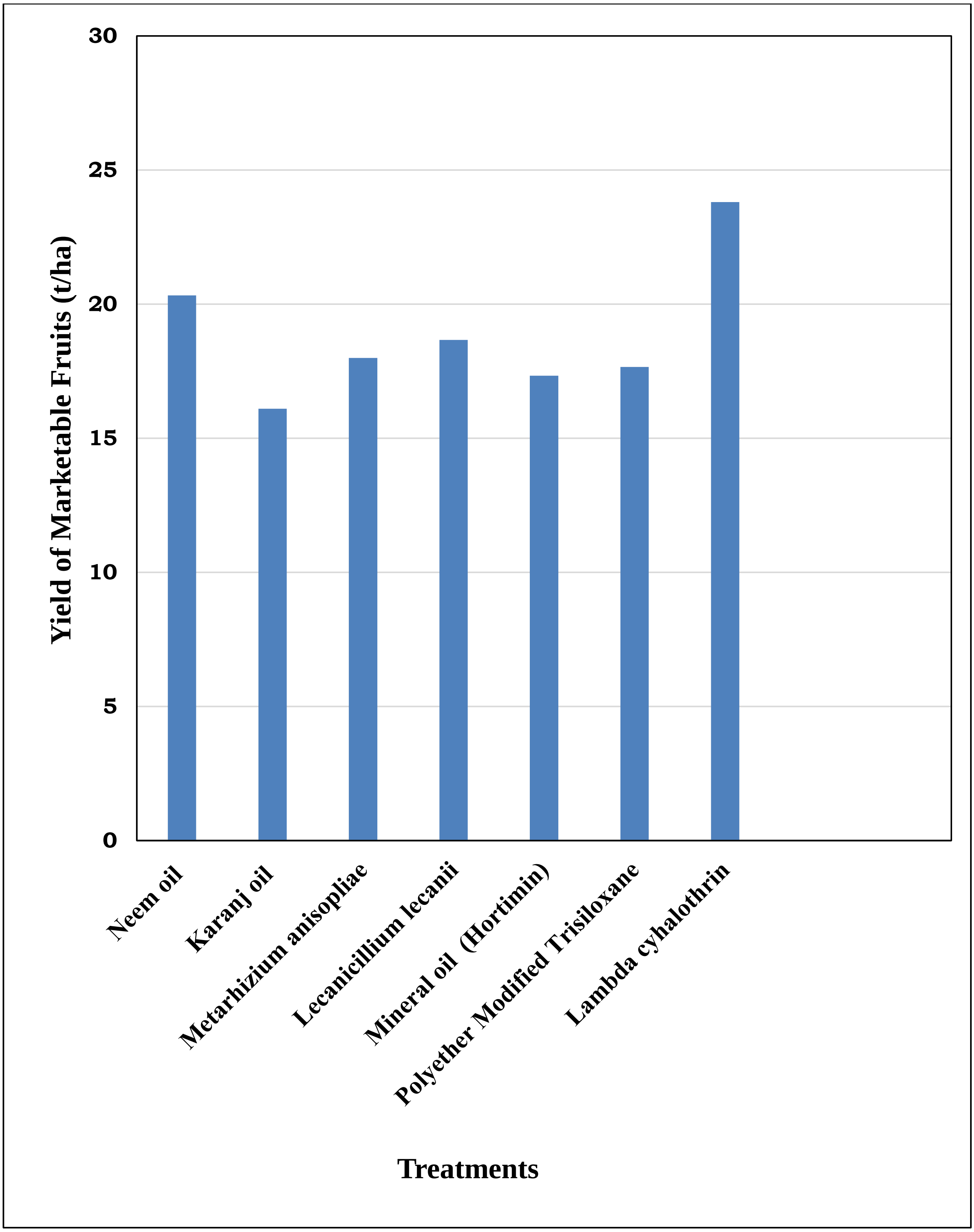

Fig. 4.8 Yield of Cucumber with Respect to Treatments

5. SUMMARY AND CONCLUSION

5.1 Summary:

The experiment was conducted on bio-rational management of thrips in cucumber under polyhouse condition at Hi-tech Floriculture and Vegetable Project, College of Agriculture, Pune in the year 2018-19. Seven bio-rational approaches were evaluated to manage the thrips, *Thrips tabaci* (Lindeman) in cucumber under polyhouse condition in *Rabi* season. Seasonal incidence of thrips were evaluated and three sprays were applied to access efficacy along with its impact on yield of cucumber were studied.

5.1.1 Seasonal Incidence of Thrips (*Thrips tabaci* L.) on Cucumber under Polyhouse Condition:

Overall results indicated that thrips population was observed highest during 43rd standard meteorological week (50.06 thrips/ 3 leaves/ plant) and lowest during 1st standard meteorological week (25.86 thrips/ 3 leaves/ plant), which indicates that hot and dry atmospheric conditions favoured the multiplication of thrips under polyhouse conditions. The correlation study revealed that there was positive correlation of thrips population with temperature and negative correlation with relative humidity. Further, regression studies about thrips incidence showed that among the linear and non-linear regression equations, cubic equation showed better precision of thrips incidence (90%) than other equations.

5.1.2 Bio-rational Management of Thrips (*Thrips tabaci* L.) on Cucumber under Polyhouse Condition:

Studies about bioefficacy indicated that average reduction of thrips after third spray revealed highest reduction of 86.16 per cent in treatment with lambda cyhalothrin @ 0.5 ml/l among all treatments, which showed that it was superior over all treatments.

Among the treatments with entomopathogenic fungi, the treatment with *Lecanicillium lecanii* @ 4 g/l and *Metarhizium anisopliae* @ 4 g/l were least effective among the all treatments after first spray, after which it showed cumulative trend of thrips population reduction at the end of experimentation (14 DAS), in which they recorded highest of 70.01 and 68.45 per cent respectively. Both these treatments were at par with each other after all sprays which indicates the equality in efficacy of these treatments.

Oils such as neem oil @ 1 ml/l showed better thrips population reduction at 7 and 10 DAS with average thrips population reduction 63.48 per cent and it was also at par with treatments *Lecanicillium lecanii* @ 4 g/l and *Metarhizium anisopliae* @ 4 g/l at 7 and 10 DAS after third spray. Treatment with karanj oil @ 1 ml/l was least effective treatment among all treatment at the end of experimentation with average 53.86 per cent reduction of thrips population.

Mineral oils, hortimin @ 0.5 ml/l and trisiloxane @ 0.25 ml/l were at par with each other at 3 DAS after first two sprays. After which, trisiloxane @ 0.25 ml/l was at par with *Lecanicillium lecanii* @ 4 g/l and *Metarhizium anisopliae* @ 4 g/l at 3 DAS (64.58%) after third spray, showing that it is effective till 3 DAS. Hortimin @ 0.5 ml/l showed better results till 7 DAS after each spray with average thrips population reduction of 59.62 per cent at the end of experimentation.

5.1.3 Effect of Treatments on Yield of Cucumber:

Studies on effect of treatments on yield of cucumber showed that treatment with lamda cyhalothrin @ 0.5 ml/l given the best yield (23.81 t/ha) followed by neem oil @ 1 ml/l and *Lecanicillium lecanii* @ 4 g/l, which were at par with each other with yield 20.33 and 18.67 t/ha respectively. While karanj oil @ 1 ml/l given lower yield (16.10 t/ha) among other treatments.

5.2 Conclusion:

1. The incidence of thrips was highest in the cucumber under polyhouse conditions during the 43rd standard meteorological week (50.06 thrips/3 leaves/plant), whereas it was minimum in 1st standard meteorological week (25.86 thrips/3 leaves/plant).
2. There was a significant positive correlation between temperature and thrips population. Whereas humidity was negatively correlated. Out of Linear and non-linear regression equations work out from the data revealed that cubic non-linear equation could give 90 per cent precision which could help the farmer in early prediction of thrips incidence in polyhouse.
3. Among the bio-rational components of pest management entomopathogenic fungi, *Lecanicillium lecanii and Metarhizium anisopliae* @ 4 g/l proved to be effective, having gradual cumulative reduction after the application of consecutive sprays.
4. Among the oils, neem oil (botanical) @ 1 ml/l and hortimin (mineral oil) @ 0.5 ml/l were the second best bio rational components.
5. The treatment with lambda cyhalothrin @ 0.5 ml/l (standard check) was significantly superior in suppressing the pest and recording the yield (23.81 t/ha) as well. However the highest yield of 20.33 t/ha was recorded in neem oil @ 1 ml/l followed by *Lecanicillium lecanii* @ 4 g/l (18.67 t/ha) among the non-chemical treatments.

6. LITERATURE CITED

Ahmed, S. S. and El-mogy, M. M. 2011. Field evaluation of some biological formulations against *Thrips tabaci* (Thysanoptera: Thripidae) in onion. *World App. Sci. J.,* **14**(1): 51-58.

Alasady, S. M. and Al-Ghadban, Z. A. M. 2018. New recorded of thrips species and seasonal fluctuation of some thrips on cucumber in the field during the Autumn season in Iraq. *J. Bio. and Env. Sci.,* **12**(2): 109-116.

Alavo, T. B. C. 2015. The insect pathogenic fungus *Verticillium lecanii (zimm.) viegas* and its use for pests control: A review. *J. of Expt. Biol. and Agric. Sci.,* **3**(4): 337-345.

Alavo, T. B. C. and Accodji, M. 2004. The entomopathogenic fungus *Verticillium lecanii* (Deuteromycetes, Moniliaceae). The protein hydrophobins and the biological control of aphids (Homoptera: Aphididae). *Arch. Phytopathol. plant protect.,* **37**(3): 201-204.

Aliakbarpour, H., Salmah, M. R. C. and Dzolkhifli, O. 2011. Efficacy of neem oil against thrips (Thysanoptera) on mango panicles and its compatibility with mango pollinators. *J. Pest Sci*., **84**(4): 503-512.

Annamalai, M., Kaushik, H. D. and Selvaraj, K. 2013. Pathogenicity of *Beauveria bassiana* (Balsamo) Vuillemin and *Lecanicillium lecanii* Zimmerman against Onion Thrips, *Thrips tabaci* Lindeman. *Biopestic. Int.,* **9**(2): 148–156.

Annamalai, M., kaushik, H. D. and Selvaraj, K. 2016. Bioefficacy of *Beauveria bassiana* (Balsamo) Vuillemin and *Lecanicillium lecanii* Zimmerman against *Thrips tabaci* Lindeman. *Nat. Acad. Biol. Sci.,* **86**(2): 505-511.

Anonymous, 2017a. Horticultural Statistics at a Glance, 2017, Published by Ministry of Agriculture and farm welfare, Government of India, pp: 303.

Anonymous, 2017b. Horticultural Statistics at a Glance, 2017, Published by Ministry of Agriculture and farm welfare, Government of India, pp: 10,13.

Anonymous, 2017c. Review Committee meeting to finalise second advance estimates of area and production figures of horticultural crops, Horticultural statistics, Government of India, pp: 01-06.

Arthurs, S. P., Aristizabal, L. F., Avery, P. B. 2013. Evaluation of entomopathogenic fungi against chilli thrips, *Scirtothrips dorsalis. J. of Insect Sci.,* **13**(31): 1-16.

Azaizeh, H., Gindin, G., Said, O. and Barash, I. 2002. Biological control of the Western flower thrips *Frankliniella occidentalis* in cucumber using the entomopathogenic fungus *Metarhizium anisopliae. Phytoparasitica,* **30**(1): 18-24.

Bemisile, B. S., Dash, C. K., Akutse, K. S., Keppanan, R. and Wang, L. 2018. Fungal Endophytes: Beyond Herbivore Management. *Front. Microbiol*., **9**(1): 544-568.

Barot, B. V., Patel, J. J. and Shaikh, A. A. 2012. Population dynamics of chilli thrips, *Scirtothrips dorsalis* Hood in relation to weather parameters. *AGRES – An Int. e-Journal,* **1**(4): 480-485.

Bergant, K., Trdan, S., Znidarcic, D., Crepinsek, Z. and Bogataj, L. K. 2005. Impact of climate change on developmental dynamics of *Thrips tabaci* (Thysanoptera: Thripidae): Can it be quantified? *Environ. Entomol.,* **34**(4): 755-766.

Bernardi, D., Botton, M., Cunha, U. S., Bernardi, O., Malausa, T., Garcia, M. S. and Nava, D. E. 2013. Effects of azadirachtin on *Tetranychus urticae* (Acari: Tetranychidae) and its compatibility with predatorymites (Acari: Phytoseiidae) on strawberry. *Pest Manag. Sci.,* **69**(1): 75–80.

Birhade, D. P., Kabre, G. B. and Khating, S. S. 2017. Seasonal incidence of thrips (*Thrips tabaci*, Lind.) on onion in Khandesh region of Maharashtra. *Int. J. of Plant Protec.*, **10**(1): 203-205.

Boll, R., Marchal, C. C., Poncet, C. and Lapchin, L. 2007. Rapid Visual Estimates of Thrips (Thysanoptera: Thripidae) Densities on Cucumber and Rose Crops. *J. Econ. Entomol.*, **100**(1): 225-232.

Bukero, A., Talpur, M. A., Rais, M. N., Lanjar, A. G., Arain, I. and Nahiyoon, S. A. 2015. Activity of thrips and their natural enemies on rose. *Sci. Int.*, **27**(4): 3293-3296.

Chandra, M. and Rana, K. S. 2014. Seasonal population fluctuation of *Thrips tabaci* and *Scirtothrips dorsalis* (Thysanoptera: Thripidae) in western Uttar Pradesh. *Bull. Env. Pharmacol. life sci*., **3**(3): 135-140.

Chaudhari, C. S., Dhane, A. S., Yadav, J. P., Gangurde, A. B. and Kharbade, S. B. 2017. Investigation of bio-rational insecticides for the management of thrips in shade net conditions. *Progressive research*, **12**(3): 410-411.

Chavan, B. P., Kadam, J. R. and Saindane, Y. S. 2008. Bioefficacy of liquid formulation of *Verticillium lecanii* against red spider mite (*Tetranychus cinnabarinus*). *Internat. J. Plant Protec.*, **1**(2): 48-51.

Cloyd, R. A. 2009. Western flower thrips (*Frankliniella occidentalis*) management on ornamental crops grown in greenhouses: Have we reached an impasse? *Pest tech.,* **3**(1): 1-9.

Dharmatti, P. R. and Beeraganni, K. M. 2013. Seasonal abundance of onion thrips, *Thrips tabaci* Lindeman. *Internat. J. Plant Protec.*, **6**(2): 428-431.

Dhillon, N. S., Sharma, P., Kumar, P. and Singh, H. 2017. Influence of Training on Vegetative Growth Characteristics and Yield of Polyhouse Grown Cucumber (*Cucumis sativus* L.) *J. of Expt. Agric. Int.*, **18**(1): 1-5.

Egho, E. O. and Emosairue, S. O. 2010. Field evaluation of mineral oils for insect pests management and yield of cowpea (*Vigna unguiculata*) (L) walp in Abraka, Southern Nigeria. *Arch. Appl. Sci. Res.*, **2**(4): 57-67.

El-Sheikh, M. F. 2017. Effectiveness of *Beauveria bassiana* (Bals.) Vuill. and *Metarhizium anisopliae* (Metsch.) (Deuteromycotina: Hyphomycetes) as biological control agents of the onion thrips, *Thrips tabaci* Lind. *J. Plant Prot. and Path.*, **8**(7): 319 – 323.

Faiz, M., Hameed, A., Hasan, M. and Wakil, W. 2012. Efficacy of plant extracts on some cotton (*Gossypium hirsutum*) pests: *Amrasca bigutulla bigutulla* Ishida and *Thrips tabaci* Lindeman. *Pakistan J. Zool.*, **44**(1): 277-283.

Fitiwy, I., Gebretsadkan, A. and Ayimut, K. M. 2015. Evaluation of botanicals for onion thrips, *Thrips tabaci* Lindeman, (Thysanoptera: Thripidae) control at Gum Selassa, South Tigray, Ethiopia. *Momona Ethiopian J. of Sci. (MEJS),* **7**(1): 32-45.

Ganchev, D. and Atanasova, D. 2018. Insecticidal action of silwet L-77 towards some aphid species. *Plovdiv Scientific Works,* **61**(2): 153-159.

Guncan, A., Madanlar, N., Yoldas, Z., Ersin, F. and Tuzel, Y. 2006. Pest status of organic cucumber production under greenhouse conditions in Izmir (Turkey). *Turk. entomol. derg.,* 2006, **30**(3): 183-193.

Gundappa, Adak, T. and Shukla, P. K. 2016. Appraisal of thrips population dynamics in mango using weather based indices. *Vegetos,* **29**(3): 138-145.

Hao, X., Shipp, J. L., Wang, K., Papadopoulos, A. P. and Binns, M. R. 2002. Impact of western flower thrips on growth, photosynthesis and productivity of greenhouse cucumber. *Scientia Hortic.*, **92**(1): 187–203.

Henderson, C. F. and Tilton, E. W. 1955. Tests with acaricides against the brown wheat mite. *J. Econ. Entomol*., **48**(1): 157-161.

Ibrahim, N. D. and Adesiyun, A. A. 2010. Seasonal Abundance of Onion thrips, *Thrips tabaci* Lindeman in Sokoto, Nigeria. *J. Agric. Sci.*, **2**(1): 107-114.

Jarosik, V., Kolias, M., Lapchin, L., Rochat, J. and Dixon, A. F. G. 1997. Seasonal trends in the rate of population increase of *Frankliniella occidentalis* (Thysanoptera: Thripidae) on cucumber. *Bull. of Entomol. Res.*, **87**(1): 487–495.

Kadri, S. and Goud, K. B. 2005. Estimation of yield loss in onion due to onion thrips, *Thrips tabaci* Lindeman. *Karnataka J. Agri. Sci*., **18**(2): 513-514.

Kaur, S., Kaur, S., Srinivasan, R., Cheema, D. S., Lal, T., Ghai, T. R. and Chadha, M. L. 2010. Monitoring of major pests on cucumber, sweet pepper and tomato under net-house conditions in punjab, india. *Pest Mang. in Hortic. Ecosys*., **16**(2): 148-155.

Kaur, S., Kular, J. S. and Chandi, R. S. 2017. Effect of temperature on growth and development of *Thrips tabaci* Lindeman in *Bt* cotton. *Int. J. Curr. Microbiol. App. Sci.,* **6**(5): 2553-2560.

Khan, S., Guo, L., Shi, H. X., Mijit, M. and Qiu, D. 2012. Bioassay and enzymatic comparison of six entomopathogenic fungal isolates for virulence or toxicity against green peach aphids *Myzus persicae. Afr. J. Biotechnol.*, **11**(77): 14193-14203.

Khoso, M., Marri, J. M., Khoso, F. N., Solangi, B. K., Ahmed, A. M., Iftikhar, Y., Ali, A., Hajano, J. D., Ahmed, M., Chand, K. and Rehman, T. 2017. Assessment of botanical insecticides against onion thrips, *Thrips tabaci* (L.) (Thysanoptera: Thripidae). *J. of Entomol. and Zool. Studies,* **5**(6): 572-575.

Koul, O., Walia, S. and Dhaliwal, G. S. 2008. Essential Oils as Green Pesticides: Potential and Constraints. *Biopestic. Internat.*, **4**(1): 63–84.

Krishnamoorthy, P. N., Shivaramu, K., Krishnakumar, N. K., Ranganath, H. R. and Saroja, S. 2013. Comparative efficacy of neem products, essential oils and synthetic insecticides for the management of onion thrips, *Thrips tabaci* Lindeman. *Pest Mang. Horti. Ecosys.*, **19**(1): 23-26.

Kumawat, K., Jat, B. L. and Kumawat, R. 2018. Seasonal incidence of thrips, *Thrips tabaci* on onion. *J. of Entomol. and Zool. Studies,* **6**(3): 1047-1049.

Laila, K., Shah, M. and Usman, A. 2015. Host Preference of Red Pumpkin Beetle (*Aulacophora faveicollis)* Lucas (Chrysomelidae: Coleoptera) among different Cucurbits. *J. of Entomol. and Zool. Studies*, **3**(2): 100-104.

Lall, B. S. and Singh, L. M. 1968. Biology and control of the onion thrips in India. *J. Econ. Entomol*., **61**(3): 676-679.

MacLeod, A., Head, J. and Gaunt, A. 2004. An assessment of the potential economic impact of Thrips palmi on horticulture in England and the significance of a successful eradication campaign. *Crop Protec.,* **23**(1): 601–610.

Maklad, A. M. H., Abolmaaty, S. M., Hassanein, M. K. and El-Ghafar, N. Y. A. 2012. Impact of Type of Greenhouse Cover Sheets on Certain Major Cucumber Pests under Protected Cultivation. *New York Sci. J.*, **5**(7): 19-24.

Mandal, S. K., Sah, S. B. and Gupta, S. C. 2006. Neem-based integrated management approaches for insect pests okra (*Abelmoschus esculentus* L. Moench.). *Internat. J. Agric. Sci.*, **2**(2): 499-502.

Mandi, N. and Senapati, A. K. 2009. Integration of chemical botanical and microbial insecticides for control of thrips, *Scirtothrips dorsalis* Hood infesting chilli. *The J. of Plant Protec. Sci.*, **1**(1): 92-95.

Mascarin, G. M., Kobori, N. N., Quintela, E. D., Arthurs, S. P. and Junior, I. D. 2014. Toxicity of non-ionic surfactants and interactions with fungal entomopathogens toward *Bemisia tabaci* biotype B. *Bio Control.*, **59**(1): 111-123.

Meyling, N. V. and Eilenberg, J. 2007. Ecology of the entomopathogenic fungi Beauveria bassiana and Metarhizium anisopliae in temperate agroecosystems: Potential for conservation biological control. *Biol. Control*, **43**(1): 145–155.

Murai, T. 2000. Effect of temperature on development and reproduction of onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) on pollen and honey solution. *Appl. Entomol. Zool.,* **35**(4): 499-504.

Murphy, G., Ferguson, G. and Shipp, L. 2014. Thrips in Greenhouse crops-Biology, Damage and Management. *OMAF Factsheet* **1**(1): 03-077.

Neergude, M., Birader, A. P., Veerendra, A. C. and Sathisha, R. 2014. Seasonal abundance of onion thrips, *Thrips tabaci* Lindeman and their natural enemies under dry land conditions. *Internat. J. Adv. Pharm. Biol. Chem.*, **3**(1): 33-36.

Panse, V. G. and Sukhatme, P. V. 1978. Statistical methods for agricultural workers: Indian council of agricultural research, New delhi. pp. 145-156.

Patel, B. H., Koshiya, D. J. and Korat, D. M. 2009. Population dynamics of chilli thrips, *Scirtothrips dorsalis* Hood in relation to weather parameters. *Karnataka J. Agric. Sci.*, **22**(1): 108-110.

Patil, S. D., Chandele, A. G., Wayal, C. B. and Game B. C. 2010. Efficacy of different newer chemicals and bio-insecticides against onion thrips in *kharif* season. *Internat. J. Plant Protec.,* **2**(2): 227-230.

Patra, B., Alam, S. K. F., Samanta, A. and Chatterjee, M. 2015. Bioefficacy of lambda cyhalothrin 4.9 CS against chilli thrips and fruit borers. *Int. Quarterly J. of Life Sci.*, **10**(3): 1367-1370.

Perdikis, D., Kapaxidi, E. and Papadoulis, G. 2008. Biological Control of Insect and Mite Pests in Greenhouse Solanaceous Crops. *The European J. Plant Sci. Biotechnol.,* **2**(1): 125-144.

Pinheiro, P. V., Quintela, E. D., Oliveira, J. P. and Seraphin, J. C. 2009. Toxicity of neem oil to *Bemisia tabaci* biotype B nymphs reared on dry bean. *Pesq. agropec. bras.*, **44**(4): 354-360.

Rabindra, R. J. and Ramanujam, B. 2007. Microbial control of sucking pests using entomopathogenic fungi. *J. Biol. Control,* **21**(1): 21-28.

Rajabpour, A., Seraj, A. A., Allahyari, H. and Shishehbor, P. 2011. Evaluation of *Orius laevigatus* Fiber (Heteroptera: Anthocoridae) for Biological Control of *Thrips tabaci*

Lindeman (Thysanoptera: Thripidae) on Greenhouse Cucumber in South of Iran. *Asian J. of Biol. Sci.,* **4**(1): 457-467.

Rathee, M., Singh, N. K., Dalal, P. K. and Mehra, S. 2018. Integrated pest management under protected cultivation. *J. of Entomol. and Zool. Studies,* **6**(2): 1201-1208.

Rosenheim, J. A., Welter, S. C., Johnson, M. W., Mau, R. F. L. and Gusukuma, M. L. R. 1990. Direct feeding damage on cucumber by mixed species infestation of *Thrips palmi* and *Frankliniella occidentalis* (Thysanoptera: Thripidae). *J. Econ. Entomol*., **83**(4): 1519-1525.

Rueda, A., Perez, F. R. B. and Shelton, A. M. 2007. Developing economic thresholds for onion thrips in Honduras. *Crop Protec.*, **26**(1): 1099–1107.

Sabir, N., Deka, S., Singh, B., Sumitha, R., Hasan, M., Kumar, M., Tanwar, R. K. and Bambawale, O. M. 2011. Integrated pest management for greenhouse cucumber: A validation under north Indian plains. *Indian J. Hort.*, **68**(3): 357-363.

Sayed, M. M. E. 2013. Evaluation of some bioinecticides against *Bemesia tabaci* (Genn.) and effect on yield component of cucumber. *Egypt. J. Agric. Res.*, **91**(3): 813-824.

Shiberu, T., and Mahammed, A. 2014. The Importance and Management Option of Onion thrips, *Thrips tabaci* (L.) (Thysanoptera: Thripidae) in Ethiopia. *J. Hortic.*, **1**(2): 102-107.

Shipp, J. L., Hao, X., Papadopoulos, A. P. and Binns, M. R. 1998. Impact of western flower thrips, (Thysanoptera: Thripidae) on growth, photosynthesis and productivity of greenhouse sweet pepper. *Scientia Hortic.*, **72**(1): 87–102.

Singh, D. K., Verma, T. C., Aswal, S. and Aswani, G. 2014. Effect of different botanical pesticides against *Thrips tabaci* on garlic crop. *Asian Agri-History*, **18**(1): 57-61.

Singh, M. C., Singh, J. P., Pandey, S. K., Mahay, D. and Shrivastva, V. 2017. Factors affecting the performance of greenhouse cucumber cultivation-a review. *Int. J. Curr. Microbiol. App. Sci.*, **6**(10): 2304-2323.

Sithanantham, S., Varatharajan, R., Ballal, C. R. and Visalakshy, P. N. G. 2007. Research status and scope for Biological control of sucking pest in India: Case study for Thrips. *J. Biol. control,* **21**(1): 1-19.

Sood, A. K. 2011. Integrated pest management under protected environment principles and practices. *Protec. Tech.*, **13**(1): 31-42.

Subba, B. and Ghosh, S. K. 2016. Population dynamics of thrips (*Thrips tabaci* L.) infesting tomato (*Lycopersicon esculentum* L.) and their sustainable management. *Int. J. of Agric. Sci. and Res. (IJASR),* **6**(3): 473-480.

Syed, T. S., Khanzada, M. S., Khanzada, S. R., Abro, G. H., Salman, M., Sarwar, M., Dayo, S. H., Anwar, S. and Su, W. 2016. Population dynamics of thrips, whiteflies and their natural enemies on mustard (*Brassica campestris* L.) Crop in different localities of Sindh, Pakistan. *J. of Entomol. and Zool. Studies*, **4**(1): 7-16.

Szalay, J. 2017. Cucumbers: Health Benefits & Nutrition Facts. *Live Science Contributor*, pp: 1-7.

Thungrabeab, M., Blaeser, P. and Sengonca, C. 2006a. Effect of temperature and host plant on the efficacy of different entomopathogenic fungi from Thailand against *Frankliniella occidentalis* (Pergande) and *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) in the laboratory. *J. of Plant Diseases and Protec.*, **113**(4): 181–187.

Thungrabeab, M., Blaeser, P. and Sengonca, C. 2006b. Possibilities for biocontrol of the onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) using different entomopathogenic fungi from Thailand. *Mitt. Dtsch. Ges. Allg. Angew. Ent.*, **15**(1): 299-307.

Tipping, C., Bikoba, V., Chander, G. J. and Mitcham, E. J. 2003. Efficacy of Silwet L-77 against several arthropod pests of table grapes. *J. Econ. Entomol.*, **96**(1): 246-250.

Tripathi, A. K., Upadhyaya, S., Mantu, B. and Bhattacharya, P. R. 2009. A review on prospects of essential oils as biopesticide in insect-pest management. *J. Pharmacognosy and Phytotherapy*, **1**(5):1-12.

Ullah, F., Mulk, M., Farid, A., Saeed, M. Q. and Sattar, S., 2010. Population dynamics and chemical control of onion thrips (*Thrips tabaci*, Lindeman). *Pakistan J. Zool.*, **42**(4): 401-406.

Vijayalakshmi, G., Ganapathy, N. and Kennedy, J. S. 2017. Influence of weather parameters on seasonal incidence of thrips and *Groundnut bud necrosis virus* (GBNV) in groundnut (*Arachis hypogea* L.). *J. of Entomol. and Zool. Studies*, **5**(3): 107-110.

Vinuthan, K. D, Rajashekharappa, K., Meghana, J. and Revannavar, R. 2018. Seasonal incidence of *Thrips tabaci* (Lind.) (Thysonoptera: Thripidae) on onion, *Allium cepa* (L.). *Int. J. Pure App. Biosci.*, **6**(6): 993-996.

Welter, S. C., Rosenheim, J. A., Johnson, M. W., Mau, R. F. L. and Minuto, L. R. G. 1990. Effects of *Thrips palmi* and western flower thrips (Thysanoptera: Thripidae) on the yield, growth and carbon allocation pattern in cucumbers. *J. Econ. EntomoI.*, **83**(5): 2092-2101.

Zahid, A. L., Rasool, S. and Batool, R. 2017. Effects of different synthetic and botanical pesticides against red pumpkin beetle under field conditions. *J. of Entomol. and Zool. Studies*, **5**(5): 1310-1314.

7. APPENDIX-I

Month	Meteorological Week	Date	Temperature (°C)		Relative Humidity (%)	
			Tmax	Tmin	RH-I (Morning)	RH-II (Evening)
September	37	10-09-18 to 15-09-18	31.7	19.5	88	54
	38	16-09-18 to 22-09-18	32.2	22.1	88	57
	39	23-09-18 to 29-09-18	34	22	94	55
October	40	30-09-18 to 06-10-18	34.2	23.2	88	47
	41	07-10-18 to 13-10-18	34.4	22.2	90	37
	42	14-10-18 to 20-10-18	35.1	23.3	89	31
	43	21-10-18 to 27-10-18	35	23.1	89	27
	44	28-10-18 to 03-11-18	33.7	20.2	83	35
November	45	04-11-18 to 10-11-18	34.9	19.4	93	36
	46	11-11-18 to 17-11-18	34	15.1	93	28
	47	18-11-18 to 24-11-18	33	18.3	87	42
	48	25-11-18 to 01-12-18	31.3	16.4	92	43
December	49	02-12-18 to 08-12-18	31.2	13.3	95	31
	50	09-12-18 to 15-12-18	30.4	14.2	91	37
	51	16-12-18 to 22-12-18	28.4	12.2	95	40
	52	23-12-18 to 29-12-18	27.8	12.1	93	32
January	1	30-12-18 to 05-01-19	26.3	10.7	93	24
	2	06-01-19 to 12-01-19	26	10.8	94	24

8. VITAE

Mr. PARAG DILIP BHOJANE

MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL ENTOMOLOGY

2019

Title of Thesis		:	Bio-rational management of thrips (*Thrips tabaci* Lindeman) infesting cucumber under polyhouse condition
Major Field		:	Agricultural Entomology
Biographical Information			
Personal	**Date of Birth**	:	30/04/1996
	Place of Birth	:	Mumbai, Maharashtra
	Father's Name	:	Mr. Dilip Bhojane
	Mother's Name	:	Mrs. Surekha Bhojane
Educational	**Bachelor Degree Obtained**	:	Bachelor of Science (Agriculture)
	Class	:	First class
	Name of University	:	Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra)
Address		:	Vill- Peth, Tah.- Ambegaon, Dist- Pune, Maharashtra
	Email- id	:	paragbhojane30@gmail.com
	Contact No.	:	8983559397/ 9518378568