

**STUDIES ON INSECTICIDE MANAGEMENT OF PESTS INFESTING  
POMEGRANATE (*Punica granatum* L.)**

by

**Konni Appala Raju**

(Reg. No. Ph.D. 017/32)

**DOCTOR OF PHILOSOPHY (AGRICULTURE)**



**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY**

**POST GRADUATE INSTITUTE**

**MAHATMA PHULE KRISHI VIDYAPEETH**

**RAHURI – 413 722, DIST-AHMEDNAGAR**

**MAHARASHTRA, INDIA**

2022

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A Thesis submitted to the  
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In partial fulfilment of the requirements for the degree  
of  
**DOCTOR OF PHILOSOPHY (AGRICULTURE)**  
in  
**AGRICULTURAL ENTOMOLOGY**



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APPROVED BY

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MAHARASHTRA, INDIA**

**2022**

## **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  
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Maharashtra, India.

## **CERTIFICATE**

This is to certify that the thesis entitled, “**STUDIES ON INSECTICIDE MANAGEMENT OF PESTS INFESTING POMEGRANATE (*Punica granatum L.*)**” 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 **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of piece of bonafide research work carried out by **KONNI APPALA RAJU** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

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Place : M.P.K.V., Rahuri

Date : / /

(P. N. Rasal)

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**(KONNI APPALA RAJU)**

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## LIST OF ABBREVIATIONS

a.i.	:	Active ingredient
ADI	:	Acceptable Daily Intake
BDL	:	Below Detection Limit
CD	:	Critical Difference
Cm	:	Centimetre
CRM	:	Certified Reference Material
Con.	:	Concentration
DAD	:	Diode Array Detector
DAS	:	Days After Spraying
EC	:	Emulsifiable Concentrate
ETL	:	Economic Threshold Level
<i>et al.</i>	:	<i>et alli</i> (and other)
etc.	:	Et cetera and so on
EU	:	European union
FAO	:	Food and Agriculture Organization
Fig.	:	Figures (s)
FSSAI	:	Food Safety and Standards Authority of India
g	:	Gram (s)
ha	:	Hectare (s)
HPLC	:	High Performance Liquid Chromatography
hr	:	Hour (s)
ICBR	:	Incremental Cost Benefit Ratio
i.e.	:	<i>id est</i> (that is)
IPM	:	Integrated Pest Management
kg	:	Kilogram (s)
lit./L	:	Litre (s)
LOD	:	Limit of Detection
LOQ	:	Limit of Quantification
Ltd.	:	Limited
MgSO <sub>4</sub>	:	Magnesium sulphate
M	:	Metre (s)

mg	:	Milligram (s)
Min	:	Minute (s)
ml	:	Milliliter (s)
mm	:	Millimeter (s)
MRL	:	Maximum Residue Limit
MT	:	Metric Tonne (s)
Na <sub>2</sub> SO <sub>4</sub>	:	Sodium sulphate
ND	:	Not Detected
nm	:	Nanometer (s)
PHI	:	Pre Harvest Interval
ppm	:	Parts Per Million
PSA	:	Primary Secondary Amine
Pvt.	:	Private
q/Q	:	Quintal (s)
QuEChERS	:	Quick Easy Cheap Effective Rugged Safe
R	:	Regression Coefficient
RL <sub>50</sub>	:	Residual Life 50
rpm	:	Revolutions per minute
Rs	:	Rupee (s)
RBD	:	Randomized Block Design
RSD	:	Relative Standard Deviation
RT	:	Retention Time
SC	:	Soluble Concentrate
SEM	:	Standard error of mean
SG	:	Soluble Granules
T	:	Tonne (s)
Tr.No.	:	Treatment Number
T <sub>1/2</sub>	:	Half life
µg	:	Microgram (s)
µl	:	Microlitre (s)
USA	:	United States of America
Viz.	:	Videlicet (Namely)
Vol.	:	Volume
Wt.	:	Weight

WHO	:	World Health Organization
-	:	Minus
>	:	Greater than
%	:	Per cent
@	:	At the rate of
+	:	Plus
±	:	Plus or minus
°C	:	Degree celcius

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**ABSTRACT**


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**STUDIES ON INSECTICIDE MANAGEMENT OF PESTS INFESTING  
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**KONNI APPALA RAJU**

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Mahatma Phule Krishi Vidyapeeth,

Rahuri - 413 722

2022

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<b>Research Guide</b>	:	Dr. C. S. Patil
<b>Department</b>	:	Agricultural Entomology

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Studies on insecticide management of pests infesting pomegranate (*Punica granatum* L.) were carried out during the year 2018-2020 at Mahatma Phule Krishi Vidyapeeth (19.3491° N, 74.6461° E), Rahuri, Maharashtra. The field experiments on bioefficacy and integrated pest management studies on pomegranate insect pests were conducted at AICRP on Arid Zone fruits, Department of Horticulture, M.P.K.V., Rahuri, Ahmednagar, Maharashtra.

Spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the most effective treatment by recording least population of aphids (3.31/shoot) with 83.49 % reduction over control. It was, however at par with the treatment fipronil @ 100 g a.i. ha<sup>-1</sup> (3.56 aphids/shoot & 82.22 % reduction over control) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (3.79 aphids/shoot & 81.11 % reduction over control).

As regards thrips, tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> proved to be the most promising insecticidal treatment by recording lowest population of thrips (1.35/shoot) with 88.62 % reduction over control. It was, however at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (1.55/shoot, 86.96 % reduction over control). This was followed by cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.10/shoot, 82.29 % reduction over control) & fipronil @ 100 g a.i. ha<sup>-1</sup> (2.22/shoot, 81.30 % reduction over control).

Studies on effect of newer insecticides on coccinellids revealed that, cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (5.70/plant), spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (5.50/plant) and tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (5.00/plant) were safer. Whereas, imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.77/plant) proved to be highly toxic by recording least coccinellid population (3.77/plant).

The safety report of newer insecticides on spiders indicated that, cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (4.65/plant) and spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (4.50/plant) recorded higher number of spiders and hence can be considered as safe. Whereas, tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> proved to be highly toxic by recording least number of spiders (3.04/plant).

Flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> (2.09 % fruit borer damage and 88.40 % reduction over control) recorded least fruit borer damage and found effective against pomegranate fruit borer with higher yield (16.81 t/ha) and highest Incremental Cost Benefit Ratio (1 : 81.76). It was, however at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.33 % fruit borer damage, 87.08 % reduction over control).

The data on safety of newer insecticides to honey bees indicated that, chlorantraniliprole @ 40 g a.i./ha (10.57/plant) and flubendiamide @ 72 g a.i./ha (10.22/plant) recorded higher number of honey bees and can be considered safe. Whereas, lambda cyhalothrin @ 25 g a.i./ha proved to be toxic by recording lowest population of honey bees (6.21/plant).

Among the biorationals, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (4.13 aphids & 2.68 thrips/shoot) and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (4.15 aphids & 2.57 thrips/shoot) proved effective against aphids and thrips.

In the present investigation, among the tested biorationals, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (6.80 % fruit borer damage) and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (7.01 % fruit borer damage) were found as most promising biorational treatments by recording lowest fruit borer damage. The efficacy of neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> also reflected in recording higher yield (11.15 t/ha) & high Incremental Cost Benefit Ratio (1 : 27.41). This was followed by azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (11.24 t/ha) which registered cost benefit ratio of 1 : 14.90, due to high cost of the insecticide.

Studies on residues and dissipation of insecticides were carried out at AINP on Pesticide Residues, Department of Agricultural Entomology, M.P.K.V., Rahuri. Flubendiamide + thiacloprid 480 SC and thiacloprid 240 SC were studied for their dissipation kinetics, at recommended and double the recommended doses. Initial residues of flubendiamide reached Below Quantification Limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. The half-life (RL<sub>50</sub>) values of flubendiamide in pomegranate were 1.79 and 2.01 days for recommended dose and double dose, respectively. Whereas, the soil collected at harvest, did not record any residues of flubendiamide at both the doses. No residues of des-iodo flubendiamide, metabolite of flubendiamide, were detected in any of the samples.

Whereas, initial residues of thiacloprid reached BQL on 7<sup>th</sup> and 10<sup>th</sup> day. The half-life (RL<sub>50</sub>) values of thiacloprid in pomegranate were 1.53 and 2.07 days for recommended dose and double dose, respectively. Whereas, the soil collected at harvest, did not record any residues of thiacloprid at both the doses.

Initial residues of thiacloprid 240 SC reached BQL on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. The half-life (RL<sub>50</sub>) values of thiacloprid in pomegranate were 1.57 and 1.97 days for recommended dose and double dose, respectively. Whereas, the soil collected at harvest, did not record any residues of thiacloprid at both the doses.

In the present investigation, IPM module i) up to 40 days, one spray of *Lecanicillium lecanii* (Zimmermann) @ 5 g L<sup>-1</sup> followed by one spray of *Metarhizium anisopliae* (Metchnikoff) @ 5 g L<sup>-1</sup> at 7 days interval and need based application of imidacloprid 17.8 SL @ 50 g a.i. ha<sup>-1</sup> ii) at 40-90 days, one spray of *L. lecanii* @ 5 g L<sup>-1</sup>, one spray of *M. anisopliae* @ 5 g L<sup>-1</sup> followed by one spray of azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> at 10 days of interval and two sprays of neem oil+ karanja oil @ 2 ml L<sup>-1</sup> + 2 ml L<sup>-1</sup> at an interval of 10 days iii) at 90-120 days, two sprays of NSE @ 5 % at 10 days of interval

and need based application of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup>, was the most effective treatment by recording minimum population of aphids, thrips and least fruit borer damage than farmer's practice. The pomegranate plants in IPM module registered highest fruit yield (14.91 t/ha) and also highest Incremental Cost Benefit Ratio (1 : 10.72).

## 1. INTRODUCTION

Pomegranate (*Punica granatum*, family: Lythraceae) is a well known arid zone horticultural crop, which is grown all over the world and more extensively cultivated in Spain, Afghanistan, United States of America, China, Japan and Russia (Khan *et al.*, 2017).

Pomegranate is a high value crop. The demand for fresh fruits and juice, processed products like wine and candy are also gaining importance in the world trade. It has more nutritional values and health benefits also. However, modern research also suggests that pomegranate is useful in treating such serious diseases like prostate cancer, skin cancer, osteoarthritis and diabetes (Bhowmik *et al.*, 2013).

The bark of the stem, root and rind of the fruit are used for slimming, control of dysentery, diarrhoea and killing of tape worms. The juice of pomegranate is cool and refreshing and has medical properties, especially patients suffering from leprosy. The rind of fruit is used as dyeing material for cloths. The juice of wild pomegranate in Azerbaijan is used in the manufacture of citric acid and sodium citrate for medicinal purpose. The bark of stem and root contain a number of alkaloids belonging to the pyridine group. It is also employed in the therapeutics in dysentery and diarrhea (Bal, 2008).

Pomegranate cultivation is unique because of its drought tolerant nature, consistent and good yields, fine table and therapeutic values, better keeping quality and the ability to put the plant to rest during periods when irrigation potential is low, particularly in hot semi-arid and desert regions. (Dongarjal *et al.*, 2019).

In India, it is grown over an area of 2,73,000 hectares with a production of 30,68,000 tonnes and a productivity of 11.20 tonnes/ha. Maharashtra, Gujarat, Uttar Pradesh, Karnataka, Andhra Pradesh and Madhya Pradesh are the major states in pomegranate production in the country. Maharashtra is the leading state in pomegranate production as the plantation reached up to 1,47,000 hectares during 2018, with a production of 17,89,000 tonnes. However, the productivity of pomegranate crop in India is 11.20 t/ha only, which is significantly lower than other pomegranate growing countries like Turkey (27.25 t/ha), Spain (20.00 t/ha), USA (16.7 t/ha) and Israel (12.5 t/ha) (Anon., 2021).

In the recent past, cultivation of high yielding varieties of pomegranate with intensive care and management under irrigated condition resulted in serious insect pest problems. Insect pests and diseases have a considerable impact on productivity of this crop. Pomegranate suffers from the infestation of several insect and non-insect pests. More than 86 insect pests that have been recorded to infest pomegranate crop around the world (Butani and Verma, 1976). Among these insect pests, sucking pests like aphids (*Aphis punicae* Passerini), thrips (*Scirtothrips dorsalis* Hood), fruit borer (*Deudorix isocrates* Fabricius) and *D. epijarbas* (Moore) can cause 40 % yield loss (Kambrekar *et al.*, 2015). In the recent years, bacterial blight is causing epidemic

in major pomegranate growing areas. The major constraints in increasing export potential is quality of the fruit, size, colour, free from blemishes and pesticide residues.

Pomegranate aphid, *A. punicae* (Passerini) (Aphididae : Homoptera) is an important pest in pomegranate. Nymphs and adults colonize on tender new shoots, flowers and flower buds, young fruits and suck the sap. The infested parts will get discoloured and severe infestation may lead to stunted growth and drying of tender shoots. In addition to this, honeydew excreted by aphids attract black sooty mould, which affects the photosynthetic activity of the pomegranate plant (Khandare *et al.*, 2018).

Pomegranate thrips, *S. dorsalis* (Hood) (Thripidae: Thysanoptera) cause qualitative and quantitative losses to pomegranate fruits. Both nymphs and adults feed on the tender shoots, developing fruits and cause deformation showing corky appearance on fruits which reduces the quality, fetches low price in domestic market and not accepted for export (Butani and Verma, 1976).

Pomegranate butterfly, *D. isocrates* (Fabricius) (Lycaenidae: Lepidoptera) also called as anar butterfly and fruit borer which can destroy more than 40 per cent of fruits. Severe infestation of fruit borer has resulted in the high reduction of yield. Female butterfly lay eggs on flowers buds and the calyx of developing fruits. Caterpillar enters the fruit and feed on the internal content of fruit (Kambrekar *et al.*, 2015). Gupta and Dubey (2005) recorded *D. epijarbas* (Moore) as serious insect pest of pomegranate recording 60 per cent damage of fruits in mid hills of Himachal Pradesh. A very high (upto 90%) infestation of pomegranate fruit borer, *D. epijarbas* was reported from Kullu valley in Himachal Pradesh, and it was further reported that the infestation started in the first week of June and reached its peak during August-September (Anon., 2008).

In order to protect the crop from insect pests and diseases, farmers are spraying different chemical pesticides. Farmers rely heavily on synthetic pesticides for the control of insect pests and diseases in pomegranate. Pesticide residues in pomegranate crop are a major concern, as this fruit has medicinal benefits and is commonly used as a table purpose. Pesticide residues are also posing a significant barrier in India's exports to international markets. The export is merely 49,757 tonnes which is 1.90 % of the total production. There is great scope for export of pomegranate (National Horticultural Board, 2018).

Recently developed selective biorational insecticides have a useful specificity to target insects while having negligible effect on natural enemies. It is imperative to evaluate biorational insecticides against pomegranate pests, so as to use them in a effective manner in the integrated pest management strategy. The chemicals should be used to supplement and not to replace natural enemies. Among the natural enemies, coccinellids are predominant in pomegranate ecosystem and needs consideration (Kapoor and Kritika, 2020).

In Maharashtra, almost all the govt. institutes like SAU'S, KVK'S, sugar factories, ICAR institutes and more than 200 NGO'S are producing huge quantity of biopesticides and botanicals which are popular among the farmers. Similarly Agricultural Departments, Taluka seed farms have unit of production of NSE.

Indiscriminate use of synthetic insecticides not only damaged the environment but also agriculture by entering into the food chain. Continuous use of chemical pesticides has led to insect pest resurgence, insecticide resistance, residues and imbalance in prey-predator dynamics. Pesticide residues are a major concern for the different stakeholders since the quality regulations and the food safety standards are becoming more stringent in importing countries. Consumers are more cautious regarding the quality of horticultural produce especially fruits and vegetables. Evidences of pesticide threat to human health have been documented in several studies (Wasim *et al.*, 2009).

Bioaccumulation of these pesticide residues in the human body over time can have long-term health consequences (Baig *et al.*, 2009). While it is necessary to regulate these pesticide residues in fruits for the domestic market, such laws are also necessary for quality control of expanding exports of fruits in the global market.

At present only three insecticides (cyantraniliprole 10.26 % OD – aphids, thrips, fruit borer & whitefly; lambda-cyhalothrin 04.90 % CS - thrips & fruit borer ; quinalphos 25 % EC - scales) are registered and recommended by CIB&RC for use on pomegranate. The issue of label claim in specific crop and for specific pest is pertaining to the manufacturers as per their policy registration. There is no role of SAU'S and ICAR institutes to register the molecules under CIB&RC.

Newer insecticides needs to be evaluated for bio efficacy, phytotoxicity and residues for label claim in pomegranate. There are number of pesticides being evaluated by the manufacturers for registration. However, in the present investigation few insecticides were evaluated. Studies on the residue dynamics of agrochemicals in pomegranate will lead to reveal the scientific data on behaviour of these chemicals. The information will be useful in formulating good agricultural practices (GAP).

Integrated pest management, which involves integration of different pest management strategies, has not only decreased pesticide applications but also increased agricultural yields and net returns. Despite these positive outcomes, it has received a small amount of adoption (Dhawan and Rajinder 2009).

This knowledge of effect of newer insecticides on the insect pests, natural enemies and honey bees assume special significance in the present studies. Unravelling of this information will enable us in careful manipulation of insecticides in sustainable pomegranate cultivation.

Keeping this in view and considering the economic importance of pomegranate crop, the present investigation was carried out with following objectives.

1. To study the bioefficacy of newer insecticides and biorationals against pests in pomegranate (aphids - *Aphis punicae*, thrips - *Scirtothrips dorsalis* and fruit borer - *Deudorix isocrates*)
2. To study the effect of insecticides on beneficial organisms (coccinellids, spiders and honey bees)
3. To study the residues and dissipation of insecticides in pomegranate fruit and cropped soil
4. To evaluate IPM module for the management of pomegranate insect pests

## 2. REVIEW OF LITERATURE

A review pertaining to “Studies on insecticide management of pests infesting pomegranate (*Punica granatum* L.)” is presented in this chapter. Since the available information is scanty, the relevant information on other horticultural crops is also reviewed and presented.

### 2.1 Bioefficacy of Newer Insecticides and Biorationals Against Insect Pests Infesting Pomegranate (Aphids - *Aphis punicae*, Thrips - *Scirtothrips dorsalis* and Fruit borer - *Deudorix isocrates*)

#### 2.1.1 Aphids - *Aphis punicae*

##### i) Bioefficacy of synthetic insecticides against aphids in pomegranate

Ismail *et al.* (1985) reported that primicarb (0.3 g/l), dimethoate (0.5 ml/l) and malathion (1.25 ml/l), as effective insecticides against pomegranate aphids and opined that a second application at 20 days after the first fortnight be necessary. Dimethoate (0.03%) and methyl demeton (0.03%) caused 90 % mortality in pomegranate aphids (Mote *et al.*, 1993).

Highest per cent decline of pomegranate aphids was observed after spraying of imidacloprid (63.20 %) followed by dimethoate (63.00 %). Maximum yields of 44.63 t/ha and 38.25 t/ha were observed in the treatments of imidacloprid and dimethoate, respectively (Biradar and Shaila 2004).

Biradar and Navi (2006) reported that significantly highest per cent reduction of pomegranate aphids was observed in the plants treated with carbofuron 3G @ 100 g/plant (97.2 % and 100 %) followed by phorate 10 G @ 30 g/plant (91.4 and 88.1 %) in 2002 and 2003, respectively.

Studies conducted by Ananda *et al.* (2010) revealed that, thiamethoxam 25 WG @ 0.20 g/L and imidacloprid 200 SL @ 0.25 ml/L were the most effective in controlling aphids by reducing the incidence by 85.90 and 83.54 per cent over control, respectively.

Mohammad *et al.* (2013) evaluated imidacloprid, thiamethoxam, thiacloprid and flonicamid on mortality of *A. punicae*. The LC<sub>50</sub> value for imidacloprid, thiamethoxam, thiacloprid and flonicamid were calculated, 0.24 µl/ml, 0.31 mg/ml, 0.48 µl/ml and 0.05 mg/ml, respectively. Probit analysis data revealed that, the sensitivity of aphids to the pesticides was :imidacloprid > thiacloprid > flonicamid > thiamethoxam. The results showed that imidacloprid and thiacloprid @ 1 µl/ml, thiamethoxam @ 0.35 mg/ml and flonicamid @ 0.1 mg/ml had the highest mortality.

Thiamethoxam 25 WG @ 0.20 g/L showed highest reduction in pomegranate aphid population followed by imidacloprid 70 WG @ 0.3 g/l. During first year, the mean reduction with thiamethoxam was 90.19 and 94.10 % after first and second spray, whereas during second year, the reduction it was in the of 91.19 and 93.42 %, respectively. Similarly, during 2010, imidacloprid recorded 87.92 and 90.39 % reduction in population after first and second sprays

whereas during 2011 it was 89.73 and 93.42%. The plants sprayed with thiamethoxam (9.15 t/ha) and imidacloprid (9.38 t/ha) recorded highest yield (Kambrekar *et al.*, 2013).

Abdella (2016) studied the efficacy of acetamiprid, imidacloprid, thiamethoxam and dinotefuran, malathion and carbamate insecticides against pomegranate aphid. The highest control of *A. punicae* was achieved by thiamethoxam (reduction in population up to 88.50 %) followed by acetamiprid (81.30 %), imidacloprid (77.70 %), pirimicarb (77.00 %), dinotefuran (63.50 %) and malathion (47.10 %).

Elango *et al.* (2017) evaluated imidacloprid 17.8 SL, thiamethoxam 25 WG, chlorantraniliprole 18.5 SC, dichlorvos 76% EC, dimethoate 30 % EC, fipronil 5% SC against *A. punicae* at Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore. The study revealed that dichlorvos 76% EC (0.076%), imidacloprid 17.8 SL (0.00712%) and dimethoate 30% EC (0.06%) were most effective with maximum mortality of 96.6, 94.4 and 92.2 per cent at 48 h after treatment, respectively.

The studies conducted by Khandare *et al.* (2018) revealed that thiamethoxam 25 WG @ 50 g a.i./ha (1.48 aphids/shoot) was found most effective molecule in reducing the population of pomegranate aphids followed by flonicamid 50 WG @ 75 g a.i./ha (1.94) and fipronil 5 SC @ 75 g a.i./ha (2.86).

Lad *et al.* (2018) conducted field experiment to assess the bioefficacy of newer insecticides along with combination of fungicides and soluble fertilizers against pomegranate aphids. Among all the tested treatments, the combination of cyantraniliprole 10.26 % OD (0.3 ml) + propineb 50 WP (1 g) with soluble fertilizer (0:52:34) (5 g per lit water) was found most effective (3.94 aphids per shoot).

Dongarjal *et al.* (2018) tested newer insecticides against aphids in pomegranate. The pooled data of *Ambia* and *Hasta* bahar showed that, the best treatment to control pest population was clothianidin (2.38 aphids/shoot). It was however at par with thiamethoxam (3.13 aphids/shoot) and flonicamid (3.42 aphids/shoot). The succeeding better treatments were fipronil (3.67 aphids/shoot), acephate (3.92 aphids/shoot), diafenthiuron (4.17 aphids/shoot), spiromesifen (4.42 aphids/shoot) and buprofezin (4.71 aphids/shoot).

Jadhao *et al.* (2019) conducted field trials on management of pomegranate aphid, *A. punicae* with newer insecticides at Central Horticultural Nursery, Department of Horticulture Vasant Rao Naik Marathwada Krishi Vidhyapeeth, Parbhani, Maharashtra. Among all the insecticides tested, clothianidin found effective treatment with 4.49 aphids/shoot, it was followed by thiamethoxam (4.75) and imidacloprid (5.28). Whereas, dinotefuran (8.53) and lambda cyhalothrin (7.98) was found less effective but it was significantly superior over control.

## ii) Bioefficacy of synthetic insecticides against aphids in other crops

Vinoth Kumar *et al.* (2008) evaluated spirotetramat 150 OD against cotton aphid, *A. gossypii*. Spirotetramat 150 OD @ 75 g a.i./ha was effective against the population of aphids and it was found at par with the standard check, imidacloprid 200 SL @ 25 g a.i./ha.

Ghosal *et al.* (2013) observed the efficacy of neonicotinoids against aphids of okra, imidacloprid 17.8 SL @ 50 g a.i. ha<sup>-1</sup> was found as the most effective. It recorded lowest aphid population and highest reduction (84.54 %) over control. Thiamethoxam 25 WG @ 50 g a.i. ha<sup>-1</sup> and acetamiprid 20 SP @ 40 g a.i. ha<sup>-1</sup> were also at par with imidacloprid.

Cyantraniliprole 10 % OD @ 90 and 105 g a.i./ha were found highly effective in managing the population of aphids compared to endosulfan and indoxacarb. Cyantraniliprole 10 % OD @ 90 g a.i./ha recorded high seed cotton yield (31.97 q/ha) and 105 g a.i./ha (33.33 q/ha) with an increase of 50.80 and 52.81 % over untreated control, respectively (Patel *et al.*, 2014).

Vikram *et al.* (2015) confirmed that highest reduction of chilli aphids (89.37 %) and highest yield (133.08 q/ha) were observed in spirotetramat + imidacloprid 240 SC @ 90 g + 90 g a.i./ha.

Dotasara *et al.* (2017) conducted field experiment to evaluate insecticides against the mustard aphid, *Lipaphis erysimi* (Klatenbach) on cauliflower. Results indicated that imidacloprid 17.8 SL @ 0.2 g/L reduced the 87.53 % incidence of mustard aphid it was followed by fipronil 5 SC @ 1.0 ml/L (83.56 % reduction).

Tukaram *et al.* (2017) tested different insecticides against chilli aphids. Among all the treatments, fipronil 200 SC 250 ml/ha (2.25 aphids/three leaves) was the effective treatment followed by fipronil 200 SC 200 ml/ha (3.06), fipronil 200 SC 150 ml/ha (3.73), lamda cyhalothrin 5 EC 300 ml/ha (4.07), fipronil 5 SC 1000ml/ha (4.17), imidacloprid 200SL 250 ml/ha (4.31), lamda cyhalothrin 4.9% CS 15 g a.i./ha (4.61) and indoxacarb 14.5% SC 60 g a.i./ha (4.74) were found most effective.

Minimum the cotton aphids (3.53/3 leaves) and highest cotton kapas yield (18.45 q ha<sup>-1</sup>) was observed in cyantraniliprole 10.26 % OD at 90 g a.i. ha<sup>-1</sup> (Karthik *et al.*, 2017).

Sangamithra *et al.* (2018a) evaluated bioefficacy of fipronil 200 SC against aphids in chilli. The results revealed that, fipronil 200 SC @ 50 g ai ha<sup>-1</sup> was found as effective in reducing the aphids with pooled mean population of 0.37 aphids/3 leaves.

## iii) Bioefficacy of biorationals against aphids in pomegranate and other crops

Marco *et al.* (2003) evaluated the effect of silicon application in wheat against green aphid, *Schizaphis graminum* (Rondani). The greenhouse experiment was conducted in a completely randomized experimental design with two treatments, consisting of silicon application and without silicon application. The silicon in the form of sodium silicate solution at 0.4 % SiO<sub>2</sub> was applied in 6 doses of 50 ml/pot each, at five-day intervals, first application at

five days after emergence of the plants. Results revealed that silicon treated plots (196 nymphs/plot) recorded lower population than silicon free plot (350 nymphs/plot).

Vishal *et al.* (2007) tested methanolic extract of neem and karanja oil alone and in combination against chrysanthemum aphid, *Macrosiphoniella sanborni* (Gillette). Combined formulation showed significant effect on chrysanthemum aphid, *M. sanborni* by causing 100 % reduction, compared to alone treatments of neem oil (68.40 %) and karanja oil (52.90 %).

Karthikeyan and Selvanarayanan (2011) studied bioefficacy of *Beauveria bassiana* against *Aphis gossypii* under laboratory conditions at Department of Entomology, Annamalai University, Tamilnadu. Among three different concentrations (0.15, 0.20 and 0.25 %) of liquid formulation of *B. bassiana* @ 0.25 % recorded the highest mortality of *A. gossypii* (100.00 %).

Sawsan *et al.* (2011) evaluated the efficacy extracts of medicinal and ornamental plants against pomegranate aphid, *A. punicae* under laboratory conditions, viz., *Aerva lanata* (Linnaeus), *Ruta chalepensis* (Linnaeus), *Fagonia Arabica* (Linnaeus), *Malva parviflora* (Linnaeus) and *Calotropis procera* (Aiton); were evaluated against pomegranate aphid, *A. punicae* under laboratory condition. Ethanol extract of *R. chalepensis* showed the highest repellency of 75 % and mortality (79.5 %) at 0.015 % concentration, it was followed by ethanol extract of *A. lanata* @ 0.015 % (high repellent effect 60.68 % and moderate mortality percentage 55.54 %). However, water extracts of *A. lanata* @ 5 % showed highest repellency (44.88 %) and mortality (61.2 %) at 5% followed by *M. parviflora* @ 5 % with slight repellency (36.22 %) and mortality (51.50 %).

Ferria *et al.*, (2011) observed that deposition of silicon on leaf epidermis reduced the whitefly (*B. tabaci*) population through increased development period and nymph mortality in both cucumber and soybean.

Akmal *et al.* (2013) used *B. bassiana* to evaluate its pathogenicity against adults of different aphid species *i.e.*, *Schizaphis graminum*, *Rhopalosiphum padi*, *Brevicoryne brassicae* and *Lipaphis erysimi*. *B. bassiana* was effective at all concentrations ( $1 \times 10^6$ ,  $1 \times 10^7$  and  $1 \times 10^8$  spores/ml) on all species, but the highest concentration ( $1 \times 10^8$  spores/ml) provided maximum control in short period of time.

Elango *et al.* (2017) evaluated different biopesticides against *A. punicae* under laboratory conditions. Spinosad 45% SC showed maximum mortality of aphids (54.40 and 75.50 %) at 24 and 48 hours after treatment. It was followed by azadirachtin 10000 ppm (38.88 % and 54.44 %) and NSE 5 % (36.66 % and 51.11 %).

Saruhan (2018) evaluated the efficacy of three different conidial concentrations ( $1 \times 10^4$ ,  $1 \times 10^5$ , and  $1 \times 10^6$  conidia/ml) of five isolates (TR-04, TR-05, TR-07, TR-08, and TR-10) of *Lecanicillium muscarium*, one isolate (TR-01) of *Simplicillium lamellicola*, a commercial bioinsecticide *L. lecanii*, and imidacloprid against the black bean aphid, *Aphis fabae* under

laboratory conditions. Results revealed that the  $1 \times 10^5$  and  $10^6$  conidia/ml concentrations of all the entomopathogenic fungal isolates tested against *A. fabae* caused > 90% mortality by the end of the seventh day. It is concluded that both conidial concentrations of these isolates had significant potential to control black bean aphid.

Tahseen *et al.* (2018) investigated the pathogenicity of *Metarhizium anisopliae* ( $1 \times 10^7$  conidia) and *Bacillus thuringiensis* ( $1 \times 10^8$  spores) against brinjal aphid. Alone treatments of *B. thuringiensis* showed maximum aphid mortality (52.46 %) and *M. anisopliae* gave 58.66 %. Combination treatment (*B. thuringiensis* + *M. anisopliae*) showed mortality of 72.45 %.

The foliar application of calcium and silicon resulted in lowest number of *Diaphorina citri* individuals (1.13) compared with untreated trees (3.13) in Tahiti Lime trees (Augusto *et al.* 2018).

Studies at Indian Institute of Horticultural Research, Bengaluru on bioefficacy of biorational insecticides (azadirachtin (1000 ppm), *L. lecanii* ( $2 \times 10^8$  spores/g), neem soap (@ 10 g/l), organic salt 30 WS, spinosad 45 SC and dimethoate 30 EC) against pomegranate aphids revealed that treatment with spinosad 45 SC @ 0.2 ml/l recorded least population of aphids (7.54/three shoots). It was followed by organic salt 30 WS @ 4ml/l (8.39) (Rajeshwari *et al.*, 2019).

The highest green apple aphid mortality of 68.91 % was recorded by azadirachtin @ 0.3 % followed by azadirachtin @ 0.2 % (65.06%). Whereas, least mean mortality of 34.32 % was exhibited by castor oil (1 %) (Akhtar 2020).

Deepak *et al.* (2020) studied the biorational approaches for management of mustard aphid, (*Lipaphis erysimi*). Results indicated that, spraying of azadirachtin followed by *L. leccani* @ 2g/l after 15 days recorded highest seed yield (2.07 kg/plot). Next best treatment was azadirachtin @ 5 ml/l followed by *B. bassiana* @2g/L after 15 days (2.00 kg/plot).

Kavitha and Faizal (2020) conducted studies on bioefficacy of entomopathogens against cowpea aphid, *Aphis craccivora*. All the entomopathogens tested were found promising in controlling the sucking pest. After 7 days of application, mortality % of *A. craccivora* was highest in *Fusarium pallidroseum* (70.97) followed by *B. bassiana* (35.54), *M. anisopliae* (23.22) and *Serratia marcescens* (11.34).

Gaikwad *et al.* (2020) evaluated different biopesticides against aphids on okra and revealed that NSE 5 % recorded lowest number of aphids of 11.11/3 leaves, followed by neem oil 0.2% (11.75), dashparni ark 0.6% (12.45), *L. lecanii* 0.4% (13.49), Karanj oil 0.5% (13.94), eucalyptus oil 0.2% (13.98), biomix 0.3% (14.47) and *Metarhizium* + *B. bassiana* 0.4% (14.61). However, aphid population was highest in untreated plot (19.12).

### 2.1.2 Thrips (*Scirtothrips dorsalis*)

#### i) Bioefficacy of synthetic insecticides against thrips in pomegranate

Bagle (1993) noticed that monocrotophos (0.5%), dimethoate (0.05%), phosphamidon (0.05%) are effective against pomegranate thrips for a period of 15 days. Kadam (2006) reported that spraying of 0.025 % spinosad was found most effective treatment against pomegranate thrips with highest fruit yield (12.6 t/ha) this was followed by 0.01 % acetamiprid (12.04 t/ha) and 0.018% spinosad (12.0 t/ha).

Evaluation of insecticides on pomegranate thrips indicated, thiamethoxam 25 WG @ 0.2 g/l and imidacloprid 200 SL @ 0.25 ml/l were the most effective molecules in controlling the population of thrips by 84.37 and 79.38 % over control, respectively (Ananda *et al.*, 2010). Field studies conducted by Kadam *et al.* (2012) revealed that fipronil @ 25 g a.i., spinosad @ 56.25 g a.i., imidacloprid @ 27 g a.i. or lambda-cyhalothrin @ 12.5 g a.i. per hectare can be used against pomegranate thrips.

Tolfenpyrad 15% EC at 150 g a.i./ha showed significantly least survival of thrips (0.73, 0.32, 0.16 and 1.33, 0.53, 0.27) on 5<sup>th</sup>, 7<sup>th</sup> and 10<sup>th</sup> days after spray in 2011-12 and 2012-13 with least fruit scarring damage. They further concluded that, it can be used for controlling the thrips in pomegranate as well as getting the higher fruit yield (Walunj *et al.*, 2015).

Studies were conducted by Walunj *et al.* (2012) on the efficacy of cyantraniliprole 10.26 OD @ 60 g a.i./ha in comparison with neonicotinoids and synthetic pyrethroids against thrips (*S. dorsalis*) infesting pomegranate during two consecutive years of the ambia bahar. The treatment cyantraniliprole @ 60 g a.i./ha showed significantly least survival of thrips and per cent fruit borer damage as against other treatments.

The combination treatment of cyantraniliprole 10.26 % OD (0.3 ml) + propineb 50 WP (1 g) with soluble fertilizer (0:52:34) (5 g/L water) was found most effective in controlling of pomegranate thrips (3.07/shoot) (Lad *et al.*, 2018).

Jagginavar *et al.* (2018) conducted experiments on bioefficacy of thiacloprid 240 SC against thrips in pomegranate at Krishi Vigyan Kendra, Vijayapur, Karnataka. At 1 and 3 days after first spray lowest thrips/10 cm tender new shoots are recorded in higher dose (1.25 ml/L) of thiacloprid 240 SC (2.15 and 2.00), which is found at par with cyantraniliprole 10.26 % OD @ 0.75ml/L (2.13 and 2.06).

Vinoth Kumar *et al.* (2019) evaluated the efficacy of thiacloprid 240 SC against pomegranate thrips, *S. dorsalis* at Tamil Nadu Agricultural University, Coimbatore. Among tested insecticides, thiacloprid 240 SC @ 0.36 g a.i. ha<sup>-1</sup> significantly reduced thrips population and recorded population reduction of more than 95 per cent over control followed by thiacloprid 240 SC @ 0.30 g a.i. ha<sup>-1</sup>.

Dongarjal *et al.* (2019) investigated newer insecticides (acephate, buprofezin, clothianidin, diafenthiuron, fipronil, flonicamid, spiromesifen and thiamethoxam) against pomegranate thrips. The pooled data of *Ambia* and *Hasta* bahar showed that fipronil was statistically superior over other insecticides and it was found at par with thiamethoxam and clothianidin. The next promising treatments were flonicamid, acephate, diafenthiuron, buprofezin and spiromesifen.

## ii) Bioefficacy of synthetic insecticides against thrips in other crops

Patel *et al.* (2014) evaluated the bioefficacy of cyantraniliprole 10 % OD (45, 60, 75, 90 and 105 g a.i./ha), indoxacarb 14.5 % SC @ 75 g a.i./ha and endosulfan 35 % EC @ 350 g a.i./ha as standard checks against cotton thrips, (*Thrips tabaci*). Cyantraniliprole 10 % OD @ 90 and 105 g a.i./ha were found highly effective against thrips compared to endosulfan and indoxacarb. Highest seed cotton yield was recorded significantly in treatments cyantraniliprole 10% OD @ 90 (31.97 q/ha) and 105 (33.33 q/ha) g a.i./ha with an increase of 50.80 and 52.81 % over untreated control, respectively.

Tatagar *et al.* (2014) carried out field experiments to find out the bioefficacy of flubendiamide + thiacloprid 480 SC against chilli thrips. Different dosages of flubendiamide + thiacloprid 480 SC *viz.*, @ 36 + 36, 48 + 48 and 60 + 60 g a.i./ha, were evaluated. Among different dosages, flubendiamide + thiacloprid 480 SC @ 48 + 48 g a.i./ha recorded least number of thrips and least leaf curl damage of 0.46/plant.

Balikai and Mallapur (2015) evaluated cyantraniliprole 10 OD, carbaryl 50 WP and malathion 50 EC against Gherkins thrips and reported that cyantraniliprole @ 90 g a.i./ha afforded highest protection against thrips (96 % reduction over control).

Yaligar *et al.* (2016) conducted field trials at Agricultural Research Station, Kawadimattii on efficacy of cyantraniliprole 10.26 % OD at different dosages for the management of brinjal thrips. These studies revealed that, cyantraniliprole 10.26 % OD @ 90 g a.i./ha registered lowest number of thrips (5.16/leaf) at 10 days after application and highest yield of 49.70 t/ha.

Nagaraj *et al.* (2017) tested efficacy of novel insecticides against grape thrips, *S. dorsalis*. Among twelve treatments, fipronil 5 % SC @ 1.0 ml/l, imidacloprid 17.8% SL @ 0.3 ml/l were significantly effective than other treatments with more than 87% reduction of thrips damage over untreated control.

Samota *et al.* (2017) investigated effect of different insecticides against thrips, *S. dorsalis* in chilli at Horticulture farm, S.K.N. College of Agriculture, Jobner. On the basis of % reduction in thrips in all sprays, acetamiprid (82.62 %) was found most effective, it was followed by thiamethoxam (80.79 %), imidacloprid (77.90 %) and fipronil (76.38 %).

Field studies on the evaluation of newer insecticides against rose thrips, *S. dorsalis* revealed that significantly lowest population of thrips/three buds was recorded in fipronil 5 % SC

@ 0.15 %, imidacloprid 17.8 % SL @ 0.02 %, tolfenpyrad 15 % EC @ 0.1 % and diafenthiuron 50 % WP @ 0.12%. The maximum reduction over % control was observed in fipronil 5 SC (82.35), imidacloprid 17.8 SL (78.55 %), tolfenpyrad 15 EC (73.52 %) and diafenthiuron 50 WP (72.95 %) (Sathyan *et al.*, 2017).

Sangamithra *et al.* (2018a) evaluated bioefficacy of fipronil 200 % SC against thrips in chilli at Tamil Nadu Agricultural University, Coimbatore. Fipronil 200 % SC @ 50 g ai ha<sup>-1</sup> was found as effective treatment in reducing thrips with pooled mean population (two consecutive seasons) of 0.00 thrips/3 leaves.

Shivaleela and Chowdary (2019) evaluated the bioefficacy of tolfenpyrad 15 % EC @ 100.5, 124.5 and 150 g a.i. /ha, imidacloprid 17.8% SL @ 22.5 g a.i./ha, fipronil 5% SC @ 40 g a.i./ha and chlorpyrifos 20% EC @ 200 g a.i./ha against cucumber thrips. Results revealed that, tolfenpyrad 15 EC @ 150 g a.i/ha was superior in managing the thrips and with highest yield (5.85 t/ha) in highest dosage of tolfenpyrad 15% EC @ 150 g a.i./ha and it was found at par with its next lowest dosage, tolfenpyrad 15% EC @ 124.5 g a.i./ha (5.75 t/ha).

Shweta *et al.* (2019) evaluated synthetic insecticides against onion thrips. Among the treatments, thiamethoxam 25 WG @ 25 g a.i./ha recorded significantly lowest population of thrips (4.90 thrips/plant). Which is found at par with imidacloprid 17.8 SL @ 22.25 g a.i./ha (5.19 thrips/plant).

### **iii) Bioefficacy of biorationals against thrips in pomegranate and other crops**

Chandrasekaran and Veeravel (1998) evaluated the bioefficacy of ahook (0.05 %, 1.0 %, 1.50 %), neem oil (1 %, 3 %, 5 %), neem cake (1 %, 3 %, 5 %), tobacco leaf extract (1 %, 3 %, 5 %) along with an insecticide monocrotophos (0.05 %) against *S. dorsalis* on chilli. These experiments revealed that monocrotophos as effective treatment and among the plant products tested ahook (1.5 %) significantly reduced the thrips number, it was followed by neem oil @ 5 % and 3 %.

Narvaria (2003) evaluated botanical products against chilli thrips and concluded that that neem oil @ 5 % was superior over the neem oil 2 % with reduction of 64.33 % and 57.33 %, respectively.

Halagatti (2006) studied on the efficacy of entomopathogens against thrips of rose under polyhouse conditions. *L. lecanii* recorded the highest mortality of 82.50 % followed by local strains of *B. bassiana*.

Mandi and Senapati (2009) evaluated the effectiveness of different conventional and eco-friendly insecticides against chilli thrips (*S. dorsalis*) at the field of Coastal Saline Zone of West Bengal. The effectiveness of four insecticides acetamiprid @ 0.004 %, thiamethoxam @ 0.005 %, neem pesticide @ 0.4 % and *Bacillus thuringiensis*, subsp. *kurstaki*. The results indicate that, acetamiprid and thiamithoxam were most effective on thrips population (93.30 % and 89.93 %

reduction over control, respectively). Neem pesticide (54.20 %) and *Bt* (43.43 %) were found moderately effective.

Jagdish and Purnima (2011) conducted polyhouse experiment to find out the efficacy of botanicals against *S. dorsalis* on different stages of rose (bud, half opened and full opened flower). Among different botanicals, NSE (2 %) recorded highest (74.37 %) mortality to thrips.

Sayeda and Mohamed (2011) evaluated the efficacy of two biopesticides, neem (Nimbecidine) and *B. bassiana* (Bio-power) for the control of onion thrips, *T. tabaci*. Nimbecidine exhibited best control of thrips in flowering period.

Rakesh and Anoorag (2017) conducted field experiment on the efficacy of biopesticides for the control of chilli thrips, *S. dorsalis* at the Central field, Sam Higginbottom University of Agriculture Technology and Sciences, Allahabad. Results revealed, spinosad (73.21 %) proved as most effective insecticide followed by imidacloprid (67.58 %), pongamia oil (55.78 %), neem oil (55.64 %), NSE (53.03 %) and garlic sap extract (50.03 %). Whereas, *B. bassiana* (33.36 %) was found less effective against pest.

Rami Reddy *et al.* (2019) evaluated the efficacy of two entomopathogenic fungi *viz.*, *M. anisopliae* and *B. bassiana* against thrips, *S. dorsalis* on grapes at Indian Institute of Horticultural Research, Bengaluru. The results clearly showed that entomopathogen, *M. anisopliae* was significantly effective against thrips. It resulted in 82.27 and 84.24 % reduction in thrips population after 14 days of spray in first and second year, respectively, which is at par with the standard check.

Rajeshwari *et al.* (2019) conducted field experiment at Indian Institute of Horticultural Research, Bengaluru to study the bioefficacy of biorational insecticides (azadirachtin (1000 ppm), *Lecanicillium lecanii* ( $2 \times 10^8$  spores/g), neem soap (@ 10 g/L), organic salt 30 WS, spinosad 45 SC and dimethoate 30 EC) against pomegranate thrips. Spinosad 45 SC @ 0.2 ml/L significantly recorded minimum population of thrips (0.92/three leaves). It was followed by organic salt 30 WS @ 4 ml/L (2.24) and azadirachtin (2.26).

Bhojane *et al.* (2019) studied the biointensive approaches against thrips on cucumber, among the biorational components entomopathogenic fungi, *L. lecanii* and *M. anisopliae* found effective with 62.36 and 60.38 % reduction of thrips, respectively. Neem oil @ 1 ml/L (54.40) and mineral oil @ 0.5 ml/L (51.22) were the second best biorational components.

Pawar *et al.* (2020) carried out field experiments for the management of onion thrips by sequential strategy. Among the sequential strategy, application of lambda cyhalothrin 5 EC @ 15 g a.i./ha, followed by *M. anisopliae* 1.15 WP @ 5 g/L followed by NSE 5 % was found most effective against the control of thrips at 3rd, 7th and 14th day after spray and this strategy recorded average survival of thrips in the range of 6.67-16.67 thrips/plant as against 28.67-31.33 thrips/plant in untreated control showing 1.2 rating of white patches on leaves. There was

remarkable impact of this sequential strategy on the yield of 261.73 q/ha marketable onion bulbs as against 160.65 q/ha in untreated control.

### 2.1.3 Fruit borer (*Deudorix isocrates*)

#### i) Bioefficacy of synthetic insecticides against fruit borer in pomegranate

Spraying of 0.05 % phosphamidon at pomegranate fruit formation stage is effective for the control of pomegranate fruit borer (Alam 1962). Zirpe (1966) recommended that six sprays of 0.2 % carbaryl at 15 days interval by initiating the first spray from flowering to control the fruit borer. Awate *et al.* (1977) while studying chemical control of pomegranate fruit borer, *V. isocrates* established a method of chemical control of the pest on pomegranate, by applying four sprays of phosphamidon (0.03%) at 15 day interval.

Singh (1985) reported that five sprays with phenthoate 0.05 % at 15 days interval starting from mid-August provided 100 % control of *V. isocrates*. Kabre (1986) reported that cypermethrin 0.0075 % found as most effective treatment to control the pomegranate fruit borer followed by decamethrin 0.025%, cyfloxiate 0.03 %, fenvalerate 0.015 %, clocythrin 0.003 % and quinalphos 0.05 %.

Studies on incidence and chemical control of pomegranate fruit borers *D. isocrates* and *D. epijarbas* recommended that application of cypermethrin and permethrin (@ 150g a.i./ha), fenvalerate (@ 50 g a.i./ha) and deltamethrin (@ 7.5g a.i. (ha) were effective. All these chemicals *i.e.* cypermethrin, fenvalerate and deltamethrin were found to be more effective than the conventional methyl parathion (Kakar *et al.*, 1987).

A study was conducted by Dubey *et al.* (1993) to manage the pomegranate fruit borers, *Deudorix isocrates* and *D. epijarbas* in Himachal Pradesh. In two years study, the conventional insecticide endosulfan 0.14 % was found most effective when compared with quinalphos (0.10 %), methyl parathion (0.05 %) and a pyrethroid, cypermenthrin (0.01 %). In the second year, the two isomers of endosulfan, alpha and beta-endosulfan were isolated. The efficacy of alpha isomer (0.07, 0.14 %) is better than beta-endosulfan (0.07, 0.14 %). Two sprays of endosulfan (0.14 %) at one month interval are recommended for saving the fruits from borer attack.

Emamectin benzoate @ 0.0022 % is a effective treatment by recording lowest fruit borer damage and highest yield of 10.89 t/ha followed by emamectin benzoate 0.0016 % and deltamethrin 0.002 % (Kadam 2006).

Ramachandra (2007) evaluated spinosad (0.018%), emamectin benzoate (0.0022%), thiodicarb (0.15%), deltamethrin (0.002%) and NSE 5 % against pomegranate fruit borer, *D. isocrates*. Emamectin benzoate and spinosad reduced the fruit borer damage to 2.37 and 3.21 % with a yield of 11.10 and 10.93 t /ha, respectively.

Kulkarni *et al.* (2009) recorded lowest damage of fruit borer (*D. isocrates*) and highest yield in emamectin benzoate (0.0022 %) and spinosad (0.018%). While evaluating various

insecticides and biopesticides against *D. epijarbas*, Kumar (2010) reported that 3 sprays of cypermethrin (0.01%), deltamethrin (0.0028%) and quinalphos (0.05%) at 21 days of interval effective with an infestation level of <15 per cent in comparison to >80 per cent in control.

Ibrahim and Serhat (2013) conducted experiment on the efficacy of different treatments on pomegranate butterfly (*Deudorix livia*). Among all the tested treatments, indoxacarb reduced the damage from 15 % to < 2 % with two applications.

Gupta and Dubey (2005) evaluated different insecticides,  $\beta$ -cyfluthrin 0.0025%, deltamethrin 0.0028% and chlorpyrifos 0.04% against pomegranate fruit borer, *D. epijarbas*. After 10 days of spray, only deltamethrin (3.3 % infestation) was statistically significant over control (11.7 % infestation). Emamectin benzoate and pyridalyl were found to be highly effective in controlling the *Virachola livia* with an infestation of 0.33 and 4.33 % and 1.00 and 6.67 % compared to methoxyfenozide (0.33 and 17.67 %) in both cultivated and reclaimed lands, respectively (Abdella, 2015).

Kambrekar *et al.* (2015) evaluated new insecticides against pomegranate fruit borer, *D. isocrates* at Bijapur, Karnataka and revealed that emamectin benzoate 5 SG @ 0.25 g/L recorded highest reduction in the fruit damage. The mean reduction of damage in emamectin benzoate was 93.45 and 96.23 % after first and second sprays during 2010, and it was to the extent of 92.68 and 96.75 per cent, respectively during 2011. Cyantraniliprole @ 60 g a.i./ha showed significantly least % of fruit borer damage in pomegranate as against other treatments (Walunj *et al.*, 2012).

Imtiaz *et al.* (2017) tested different insecticides *viz.*, cypermethrin, bifenthrin, lambda-cyhalothrin and methomyl against *V. isocrates* at Agriculture Research Institute, Mingora. Results showed lambda cyhalothrin is the effective treatment which reduced the infestation level from 6.98 to 1.68 followed by methomyl (1.73), bifenthrin (2.05) and cypermethrin (2.58).

Nadaf (2017) conducted experiment to assess the bioefficacy of newer insecticides against anar butterfly, *D. isocrates* on pomegranate at Horticulture research and Extension station, Vijayapur, Karnataka. Among different insecticides tested for the management of fruit borer significantly lower per cent fruit damage (20.62) was recorded in chlorantraniliprole 18.5 SC @ 0.15 ml per liter and highest marketable yield (13.50 t/ha).

Kumar and Gupta (2018) evaluated the efficacy of insecticides for the management of the pomegranate fruit borer, *Deudorix epijarbas*. Among the new insecticides, chlorantraniliprole (0.006 %), spinosad (0.002 %), emamectin benzoate (0.002 %) and cyantraniliprole (0.0075 %) with 16.11, 16.67, 17.78 and 17.78 per cent infestation, respectively proved effective in managing the pest.

Lad *et al.* (2018) studied the bioefficacy of combination of insecticides, fungicides and soluble fertilizers against pomegranate fruit borer. Among all the tested treatments, the

combination of cyantraniliprole 10.26 % OD (0.3 ml) + propineb 50 WP (1 g) with soluble fertilizer (0:52:34) (5 g/L water) was found most effective in control of fruit borer (1.17 fruit borer damage %).

## ii) Bioefficacy of synthetic insecticides against fruit borer in other crops

Two applications of dimethoate 30 EC (9.16 % fruit damage) were found most effective against *Virachola isocrates* in guava followed by polytrin-C (10 %) (Kaul *et al.* 2003). Mandal (2012) reported that cyantraniliprole 10 % OD @ 90 and 100 g a.i./ha was found effective against the fruit borer, *H. armigera* in tomato.

Balikai and Mallapur (2015) found that cyantraniliprole @ 90 g a.i./ha afforded highest protection against Gherkin fruit borer (90.70 % reduction over control).

Studies on efficacy of newer insecticides against brinjal shoot and fruit borer in brinjal revealed that, flubendiamide 480 SC @ 0.1 ml (11.66 % fruit damage), cyantraniliprole 10 OD @ 0.3 ml/L (8.89 % infestation) and spinosad 45 SC @ 0.1 ml/L (10.65 % infestation) were found as most effective insecticides (Sajjan and Rafee 2015).

Yaligar *et al.* (2016) conducted field trials and revealed that cyantraniliprole 10.26 % OD @ 90 g a.i./ha recorded lowest fruit damage % by brinjal shoot and fruit borer (1.09 %) and highest yield of 49.70 t/ha.

Sen *et al.* (2017) studied the efficacy of different insecticides against brinjal shoot and fruit borer (*Leucinodes orbonalis*). Flubendiamide 480 SC @ 90 g a.i./ha is the most effective treatment (shoot and fruit infestations of 1.28 % and 2.15%) followed by quinalphos 20 EC @ 200 g a.i./ha (3.99 % and 3.57%). Highest yield was obtained with flubendiamide 480 SC @ 90 g a.i. /ha (87.05 q/ha).

Among the various treatments tested in chilli, flubendiamide + thiacloprid 480 SC @ 120 g a.i./ha was found superior with lowest larval population of *Helicoverpa armigera* (0.13 larvae/plant), *Spodoptera* spp. (0.33 larvae/meter row length) and least fruit damage (1.73 %). It was, however at par with chlorantraniliprole 20SC @ 30 g a.i./ha followed by flubendiamide 480 SC @ 60 g a.i./ha (Guru and Patil, 2018).

## iii) Bioefficacy of biorationals against fruit borer in pomegranate and other crops

Karuppuchamy *et al.* (2001) carried out studies on effect of biological control agents for the management of pomegranate fruit borer, *D. isocrates*. Three sprays of endosulfan at 15 days interval and inundative release of *T. chilonis* four times at 10 days interval were effective by recording lesser fruit damage (9.04 and 10.25 per cent, respectively), which was statistically superior to control (27.58 % fruit damage).

Bhut *et al.* (2013) evaluated different biocides against anar butterfly, *V. isocrates* and concluded that neem oil @ 0.5 % (22.71% fruit damage), neem seed kernel extract @ 5 % (23.01%) and *Bacillus thuringiensis* @ 0.15% (23.87%) were found more effective.

The plant extracts and *M. anisopliae* have a high toxicity on the 3<sup>rd</sup> and 5<sup>th</sup> instar larvae of pomegranate carob moth. The larval mortality percentages increased significantly with neem extract at (15 %) reached (43.33 and 56.70 %) after 4 days of treatment for 3<sup>rd</sup> and 5<sup>th</sup> instar larvae, respectively. The mortality percentage for 3<sup>rd</sup> and 5<sup>th</sup> instar larvae treated with *M. anisopliae* at (1×10<sup>6</sup> spore /ml) reached to 93.33 % after 6 days of treatment (Rebwar and Hemin, 2016).

Lowest per cent of brinjal shoot, fruit infestation and highest B:C ratio were recorded in cypermethrin 10 EC (7.60 %, 7.41% and 1: 4.083) which was followed by pongamia oil @ 2 % (8.21 %, 8.27 % and 1:3.913), iuppai oil @ 2 % (8.55 %, 8.55 % and 1:3.620), NSE @ 5 % (10.11 %, 10.49 % and 1:2.936), neem oil @ 2 % (10.55 %, 10.01 %, and 1:3.38), neem leaf extract (12.27 %, 10.55 % and 1:3.26) and *B. bassiana* (16.44 %, 14.11 % and 1:3.11) (Arvind Kumar and Sasya Thakur 2017).

Sameer Kumar and Singh (2017) conducted studies on different insecticides and biopesticides for the management of pod borer, *Maruca vitrata* on green gram. The data indicated that spinosad 60 g a.i./ha and emamectin benzoate 8 g a.i./ha were the most effective treatments in reducing *M. vitrata* larval population whereas *L. lecanii* (1×10<sup>8</sup> spores/g) 5 g/L was observed to be the least effective treatment.

Application of orthosilicic acid @ 4 ml L<sup>-1</sup> as foliar spray four times starting from 15 days after transplanting at weekly intervals reduced yellow stem borer infestation in rice significantly (1.51 % dead heart and 3.33 % white ear head) as compared to control treatment (5.00 % of dead heart and 11.44 % of white ear) (Tripathy and Kishore 2017).

Sujit *et al.* (2018) conducted field trails on efficacy of biopesticides (*B. thuringiensis* var. *kurstaki*, *M. anisopliae*, *L. lecanii*, azadirachtin 1 % EC, annonin 1 % EC, *B. bassiana*, karanjin 2 % EC and yam bean seed extract 5% EC) on brinjal shoot and fruit borer. Among the treatments, azadirachtin 1 % EC @ 2ml/L was found superior than other treatments with 10.92 % mean shoot infestation and 10.04 % fruit infestation, it was followed by karanjin 2 % EC @ 2ml/L (13.42 % shoot and 12.83 % fruit infestation).

NSE 5 % found as effective treatment with lowest chick pea pod borer damage (10.41 %) followed by azadirachtin (10.84 %) and nuclear polyhedrosis virus (11.83 %). *B. thuringiensis* (12.10 %) found moderately effective in reducing pod borer population, while garlic extract (14.27) was found least effective (Meena *et al.*, 2018).

Mishra *et al.* (2018) conducted field experiment on the effect of organic and inorganic silicon amendments against yellow stem borer and revealed the superiority of Calcium silicate @ 2 t/ha and Diatomaceous earth @ 0.45 t/ha in arresting stem borer damage *i.e.* dead heart (0.00-3.09 %) and white ear head (0.35 % and 0.69 %) as against 2.34-11.43 % dead heart and 4.47 % white ear head in control.

Among the biopesticides tested, lowest gram pod borer damage % was recorded in azadirachtin 1500 ppm @ 5.0 ml/L (7.33 %) followed by *Bt. kurastaki* @ 1.0 g/L (9.33), *L. lecanii* @ 5.0 g/L (10.58), *M. anisopliae* @ 5.0 g/L (12.33) and *B. bassiana* @ 5.0 g/L (13.08) (Abbas 2020).

Madhu *et al.* (2020) tested different biopesticides (*B. bassiana*, *B. thuringiensis*, neem oil, azadirachtin 0.03%, lantana leaf extract) on rice yellow stem borer, *Scirpophaga incertulas*. Among all the treatments, neem oil (6.43 % dead hearts) was the most effective treatment followed by azadirachtin (6.84 %), *B. bassiana* (7.64), *B. thuringiensis* (8.04 %) and lantana leaf extract (8.59 %).

## 2.2 Effect of Insecticides on Beneficial Organisms (Coccinellids, Spiders and Honey Bees)

Ananda *et al.* (2009) taken up a roving survey in pomegranate ecosystem at Bagalkot, Karnataka and reported the different predators belongs to coleoptera (*Cryptolaemus montrouzieri*, *Scymnus coccivora*, *Cheilomenus sexmaculata*, *Hippodamia variegata* and *Coccinella septempunctata*), neuroptera (*Chrysoperla carnea*) and hymenoptera (*Encarsia* sp.). Three species of praying mantids (*Statilia* sp., *Amorphoscelis* sp. and *Phyllothelys* sp.).

Jadhav and Shukla (2013) studied the relative toxicity of insecticides on eggs, larvae and adult of *Coccinella transversalis*. Acetamiprid 0.004 % and thiomethoxam 0.005 % were moderately toxic to the egg, larva and adult. Whereas, imidacloprid 0.005 % was found least toxic to the larvae.

Neem oil @ 2.5 ml/L (22.45/plot), curtap 50 SP @ 2.0 g/L (17.97/plot) and emamectin benzoate 5 SG @ 1.0 g/L (15.63/plot) recorded highest population of lady bird beetle after untreated control (28.78/plot). Maximum number of dead beetles were observed in esfenvelarate 5 EC @ 1.0 ml/L (4.29/plot) and deltamethrin 2.5 EC @ 1.0 ml/L (3.96/plot) treated plot in country bean ecosystem (Mollah *et al.*, 2013).

Nahar and Ohtani (2015) investigated the effect of sub-lethal doses of imidacloprid and fipronil on behavior and homing ability of *Apis mellifera*. Imidacloprid and fipronil induced abnormal behaviors. Treated foragers showed trembling, tumbling, abnormal fanning and grooming, restless running, being stationary, lying on its back and lack of co-ordination. Imidacloprid treated foragers took 54 minutes to recover whereas fipronil treated foragers took 38 minutes. After recovery, foragers were released from 50 m away from the hive to see whether they can come back. Treated foragers showed reduced homing rate. Maximum foragers failed to come back hive.

Acetamiprid, imidacloprid, thiamethoxam and malathion are harmful to predators in pomegranate ecosystem *viz.*, *Coccinella undecimpunctata*, *Chrysoperla carnea* and *Syrphus corolla* and with the reduction from 75.40 to 100 %. Dinotefuran was moderately toxic to lacewings with an average reduction about 64.40 % (Abdella, 2015).

Tahir *et al.* (2015) studied effects of lambda cyhalothrin and emamectin benzoate on predatory potential of lycosid spiders, *Pardosa birmanica*. Experimental groups were exposed to sub-lethal (1/20<sup>th</sup> of field rate) doses of insecticides for one hour and then transferred to separate clean jars. Results showed that both lambda-cyhalothrin and emamectin benzoate significantly affected the predation of spiders.

Deekshita *et al.* (2017) evaluated the toxicity of different newer insecticides viz., imidacloprid 17.8 SL, thiamethoxam 25 WG, acetamiprid 20 SP, sulfoxaflor 25 SC, dinotefuran 20 SG, pymetrozine 50 WG, buprofezin 25 SC and monocrotophos + dichlorvos 36 SL + 76 EC against spiders of rice ecosystem. Among all the insecticides safest treatment to spiders was sulfoxaflor with 20.40 per cent mortality of spiders followed by pymetrozine 50 WG (23.89 %).

The direct application of methyl demeton resulted 100 and 95 % mortality of *A. mellifera* within 1 hour after spraying, followed by imidacloprid (76.5, 100 %), acetamiprid (55.0, 62.5 %), dimethoate (47.5, 59.00 %) and thiamethoxam (42.5, 51.5 %) during 2014 and 2015, respectively in mustard crop (Bajjiya and Abrol, 2017).

Indhumathi *et al.* (2017b) conducted field study to find out the effect of fipronil 200 SC on natural enemies of chilli pests and revealed that the mean coccinellids population was found more in the untreated check (11.90/10 plants) than fipronil 200 SC at 30 g a.i. ha<sup>-1</sup> (8.91/10 plants).

Highest population of spiders and coccinellids were recorded in untreated control (7.50 and 7.83) followed by flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> (6.29 and 6.41) and thiacloprid 84 g a.i. ha<sup>-1</sup> (6.23 and 6.43) in brinjal ecosystem (Sangamithra *et al.* 2018b).

Khandare *et al.* (2018) conducted experiments on safety of newer insecticides on natural enemies in pomegranate crop. Lambda cyhalothrin 5 EC @ 15 g a.i./ha (0.19 and 0.00) and fipronil 5 SC @ 75 g a.i./ha (0.30 and 0.00) were highly toxic to coccinellids and chrysopids. Whereas, buprofezin 25 SC @ 250 g a.i./ha (0.71 and 1.32) and cyantraniliprole 10.26 OD 75 g a.i./ha (1.36 and 1.06) were found comparatively safer.

Vrushali and Patil (2018) conducted experiments on toxicity of insecticides to *A. mellifera*. The results (LC<sub>50</sub>) are in the following order, imidacloprid (0.0070) > fipronil (0.0125) > indoxacarb (0.0266) > cypermethrin (0.0370) > dimethoate (0.0385). The lethal time (LT<sub>50</sub>) values (h) in the order of toxicity of insecticides were as follows: fipronil (6.56), cypermethrin (6.69), dimethoate (8.00), imidacloprid (9.85) and indoxacarb (13.45). Distinct poisoning symptoms observed in *A. mellifera* were extended proboscis, expanded wings, unhooked wings, extended legs and twisted bodies, defecation on cage covers, sting in release-out position and anus with excreta. All the tested pesticides were harmful to the honey bees.

Maximum foraging activity of *Apis cerana* in mango crop was observed in the treatment N.S.E. 5 % followed by *Metarhizium anisopliae* and minimum activity observed in the treatment

imidacloprid, thiamethoxam, lambda cyhalothrin and dimethoate, respectively (Phadatare *et al.*, 2019).

Sharanappa *et al.* (2019) studied the safety of insecticides on natural enemies of insect pests in rice and revealed that all insecticides were significantly to suppressed the population of coccinellids as compared with control (1.32 coccinellids/hill). The treatment monocrotophos recorded lowest population of coccinellids (0.63 coccinellids/hill). This was followed by acephate (0.69), flubendiamide (0.74), cartap hydrochloride (0.74), fipronil (0.82), chlorpyrifos (0.85) and imidacloprid (0.93), respectively.

Rajeshwari *et al.* (2019) studied the effect of biorational insecticides on natural enemies (*Coccinella transversalis*) in pomegranate ecosystem. The results revealed organic salt (2.81) and spinosad (2.70) were found to be safest chemicals to coccinellids.

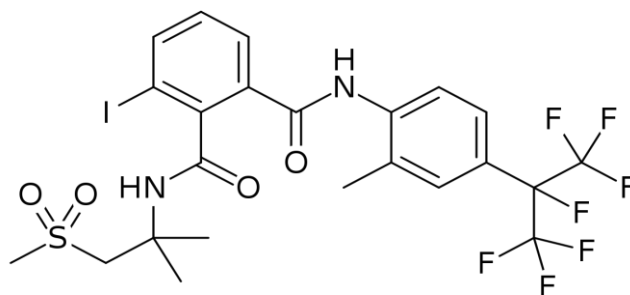
Khandare *et al.* (2019) evaluated the effect of stem smearing against ladybird beetle in cotton ecosystem. Among the treatments, seed treatments with imidacloprid 70 WS at 10 g/kg recorded comparatively higher population of ladybird beetles (0.47 per plant). This was followed by treatments with acephate 50 + imidacloprid 1.8 SP, clothianidin 50 WDG, clothianidin 50 WDG and imidacloprid 48 FS.

Emamectin benzoate 1.9 EC @ 5.00, 6.75, 8.50 and 11.00 g.ai ha<sup>-1</sup> can be considered as safer to coccinellids at all concentrations and the highest coccinellid population was recorded in the plots treated with emamectin benzoate 1.9 EC at 5.00 g a.i. ha<sup>-1</sup> followed by emamectin benzoate 1.9 EC at 6.75, 8.50 and 11.00 g a.i. ha<sup>-1</sup>, respectively in okra (Karthikeyan and Ayysamy 2017).

### **2.3. Studies on the Residues and Dissipation of Insecticides in Pomegranate Fruits and Cropped Soil**

#### **2.3.1 Flubendiamide**

Flubendiamide @ 24 and 48 g a.i. ha<sup>-1</sup> in cabbage recorded initial residue of 0.33 and 0.49 µg g<sup>-1</sup>. The residues persisted up to 10 days in the both the treatments and dissipated with the half-life of 3.9 and 4.45 days, respectively. Des-iodo flubendiamide, a metabolite of flubendiamide, was not detected in cabbage during the analysis. Soil samples from the treated field after 15 days were free from any residue of flubendiamide or its metabolite (Mohapatra *et al.*, 2010).



Flubenidamide -  $C_{23}H_{22}F_7IN_2O_4S$  Molar mass : 682.39 g/mol  
 IUPAC Name :  $N^1$ -[4-(1,1,1,2,3,3,3-Heptafluoropropan-2-yl)-2-methylphenyl]-3-iodo- $N^2$ -[1-(methanesulfonyl)-2-methylpropan-2-yl]benzene-1,2-dicarboxamide

Kanwar *et al.* (2011) worked on residues and dissipation of flubendiamide 480 SC (150 ml a.i. ha<sup>-1</sup>) and reported that average initial residues of 0.220  $\mu\text{g g}^{-1}$  in tomato. More than 85 per cent of flubendiamide residue dissipated in just after 5 days of the last application. Residues of flubendiamide dissipated below detectable level of 0.01  $\mu\text{g g}^{-1}$  in 7 days. The half-life value and the safe waiting period of flubendiamide 480 SC at 150 ml/ha were found to be 1.80 and 2.00 days. Soil samples collected at the time of harvest were free from residue of flubendiamide 480 SC.

Suchi *et al.* (2011) conducted field experiment at Anand Agricultural University, Anand to study the rate of degradation of flubendiamide 480 SC @ 90 and 180 g a.i. ha<sup>-1</sup> on brinjal fruits and revealed that persistence of flubendiamide till 3<sup>rd</sup> and 7<sup>th</sup> day at standard and double dose, respectively. The initial residues of 0.17 and 0.42  $\mu\text{g g}^{-1}$  reached below determination level on the 5th and 10th day. The half life of flubendiamide on brinjal fruits ranged from 2.68 to 2.55 days. Soil samples analysis revealed that residues at below determination level.

Dissipation studies conducted on flubendiamide @ 48 and 96 g a. i. ha<sup>-1</sup> in tomato and revealed that, initial residues of 0.83 and 1.68  $\mu\text{g g}^{-1}$ , respectively. The residues of flubendiamide dissipated at the half-life of 3.9 and 4.4 days from treatments @ 48 and 96 g a.i. ha<sup>-1</sup>, respectively and persisted for 15 days from both the treatments. Des-iodo flubendiamide (metabolite) was not detected during the study period (Mohapatra *et al.*, 2011).

The studies on residues and persistence of flubendiamide 39.35 % SC @ 24 and 48 g a.i. ha<sup>-1</sup> in okra fruits revealed that residues of metabolite of flubendiamide (des-iodo), was not detected in okra during the study period. The initial residues of 0.28 and 0.53  $\mu\text{g g}^{-1}$  in/on okra fruits reached below determination level on the 7<sup>th</sup> and 10<sup>th</sup> day, respectively. The half-life of flubendiamide in okra fruits ranged from 4.7 to 5.1 days, respectively (Das *et al.*, 2012).

After two applications of flubendiamide 20 WG at 12.5 and 25 g a.i. ha<sup>-1</sup> in cabbage the initial residues of were 0.16 and 0.31  $\mu\text{g g}^{-1}$ , respectively. These residues of flubendiamide 20 WG @ 12.5 g a.i. ha<sup>-1</sup> persisted up to 7<sup>th</sup> day. At 25 g a.i. ha<sup>-1</sup> flubendiamide 20 WG persisted up

to 10 days. The half life values of flubendiamide on cabbage ranged from 3.4 to 3.6 days. When flubendiamide applied at both the standard and double dose, no detectable residues were found in the time of harvesting (Paramasivam and Hemanta, 2013)

Studies were conducted on dissipation pattern of flubendiamide @ 48 and 96 g a.i. ha<sup>-1</sup> on tomato. Residues of flubendiamide were found below the determination limit in 20 days at both the dosages in all the locations. The half-life of flubendiamide @ 48 g a.i. ha<sup>-1</sup> (0.33 to 3.28 days) and @ 96 g a.i. ha<sup>-1</sup> (1.21 to 3.00 days) (Sharma *et al.*, 2014).

Studies were conducted on dissipation pattern of flubendiamide and its metabolite (des-iodo) on chili at 60 and 120 g a.i. ha<sup>-1</sup>. Flubendiamide was found to be below the determination limit in 15 days at both the dosages in all locations. Half-life of flubendiamide when applied at 60 (0.85 to 1.80) and 120 g a.i. ha<sup>-1</sup> (0.95 to 2.79). On the basis of data, a preharvest interval of 1 day was recommended (Sharma *et al.*, 2015).

George *et al.* (2015) conducted residues and dissipation studies of flubendiamide at 0.72 g a.i. 10 L<sup>-1</sup> and 1.44 g a.i. 10 L<sup>-1</sup> on cardamom. The initial residues of flubendiamide in capsules was 0.42 and 0.60 µg g<sup>-1</sup> dissipated with a half-life of 1.25 and 2.53 days, respectively. No residue of des-iodo flubendiamide (the metabolite of flubendiamide) was detected during the study.

Radhika *et al.* (2016) investigated the dissipation of flubendiamide @ 48 g a.i. ha<sup>-1</sup> and 96 g a.i. ha<sup>-1</sup> in capsicum fruits in poly house and open field. Initial residues of flubendiamide grown under poly house conditions were (0.977 and 1.834 µg g<sup>-1</sup>) higher than open field (0.665 and 1.545 µg g<sup>-1</sup>). Flubendiamide residues persisted for 15 days in field grown and for 25 days in poly house grown capsicum. These residues were degraded with the half lives of 4.3 - 4.7 and 5.6 - 6.6 days in field and poly-house, respectively. Des-iodo flubendiamide (metabolite) was not detected in capsicum fruits or soil.

An initial residue of flubendiamide was recorded as 1.49 µg g<sup>-1</sup> which was dissipated to below detectable level on 10<sup>th</sup> day. The half-life was 1.83 days with waiting period for safe harvest of okra fruit was 4.19 days (Deepak *et al.*, 2017).

Pathipati *et al.* (2017) worked on dissipation dynamics of flubendiamide 20 % WG @ 48 g a.i. ha<sup>-1</sup> on capsicum in field and poly house. Flubendiamide resulted in 2.40 µg g<sup>-1</sup> initial residue at 2 hr after spray which was dissipated to BDL by 10<sup>th</sup> day in poly house. Whereas in open field, 2.13 µg g<sup>-1</sup> initial residue at 2 hr after spray which dissipated to BDL by 10<sup>th</sup> day in open field.

Meenambigai *et al.* (2017) worked on dissipation pattern of flubendiamide, the mean initial residue after two sprays of flubendiamide in okra fruit at 48 g a.i. ha<sup>-1</sup> was found to be 1.16 µg g<sup>-1</sup>. Maximum residue (>80 %) of flubendiamide got dissipated on 5 days after treatment. The residues persisted up to 7 days after treatment and further dissipated to below

detectable limit ( $< 0.05 \mu\text{g g}^{-1}$ ) on 10 days after treatment. Dissipation of flubendiamide followed first order reaction kinetics and the calculated half-life was 1.64 days.

Preethi *et al.* (2019) studied the dissipation pattern of flubendiamide in cabbage at Coimbatore and Nilgiris. Flubendiamide 39.35 SC @  $18.24 \text{ g a.i. ha}^{-1}$  and  $36.48 \text{ g a.i. ha}^{-1}$  were sprayed twice at 10 days interval. The mean initial residue of flubendiamide after the second spray was  $0.191$  and  $0.258 \mu\text{g g}^{-1}$  in Coimbatore and  $0.195$  and  $0.281 \mu\text{g g}^{-1}$  in the Nilgiris at  $18.24 \text{ g a.i. ha}^{-1}$  and  $36.48 \text{ g a.i. ha}^{-1}$  doses, respectively. More than 80 per cent of flubendiamide residues were dissipated on 7<sup>th</sup> and 10<sup>th</sup> day after second spray and recorded below detected level at 10 and 15 DAS in Coimbatore and Nilgiris, respectively. Dissipation of flubendiamide followed first order reaction kinetics and the calculated half life was 2.8 to 2.9 days, in Coimbatore and 3.7 to 3.9 days in the Nilgiris.

### 2.3.2 Flubendiamide + thiacloprid 480 SC

Battu *et al.* (2010) studied the residues and persistence of flubendiamide and thiacloprid @  $48+48$  and  $84+84 \text{ g a.i. ha}^{-1}$  in tomato and revealed that half life values of flubendiamide and thiacloprid were found to be 0.33 and 1.00 days, 1.18 and 0.95 days, respectively. Flubendiamide and thiacloprid residues were observed to be dissipate below determination limit after 3 and 5 days, respectively. Soil samples collected after 15 days did not showed the flubendiamide, des-iodo flubendiamide, and thiacloprid.

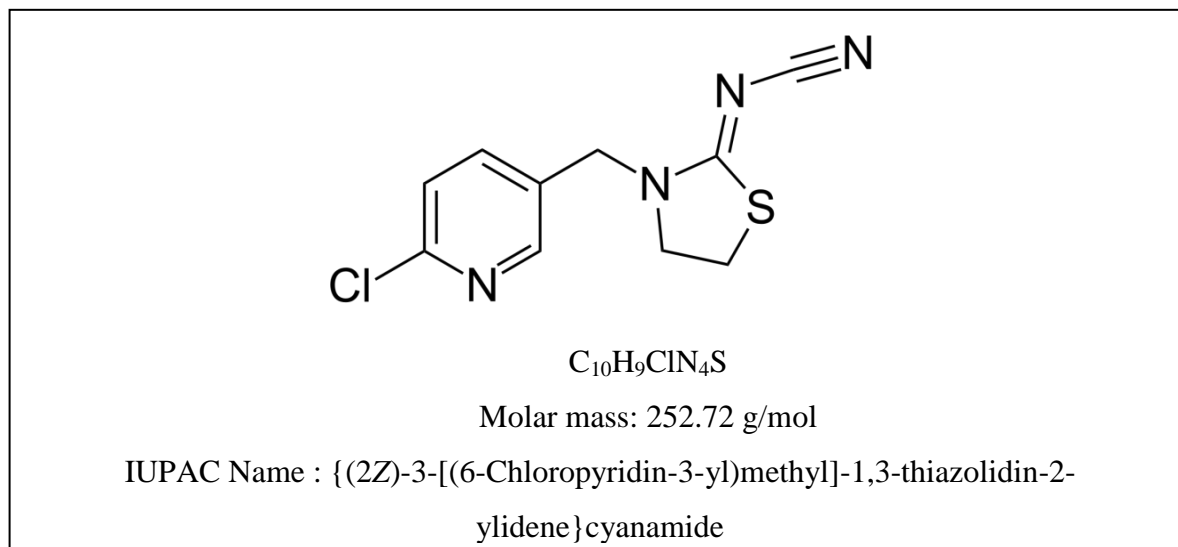
Flubendiamide @  $60 \text{ g}$  and  $120 \text{ g a.i. ha}^{-1}$  in chilli recorded initial residues of  $0.22$  and  $0.31 \mu\text{g g}^{-1}$ , respectively. These levels gradually declined and reached below its determination limit of  $0.05 \mu\text{g g}^{-1}$  after 3 and 5 days at single and double of the recommended doses, respectively. Half-life of flubendiamide on chilli were 1.12 and 1.76 days, respectively. The application of thiacloprid @  $60$  and  $120 \text{ g a.i. ha}^{-1}$  resulted in the residue level of  $0.15$  and  $0.21 \mu\text{g g}^{-1}$  respectively, one hour after application. The levels gradually declined and reached below detectable at 5<sup>th</sup> and 7<sup>th</sup> days after application in lower and higher dose, respectively. Half-life of thiacloprid on chilli was 2.17 and 2.13 days, at single and double dosages, respectively. Red chilli and soil samples collected after 20 days didn't have of flubendiamide and thiacloprid (Parmar *et al.*, 2012).

Residues of flubendiamide declined below detectable level of  $0.01 \mu\text{g g}^{-1}$  in tomato fruits after 5 and 7 days of application @  $48 \text{ g a.i. ha}^{-1}$  and  $96 \text{ g a.i. ha}^{-1}$  with  $RL_{50}$  of 0.72 and 1.32 days, respectively. Thiacloprid residues reached below its detectable level after 5 and 7 days @  $48 \text{ g a.i. ha}^{-1}$  and  $96 \text{ g a.i. ha}^{-1}$  with  $RL_{50}$  of 0.83 and 1.79 days, respectively (Sharma and Parihar, 2013).

Parmar *et al.* (2016) undertaken a study on residue persistence of flubendiamide + thiacloprid @  $48 + 48$  and  $96 + 96 \text{ g a.i. ha}^{-1}$  on red gram. flubendiamide resulted initial residues of  $0.062$  and  $0.108 \mu\text{g g}^{-1}$ , respectively in the immature grains which reached below

determination limit on the 1st day after application. Thiacloprid recorded initial residues of 0.179 and 0.251  $\mu\text{g g}^{-1}$  in the immature grains which reached BDL on the 10th and 20th days, respectively. At harvest, these residues were below determination limit in matured pods and soil.

### 2.3.3 Thiacloprid 240 SC



Studies revealed that the thiacloprid residues dissipates rapidly and does not accumulate in apple and tea. The half-life of thiacloprid residue on apple fruits ranged between 4.1 to 4.6 days and 3.8 to 4.1 days at 120 and 240 g a.i.  $\text{ha}^{-1}$ , respectively. On green tea shoots, the half-life values were around 3.3 days (Dubey *et al.*, 2008).

Studies on persistence of thiacloprid 240 % SC on tomato @ 48 and 96 g ai  $\text{ha}^{-1}$  revealed that initial residues of thiacloprid ranged between 0.76 and 1.38  $\mu\text{g g}^{-1}$ . Thiacloprid residues dissipated at faster rate during initial days compared to later period. However, residues were short lived and reached the below detectable level by around 10<sup>th</sup> day (Bikramjit and Dikshit, 2011).

Sanjay Kumar *et al.* (2013) studied persistence of thiacloprid 240 % SC in brinjal at 180 and 360 g a.i.  $\text{ha}^{-1}$  at 7 days interval. The average initial residues of thiacloprid were observed to be 0.48 and 1.05  $\mu\text{g g}^{-1}$  at 180 and 360 g a.i.  $\text{ha}^{-1}$ , respectively with half life periods of 0.47 and 0.50 days. Residues of thiacloprid declined below its limit of quantification of 0.05  $\mu\text{g g}^{-1}$  after 3 and 5 days, respectively at recommended and double the recommended application rates.

Studies on residues of thiacloprid 240 SC on apples recorded initial residues of 0.784 ppm and 0.901 ppm from 0.0096 and 0.0192 per cent concentrations with a dissipation of 91.07 and 89.78 per cent in 15 days, respectively. The dissipation was dose dependent as residues from higher concentration of 0.0192 per cent persisted for 30 days while residues from lower concentration of 0.0096 per cent persisted only up to 15 days. The higher concentration of thiacloprid (0.0192 per cent) degraded with half-life value of 6.57 days while the lower concentration of 0.0096 per cent dissipated with half-life value of 4.70 days (Khan *et al.*, 2018).

## 2.4 Evaluation of IPM Module For The Management of Insect Pests in Pomegranate

Shukla and Prasad (1983) compared the efficacy of bagging of fruits with different materials and spraying with different synthetic insecticides (organophosphate, carbamate and synthetic pyrethroids) against *D. isocrates* and revealed that bagging with polyethylene, muslin cloth and spraying of permethrin @ 0.02 %, cypermethrin @ 0.02 %, phosphamidon @ 0.05 %, monocrotophos @ 0.05 %, dimethoate @ 0.05 %, quinalphos @ 0.05 % and dichlorvos @ 0.01 % were effective in managing the pest.

Karuppuchamy *et al.* (2001) developed IPM module against the pomegranate fruit borer with the components like spraying neem oil @ 3 % at the time of butterfly activity, 1 week later release of *T. chilonis* at 2.5 lakh parasitoids ha<sup>-1</sup>, 5 days later spraying of monocrotophos @ 0.05 % as an ovicide and spraying of endosulfan 0.07 % twice, first 15 days after ovicide spray and the second 15 days thereafter, to reduced the incidence of the pest.

Murugan and Thirumurugan (2001) confirmed that to manage pomegranate fruit borer, clipping of calyx cup immediately after pollination followed by two rounds of spray with neem oil (0.3 %), was as effective as application of malathion (0.1 %) as fruit damage of 9.3 and 7.2 per cent, respectively, was recorded at the time of harvest, in comparison to 49.3 per cent damage observed in control.

Halagatti (2006) reported that *L. lecanii* recorded the highest mortality of rose thrips (82.50 and 80 %) in pre-pupal and pupal stage at 60 DAT. Jagdish and Purnima (2011) conducted experiments to find out the efficacy of botanicals against *S. dorsalis* on rose. Among different botanicals NSE (2 %) was recorded highest (74.37 per cent) mortality to thrips.

Bhut *et al.* (2013) evaluated biorationals against anar butterfly, *V. isocrates* infesting pomegranate. Among them, neem oil @ 0.5 % (22.71% fruit damage), neem seed kernel extract @ 5 % (23.01%) and *B. thuringiensis* @ 0.15% (23.87%) were found more effective.

Arvind Kumar and Sasya Thakur (2017) evaluated different biorationals against brinjal shoot and fruit borer. Minimum shoot and fruit infestation % were observed in cypermethrin with (7.60 % and 7.41%) which is followed by pongamia oil (8.21% and 8.27%), iiuppai oil (8.55% and 8.55%), NSKE (10.11% and 10.49%), neem oil (10.55% and 10.01%) and neem leaf extract (12.27% and 10.55%).

Sruthi *et al.* (2018) evaluated different modules against sucking pests of capsicum, Module A - Biointensive module comprising of i) Both neemcake and vermicompost application at 50 g per plant each at 30 days interval from transplanting to flowering and root dip with imidacloprid 17.8 SL @ 0.5 ml/L, ii) three sprays of azadirachtin 10000 ppm @ 1.0 ml/L + *L. lecanii* @ 5.0 g/L iii) spraying of *Pseudomonas fluorescens* @ 5.0 g/L iv) chilli – garlic extract @ 0.5 % vi) cyantraniliprole 10.26 OD @ 1.5 ml/L and vii) two sprays of ecomite @ 3.0 ml/L

proved to be quite effective against capsicum sucking pests and obtaining higher yield (54.53 t/ha), higher net returns (Rs. 2171810) and B:C ratio (2.97) than other modules.

Akshata Kurbett *et al.* (2018) evaluated different IPM modules for the management of pest complex in chilli revealed that Module –III (M-III) was the most effective module against thrips, mites and *H. armigera*. Higher chilli yield 12.36 q/ha was observed in M-III (root dip with imidacloprid 17.8 SL @ 0.5 ml/l for 30 min. at the time of transplanting + acetamiprid 20 SP @ 0.2 g/l + fenpropathrin 30 EC @ 0.5 ml/l + diafenthiuron 50 WP @ 1.0 g/l + spiromesifen 240 SC @ 1ml/l + spinosad 45 SC @ 0.2 ml/l + chlorantraniliprole 18.5 SC @ 0.2 ml/l) followed by M-II (Application of neem cake @ 2.5 q/ha at the time of sowing + Growing one row of marigold as a trap crop and two rows of maize as barrier crop + root dip with imidacloprid 17.8 SL @ 0.5 ml/l for 30 min. at the time of transplanting + azadirachtin 10,000 ppm @ 1.0 ml/l.+ *L. lecanii* (1x10<sup>8</sup> CFU/g) @ 5 g/l + diafenthiuron 50 WP @ 1.0 g/l @ 0.5 ml/l + chlorantraniliprole 18.5 SC @ 0.2 ml/l) was equally effective in recording the yield of 11.84 q/ha with 33.78% increase in yield over control.

Sujit *et al.* (2018) tested the efficacy of different biorationals against brinjal shoot and fruit borer. Among the tested treatments, azadirachtin 1% EC @ 2ml/L found superior with 10.92 % shoot infestation and 10.04 % fruit infestation. Followed by karanjin 2% EC @ 2ml/L (13.42% shoot and 12.83% fruit infestation).

Rami Reddy *et al.* (2019) evaluated the efficacy of *M. anisopliae* and *B. bassiana* against grape thrips, *S. dorsalis*. The results clearly showed that, *M. anisopliae* was significantly effective against thrips. It resulted 82.27 and 84.24 per cent reduction in population after 14 days of spray in first and second year, respectively.

Divya and Nethaji Mariappan (2019) evaluated the efficacy of agro ecosystem analysis (AESA) based integrated pest management (IPM) practices with the farmer practice of spraying different insecticides against *L. orbonalis* on brinjal. The findings revealed that, in AESA based IPM recorded minimum brinjal shoot and fruit borer (8.90 %) with highest abundance of parasitoids (5.82) and least population of aphid and whitefly (2.16 and 1.19/3 leaves). Whereas in farmers practices with 25 % brinjal shoot and fruit borer damage with minimum parasitoid (1.15) and maximum population of aphid (16.5) and whitefly (14.58).

*L. lecanii* @ 4 gm/L and *M. anisopliae* @ 4 gm/L effective with 62.36 and 60.38 % reduction of thrips in cucumber, respectively. Among the oils, neem oil @ 1 ml/L (54.40) and mineral oil @ 0.5 ml/L (51.22) were the second best biorational components (Bhojane *et al.*, 2019).

Saikia and Borkakati (2019) conducted field experiments to study the impact of Biointensive IPM (BIPM) on insect pests of tomato (fruit borer and whitefly). The data revealed that no significance differences was observed in reducing the larval populations of *H. armigera*

in between biointensive integrated pest management (2.23/plant) and chemical control (3.02/plant) plot. Whereas the mean population of insect was only 2.32/plant at BIPM plot with a significant difference from that of chemical control plots (2.90/plant). Highest number of *B. tabaci* was observed in untreated check *i.e.*, 5.36, 8.11 and 4.99 per plant in comparison to BIPM (3.03, 2.67 and 2.60) and chemical control (2.58, 8.11 and 4.94) during 2014-15, 2015-16 and 2016-17, respectively.

Abbas (2020) reported that minimum pigeon pea pod borer damage % found in plots treated with Azadirachtin 1500 ppm @ 5.0 ml/L (7.33 %) followed by *Bt. kurastaki* @ 1.0 g/L (9.33), *L. lecanii* @ 5.0 g/L (10.58), *M. anisopliae* @ 5.0 g/L (12.33) and *B. bassiana* @ 5.0 g/L (13.08).

Pawar *et al.* (2020) revealed that sequential strategy, which includes application of lambda cyhalothrin 5 EC @ 15 g a.i./ha, followed by *M. anisopliae* 1.15 wp @ 5 g/l. followed by NSE 5% was found highly effective for control of onion thrips at 3, 7 and 14 DAS and this strategy recorded average survival of thrips of 6.67-16.67 thrips/plant as against 28.67-31.33 thrips/plant in untreated control.

Divya and Nethaji Mariappan (2020) studied the efficacy of IPM technology against the insect pests of maize (white grub, *Holotrichia serrata*) and stem borer in the maize (*Chilo partellus*). The findings revealed that, white grub infestation after two months was recorded as 35.50 % in the farmers practice and minimum infestation of 0.30 % was noticed in IPM fields. Minimum stem borer infestation of 4 % was recorded in IPM fields and maximum infestation was recorded 15.40 % in farmers practice. The maize yields harvested from the plots treated with IPM technologies were at least 35.33 % higher than that from farmers practices.

Lowest per cent of rosette flowers (5.60 %), green boll damage (8 %), open boll damage (17 %) were recorded in IPM module compared to farmers practice rosette flowers (14 %), green boll damage (15 %) and open boll damage (35 %), respectively. IPM module recorded 12 q/ha (C:B ratio 1: 0.8) which is 20 % higher than the farmers practice (10 q/ha with C:B ratio of 1:0.6) (Jahnavi *et al.*, 2019).

Deepak *et al.* (2020) suggested that azadirachtin @ 5 ml/L followed by *L. lecanii* @ 2g/L after 15 days resulted lowest population (2.56) of mustard aphid and highest seed yield of 2.07 kg/plot. Akhtar (2020) evaluated neem oil (2 % and 3 %), castor oil (2 % and 3 %), artemisia leaf extract (2 % and 3 %), NSE (4 % and 5 %) and azadirachtin (0.2 % and 0.3 %) against green apple aphid, *Aphis pomi*. The highest mean per cent aphid mortality of 68.91 was recorded by azadirachtin @ 0.3 % followed by azadirachtin @ 0.2 % (65.06%).

Gaikwad *et al.*, (2020) tested different biopesticides against aphids in okra and revealed that NSE @ 5 % recorded lowest number of aphids (11.11/3 leaves) it was followed by neem oil 0.2 % (11.75), dashparni ark 0.6 % (12.45), *L. lecanii* 0.4 % (13.49), karanj oil 0.5 % (13.94),

eucalyptus oil 0.2 % (13.98), biomix 0.3 % (14.47) and *Metarhizium* + *B. bassiana* 0.4 % (14.61).

IPM module decreased the incidence of cotton leafhopper and thrips (1.90 to 4.83/ 3 leaves and 6.3 to 11.8/ 3 leaves) over the farmer's practice (6.33/3 leaves and 13.2/3 leaves, respectively). IPM module recorded higher yield (6.31 q/ha) and C:B ratio (1: 0.5) which is 9.56 % higher than the farmer's practice (Jahnavi *et al.*, 2021).

### 3. MATERIALS AND METHODS

Present investigation entitled, “Studies on insecticide management of pests infesting pomegranate (*Punica granatum* L.)” was carried out during the year 2018-20 at Post Graduate Institute (P.G.I), Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (19.3491° N, 74.6461° E). The field experiments on bioefficacy, residues and dissipation and integrated pest management studies were conducted at All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, M.P.K.V., Rahuri, Maharashtra. The laboratory studies on dissipation of insecticides were carried out at All India Network Project on Pesticide Residues Laboratory, Department of Agricultural Entomology, M.P.K.V., Rahuri. The details of material used and methods followed during the experimentation are described hereunder.

#### 3.1 Studies on Bioefficacy of Newer Insecticides and Biorationals Against Pest Complex in Pomegranate (Aphids, Thrips and Fruit Borer)

##### 3.1.1. Material required

##### 3.1.1.1 Selection of pomegranate orchard

The field experiments were conducted during the *Ambia bahar* 2018 and 2019 in the orchard of All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, India (Table 3.1). Three separate rows (for three replications) of pomegranate variety ‘Bhagwa’ plants were maintained in the *Ambia bahar* season. All trees in the block were kept free from application of insecticides. All other agronomical practices were followed as per the recommendations made by M.P.K.V., Rahuri (Plate 3.1, 3.2, 3.3 and 3.4).

**Table 3.1 Details of field experimentation**

1.	Location	:	AICRP on Arid Zone Fruits, Department of Horticulture, M.P.K.V., Rahuri
2.	Crop	:	Pomegranate
3.	Variety	:	Bhagwa
4.	Spacing	:	4.5 m X 3.0 m
5.	Design	:	Randomized Block Design (R.B.D)
6.	Replications	:	Three (Two plants treated as one unit)
7.	Season	:	<i>Ambia bahar</i> 2018 and 2019
8.	Number of sprays	:	Two

##### 3.1.2 Preparation of spray solution and insecticidal application

The measured quantity of insecticides were mixed with small quantity of water and the remaining quantity of water was added subsequently to make up the spray fluid required for trees. The spray fluid solution was evenly mixed with the help of stick before spraying. The sprayer and the container used for preparing spray fluid were thoroughly cleaned with water before changing the insecticide and rinsed with the water (Plate 3.5). With the incidence of

aphids, thrips and fruit borer infestation, the first spray was applied followed by another spray with an interval of 15 days. Spraying was taken up in the morning hours by using a high volume knapsack sprayer with hollow cone nozzle. The insecticidal requirement was calculated by using below formula (Table 3.2, 3.3 & 3.4).

$$\text{Insecticide quantity required (per ha)} = \frac{100 \times \text{Insecticide dose (g a.i. ha}^{-1}\text{)}}{\text{Insecticide formulation \%}}$$

### **3.1.3 Method of recording observation**

#### **3.1.3.1 Aphids**

Number of aphids (nymphs and adults) were counted from five terminals (each of 5 cm shoot length) on five branches in a plant. The mean number of aphids per shoot were worked out (Plate 3.6, 3.7 and 3.8). The population of aphids on shoots were recorded one day before spray as precount and subsequently 3, 7, 10 and 15 days after each spray as post treatment count.

#### **3.1.3.2 Thrips**

Number of thrips per shoot (nymphs and adults) were recorded by counting from five new shoots (each of 5 cm shoot length) per plant, by shaking the shoots on hard card board pasted with black paper to facilitate easy visibility. The mean number of thrips per shoot were worked out (Plate 3.6, 3.7 and 3.9). The population of thrips on shoots was recorded one day before to spray as pre count and subsequently 3, 7, 10 and 15 days after each spray as post treatment count.

#### **3.1.3.3 Fruit borer**

Observations on fruit borer infestation were periodically recorded during fruiting season and the pest intensity judged on the basis of per cent damaged fruits on the pomegranate plant. While harvesting, at each picking, total number of infested as well as healthy fruits were recorded. Percentage of damaged fruits were calculated as average of the plant (Plate 3.10, 3.11 and 3.12).

### **3.1.4 Statistical Analysis**

The data collected on population count of aphids and thrips per shoot and fruit borer damage (%) were transformed into square root values and arc sin values, respectively. The analysis of pooled data of two bahars was carried out to find the relative efficacy of the insecticides against aphids, thrips and fruit borer. Appropriate statistical methods were employed to work out standard error mean and critical difference to find out the significance of treatments (Gomez and Gomez, 1984).

In the jurisdiction of M.P.K.V., Rahuri most of the pomegranate growers are using various newer insecticides for the management of pomegranate pests. Based on the feedback from Agro-service centers most frequently used insecticides are selected.

Present investigation emphasized on bioefficacy of certain newer insecticides against the pomegranate insect pests. Though, no pesticides under this study except cyantraniliprole 10.26 % OD and lambda-cyhalothrin 04.90 % CS has been recommended by CIB&RC on pomegranate. The pomegranate growers are using these insecticides because these insecticides are recommended for sucking pests and borer complex in other crops.

If we see the mode of action of these insecticides, all of these having new mode of action viz., tolfenpyrad (Mitochondrial Complex I Electron Transport Inhibitors), imidacloprid, acetamiprid and thiacloprid (Nicotinic Acetylcholine Receptor (nAChR) competitive modulators), fipronil (GABA-gated chloride channel blockers), spirotetramat (Inhibitors of acetyl CoA carboxylase), lambda cyhalothrin (sodium channel modulators), spinosad (Nicotinic Acetylcholine Receptor (nAChR) allosteric modulators – Site I), emamectin benzoate (Glutamate-gated Chloride channel (GluCl) allosteric modulators), thiodicarb (Acetyl Cholinest Erase (AChE) inhibitors), cyantraniliprole, flubendiamide and chlorantraniliprole (Ryanodine receptor modulators),

**Table 3.2 Newer insecticides evaluated for their bioefficacy against aphids and thrips**

S. No.	Treatment	Trade Name	Dose (g a.i. ha <sup>-1</sup> )	Source of product
1.	Tolfenpyrad 15 % EC	Keefun	150	M/S P.I. Industries, Haryana
2.	Cyantraniliprole 10.26 % OD	Benevia	75	M/S Dupont India Private Ltd., Mumbai
3.	Imidacloprid 17.80 % SL	Confidor	50	M/S Bayer Crop Science Ltd., Mumbai
4.	Acetamiprid 20 % SP	Pride	20	M/S Gharda Chemicals Ltd., Dombiwali
5.	Thiacloprid 21.70 % SC	Alanto	180	M/S Bayer Crop Science Ltd., Mumbai
6.	Fipronil 5 % SC	Regent	100	M/S Bayer Crop Science Ltd., Mumbai
7.	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	Movento Energy	60+60	M/S Bayer Crop Science Ltd., Mumbai
8.	Untreated control	-	-	-

**Table 3.3 Newer insecticides evaluated against pomegranate fruit borer**

S. No.	Treatment	Trade Name	Dose (g a.i. ha <sup>-1</sup> )	Source of product
1.	Flubendiamide 39.35 % SC	Fame	72	M/S Bayer Crop Science Ltd., Mumbai
2.	Flubendiamide 19.92 % + Thiachloprid 19.92 % SC	Belt Expert	60+60	M/S Bayer Crop Science Ltd., Mumbai
3.	Lambda cyhalothrin 5 % EC	Karate	25	M/S Syngenta India Ltd, Mumbai
4.	Spinosad 45 % SC	Spintor	75	M/S Bayer Crop Science Ltd., Mumbai
5.	Emamectin benzoate 5 % SG	Proclaim	11	M/S Syngenta India Ltd, Mumbai
6.	Chlorantraniliprole 18.50 % SC	Coragen	40	M/S Dupont India Private Ltd., Mumbai
7.	Cyantraniliprole 10.26 % OD	Benevia	75	M/S Dupont India Private Ltd., Mumbai
8.	Thiodicarb 75 % WP	Larvin	750	M/S Bayer Crop Science Ltd., Mumbai
9.	Untreated control	-	-	-

**Table 3.4 Biorationals evaluated for their bioefficacy against pomegranate aphids, thrips and fruit borer**

S. No.	Treatment	Trade Name	Dose (g or ml L <sup>-1</sup> )	Source of product
1.	Silicon	Prosilica	1000 ppm	M/S Mangal Products, Mumbai
2.	<i>Lecanicillium lecanii</i>	Phule Bugicide	5 g	Biocontrol laboratory, Department of Agril. Entomology, M.P.K.V., Rahuri
3.	Azadirachtin 10000 ppm	Neemazol	3 ml	M/S Mangal Products, Mumbai
4.	<i>Metarhizium anisopliae</i>	Phule Metarhizium	5 g	Biocontrol laboratory, Department of Agril. Entomology, M.P.K.V., Rahuri
5.	<i>Beauveria bassiana</i>	Phule Beauveria	5 g	Biocontrol laboratory, Department of Agril. Entomology, M.P.K.V., Rahuri
6.	Neem oil + Karanja oil	Bio Neem oil + Karanjin	2 ml+2 ml	M/S Mangal Products, Mumbai
7.	Neem Seed Extract (N.S.E)		5 %	M/S Mangal Products, Mumbai
8.	Untreated control	--	--	--

### **3.1.5 Preliminary studies on mycoinsecticides to evaluate their bioefficacy against pomegranate thrips and aphids**

In this test, growth of different mycoinsecticides (*B. bassiana*, *M. anisopliae* and *L. lecanii*) on pomegranate aphids and thrips were observed under compound microscope.

#### **3.1.5.1 Methodology**

Mycoinsecticides viz., *B. bassiana*, *M. anisopliae*, *L. lecanii* were studied for mycosis test. The fungal suspension of three mycoinsecticides were separately prepared in beakers by mixing 5 g of each myco insecticide in 100 ml of water in beaker. The young pomegranate leaves were collected from field and their surface was cleaned with Mercuric Chloride 0.1 % by using cotton, in order to remove fungal spores present on the leaves. Later on, the leaves were rinsed with the distilled water to remove the chemical on leaves.

The pomegranate leaves were smeared with the fungal suspension prepared and placed in the petri plates. For each mycoinsecticide, three petri plates were prepared for mycosis test. The collected aphids and thrips were released into each petri plates in numbers of 10. Petri plates were then packed with the polythene strip in order to avoid the escape of aphids and thrips from petri plates and were incubated in cool place for seven days to promote the infection of fungus (Latha, 2010) (Plate 3.13).

Detailed microscopic examination of thrips and aphids samples collected from the petri plates of different treatments were observed after 7 days of treatment under the microscope with resolutions like 10 and 40 X for the growth of different fungus on various body parts of the test insects.

## **3.2 Effect of Insecticides on Beneficial Organisms (Coccinellids, Spiders and Honey Bees)**

### **3.2.1 Method of recording observation**

In field experiment on bioefficacy of newer insecticides against pomegranate insect pests, the effect of insecticides on beneficial organisms was also studied simultaneously. The number of beneficial organisms viz., coccinellids (grubs and beetles), spiders and honey bees were counted manually while taking pest count after spraying. Ten branches were taken from each tree to count the coccinellids (grubs and beetles), spiders. The population of coccinellids and spiders were taken at 7 DAS and 14 DAS after the last spray, whereas, honey bee population was recorded on 3, 7, 10 and 15 DAS after each spray (Plate 3.14).

The observations on honey bees were recorded during morning hours i.e. at 08.00 AM to 10.00 AM. From each treatment twelve flowers of four sides (directions) of each plant (i.e. East, West, South and North) were randomly selected and were separately labeled with identifying tags. The number of honey bees visiting pomegranate flowers was counted through visual observations. A bee landing on an open flower for 5-10 seconds was considered as a bee visit. The treatment receiving maximum visits of honey bees was considered as least harmful than other treatments.

### 3.2.2 Statistical Analysis

The data collected on population counts of beneficial organisms (coccinellids, spiders and honey bees) were transformed into square root values. Appropriate statistical methods were employed to find out standard error and critical difference to decide the significance of treatments (Gomez and Gomez, 1984).

### 3.3 Studies on Residues and Dissipation of Insecticides in Pomegranate Fruits and Cropped Soil

In order to study the dissipation of flubendiamide + thiacloprid 480 % SC and thiacloprid 240 % SC, a field experiment was conducted at All India Coordinated Research Project on Arid Zone fruits, Department of Horticulture, M.P.K.V., Rahuri. The laboratory studies on dissipation of insecticides were carried out at All India Network Project on Pesticide Residues, Department of Agricultural Entomology, M.P.K.V., Rahuri (Plate 3.15, Table 3.5, 3.6 & 3.7).

All the trees were maintained by following standard package of practices except insecticide application. Two foliar sprays of insecticides were sprayed at an interval of ten days starting from the fruit initiation stage with the help of knapsack sprayer. The due care was taken to wash the spray pump with water, in the beginning and while switching over from one dose to another during spraying. The related experimentation and methodology is detailed as below.

#### 3.3.1 Glasswares

All glass items were of 'A' grade. Glasswares were initially cleaned with aqueous soap solution and were rinsed thoroughly with tap water. Acetone rinsed glasswares were oven-dried prior to use.

**Table 3.5 Experiment details of residues and dissipation studies**

1.	Location	:	All India Coordinated Research Project on Arid Zone fruits, Department of Horticulture, M.P.K.V., Rahuri, Maharashtra
2.	Crop and Variety	:	Pomegranate (Bhagwa)
3.	Season and Year	:	<i>Ambia bahar</i> – 2019
4.	Experimental Design	:	Randomized Block Design (RBD )
5.	Treatments	:	Six
6.	Replication	:	Three
7.	Spacing	:	4.5 m X 3.0 m
8.	Number of applications	:	Two
9.	Time of application	:	10.4.2019 (1 <sup>st</sup> spray) and 20.4.2019 (2 <sup>nd</sup> spray)
10.	Sampling	:	Immature fruits at 0 (2 hr after spraying), 1, 3, 5, 7, 10 and 15 days after 2 <sup>nd</sup> spray, matured fruits and soil at the time of harvesting

**Table 3.6 Treatment details for dissipation of flubendiamide + thiacloprid 480 SC**

Tr. No.	Insecticide	Dose (g a.i. ha <sup>-1</sup> )	Formulation (ml ha <sup>-1</sup> )
1.	Flubendiamide + thiacloprid 480 SC (Recommended dose)	60+60	250
2.	Flubendiamide + thiacloprid 480 SC (Double the recommended dose)	120+120	500
3.	Untreated control	-	-

**Table 3.7 Treatment details for dissipation studies of thiacloprid 240 SC**

Tr. No.	Insecticide	Dose (g a.i. ha <sup>-1</sup> )	Formulation (ml ha <sup>-1</sup> )
1.	Thiacloprid 240 SC (Recommended dose)	60	250
2.	Thiacloprid 240 SC (Double the recommended dose)	120	500
3.	Untreated control	-	-

### 3.3.2 Chemicals and Reagents

1. Acetonitrile (HPLC Grade), Avantor Performance Material Ltd., Mumbai (M.S.).
2. Sodium sulphate anhydrous purified, SDFCL, Mumbai.
3. Magnesium sulphate (Analytical reagent grade), Avantor Performance Material Ltd., Mumbai (M.S.).
4. Primary Secondary Amine (PSA), Agilent Technology, Bengaluru.
5. Acetone (Analytical Reagent grade), Avantor Performance Material Ltd., Mumbai (M.S.).
6. Sodium chloride (Analytical Reagent grade), Avantor Performance Material Ltd., Mumbai (M.S)
7. Certified Reference Materials (CRMs) of pesticides (flubendiamide, thiacloprid and des-iodo) were purchased from Dr. Ehrenstorfer GmbH (Augsburg, Germany) and Sigma Aldrich.

### 3.3.3 Instrumental analysis

The residue estimation of flubendiamide + thiacloprid 480 % SC and thiacloprid 240 % SC were carried out by using High Performance Liquid Chromatography (HPLC) (Table 3.8).

**Table 3.8 Apparatus, Equipments and Instruments used during the course of study**

S. No.	Apparatus/Equipment	Maker	Model	Range and Accuracy
1.	Weighing balance	Citizen	Cy-204	0.0001 to 220 gm
2.	Weighing balance	Citizen	CTG 302-300	Min 0.02 to 300 mg
3.	Grinder	Robot Coupe	Blixer 6 v.v.	7 L
4.	Centrifuge	Remi	R-8-CHDLC-10151	5000 RPM
5.	Vortex	Spinix	--	--
6.	Deep Freezer	Sanyo	MDF-U5411	Ambient to - 40 <sup>0</sup> C
7.	Micro Pipette	Eppendorf	--	100 to 1000 $\mu$ L
8.	Micro Pipette	Eppendorf	--	10 to 100 $\mu$ L

### 3.3.4 Liquid chromatographic conditions

Residue estimation of flubendiamide + thiacloprid 480 % SC and thiacloprid 240 % SC were performed by using high performance liquid chromatography with auto sampler and Photo Diode Array (PDA) (Shimadzu/HPLC-LC-20AT). LC-Solution software was used for data analysis. The operating parameters of the instrument are given below (Table 3.9).

**Table 3.9 Liquid chromatographic conditions**

Parameters	Flubendiamide and Des-iodo flubendiamide	Thiacloprid
Mobile phase (Acetonitrile : Water)	80 : 20	80 : 20
Wavelength	254 and 210 nm	254 nm
Flow rate	0.8 ml/min	0.8 ml/min
Column	RP-18, 150 $\times$ 4.6 mm i.d 5 $\mu$ m	RP-18, 150 $\times$ 4.6 mm i.d 5 $\mu$ m
Injection volume	20 $\mu$ l	20 $\mu$ l
Retention time	5.00 and 4.50 min	3.30 min

### 3.3.5 Standards preparation

#### a. Primary standard

A technical grade pesticide standard accurately weighed (10 mg) (purity : flubendiamide (98.10 %), des-iodo flubendiamide (99.80 %) and thiacloprid (99 %)) on weighing balance

(Citizen CTG 302-3). Then it was dissolved in 1 ml acetonitrile than the volume was made to 10 ml in volumetric flask using acetonitrile as solvent to prepare the stock solution of  $1000 \mu\text{g m L}^{-1}$ .

#### **b. Intermediate standard**

The primary standard of each insecticide was diluted to prepare intermediate lower concentration of  $100 \mu\text{g m L}^{-1}$ . They were stored in a refrigerator at  $-30^{\circ}\text{C}$ . The intermediate solutions can be stored up to 6 months for their usage to proper results.

#### **c. Working standards**

Working standards of concentrations *viz.*, 0.05, 0.10, 0.15, 0.25, 0.40, 0.50 and 1 ppm were prepared from the intermediate standards. The working standards were prepared by suitably diluting the intermediate solution in acetonitrile (HPLC) and used as standard checks in analysis of linearity, recovery studies and quantitative analysis of tested insecticides (Plate 3.16).

### **3.3.6 Method validation**

Before the pesticide application and field sample analysis, the residue analysis method was validated following the SANTE/11813/2017. Method validation is a process used to confirm that the analytical procedure employed for a specific test is suitable for its intended use. The results from method validation can be used to judge the quality, reliability and consistency of analytical results. It is an integral part of any good analytical practice. Limit of detection (LOD), limit of quantification (LOQ), linearity and recovery studies were performed to validate the method.

#### **a. Limit of Detection (LOD) and Limit of Quantification (LOQ)**

The limits of detection (LOD) of tested insecticides were determined by considering a signal-to-noise ratio of three with reference to the background noise obtained for the blank sample. The limits of quantification (LOQ) were found as three times of LOD.

#### **b. Specificity**

Specificity studies were performed by spiking the pomegranate sample and reagent blank with working standards of flubendiamide, its metabolite des-iodo flubendiamide and thiacloprid at the concentration of  $0.05 \mu\text{g g}^{-1}$ . The area of sample and reagent blank was compared with spiked matrix match area.

#### **c. Linearity studies**

Six linear concentrations (0.05, 0.10, 0.25, 0.40, 0.50 and 1 ppm) of working standards *i.e.*, flubendiamide, its metabolite des-iodo flubendiamide and thiacloprid were injected in three replications and the linearity line was drawn based on area obtained.

#### d. Recovery studies

The analytical method for estimation of residues of flubendiamide, des-iodo flubendiamide and thiacloprid in pomegranate was validated by conducting recovery studies using pomegranate samples from control plots (insecticide free samples).

Fifteen gram of homogenized pomegranate fruit samples from untreated plot was taken in 50 ml centrifuge tube in three replicates. Sample was spiked with flubendiamide, des-iodo flubendiamide and thiacloprid at required fortification levels *i.e.* LOQ, 5×LOQ and 10×LOQ, as per method. Than this mixture was shaken to attain a proper homogeneity of insecticides in the sample. The extraction and cleanup was followed as per QuEChERS method and analysed under HPLC.

The quantity to be spiked for recovery analysis can be calculated using,

$$\text{Volume of standard required for fortification (ml)} = \frac{\text{Weight of sample (g)} \times \text{Required fortification level (ppm)}}{\text{Concentration of standard (ppm)}}$$

The recovery (%) was calculated by using below formula.

$$\text{Per cent recovery} = \frac{\text{Quantity of insecticide recovered}}{\text{Quantity of insecticide fortified}} \times 100$$

#### e. Repeatability and reproducibility

Repeatability or retest reliability was performed to check the variation in measurements taken by the same person on same instrument on the same substrate in the same conditions. Reproducibility was performed to test the ability of an entire analysis of an experiment by another person on the same instrument with same substrate under same conditions.

### 3.3.7. Extraction and clean up procedure for pomegranate fruits and soil

#### 3.3.7.1 Pomegranate fruits

The extraction and cleanup procedure of Anastassiades *et al.*, (2003) with slight modification was followed for pomegranate fruits and soil. Fifteen grams of homogenized sample was taken in a 50 ml polypropylene tube and tube was kept in deep freezer for 10 minutes. To this, added 15 ml of 1 % Acetic Acid in Acetonitrile (v/v), 6.0 g Magnesium Sulphate (anhydrous) and 1.5 g Sodium Acetate (anhydrous), shaken vigorously for 1.0 min (manually) and centrifuged at 3500 rpm for 1.0 min. Transferred 6.0 ml supernatant to the tube containing of 300 mg Primary Secondary Amine + 900 mg Magnesium Sulphate. Shaked vigorously for 30 seconds and centrifuged at 3500 rpm for 1.0 min to separate the solid material. Supernatant of 2 ml was taken and evaporated to dryness and made up to 2.0 ml with acetonitrile for analysis (HPLC) (Plate 3.17, 3.18 and 3.19).

### 3.3.7.2 Soil

Ten grams of soil sample was taken in a clean 50 ml polypropylene tube. To this added 20 ml of acetonitrile, shaken vigorously and added 4 g of MgSO<sub>4</sub> and 1 g of NaCl. Centrifuged at 3300 rpm for 5 minutes and transferred 10ml supernatant in 15 ml tube, containing 250 mg of PSA and 1.5 g of MgSO<sub>4</sub> and sonicated for 1 minute. Centrifuged for 10 minutes at 4000 rpm and collected 4 ml supernatant from that and evaporated to nearly dryness and reconstituted residues to 1 ml with cyclohexane.

### 3.3.7.3 Residue Determination

Residues of flubendiamide + thiacloprid 480 SC and thiacloprid 240 SC were estimated by using HPLC. Identification of insecticide residue was accomplished by retention time (RT) and compared with known standard (CRM) at the same conditions. The quantities were calculated on peak area basis by using following formula,

$$\text{Residues } (\mu\text{g g}^{-1}) = \frac{\text{Area of sample}}{\text{Area of standard}} \times \frac{\text{sample injected } (\mu\text{l})}{\text{standard injected } (\mu\text{l})} \times \frac{\text{Conc. of standard (ppm)}}{\text{wt .of sample (g)}} \times \text{Final volume (ml)}$$

$$\text{Wt. of sample (g)} = \frac{\text{Sample Wt. (g)} \times \text{Aliquot taken (ml)}}{\text{Volume of solvent added (ml)}}$$

The half-life value of insecticides as indices of the rates of residue dissipation was calculated as per Hoskins (1961) as below.

$$T_{1/2} = \log 2/k_1 = 0.301/k_1$$

Where  $T_{1/2}$  = half-life value of residues

$k_1$  = slope of regression coefficient (b) of the log residues in  $\mu\text{g g}^{-1}$  (y) on the number of elapsed days (x).

## 3.4 Evaluation of IPM Module for the Management of Insect Pests in Pomegranate

The experiment was conducted to evaluate IPM module for the management of insect pests in pomegranate during the *Ambia bahar*, 2020 in the orchard at All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, India. All the recommended package of practices were followed in raising the crop (Plate 3.20 and 3.21, Table 3.10, 3.11 & 3.12).

### 3.4.1 Material required

**Table 3.10 List of insecticides and biorationals used in IPM module and farmer's practice**

S. No.	Treatment	Trade Name	Dose (g/L or g a.i./ha)	Source of product
1.	<i>Lecanicillium lecanii</i>	Phule Bugicide	5 g	Biocontrol laboratory, Department of Agril. Entomology, M.P.K.V., Rahuri
2.	<i>Metarhizium anisopliae</i>	Phule Metarhizium	5 g	Biocontrol laboratory, Department of Agril. Entomology, M.P.K.V., Rahuri
3.	Azadirachtin 10000 ppm	Neemazol	3 ml	M/S Mangal Products, Mumbai
4.	Neem oil+ Karanja oil	Bio Neem oil + Karanjin	2 ml+2 ml	M/S Mangal Products, Mumbai
5.	NSE	--	5 %	M/S Mangal Products, Mumbai
6.	Imidacloprid 17.80 % SL	Confidor	50 g	M/S Bayer Crop Science Ltd., Mumbai
7.	Cyantranilprole 10.26 % OD	Benevia	75	M/S Dupont India Private Ltd., Mumbai
8.	Spinosad 45 % SC	Spintor	75	M/S Bayer Crop Science Ltd., Mumbai
9.	Emamectin Benzoate 5 % SG	Proclaim	11	M/S Syngenta India Ltd, Mumbai

**Table 3.11 Details of experimentation**

1	Location	:	All India Coordinated Research Project on Arid Zone fruits, Department of Horticulture, M.P.K.V., Rahuri, Maharashtra
2	Crop	:	Pomegranate
3	Variety	:	Bhagwa
4	Spacing	:	4.5 m X 3.0 m
5	Year and season	:	<i>Ambia bahar</i> , 2020
6	Treatments	:	Three (IPM module, Farmer's practice and Untreated control)
7	Replication	:	Eight

After analyzing the earlier literature and findings (Shewale and Padule 1992, Chadha 2003, Halagatti (2006), Jagdish and Purnima (2011), Walunj *et al.* (2012), Bhut *et al.* (2013), Walunj *et al.* (2015), Arvind Kumar and Sasya Thakur (2017), Walunj, 2017, Anon., 2017, Anon., 2018, Sujit *et al.* (2018), Bhojane *et al.* (2019), Rami Reddy *et al.* (2019), Abbas (2020), Pawar *et al.* (2020), Gaikwad *et al.* (2020), Akhtar (2020), Anon., 2020, Deepak *et al.* (2020), Annual report, M.P.K.V., Rahuri 2019 – 2020) on effectiveness of biorationals in IPM of

different crops, the following module have been prepared to manage the pomegranate insect pests.

**Table 3.12 Details of IPM module and farmers practice for the management of insect pests in pomegranate**

Time line of bahar	ETL to start the insecticide application in IPM module (NCIPM, 2014)	IPM module	Farmer's practice
<b>Up to 40 days</b>			
<b>Aphids</b>	When 10 aphids/shoot were observed	One spray of <i>Lecanicillium lecanii</i> @ 5 g L <sup>-1</sup> followed by one spray of <i>Metarhizium anisopliae</i> @ 5 g L <sup>-1</sup> at 7 days interval	One spray of imidacloprid 17.8 SL @ 0.3 ml L <sup>-1</sup> followed by one spray of cyantraniliprole 10.26 OD @ 75 g a.i. ha <sup>-1</sup> at 10 days of interval
		Need based application of imidacloprid 17.8 SL @ 50 g a.i. ha <sup>-1</sup>	
<b>40-90 Days</b>			
<b>Thrips, Aphids, Whitefly and Mealy bug</b>	i) When 10 thrips/shoot or fruit infestation > 1 % ii) When 10 aphids/shoot were observed	One spray of <i>Lecanicillium lecanii</i> @ 5 g L <sup>-1</sup> + one spray of <i>Metarhizium anisopliae</i> @ 5 g L <sup>-1</sup> followed by one spray of azadirachtin 10000 @ 3 ml L <sup>-1</sup> at 10 days of interval	Two sprays of spinosad 480 SC @ 75 g a.i. ha <sup>-1</sup> at 10 days of interval
		Two sprays of Neem oil+ Karanja oil @ 2 ml L <sup>-1</sup> + 2 ml L <sup>-1</sup> at an interval of 10 days	
<b>90-120 days</b>			
<b>Thrips, Fruit borer</b>	i) When 10 thrips/shoot or fruit infestation > 1 % ii) When 5 eggs/tree or fruit borer infestation > 1 % were observed	Two sprays of NSE @ 5% at 10 days of interval	One spray of cyantraniliprole 10.26 OD @ 75 g a.i. ha <sup>-1</sup> followed by one spray of emamectin benzoate @ 11 g a.i. ha <sup>-1</sup> at 10 days of interval
		Need based application of cyantraniliprole @ 75 g a.i. ha <sup>-1</sup>	

The above IPM module consisted of three stages which included up to 40, 40-90 and 90-120 days after bahar initiation. On the basis of ETL monitoring, in the three stages different biorationals and insecticides were applied to manage the pomegranate aphids, thrips and fruit borer. After collection of information from different pomegranate farmers from Ahmednagar district, most used insecticides by the farmers were included in the module.

### **3.4.2. Method of recording observation**

#### **3.4.2.1 Aphids**

Mean number of aphids (nymphs and adults) were counted from 5 terminals (each of 5 cm shoot length) on five branches in a plant. The average number of aphids per shoot were worked out. The count of aphids on shoots was recorded one day before the spray as pre count and subsequently after 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> week as post treatment count.

#### **3.4.2.2 Thrips**

Number of thrips (nymphs and adults) were recorded by counting from five new shoots (each of 5 cm shoot length) per plant, by shaking the shoots on hard card board pasted with black paper to facilitate easy visibility. The average number of thrips per shoot were worked out. The count of thrips on shoots was recorded one day before the spray as pre count and subsequently after 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> week as post treatment count.

#### **3.4.2.3 Fruit borer**

Observations on fruit borer incidence were periodically recorded during fruiting season and the pest intensity was judged on the basis of per cent damaged fruits per plant. While harvesting, at each picking, total number of infested and healthy fruits were recorded. Percentage of damaged fruits were calculated as average of the plant.

#### **3.4.3 Yield**

The pomegranate fruit yield from the individual plant of each treatment in the field at each picking made at 15 days interval commencing from 150 days after “bahar” treatment up to termination was recorded in kg per plant and expressed in tonnes per hectare.

#### **3.4.4 Statistical analysis of the data**

The data collected on population count of aphids and thrips per shoot and fruit borer damage were transformed into square root values and arc sin values, respectively. Appropriate statistical methods were employed to find out the standard error and critical difference to observe the significance of treatments (Gomez and Gomez, 1984).



**Plate 3.7** Field view of the experimental field for evaluating biorationals against aphids & thrips



**Plate 3.10** Field view of the experimental field for evaluating newer insecticides against fruit borer



**Plate 3.20 Field view of the experimental field for evaluating IPM module & farmer's practice**



**Plate 3.15 Field view of the experimental field to study the residues and dissipation of insecticides in pomegranate**



**Plate 3.6 Field view of the experimental field for evaluating newer insecticides against aphids & thrips**



**Plate 3.11 Field view of the experimental field for evaluating biorationals against fruit borer**



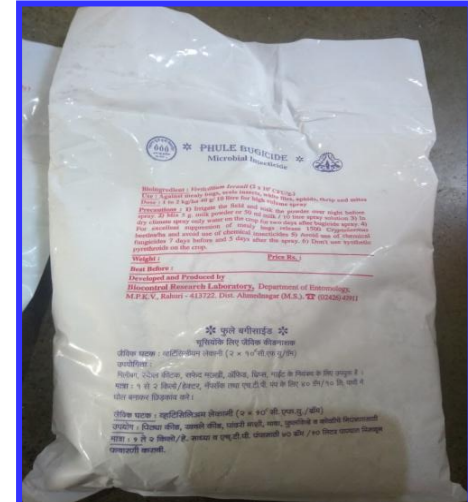
**Plate 3.5 Spraying of newer insecticides against pomegranate insect pests**



A) *Metarhizium anisopliae* (Phule Metarhizium)



B) *Beauveria bassiana* (Phule Beauveria)



C) *Lecanicillium lecanii* (Phule Bugicide)



1) Mixing of biorationals with water



2) Adding jaggery



3) Final spray fluid solution

Plate 3.21 Spray fluid solution preparation of different biorational insecticides



**Plate 3.8 Aphids (*Aphis punicae*) and its infestation on flowers and branches of pomegranate**



**Plate 3.9** Thrips (*Scirtothrips dorsalis*) and its infestation on leaves & fruits of pomegranate



Plate 3.12 Fruit borer (*Deudorix isocrates*) larvae, adult and its infestation on fruits of pomegranate

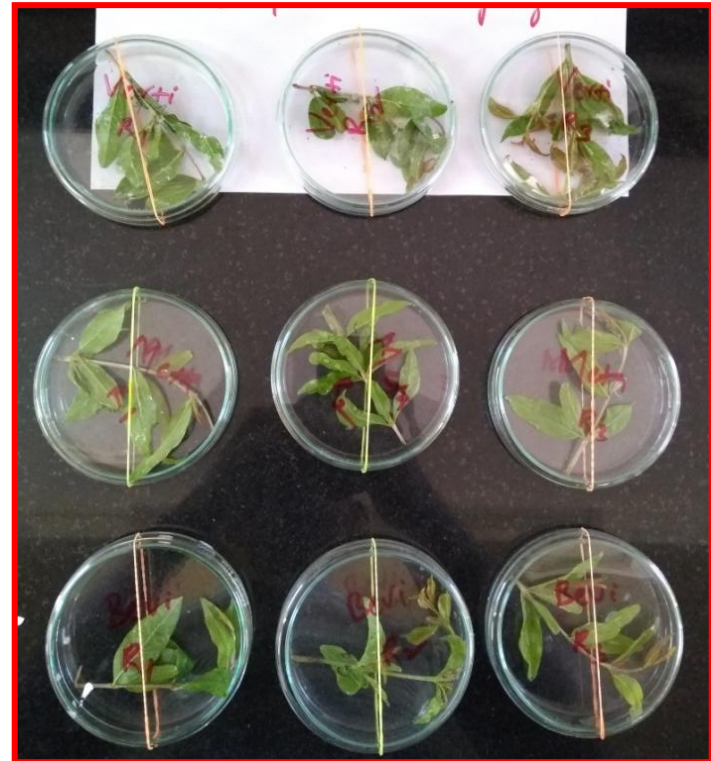
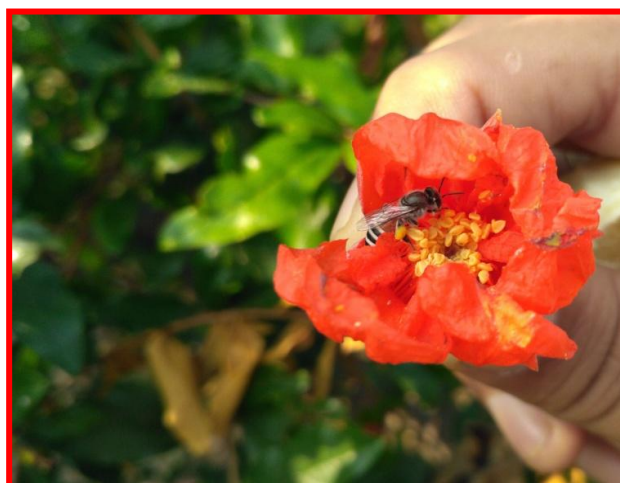


Plate 3.13 Preliminary mycosis test on pomegranate aphids & thrips with biorational insecticides



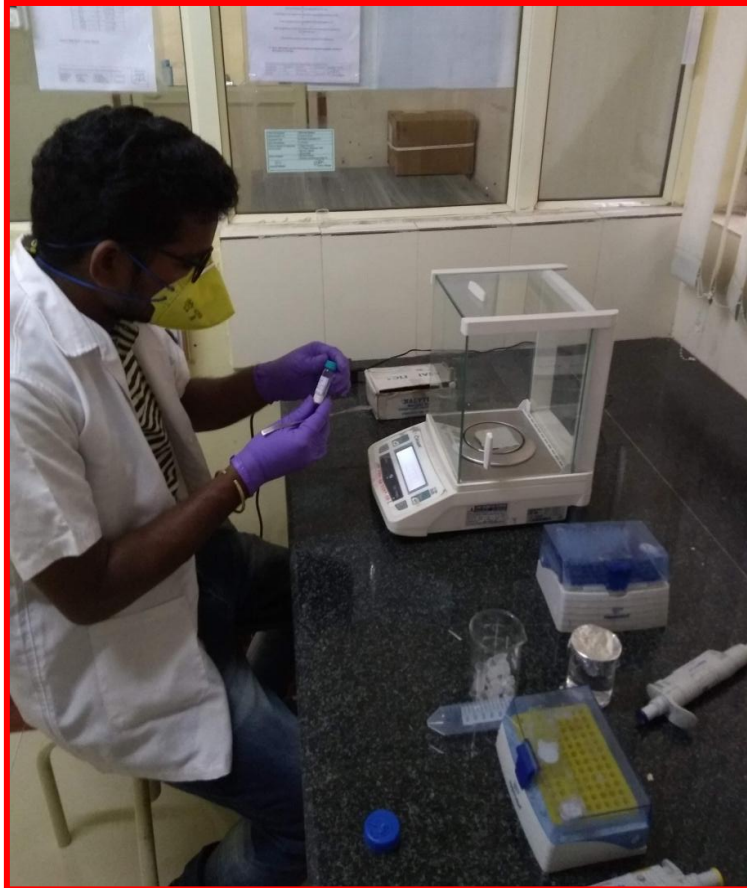
a) Adult and grub of coccinellid (*Cheilomenes sexmaculata*)

b) Spider (*Peucetia viridana*)



c) Honey bees (*Apis florea* and *Apis dorsata*)

Plate 3.14 Different beneficial organisms in pomegranate ecosystem



**Plate 3.16 Preparation of primary, intermediate stock solution and working standards**



**Plate 3.17 Collection of pomegranate fruits after insecticidal spray**



**A. Digital weigh balance**



**B. Deep freezer**



**C. Grinder**



**D. Vertex**

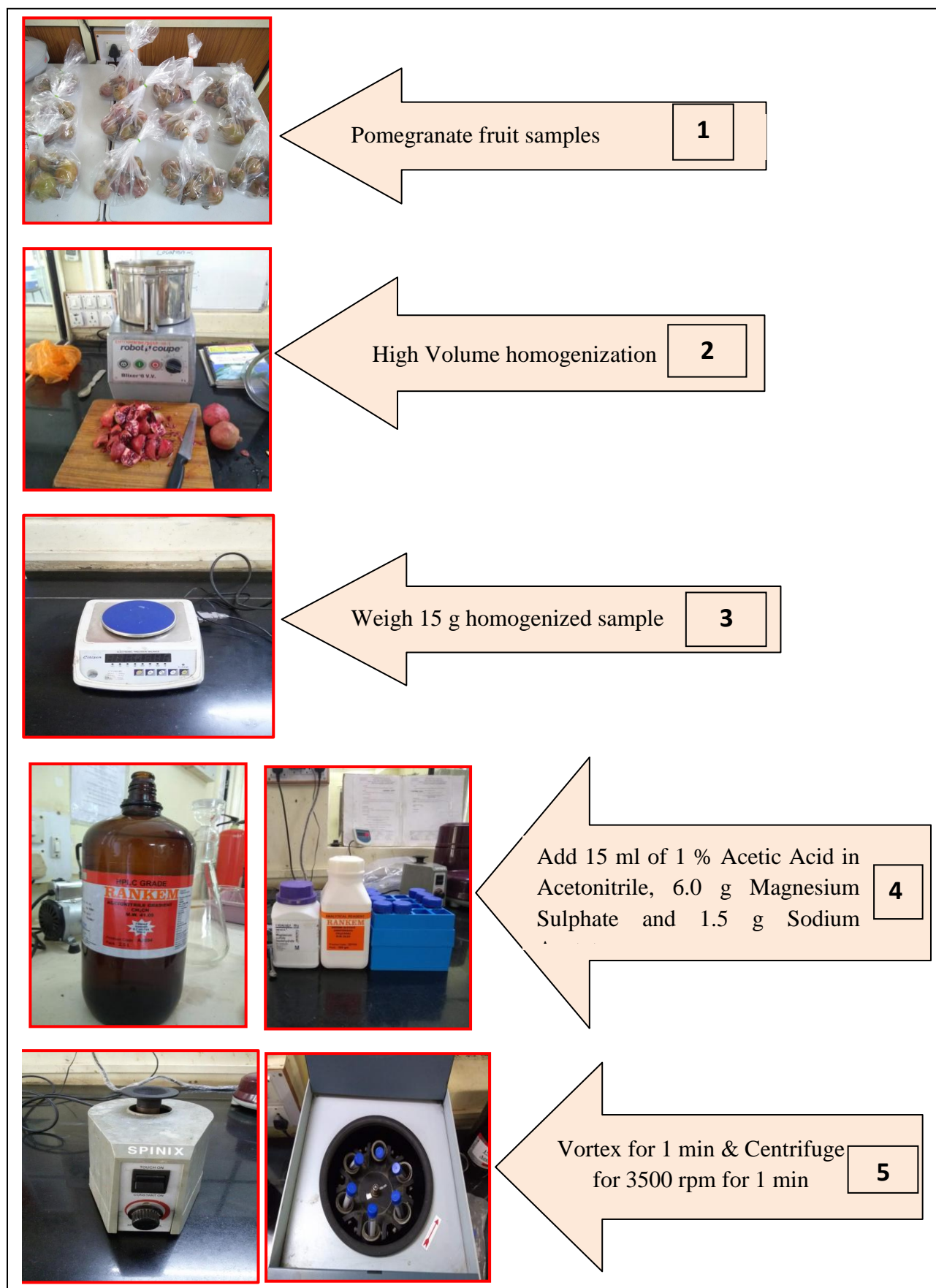


**E. Centrifuge**

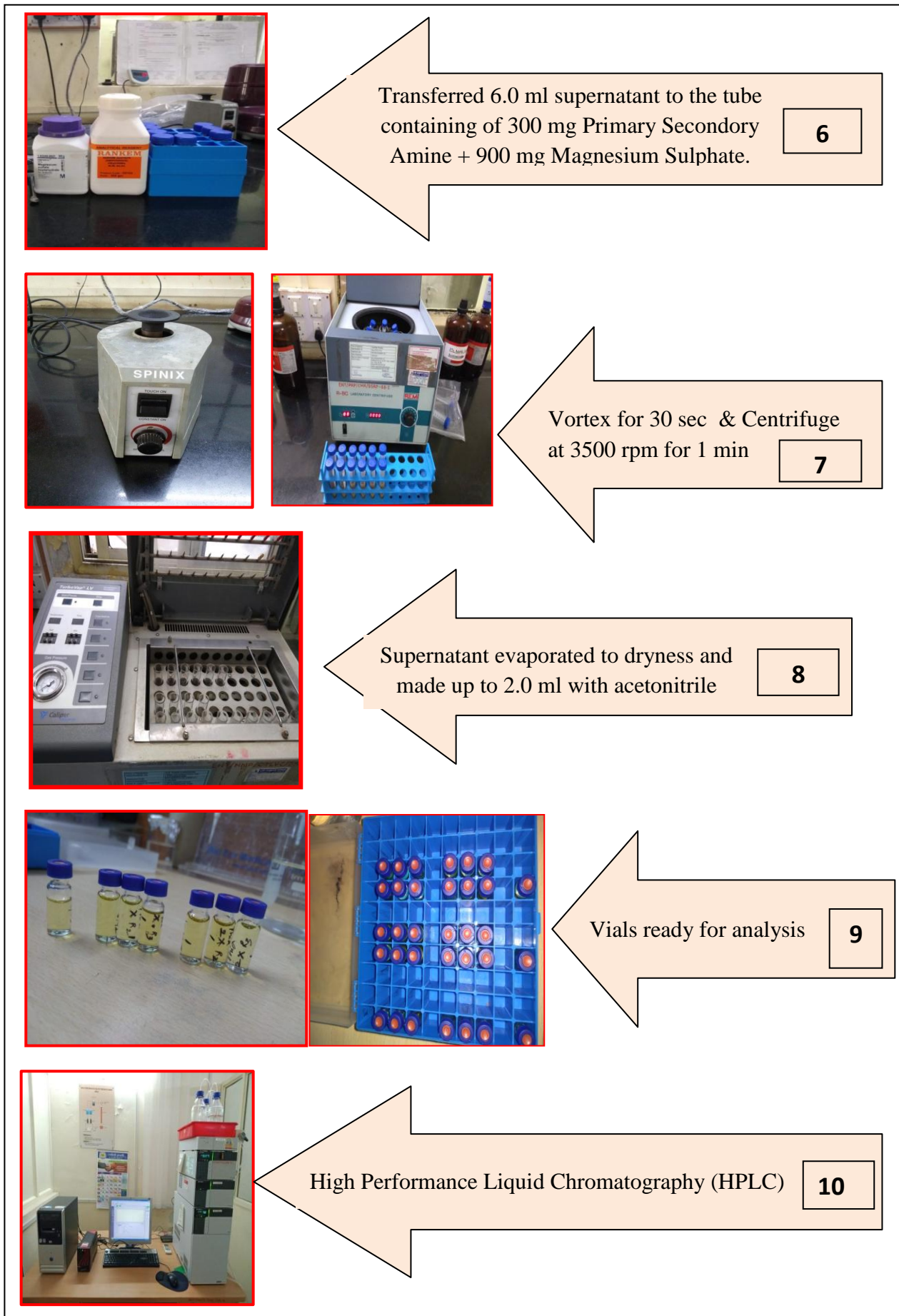


**F. Low volume evaporator**

**Plate 3.18 Different apparatus used during residue analysis**



**Fig 3.19 Working flowchart of QuEChERS method (HPLC method)**



**Fig. 3.19 Working flowchart of QuEChERS method (HPLC method)**

## 4. RESULTS AND DISCUSSION

Present investigation, “Studies on insecticide management of pests infesting pomegranate (*Punica granatum* L.)” was carried out during the *Ambia bahar*, 2018 to 2020 at Post Graduate Institute (P.G.I), Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (19.3491° N, 74.6461° E). The field experiments on bioefficacy, estimation of residues & dissipation and integrated pest management studies were conducted at All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, M.P.K.V., Rahuri, Maharashtra. The laboratory studies on residues and dissipation of insecticides were carried out at All India Network Project on Pesticide Residues, Department of Agricultural Entomology, M.P.K.V., Rahuri. The results obtained during the studies have been presented and discussed in this chapter.

### 4.1 Bioefficacy of Newer Insecticides Against Pomegranate Aphids & Thrips

#### 4.1.1 Aphids, *Aphis punicae*

Under each sub-head, the results of the mean population of aphids per shoot computed from 3 DAS to 15 DAS from each spray, as well as pooled data, have been presented.

##### 4.1.1.1 *Ambia bahar* – 2018

#### First spray

The data pertaining to efficacy of insecticides against aphids after first spray are presented in Table 4.1. The pre count of aphids was found non-significant and registered in the range of 25.16 to 27.45/shoot indicating homogenous population in the field. The data also showed that all insecticidal treatments were significantly more effective than the untreated control in suppressing the aphid population.

At 3 DAS, the treatment of fipronil @ 100 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population (10.98/shoot) of aphids. It was, however at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (11.56/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (12.45/shoot). The next treatments in the order of superiority were thiacloprid @ 180 g a.i. ha<sup>-1</sup> (14.98), tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (15.10), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (16.08) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (17.10) as against 26.54 aphids/shoot in untreated control.

At 7 DAS, the treatment of spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the most effective treatment with lowest population (4.86/shoot) of aphids. However, it was at par with fipronil @ 100 g a.i. ha<sup>-1</sup> (5.45/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (5.78/shoot). The next effective treatments were, tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (6.84), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (7.16), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (8.98) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (9.10) as against maximum population of aphids (27.11/shoot) was recorded in untreated control. Similar pattern was seen at 10 days after spray.

The treatment of spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (1.17/shoot). This was followed by fipronil @ 100 g a.i. ha<sup>-1</sup> (1.48/shoot), cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (1.66/shoot), tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (2.86/shoot), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (2.98/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.10/shoot) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (3.45/shoot) as against 26.32/shoot in untreated control.

### **Second spray**

The data pertaining to efficacy of insecticides against aphids after second spray are presented in Table 4.1. The data also showed that all insecticidal treatments were considerably more effective than the untreated control in suppressing aphid population.

At 3 DAS, cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population of aphids (7.42/shoot). It was, however at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (7.61/shoot) and fipronil @ 100 g a.i. ha<sup>-1</sup> (8.54/shoot). The next treatments in the order of superiority were tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (10.12/shoot), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (10.72/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (11.96/shoot) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (12.10/shoot). However, highest population of aphids (19.67/shoot) was recorded in untreated control.

At 7 DAS, spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the most effective treatment with lowest population of aphids (2.54/shoot). It was, however at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.69/shoot) and fipronil @ 100 g a.i. ha<sup>-1</sup> (3.11/shoot). The next effective treatments were, thiacloprid @ 180 g a.i. ha<sup>-1</sup> (5.18/shoot), tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (6.06/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (7.19/shoot) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (7.44/shoot). At 10 DAS, same trend was observed.

Spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (1.02/shoot), which was found at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (1.08/shoot) & fipronil @ 100 g a.i. ha<sup>-1</sup> (1.11/shoot). This was followed by acetamiprid @ 20 g a.i. ha<sup>-1</sup> (2.41/shoot), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (2.48/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (2.50/shoot) & tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (2.61/shoot). Untreated control recorded highest population of aphids (19.45/shoot).

#### **4.1.1.2 *Ambia bahar* – 2019**

##### **First spray**

The data pertaining to efficacy of insecticides against aphids after first spray are presented in Table 4.2. The pre count of aphids registered in the range of 15.48 to 17.91/shoot and found to be non significant, indicating homogenous population of aphids in the field.

The results revealed that, all insecticidal treatments were considerably more effective than the untreated control at reducing aphid population.

**Table 4.1 Bioefficacy of newer insecticides against aphids (*Ambia bahar*-2018)**

Tr. No.	Treatment	Dose (g a.i.ha <sup>-1</sup> )	Number of aphids per shoot (nymphs and adults)								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Tolfenpyrad 15 % EC	150	25.16 (5.07)	15.10 <sup>b</sup> (3.95)	6.84 <sup>b</sup> (2.71)	3.45 <sup>b</sup> (1.99)	2.86 <sup>b</sup> (1.83)	10.12 <sup>b</sup> (3.26)	6.06 <sup>b</sup> (2.56)	3.14 <sup>b</sup> (1.91)	2.61 <sup>b</sup> (1.76)
T2	Cyantraniliprole 10.26 % OD	75	27.45 (5.29)	12.45 <sup>a</sup> (3.60)	5.78 <sup>a</sup> (2.51)	2.91 <sup>b</sup> (1.85)	1.66 <sup>a</sup> (1.47)	7.42 <sup>a</sup> (2.81)	2.69 <sup>a</sup> (1.79)	1.19 <sup>a</sup> (1.30)	1.08 <sup>a</sup> (1.26)
T3	Imidacloprid 17.80 % SL	50	26.43 (5.19)	16.08 <sup>b</sup> (4.07)	8.98 <sup>c</sup> (3.08)	4.14 <sup>c</sup> (2.15)	3.10 <sup>b</sup> (1.90)	11.96 <sup>b</sup> (3.53)	7.19 <sup>c</sup> (2.77)	4.10 <sup>c</sup> (2.14)	2.50 <sup>b</sup> (1.73)
T4	Acetamiprid 20 % SP	20	26.12 (5.16)	17.10 <sup>b</sup> (4.20)	9.10 <sup>c</sup> (3.10)	4.74 <sup>c</sup> (2.29)	3.45 <sup>b</sup> (1.99)	12.10 <sup>b</sup> (3.55)	7.44 <sup>c</sup> (2.82)	4.26 <sup>c</sup> (2.18)	2.41 <sup>b</sup> (1.71)
T5	Thiacloprid 21.70 % SC	180	25.81 (5.13)	14.98 <sup>b</sup> (3.93)	7.16 <sup>b</sup> (2.77)	3.71 <sup>b</sup> (2.05)	2.98 <sup>b</sup> (1.87)	10.72 <sup>b</sup> (3.35)	5.18 <sup>b</sup> (2.38)	3.11 <sup>b</sup> (1.90)	2.48 <sup>b</sup> (1.73)
T6	Fipronil 5 % SC	100	26.10 (5.16)	10.98 <sup>a</sup> (3.39)	5.45 <sup>a</sup> (2.44)	2.45 <sup>b</sup> (1.72)	1.48 <sup>a</sup> (1.41)	8.54 <sup>a</sup> (3.01)	3.11 <sup>a</sup> (1.90)	1.28 <sup>a</sup> (1.33)	1.11 <sup>a</sup> (1.27)
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	27.15 (5.25)	11.56 <sup>a</sup> (3.47)	4.86 <sup>a</sup> (2.32)	2.12 <sup>a</sup> (1.62)	1.17 <sup>a</sup> (1.29)	7.61 <sup>a</sup> (2.85)	2.54 <sup>a</sup> (1.74)	1.07 <sup>a</sup> (1.25)	1.02 <sup>a</sup> (1.23)
T8	Untreated control	--	26.48 (5.19)	26.54 <sup>c</sup> (5.20)	27.11 <sup>d</sup> (5.25)	25.77 <sup>d</sup> (5.13)	26.32 <sup>c</sup> (5.18)	19.67 <sup>c</sup> (4.49)	19.78 <sup>d</sup> (4.50)	20.02 <sup>d</sup> (4.53)	19.45 <sup>c</sup> (4.47)
	SeM		-	0.12	0.09	0.07	0.06	0.10	0.08	0.06	0.05
	CD		NS	0.38	0.28	0.20	0.18	0.32	0.23	0.18	0.15

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

At 3 DAS, the treatment with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population of aphids (6.54/shoot), which was found at par with fipronil @ 100 g a.i. ha<sup>-1</sup> (7.11/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (7.79/shoot). The next treatments, thiacloprid @ 180 g a.i. ha<sup>-1</sup> (9.96/shoot), tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (10.17/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (11.24/shoot) and acetamiprid @ 20 g a.i. ha<sup>-1</sup> (11.45/shoot) were found equally effective as against highest population of aphids was recorded in untreated control (19.21/shoot). Similar trend was observed on 7 DAS & 10 DAS.

Spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (1.02/shoot). Fipronil @ 100 g a.i. ha<sup>-1</sup> (1.26/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (1.37/shoot) as they are equally effective and at par with each other. This was followed by tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (2.57/shoot). However, the treatment of thiacloprid @ 180 g a.i. ha<sup>-1</sup> (4.48/shoot), acetamiprid @ 20 g a.i. ha<sup>-1</sup> (4.88/shoot) & imidacloprid @ 50 g a.i. ha<sup>-1</sup> (4.96/shoot) were less effective in controlling of aphid population. Whereas, untreated control recorded highest population of aphids (19.56/shoot).

### **Second spray**

The data pertaining to efficacy of insecticides against aphids after second spray are presented in Table 4.2. The data also indicated that, all the insecticidal treatments were significantly superior over untreated control in reducing the population of aphids.

At 3 DAS, the results indicated that spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population of aphids (4.13/shoot). It was, however at par with fipronil @ 100 g a.i. ha<sup>-1</sup> (4.24/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (4.81/shoot). The next treatments in the order of superiority were thiacloprid @ 180 g a.i. ha<sup>-1</sup> (6.11/shoot), tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (6.41/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (7.26/shoot) and acetamiprid @ 20 g a.i. ha<sup>-1</sup> (7.89/shoot). However, highest population of aphids (12.96/shoot) was recorded in untreated control. Almost a similar trend was observed at 7 DAS & 10 DAS.

Spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> maintained its superiority even at 15 DAS by recording least population of aphids (1.11/shoot). This was followed by cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (1.19/shoot), fipronil @ 100 g a.i. ha<sup>-1</sup> (1.27/shoot), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (2.14/shoot), tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (2.48/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.14/shoot) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (3.28/shoot).

#### **4.1.1.3 Pooled data (*Ambia bahar* 2018 and 2019)**

The data pertaining to efficacy of insecticides against aphids during *Ambia bahar* 2018 & 2019 was pooled and presented in Table 4.3. It could be seen that, all the insecticidal treatments were significantly superior over untreated control.

**Table 4.2 Bioefficacy of newer insecticides against aphids (*Ambia bahar*-2019)**

Tr. No.	Treatment	Dose (g a.i.ha <sup>-1</sup> )	Number of aphids per shoot (nymphs and adults)								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Tolfenpyrad 15 % EC	150	15.48 (4.00)	10.17 <sup>b</sup> (3.27)	5.89 <sup>b</sup> (2.53)	4.77 <sup>b</sup> (2.30)	2.57 <sup>b</sup> (1.75)	6.41 <sup>b</sup> (2.63)	4.17 <sup>b</sup> (2.16)	2.41 <sup>b</sup> (1.71)	2.48 <sup>b</sup> (1.73)
T2	Cyantraniliprole 10.26 % OD	75	16.71 (4.15)	7.79 <sup>a</sup> (2.88)	4.16 <sup>b</sup> (2.16)	2.25 <sup>a</sup> (1.60)	1.37 <sup>a</sup> (1.37)	4.81 <sup>a</sup> (2.30)	2.41 <sup>a</sup> (1.71)	1.43 <sup>a</sup> (1.39)	1.19 <sup>a</sup> (1.30)
T3	Imidacloprid 17.80 % SL	50	16.11 (4.08)	11.24 <sup>b</sup> (3.43)	6.68 <sup>b</sup> (2.68)	5.11 <sup>b</sup> (2.37)	4.96 <sup>c</sup> (2.34)	7.26 <sup>b</sup> (2.79)	6.13 <sup>c</sup> (2.57)	4.02 <sup>c</sup> (2.13)	3.14 <sup>c</sup> (1.91)
T4	Acetamiprid 20 % SP	20	15.56 (4.01)	11.45 <sup>b</sup> (3.46)	7.10 <sup>c</sup> (2.76)	5.29 <sup>b</sup> (2.41)	4.88 <sup>c</sup> (2.32)	7.89 <sup>c</sup> (2.90)	6.07 <sup>c</sup> (2.56)	3.96 <sup>c</sup> (2.11)	3.28 <sup>c</sup> (1.94)
T5	Thiacloprid 21.70 % SC	180	16.15 (4.08)	9.96 <sup>b</sup> (3.23)	5.78 <sup>b</sup> (2.51)	4.86 <sup>b</sup> (2.32)	4.48 <sup>c</sup> (2.23)	6.11 <sup>b</sup> (2.57)	3.51 <sup>b</sup> (2.00)	2.68 <sup>b</sup> (1.78)	2.14 <sup>b</sup> (1.62)
T6	Fipronil 5 % SC	100	15.78 (4.03)	7.11 <sup>a</sup> (2.76)	3.46 <sup>a</sup> (1.99)	2.13 <sup>a</sup> (1.62)	1.26 <sup>a</sup> (1.33)	4.24 <sup>a</sup> (2.18)	1.96 <sup>a</sup> (1.57)	1.20 <sup>a</sup> (1.30)	1.27 <sup>a</sup> (1.33)
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	16.48 (4.12)	6.54 <sup>a</sup> (2.65)	3.17 <sup>a</sup> (1.92)	1.80 <sup>a</sup> (1.52)	1.02 <sup>a</sup> (1.23)	4.13 <sup>a</sup> (2.15)	2.18 <sup>a</sup> (1.64)	1.05 <sup>a</sup> (1.24)	1.11 <sup>a</sup> (1.27)
T8	Untreated control	--	17.91 (4.29)	19.21 <sup>c</sup> (4.44)	18.56 <sup>d</sup> (4.37)	20.12 <sup>c</sup> (4.54)	19.56 <sup>d</sup> (4.48)	12.96 <sup>d</sup> (3.67)	14.01 <sup>d</sup> (3.81)	15.45 <sup>d</sup> (3.99)	16.28 <sup>d</sup> (4.10)
	SeM		-	0.10	0.08	0.07	0.06	0.08	0.07	0.05	0.05
	CD		NS	0.31	0.23	0.20	0.18	0.24	0.20	0.17	0.16

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.3 Bioefficacy of newer insecticides against aphids (Pooled mean, *Ambia bahar*- 2018 & 2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of aphids per shoot (nymphs and adults)				Mean	Reduction over control (%)
			2018		2019			
			1 <sup>st</sup> spray	2 <sup>nd</sup> spray	1 <sup>st</sup> spray	2 <sup>nd</sup> spray		
T1	Tolfenpyrad 15 % EC	150	7.06 <sup>b</sup> (2.75)	5.48 <sup>b</sup> (2.45)	5.85 <sup>b</sup> (2.52)	3.87 <sup>b</sup> (2.09)	5.57 <sup>b</sup> (2.46)	72.24
T2	Cyantraniliprole 10.26 % OD	75	5.70 <sup>a</sup> (2.49)	3.10 <sup>a</sup> (1.90)	3.89 <sup>a</sup> (2.10)	2.46 <sup>a</sup> (1.72)	3.79 <sup>a</sup> (2.07)	81.11
T3	Imidacloprid 17.80 % SL	50	8.08 <sup>b</sup> (2.93)	6.44 <sup>b</sup> (2.63)	7.00 <sup>b</sup> (2.74)	5.14 <sup>c</sup> (2.37)	6.66 <sup>c</sup> (2.68)	66.77
T4	Acetamiprid 20 % SP	20	8.60 <sup>b</sup> (3.02)	6.55 <sup>c</sup> (2.66)	7.18 <sup>b</sup> (2.77)	5.30 <sup>c</sup> (2.41)	6.91 <sup>c</sup> (2.72)	65.55
T5	Thiacloprid 21.70 % SC	180	7.21 <sup>b</sup> (2.78)	5.37 <sup>b</sup> (2.42)	6.27 <sup>b</sup> (2.60)	3.61 <sup>b</sup> (2.03)	5.62 <sup>b</sup> (2.47)	72.00
T6	Fipronil 5 % SC	100	5.09 <sup>a</sup> (2.36)	3.51 <sup>a</sup> (2.00)	3.49 <sup>a</sup> (2.00)	2.17 <sup>a</sup> (1.63)	3.56 <sup>a</sup> (2.01)	82.22
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	4.93 <sup>a</sup> (2.33)	3.06 <sup>a</sup> (1.89)	3.13 <sup>a</sup> (1.91)	2.12 <sup>a</sup> (1.62)	3.31 <sup>a</sup> (1.95)	83.49
T8	Untreated control	--	26.44 <sup>c</sup> (5.19)	19.73 <sup>d</sup> (4.50)	19.36 <sup>c</sup> (4.46)	14.68 <sup>d</sup> (3.90)	20.05 <sup>d</sup> (4.53)	-
	SeM		0.09	0.08	0.08	0.06	0.05	
	CD		0.27	0.23	0.24	0.20	0.16	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

The pooled analysis of two years revealed that, the treatment with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> consistently proved to be the most promising insecticide by recording lowest population of aphids (3.31/shoot). It was, however at par with fipronil @ 100 g a.i. ha<sup>-1</sup> & cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> which recorded 3.56 & 3.79 aphids/shoot, respectively. This was followed by tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (5.57/shoot) & thiacloprid @ 180 g a.i. ha<sup>-1</sup> (5.62/shoot) but were at par with each other. Imidacloprid @ 50 g a.i. ha<sup>-1</sup> (6.66/shoot) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (6.91/shoot) were next to follow in the order of effectiveness.

#### **4.1.2 Thrips, *Scirtothrips dorsalis***

The results from the mean population of thrips/shoot computed from 3 DAS to 15 DAS from each spray along with pooled data have been presented under each sub-head.

##### **4.1.2.1 *Ambia bahar* – 2018**

###### **First spray**

The data pertaining to efficacy of insecticides against thrips after first spray are presented in Table 4.4. The pre count of thrips ranged between 11.05 and 12.11/shoot & found to be non significant, indicating homogenous population of thrips in the field. The data also indicated that, all the insecticidal treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS, the results indicated that, the treatment with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population (4.10/shoot) of thrips. However, it was at par with tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (4.27/shoot) as against 12.11 thrips/shoot recorded in untreated control. Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (6.67/shoot), fipronil @ 100 g a.i. ha<sup>-1</sup> (6.88/shoot), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (7.15/shoot) and imidacloprid @ 50 g a.i. ha<sup>-1</sup> (8.14/shoot) being at par with each other were next to follow in the order of effectiveness. This was followed by acetamiprid @ 20 g a.i. ha<sup>-1</sup> (9.91/shoot).

At 7 DAS, it was evident that, the treatment with tolfenpyrad @ 150 g a.i. ha<sup>-1</sup>, spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> & cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> were found equally effective in minimizing the thrips population and recorded in the range of 2.10 to 2.99 thrips/shoot as against 12.35/shoot in untreated control. Similar trend was observed at 10 days after spray.

Tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> retained its superiority even at 15 DAS by recording lowest population (0.29/shoot) of thrips. However, it was at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (0.34/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (0.30/shoot), The next effective treatments were fipronil @ 100 g a.i. ha<sup>-1</sup> (0.69/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (2.11/shoot) and thiacloprid @ 180 g a.i. ha<sup>-1</sup> (2.17/shoot) being at par with each other were next to follow in the order of effectiveness. This was followed by acetamiprid @ 20 g a.i.

ha<sup>-1</sup> (3.11/shoot). Whereas, maximum population of thrips (13.10/shoot) was recorded in untreated control.

### **Second spray**

The data pertaining to efficacy of insecticides against thrips after second spray are presented in Table 4.4. The data also indicated that all the insecticidal treatments were significantly superior over untreated control in reducing the population of thrips. It was evident that, similar trend in the order of effectiveness was observed in second spray as observed in the first spray.

#### **4.1.2.2 *Ambia bahar* – 2019**

### **First spray**

The data pertaining to efficacy of insecticides against thrips after first spray are presented in Table 4.5. The pre count of thrips ranged between 9.11 and 10.11/shoot and found to be non significant, indicating homogenous population of thrips in the field. The data also indicated that, all the insecticidal treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS, the results indicated that, the treatment tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population of thrips (3.18/shoot). It was, however at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (3.96/shoot). Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (4.19/shoot) and fipronil @ 100 g a.i. ha<sup>-1</sup> (4.78/shoot) being at par with each other were next to follow in the order of effectiveness. This was followed by imidacloprid @ 50 g a.i. ha<sup>-1</sup> (6.01/shoot), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (6.11/shoot) and acetamiprid @ 20 g a.i. ha<sup>-1</sup> (7.55/shoot). However, highest population of thrips (11.44/shoot) was recorded in untreated control. Similar trend was observed at 7 DAS, 10 DAS & 15 DAS.

### **Second spray**

The data pertaining to efficacy of insecticides against thrips after second spray are presented in Table 4.5. The data also indicated that, all the insecticidal treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS, the results indicated that, the treatment with tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population of thrips (2.16/shoot). However, it was at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (2.76/shoot). Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (3.11) and fipronil @ 100 g a.i. ha<sup>-1</sup> (3.28) being at par, with each other next to follow in the order of effectiveness. This was followed by imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.90), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (4.10) and acetamiprid @ 20 g a.i. ha<sup>-1</sup> (5.10). However, highest population of thrips (8.15) was recorded in untreated control. Almost a similar trend of effectiveness was observed at 7 DAS & 10 DAS.

**Table 4.4 Bioefficacy of newer insecticides against thrips (*Ambia bahar*-2018)**

Tr. No.	Treatment	Dose (g a.i.ha <sup>-1</sup> )	Number of thrips per shoot (nymphs and adults)								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Tolfenpyrad 15 % EC	150	11.45 (3.46)	4.27 <sup>a</sup> (2.18)	2.10 <sup>a</sup> (1.61)	1.00 <sup>a</sup> (1.22)	0.29 <sup>a</sup> (0.89)	2.00 <sup>a</sup> (1.58)	1.11 <sup>a</sup> (1.27)	0.50 <sup>a</sup> (1.00)	0.29 <sup>a</sup> (0.89)
T2	Cyantraniliprole 10.26 % OD	75	12.11 (3.55)	6.67 <sup>b</sup> (2.68)	2.99 <sup>b</sup> (1.87)	1.15 <sup>a</sup> (1.28)	0.30 <sup>a</sup> (0.89)	4.17 <sup>b</sup> (2.16)	2.10 <sup>b</sup> (1.61)	1.10 <sup>b</sup> (1.26)	0.56 <sup>b</sup> (1.03)
T3	Imidacloprid 17.80 % SL	50	11.50 (3.46)	8.14 <sup>b</sup> (2.94)	6.15 <sup>c</sup> (2.58)	4.74 <sup>c</sup> (2.29)	2.11 <sup>c</sup> (1.62)	4.99 <sup>b</sup> (2.34)	3.11 <sup>c</sup> (1.90)	1.87 <sup>c</sup> (1.54)	0.86 <sup>c</sup> (1.17)
T4	Acetamiprid 20 % SP	20	11.88 (3.52)	9.91 <sup>c</sup> (3.23)	7.89 <sup>d</sup> (2.90)	6.14 <sup>d</sup> (2.58)	3.11 <sup>d</sup> (1.90)	6.98 <sup>c</sup> (2.73)	4.10 <sup>d</sup> (2.14)	2.10 <sup>c</sup> (1.61)	1.80 <sup>d</sup> (1.52)
T5	Thiacloprid 21.70 % SC	180	12.10 (3.55)	7.15 <sup>b</sup> (2.77)	6.35 <sup>c</sup> (2.62)	4.11 <sup>c</sup> (2.15)	2.17 <sup>c</sup> (1.63)	5.10 <sup>b</sup> (2.37)	2.90 <sup>c</sup> (1.84)	1.90 <sup>c</sup> (1.55)	0.90 <sup>c</sup> (1.18)
T6	Fipronil 5 % SC	100	11.05 (3.40)	6.88 <sup>b</sup> (2.72)	3.19 <sup>b</sup> (1.92)	1.55 <sup>b</sup> (1.43)	0.69 <sup>b</sup> (1.09)	4.23 <sup>b</sup> (2.17)	2.27 <sup>b</sup> (1.66)	1.07 <sup>b</sup> (1.25)	0.46 <sup>a</sup> (0.98)
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	11.77 (3.50)	4.10 <sup>a</sup> (2.14)	2.25 <sup>a</sup> (1.66)	1.19 <sup>a</sup> (1.30)	0.34 <sup>a</sup> (0.92)	2.91 <sup>a</sup> (1.85)	1.20 <sup>a</sup> (1.30)	0.48 <sup>a</sup> (0.99)	0.27 <sup>a</sup> (0.88)
T8	Untreated control	--	11.91 (3.52)	12.11 <sup>d</sup> (3.55)	12.35 <sup>e</sup> (3.58)	13.14 <sup>e</sup> (3.69)	13.10 <sup>e</sup> (3.69)	13.77 <sup>d</sup> (3.78)	14.11 <sup>c</sup> (3.82)	14.34 <sup>d</sup> (3.85)	13.05 <sup>e</sup> (3.68)
	SeM		-	0.08	0.07	0.06	0.04	0.07	0.05	0.04	0.03
	CD		NS	0.26	0.21	0.17	0.15	0.21	.016	0.13	0.10

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.5 Bioefficacy of newer insecticides against thrips (*Ambia bahar*-2019)**

Tr. No.	Treatment	Dose (g a.i.ha <sup>-1</sup> )	Number of thrips per shoot (nymphs and adults)								
			First spray					Second spray			
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Tolfenpyrad 15 % EC	150	9.11 (3.10)	3.18 <sup>a</sup> (1.92)	1.44 <sup>a</sup> (1.39)	0.96 <sup>a</sup> (1.21)	0.42 <sup>a</sup> (0.96)	2.16 <sup>a</sup> (1.63)	1.07 <sup>a</sup> (1.25)	0.56 <sup>a</sup> (1.03)	0.24 <sup>a</sup> (0.86)
T2	Cyantranilprole 10.26 % OD	75	9.87 (3.22)	4.19 <sup>b</sup> (2.17)	1.96 <sup>b</sup> (1.57)	1.02 <sup>a</sup> (1.23)	0.86 <sup>b</sup> (1.17)	3.11 <sup>b</sup> (1.90)	1.86 <sup>b</sup> (1.54)	0.97 <sup>b</sup> (1.21)	0.60 <sup>b</sup> (1.05)
T3	Imidacloprid 17.80 % SL	50	10.11 (3.26)	6.01 <sup>a</sup> (7.55)	3.87 <sup>a</sup> (2.09)	2.17 <sup>a</sup> (1.63)	1.10 <sup>a</sup> (1.26)	3.90 <sup>c</sup> (2.10)	2.10 <sup>b</sup> (1.61)	1.10 <sup>b</sup> (1.26)	0.90 <sup>c</sup> (1.18)
T4	Acetamiprid 20 % SP	20	9.17 (3.11)	7.55 <sup>c</sup> (2.84)	6.10 <sup>d</sup> (2.57)	3.15 <sup>b</sup> (1.91)	1.86 <sup>c</sup> (1.54)	5.10 <sup>d</sup> (2.37)	3.07 <sup>c</sup> (1.89)	2.27 <sup>c</sup> (1.66)	1.10 <sup>c</sup> (1.26)
T5	Thiacloprid 21.70 % SC	180	9.40 (3.15)	6.11 <sup>d</sup> (2.57)	3.06 <sup>e</sup> (1.89)	2.13 <sup>c</sup> (1.62)	1.07 <sup>d</sup> (1.25)	4.10 <sup>c</sup> (2.14)	2.05 <sup>b</sup> (1.60)	1.07 <sup>b</sup> (1.25)	0.87 <sup>c</sup> (1.17)
T6	Fipronil 5 % SC	100	9.67 (3.19)	4.78 <sup>c</sup> (2.30)	2.01 <sup>c</sup> (1.58)	1.10 <sup>b</sup> (1.26)	0.81 <sup>b</sup> (1.14)	3.28 <sup>b</sup> (1.94)	1.74 <sup>b</sup> (1.50)	0.87 <sup>b</sup> (1.17)	0.55 <sup>b</sup> (1.02)
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	10.10 (3.26)	3.96 <sup>a</sup> (2.11)	1.86 <sup>a</sup> (1.54)	0.89 <sup>a</sup> (1.18)	0.38 <sup>a</sup> (0.94)	2.76 <sup>a</sup> (1.81)	1.27 <sup>a</sup> (1.33)	0.60 <sup>a</sup> (1.05)	0.29 <sup>a</sup> (0.89)
T8	Untreated control	--	9.16 (3.11)	11.44 <sup>e</sup> (3.46)	12.10 <sup>f</sup> (3.55)	11.74 <sup>d</sup> (3.50)	12.81 <sup>e</sup> (3.65)	8.15 <sup>c</sup> (2.94)	8.96 <sup>d</sup> (3.08)	9.50 <sup>d</sup> (3.16)	9.10 <sup>d</sup> (3.10)
	SeM		-	0.07	0.06	0.04	0.04	0.06	0.04	0.04	0.03
	CD		NS	0.22	0.17	0.13	0.11	0.18	0.14	0.11	0.09

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.6 Bioefficacy of newer insecticides against thrips (Pooled mean, *Ambia bahar*- 2018 & 2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of thrips per shoot (nymphs and adults)				Mean	Reduction over control (%)
			2018		2019			
			1 <sup>st</sup> spray	2 <sup>nd</sup> spray	1 <sup>st</sup> spray	2 <sup>nd</sup> spray		
T1	Tolfenpyrad 15 % EC	150	1.92 <sup>a</sup> (1.56)	0.98 <sup>a</sup> (1.22)	1.50 <sup>a</sup> (1.41)	1.01 <sup>a</sup> (1.23)	1.35 <sup>a</sup> (1.36)	88.62
T2	Cyantraniliprole 10.26 % OD	75	2.78 <sup>b</sup> (1.81)	1.98 <sup>b</sup> (1.57)	2.01 <sup>a</sup> (1.58)	1.64 <sup>b</sup> (1.46)	2.10 <sup>b</sup> (1.61)	82.29
T3	Imidacloprid 17.80 % SL	50	5.29 <sup>c</sup> (2.41)	2.71 <sup>c</sup> (1.79)	3.29 <sup>c</sup> (1.95)	2.00 <sup>c</sup> (1.58)	3.32 <sup>c</sup> (1.95)	72.01
T4	Acetamiprid 20 % SP	20	6.76 <sup>d</sup> (2.69)	3.75 <sup>d</sup> (2.06)	4.67 <sup>d</sup> (2.27)	2.89 <sup>d</sup> (1.84)	4.51 <sup>d</sup> (2.24)	61.94
T5	Thiacloprid 21.70 % SC	180	4.95 <sup>c</sup> (2.33)	2.70 <sup>c</sup> (1.79)	3.09 <sup>c</sup> (1.89)	2.02 <sup>c</sup> (1.59)	3.19 <sup>c</sup> (1.92)	73.10
T6	Fipronil 5 % SC	100	3.08 <sup>b</sup> (1.89)	2.01 <sup>b</sup> (1.58)	2.18 <sup>b</sup> (1.64)	1.61 <sup>b</sup> (1.45)	2.22 <sup>b</sup> (1.65)	81.30
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	1.97 <sup>a</sup> (1.57)	1.22 <sup>a</sup> (1.31)	1.77 <sup>a</sup> (1.51)	1.23 <sup>a</sup> (1.32)	1.55 <sup>a</sup> (1.43)	86.96
T8	Untreated control	--	12.68 <sup>e</sup> (3.63)	13.82 <sup>e</sup> (3.78)	12.02 <sup>e</sup> (3.54)	8.93 <sup>e</sup> (3.07)	11.86 <sup>e</sup> (3.52)	
	SeM		0.06	0.05	0.05	0.04	0.07	
	CD		0.20	0.15	0.17	0.13	0.21	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

At 15 DAS, the treatment with tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> retained its superiority by recording least population of thrips (0.24/shoot). It was, however at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (0.29/shoot). Fipronil @ 100 g a.i. ha<sup>-1</sup> (0.55/shoot) and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (0.60/shoot) being at par with each other were next to follow in the order of effectiveness. The next treatments were thiacloprid @ 180 g a.i. ha<sup>-1</sup> (0.87/shoot), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (0.90/shoot) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (1.10/shoot). However, maximum population of thrips (9.10/shoot) was recorded in untreated control.

#### **4.1.2.3. Pooled data (*Ambia bahar* 2018 and 2019)**

The data pertaining to efficacy of insecticides against thrips during *Ambia bahar* 2018 & 2019 was pooled and presented in Table 4.6. It could be seen that, all the insecticidal treatments were significantly superior over untreated control.

The pooled analysis of two years revealed that, the treatment with tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> consistently proved to be the most promising insecticidal treatment by recording lowest population of thrips (1.35/shoot), which was at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (1.55 thrips/shoot). This was followed by cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.10/shoot) and fipronil @ 100 g a.i. ha<sup>-1</sup> (2.22/shoot) but were at par with each other. In the rest of the treatments, the population was ranged from 3.19 to 4.51/shoot and found less effective against pomegranate thrips.

#### **4.1.3 Effect of newer insecticides on coccinellids**

In field experiment on bioefficacy of newer insecticides against pomegranate aphids & thrips, the effect of insecticides on the population of coccinellids was also studied. The data on the mean number of coccinellids/plant (grubs & adults) were computed on 7 & 14 days after last spray along with pooled data have been presented under each sub-head.

##### **4.1.3.1 *Ambia bahar* – 2018**

It is revealed from the data presented in Table 4.7 that, the pre count of coccinellids ranged from 5.32 to 6.42/plant and found to be non-significant, indicating homogenous population of coccinellids in the field.

At 7 DAS, the untreated control recorded maximum population of coccinellids (6.36/plant), which is found at par with the treatment of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (5.54/plant). This was followed by spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (5.16/plant) & tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (4.71/plant). However, the population of coccinellids was not significantly different in the rest of the treatments. Whereas, significant reduction of coccinellid population was observed in the treatment of imidacloprid @ 50 g a.i. ha<sup>-1</sup>, which recorded lowest population of coccinellids (3.41/plant).

At 14 DAS, maximum number of coccinellids were recorded in untreated control (7.32/plant). Among the insecticidal treatments, highest number of coccinellids were observed in

the treatment of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (5.87/plant). Which is at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (5.84/plant) & tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (4.91/plant). In the rest of the treatments, the population of coccinellids was not significantly different. However, significant reduction of coccinellid population was noticed in the treatment of imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.93/plant) indicating its toxicity.

The data on per cent reduction of coccinellids during *Ambia bahar* – 2018 indicated that, the plants treated with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded lowest per cent of reduction of coccinellids (8.14 %). It was followed by spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (15.61 %), tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (18.03 %), acetamiprid @ 20 g a.i. ha<sup>-1</sup> (18.98 %), fipronil @ 100 g a.i. ha<sup>-1</sup> (26.33 %), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (27.87 %) & imidacloprid @ 50 g a.i. ha<sup>-1</sup> (40 %).

#### **4.1.3.2 *Ambia bahar* – 2019**

It is revealed from the data presented in Table 4.8 that, the pre count of coccinellids ranged from 7.11 to 8.47/plant and found to be non-significant, indicating homogenous population of coccinellids in the field.

At 7 DAS, the population of coccinellids was maximum in untreated control (7.86/plant). Significantly lowest number of coccinellids were observed in the treatment of imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.45/plant) and thiacloprid @ 180 g a.i. ha<sup>-1</sup> (4.11/plant). However, the population of coccinellids was not significantly different in the rest of the treatments which ranged from 5.08 to 4.28/plant.

At 14 DAS, maximum number of coccinellids were recorded in untreated control (8.24/plant). Among the insecticidal treatments, highest number of coccinellids were recorded in cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (6.33/plant), which is found at par with the rest of the treatments. However, significant reduction of coccinellid population was noticed in the treatment of imidacloprid @ 50 g a.i. ha<sup>-1</sup> (4.29/plant) indicating its toxicity.

The data on per cent reduction of coccinellids during *Ambia bahar* – 2019 indicated that, the plants treated with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded lowest per cent of reduction of coccinellids (9.57 %). It was followed by spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (16.74 %), tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (22.04 %), acetamiprid @ 20 g a.i. ha<sup>-1</sup> (25.74 %), fipronil @ 100 g a.i. ha<sup>-1</sup> (29.38 %), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (35.32 %) & imidacloprid @ 50 g a.i. ha<sup>-1</sup> (46.71 %).

**Table 4.7 Effect of newer insecticides on coccinellids (*Ambia bahar*-2018)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of coccinellids per plant (grubs and adults)			Reduction (%)
			Pre count	7 DAS	14 DAS	
T1	Tolfenpyrad 15 % EC	150	5.99 (2.55)	4.71 <sup>b</sup> (2.28)	4.91 <sup>b</sup> (2.33)	18.03
T2	Cyantraniliprole 10.26 % OD	75	6.39 (2.62)	5.54 <sup>a</sup> (2.46)	5.87 <sup>b</sup> (2.52)	8.14
T3	Imidacloprid 17.80 % SL	50	6.55 (2.66)	3.41 <sup>d</sup> (1.98)	3.93 <sup>c</sup> (2.10)	40.00
T4	Acetamiprid 20 % SP	20	5.32 (2.41)	3.89 <sup>c</sup> (2.10)	4.31 <sup>c</sup> (2.19)	18.98
T5	Thiacloprid 21.70 % SC	180	6.28 (2.60)	3.78 <sup>c</sup> (2.07)	4.53 <sup>c</sup> (2.24)	27.87
T6	Fipronil 5 % SC	100	5.81 (2.51)	3.67 <sup>c</sup> (2.04)	4.28 <sup>c</sup> (2.19)	26.33
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	6.92 (2.72)	5.16 <sup>b</sup> (2.38)	5.84 <sup>b</sup> (2.52)	15.61
T8	Untreated control	--	6.24 (2.60)	6.36 <sup>a</sup> (2.62)	7.32 <sup>a</sup> (2.80)	
	SeM		-	0.07	0.07	
	CD		NS	0.20	0.22	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.8 Effect of newer insecticides on coccinellids (*Ambia bahar*-2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of coccinellids per plant (grubs and adults)			Reduction (%)
			Pre count	7 DAS	14 DAS	
T1	Tolfenpyrad 15 % EC	150	7.35 (2.80)	4.65 <sup>b</sup> (2.27)	5.73 <sup>b</sup> (2.50)	22.04
T2	Cyantraniliprole 10.26 % OD	75	7.00 (2.74)	5.08 <sup>b</sup> (2.36)	6.33 <sup>b</sup> (2.61)	9.57
T3	Imidacloprid 17.80 % SL	50	8.05 (2.92)	3.45 <sup>c</sup> (1.99)	4.29 <sup>c</sup> (2.19)	46.71
T4	Acetamiprid 20 % SP	20	7.11 (2.76)	4.28 <sup>b</sup> (2.19)	5.28 <sup>b</sup> (2.40)	25.74
T5	Thiacloprid 21.70 % SC	180	8.38 (2.98)	4.11 <sup>c</sup> (2.15)	5.42 <sup>b</sup> (2.43)	35.32
T6	Fipronil 5 % SC	100	7.59 (2.84)	4.34 <sup>b</sup> (2.20)	5.36 <sup>b</sup> (2.42)	29.38
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	7.11 (2.76)	5.04 <sup>b</sup> (2.35)	5.92 <sup>b</sup> (2.53)	16.74
T8	Untreated control	--	7.54 (2.84)	7.86 <sup>a</sup> (2.89)	8.24 <sup>a</sup> (2.96)	
	SeM		-	0.07	0.07	
	CD		NS	0.20	0.23	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.9 Effect of newer insecticides on coccinellids (Pooled mean, *Ambia bahar*- 2018 & 2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of coccinellids per plant (grubs and adults)			Reduction (%)
			7 DAS	14 DAS	MEAN	
T1	Tolfenpyrad 15 % EC	150	4.68 <sup>b</sup> (2.28)	5.32 <sup>b</sup> (2.41)	5.00 <sup>b</sup> (2.35)	20.24
T2	Cyantraniliprole 10.26 % OD	75	5.31 <sup>b</sup> (2.41)	6.10 <sup>b</sup> (2.57)	5.71 <sup>b</sup> (2.49)	8.89
T3	Imidacloprid 17.80 % SL	50	3.43 <sup>c</sup> (1.98)	4.11 <sup>c</sup> (2.15)	3.77 <sup>c</sup> (2.07)	43.70
T4	Acetamiprid 20 % SP	20	4.09 <sup>c</sup> (2.14)	4.80 <sup>c</sup> (2.30)	4.44 <sup>c</sup> (2.22)	22.85
T5	Thiacloprid 21.70 % SC	180	3.95 <sup>c</sup> (2.11)	4.98 <sup>c</sup> (2.34)	4.46 <sup>c</sup> (2.23)	32.13
T6	Fipronil 5 % SC	100	4.01 <sup>c</sup> (2.12)	4.82 <sup>c</sup> (2.31)	4.41 <sup>c</sup> (2.22)	28.06
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	5.10 <sup>b</sup> (2.37)	5.88 <sup>b</sup> (2.53)	5.49 <sup>b</sup> (2.45)	16.18
T8	Untreated control	--	7.11 <sup>a</sup> (2.76)	7.78 <sup>a</sup> (2.88)	7.45 <sup>a</sup> (2.82)	
	SeM		0.07	0.07	0.07	
	CD		0.20	0.22	0.21	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

#### 4.1.3.3 Pooled data (*Ambia bahar* 2018 & 2019)

The pooled data of *Ambia bahar* 2018 & 2019 presented in Table 4.9 revealed that, the treatment of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> consistently proved to be the most promising insecticidal treatment by recording highest number of coccinellids (5.71/plant) & lowest per cent of reduction (8.89 %) can be considered as safe, which is found at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (5.49/plant & 16.18 % reduction) and tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (5.00/plant & 20.24 % reduction). However, thiacloprid @ 180 g a.i. ha<sup>-1</sup> (4.46/plant & 32.13 % reduction), fipronil @ 100 g a.i. ha<sup>-1</sup> (4.41/plant & 28.06 % reduction) & acetamiprid @ 20 g a.i. ha<sup>-1</sup> (4.44/plant & 22.85 %) appears to be moderately toxic. Whereas, significant reduction of coccinellid population was observed in the treatment of imidacloprid @ 50 g a.i. ha<sup>-1</sup>, which recorded lowest population of coccinellids (3.77/plant) & highest per cent reduction (43.70 %) and proved to be highly toxic.

#### 4.1.4 Effect of newer insecticides on spiders

In field experiment on bioefficacy of newer insecticides against pomegranate aphids & thrips, the effect of insecticides on the population of spiders was also studied. The data on the mean number of spiders/plant were computed on 7 & 14 days after last spray along with pooled data have been presented under each sub-head.

##### 4.1.4.1 *Ambia bahar* – 2018

It is revealed from the data presented in Table 4.10 that, the pre count of spiders ranged from 4.75 to 5.78/plant and found to be non-significant, indicating homogenous population of spiders in the field.

At 7 DAS, the untreated control recorded maximum population of spiders (6.75/plant). Among the insecticidal treatments, highest number of spiders were recorded in the treatment cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (4.35/plant), which is found at par with the treatment of spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (4.18/plant). However, the population of spiders was not significantly different in the rest of the treatments. Whereas, significant reduction of spider population was observed in the treatment of tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup>, which recorded lowest number of spiders (2.74/plant). Similar trend of effect was observed on spiders at 14 DAS.

The data on per cent reduction of spiders during *Ambia bahar* – 2018 indicated that, the plants treated with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded lowest per cent of reduction of spiders (7.27 %). It was followed by spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (12.98 %), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (24.07 %), acetamiprid @ 20 g a.i. ha<sup>-1</sup> (27.27 %), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (29.48 %), fipronil @ 100 g a.i. ha<sup>-1</sup> (30.35 %) & tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (34.10 %).

#### 4.1.4.2 *Ambia bahar* – 2019

It is revealed from the data presented in Table 4.11 that, the pre count of spiders ranged from 5.08 to 5.78/plant and found to be non-significant, indicating homogenous population of spiders in the field.

At 7 DAS, the untreated control recorded maximum population of spiders (7.28/plant). Among the tested insecticides, highest number of spiders were observed in the treatment cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (4.28/plant), which was found at par with the treatment of spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (4.11/plant). However, the population of spiders was not significantly different in the rest of the treatments. Whereas, significant reduction of spider population was observed in the treatment of tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup>, which recorded lowest number of spiders (2.74/plant) indicating its toxicity. Similar trend of effect was observed on spiders at 14 DAS.

The data on per cent reduction of spiders during *Ambia bahar* – 2019 indicated that, the plants treated with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded lowest per cent of reduction of spiders (9.35 %). It was followed by spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (14.75 %), acetamiprid @ 20 g a.i. ha<sup>-1</sup> (32.87 %), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (35.23 %), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (36.06 %), fipronil @ 100 g a.i. ha<sup>-1</sup> (37.02 %) & tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> (40.26 %).

#### 4.1.4.3 Pooled data (*Ambia bahar* 2018 & 2019)

The pooled data of *Ambia bahar* 2018 & 2019 presented in Table 4.12 revealed that, the treatment of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> consistently proved to be the most promising insecticidal treatment by recording highest number of spiders (4.65/plant) & lowest per cent reduction (8.27 %) and can be considered as safe, which is found at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (4.50/plant & 13.84 % reduction). However, acetamiprid @ 20 g a.i. ha<sup>-1</sup> (3.46/plant & 30.02 % reduction), thiacloprid @ 180 g a.i. ha<sup>-1</sup> (3.44/plant & 29.97 % reduction), imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.42/plant & 32.77 % reduction) & fipronil @ 100 g a.i. ha<sup>-1</sup> (3.22/plant & 33.88 % reduction) were appears to be moderately toxic. Whereas, significant reduction of spider population was observed in the treatment of tolfenpyrad 15 EC @ 150 g a.i. ha<sup>-1</sup> which recorded lowest population of spiders (3.04/plant) and highest per cent reduction (37.23 % reduction) proved to be highly toxic.

In the present investigation, spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (3.31 aphids/shoot) was the best treatment against aphids which recorded highest per cent reduction of aphids over control (89.49 %). It was, however at par with fipronil @ 100 g a.i. ha<sup>-1</sup> (3.56 aphids/shoot, 82.22 % reduction) & cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (3.79 aphids/shoot, 81.11 % reduction) (Fig. 4.1).

**Table 4.10 Effect of newer insecticides on spiders (*Ambia bahar*-2018)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of spiders per plant			Reduction (%)
			Pre count	7 DAS	14 DAS	
T1	Tolfenpyrad 15 % EC	150	5.22 (2.39)	2.74 <sup>c</sup> (1.80)	3.44 <sup>c</sup> (1.98)	34.10
T2	Cyantraniliprole 10.26 % OD	75	5.64 (2.48)	4.35 <sup>b</sup> (2.20)	5.23 <sup>b</sup> (2.39)	7.27
T3	Imidacloprid 17.80 % SL	50	5.36 (2.42)	3.20 <sup>c</sup> (1.93)	3.78 <sup>c</sup> (2.07)	29.48
T4	Acetamiprid 20 % SP	20	5.28 (2.40)	3.13 <sup>c</sup> (1.91)	3.84 <sup>c</sup> (2.08)	27.27
T5	Thiacloprid 21.70 % SC	180	4.86 (2.32)	3.19 <sup>c</sup> (1.92)	3.69 <sup>c</sup> (2.05)	24.07
T6	Fipronil 5 % SC	100	4.91 (2.33)	2.85 <sup>c</sup> (1.83)	3.42 <sup>c</sup> (1.98)	30.35
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	5.78 (2.51)	4.18 <sup>b</sup> (2.16)	5.03 <sup>b</sup> (2.35)	12.98
T8	Untreated control	--	4.75 (2.29)	6.75 <sup>a</sup> (2.69)	7.27 <sup>a</sup> (2.79)	
	SeM		-	0.06	0.06	
	CD		NS	0.18	0.19	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.11 Effect of newer insecticides on spiders (*Ambia bahar*-2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of spiders per plant			Reduction (%)
			Pre count	7 DAS	14 DAS	
T1	Tolfenpyrad 15 % EC	150	5.39 (2.43)	2.74 <sup>c</sup> (1.80)	3.22 <sup>c</sup> (1.93)	40.26
T2	Cyantraniliprole 10.26 % OD	75	5.24 (2.40)	4.28 <sup>b</sup> (2.19)	4.75 <sup>b</sup> (2.29)	9.35
T3	Imidacloprid 17.80 % SL	50	5.38 (2.42)	3.24 <sup>c</sup> (1.93)	3.44 <sup>c</sup> (1.98)	36.06
T4	Acetamiprid 20 % SP	20	5.08 (2.36)	3.44 <sup>c</sup> (1.98)	3.41 <sup>c</sup> (1.98)	32.87
T5	Thiacloprid 21.70 % SC	180	5.45 (2.44)	3.36 <sup>c</sup> (1.96)	3.53 <sup>c</sup> (2.01)	35.23
T6	Fipronil 5 % SC	100	5.51 (2.45)	3.12 <sup>c</sup> (1.90)	3.47 <sup>c</sup> (1.99)	37.02
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	5.49 (2.45)	4.11 <sup>b</sup> (2.15)	4.68 <sup>b</sup> (2.28)	14.75
T8	Untreated control	--	5.78 (2.51)	7.28 <sup>a</sup> (2.80)	7.25 <sup>a</sup> (2.78)	
	SeM		-	0.06	0.06	
	CD		NS	0.18	0.19	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.12 Effect of newer insecticides on spiders (Pooled mean, *Ambia bahar*- 2018 & 2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of spiders per plant			Reduction (%)
			7 DAS	14 DAS	MEAN	
T1	Tolfenpyrad 15 % EC	150	2.74 <sup>c</sup> (1.80)	3.33 <sup>c</sup> (1.96)	3.04 <sup>c</sup> (1.88)	37.23
T2	Cyantraniliprole 10.26 % OD	75	4.32 <sup>b</sup> (2.19)	4.99 <sup>b</sup> (2.34)	4.65 <sup>b</sup> (2.27)	8.27
T3	Imidacloprid 17.80 % SL	50	3.23 <sup>c</sup> (1.93)	3.61 <sup>c</sup> (2.03)	3.42 <sup>c</sup> (1.98)	32.77
T4	Acetamiprid 20 % SP	20	3.29 <sup>c</sup> (1.95)	3.63 <sup>c</sup> (2.03)	3.46 <sup>c</sup> (1.99)	30.02
T5	Thiacloprid 21.70 % SC	180	3.28 <sup>c</sup> (1.94)	3.61 <sup>c</sup> (2.03)	3.44 <sup>c</sup> (1.99)	29.97
T6	Fipronil 5 % SC	100	2.99 <sup>c</sup> (1.87)	3.45 <sup>c</sup> (1.99)	3.22 <sup>c</sup> (1.93)	33.88
T7	Spirotetramat 11.01 % + Imidacloprid 11.01 % SC	60+60	4.15 <sup>b</sup> (2.16)	4.86 <sup>b</sup> (2.31)	4.50 <sup>b</sup> (2.24)	13.84
T8	Untreated control	--	7.02 <sup>a</sup> (2.74)	7.26 <sup>a</sup> (2.79)	7.14 <sup>a</sup> (2.76)	
	SeM		0.06	0.06	0.06	
	CD		0.18	0.19	0.18	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

Since, the literature is scanty with respect to efficacy of newer molecules on pomegranate aphids, similar studies in other crops and even the related molecules tested are discussed.

Spirotetramat is a new keto-enol and acts through lipid biosynthesis inhibition. It has a long duration efficacy against developmental stages of multiple sucking pests. Imidacloprid is agonist of nicotinic acetylcholine receptor and results in disruption of the insect's nervous system (IRAC Mode of Action Classification Scheme, 2020). Further in the present investigation, spirotetramat exhibited excellent efficacy and very good persistence, allowing effective control of peach aphid, *Myzus persicae* for more than a month (Arnaudov and Petkova 2020). Spirotetramat @ 60 g a.i. ha<sup>-1</sup> proved highly toxic to chilli aphids and exhibited up to 80 % mortality (Thania and Thomas 2012). Pasqualini and Scannavini (2015) also confirmed the long lasting efficacy of spirotetramat against peach aphid. According to Kumar and Kuttalam (2011), spirotetramat @ 60 g a.i. ha<sup>-1</sup> recorded 88.80 per cent reduction of chilli aphids. Similarly, Vikram *et al.*, (2015) also reported that spirotetramat + imidacloprid 240 % SC @ 90 g + 90 g a.i./ha exhibited maximum reduction of aphids in chilli with highest marketable yield of 133.08 q/ha. Vinoth kumar *et al.*, (2008) also reported that, the spirotetramat 150 OD at 75 g a.i./ha was highly effective in checking the population of *A. gossypii*. All these reports lend support to the present finding.

Fipronil was next best treatment against aphids as observed in the present investigation. This is in agreement with many earlier reports. Fipronil 5 % SC, a phenyl pyrazole insecticide primarily acts as an ingestion toxicant with some complimentary contact action and acts by interfering in nerve impulse transmission. It interferes with the passage of chloride ions through the Gamma Amino Butyric Acid regulated chloride channel, thereby disrupting central nervous system activity (IRAC Mode of Action Classification Scheme, 2020). Similar to the present investigations, fipronil 200 % SC @ 40 and 50 g a.i. ha<sup>-1</sup> was highly effective in controlling the chilli aphids (11.59/five leaves) (Indhumathi *et al.*, 2017a). Sangamithra *et al.*, (2018a) revealed that, fipronil 200 SC @ 50 g a.i. ha<sup>-1</sup> was found as effective treatment in reducing the chilli aphids (0.37/3 leaves). Dotasara *et al.* (2017) also confirmed the efficacy of fipronil 5 % SC @ 1 ml L<sup>-1</sup> against mustard aphid with highest reduction of aphids over control (84.54 %). Fipronil 200 % SC @ 250 ml ha<sup>-1</sup> was the best treatment in reducing the population of aphids (2.11/ 3 leaves) in chilli (Tukaram *et al.*, 2017). All these reports lend support to the present finding.

Cyantraniliprole is a second generation anthranilic diamide label claimed insecticide for the control of insect pest complex in pomegranate. It acts by inhibiting the ryanodine receptors in insect muscle cells leading to impairment of insect muscle function, rapid cessation of feeding cell sap and death of insects (IRAC Mode of Action Classification Scheme, 2020).

Cyantraniliprole 10.26 % OD is recommended for the control of aphids on pomegranate (Anonymous, 2020). Lad *et al.* (2018) reported that cyantraniliprole 10.26 % OD (0.3 ml) + propineb 50 WP (1 g) with soluble fertilizer (0:52:34) (5 g L<sup>-1</sup>) was found most effective treatment for the control of aphids (3.94/shoot) in pomegranate. Aphids infesting crucifer vegetables were highly susceptible to cyantraniliprole @ 60 g a.i./ha with the highest mortality (Kodandaram *et al.*, 2017). The treatment of cyantraniliprole 10% OD @ 60 g a.i./ha found effective as it provided excellent protection against potato aphids (1.24 aphids/3 leaves) (Lodaya *et al.*, 2017). These earlier findings support the present investigation.

Tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (1.35 thrips/shoot, 88.62 % reduction of thrips over control) was the best treatment against thrips as observed in the present investigation is in agreement with many earlier reports (Fig 4.2). Tolfenpyrad, a Mitochondrial Electron Transfer Inhibitor compound which acts through contact and ingestion. It inhibits the electron transport chain in the mitochondria of the cell, leading to the cessation of the production and supply of the energy in the cell, resulting in the death of the target pest (IRAC Mode of Action Classification Scheme, 2020). Tolfenpyrad @ 150 g a.i./ha showed significantly least number of pomegranate thrips on 5<sup>th</sup>, 7<sup>th</sup> & 10<sup>th</sup> days after spray and resulting in least fruit scaring damage (Walunj *et al.*, 2015). Misra and Sahu (2018) also observed excellent control of cucumber thrips with tolfenpyrad 15 EC @ 150 g a.i./ha (83.60 % reduction of population over control). Tolfenpyrad 15 EC @ 150 g a.i./ha recorded highest mean reduction of brinjal thrips (86.47 %) (Lekha *et al.*, 2018). Shivaleela and Rajesh Chowdary (2019) also concluded that, tolfenpyrad 15 EC @ 150 g a.i./ha is superior in managing the cucumber thrips (2.44/leaf). All these earlier findings lend support to the present finding.

Spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (1.55 thrips/shoot, 86.96 % reduction of thrips over control) was next best treatment against thrips as observed in the present investigation is also in agreement with many earlier reports (Fig 4.2). Spirotetramat + imidacloprid 240 SC @ 60+60 a.i. ha<sup>-1</sup> was the effective insecticide against chilli thrips (90.73 % reduction in population) as reported by Siddesha *et al.* (2021). Spirotetramat + imidacloprid 240 SC @ 90 g + 90 g a.i./ha caused maximum reduction of thrips in chilli at 5 and 10 days after each spray (Vikram *et al.*, 2015). Koushik *et al.* (2017) revealed that spirotetramat + imidacloprid 240 SC @ 75 + 75 g a.i./ha was found more effective against sucking pest complex in brinjal with highest per cent reduction of the population. Patel and Sarkar (2019) also confirmed the efficacy of spirotetramat + imidacloprid 240 SC @ 625 ml ha<sup>-1</sup> on sucking pest complex in tomato. These earlier findings lend support to the present finding.

In the present investigation, the treatment of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded highest number of coccinellids (5.70/plant) & spiders (4.65/plant) which can be considered safe.

It was, found at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (5.50 coccinellids & 4.50 spiders/plant) (Fig 4.3 & 4.4).

The safety of cyantraniliprole 10.26 % OD to coccinellids in pomegranate as observed in the preset investigation is in conformity with many earlier reports. Cyantraniliprole 10.26 % OD @ 40, 50, 60 & 70 ml a.i ha<sup>-1</sup> were found safe to ladybird beetles (0.59, 0.58, 0.58 & 0.57 grubs and adults) in capsicum ecosystem (Nandini and Mandal 2020). Cyantraniliprole 10.26 % OD (45 & 60 g a.i./ha) recorded 0.70 coccinellids/plant, which was at par with control treatment (0.70) in cotton crop indicating the safety of cyantraniliprole to these predators (Patel *et al.*, 2015). The safety of cyantraniliprole to coccinellids was also endorsed by earlier workers (Mandal 2012, Misra & Mukherjee 2012 and Misra, 2013) who observed similar trends in tomato ecosystem. Misra (2012) also revealed that cyantraniliprole 10% OD @ 45 g a.i./ha recorded 4.08 coccinellid/plant, which was at par with control treatment (4.11) in tomato crop. All these findings of the previous workers are in full agreement with the present finding.

Cyantraniliprole 10.26 OD @ 40, 50, 60 & 70 ml a.i ha<sup>-1</sup> was found safe to spiders (0.75, 0.74, 0.73 and 0.73/plant) in capsicum ecosystem (Nandini and Mandal 2020). According to Patel *et al.* (2015) cyantraniliprole 10 OD @ 45 g a.i ha<sup>-1</sup> recorded 1.00 spider/plant, which was at par with control treatment (1.00 spider/plant) in cotton. Parvathi and Yurnus (2000) also confirmed that the population of spiders was on par with that of control after application of cyantraniliprole 10 OD @ 45, 60, 75, 90 and 105 g a.i ha<sup>-1</sup> indicating safety to this predator. Cyantraniliprole 10 % OD showed the least effect against the spiders in cotton ecosystem (Karthik *et al.*, 2017). These earlier findings support the present finding.

The present safety report of spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> against coccinellids in pomegranate is in conformity with Patel and Sarkar (2019). Coccinellid population recorded in spirotetramat 11.01 + imidacloprid 11.01 SC @ 500 ml/ha plot (10.00) and untreated control plot (10.67) were at par with each other in tomato. Fahimeh *et al.*, (2016) also found that spirotetramat @ 2/1, 1/1 & 1/2 of its maximum field recommended concentration did not affect adult survival of coccinellid, *Menochilus sexmaculatus* at all three concentrations when ingested via treated prey. Similar to the present investigations, Spirotetramat exhibited lower lethality to seven spot lady bird beetle, *Coccinella septempunctata* and showed higher LC<sub>50</sub> values also did not affect survival, longevity, fecundity and egg hatching (Liu *et al.*, 2019). According to Planes *et al.* (2013) spirotetramat was harmless, when directly applied on grubs and adults of *Cryptolaemus montrouzieri*. It did not affect survival, longevity, fecundity, egg hatching and offspring survival. Spirotetramat 150 OD (60 g a.i./ha) recorded considerably less toxic effect on coccinellids in chilli ecosystem (Kumar and Kuttalam, 2009). All these reports lend support to the present finding.

Patel and Sarkar (2019) revealed the safety of spirotetramat + imidacloprid (375 to 625 ml ha<sup>-1</sup>) to the spiders as population was significantly at par with untreated control in tomato ecosystem, which strongly supports the present finding. Patel *et al.* (2010) also found that, spider population was more in spirotetramat + imidacloprid 480 % SC @ 625 ml/ha than other treatments in cotton crop. Spirotetramat 150 OD (60 g a.i./ha) exhibited considerably less toxic effect on spiders in chilli eco system as reported by Kumar and Kuttalam (2009). All these reports lend support to the present finding.

In the present investigation, significant reduction of coccinellid population was observed in the treatment of imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.77 coccinellids/plant) and proved to be highly toxic.

The toxicity of imidacloprid @ 50 g a.i. ha<sup>-1</sup> against coccinellids in pomegranate ecosystem as observed in the present investigation is in conformity with many earlier reports. Imidacloprid negatively affected the survival, development, longevity and reduced the net reproduction rate ( $R_0$ ) of black spotted lady bird beetle, *Ceratomegilla undecimnotata* populations in peach orchards (Panagiotis *et al.*, 2021). Imidacloprid @ 0.7 % recorded highest mortality of *Coccinella septempunctata* of 75 % and 72.66 % after 48 and 24 h of exposure, respectively and also affected the voracity of *C. septempunctata* (Mubashar *et al.*, 2017). Similarly, the insecticide imidacloprid was highly toxic to other coccinellid predators, such as *Hippodamia variegata* and *Coleomegilla maculate* (Skouras *et al.*, 2019). Imidacloprid reduced the fecundity, female oviposition period & adult longevity of coccinellids. A decrease in the number of eggs laid by females was also found in other coccinellid species, such as *C. septempunctata*, *Rodolia cardinalis* & *Hippodamia undecimnotata* (Yu *et al.*, 2014). Patil and lingappa (2000) recorded that imidacloprid exhibited lowest selectivity ratio of tobacco aphid, *Myzus nicotianae* and its coccinellid predator, *Cheilomenes sexmaculata*. All these reports lend support to the present finding.

#### **4.2 Bioefficacy of Newer Insecticides Against Fruit Borer, *Deudorix isocrates***

The results from the fruit borer damage per cent/tree computed at the time of harvesting along with pooled data have been presented under each sub-head.

##### **i) *Ambia bahar* – 2018**

The data on per cent fruit borer damage per tree at the time of harvesting (Table 4.13) indicated that, all the insecticidal treatments were significantly superior over untreated control in reducing the fruit borer damage in pomegranate.

At the time of harvesting, the treatment with flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> proved to be the most effective treatment by recording lowest fruit borer damage (2.30 %) and found at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> which recorded 2.61 per cent fruit borer damage. The next treatments were, chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> (4.64 %), flubendiamide

@ 72 g a.i. ha<sup>-1</sup> (4.68 %) and thiodicarb @ 750 g a.i. ha<sup>-1</sup> (5.58 %) being at par with each other were next to follow in the order of effectiveness. This was followed by emamectin benzoate 5 SG @ 11 g a.i. ha<sup>-1</sup> (6.07 %), spinosad @ 75 g a.i. ha<sup>-1</sup> (7.65 %) & lambda cyhalothrin @ 25 g a.i. ha<sup>-1</sup> (7.83 %) which were found less effective as against highest fruit borer damage (18.13 %) was recorded in untreated control.

#### ii) *Ambia bahar* – 2019

The data (Table 4.13) indicated that, all the insecticidal treatments were significantly superior over untreated control in reducing the fruit borer damage in pomegranate.

At the time of harvesting, flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> proved to be the most effective treatment by recording lowest fruit borer damage (1.88 %). It was, however at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> which recorded 2.05 per cent fruit borer damage. The next treatments were, chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> (4.01 %), flubendiamide @ 72 g a.i. ha<sup>-1</sup> (4.09 %), thiodicarb @ 750 g a.i. ha<sup>-1</sup> (4.86 %) and emamectin benzoate 5 SG @ 11 g a.i. ha<sup>-1</sup> (4.96 %) being at par with each other were next to follow in the order of effectiveness. Highest fruit borer damage (17.92 %) was recorded in untreated control.

#### iii) Pooled data (*Ambia bahar* 2018 & 2019)

The data pertaining to efficacy of insecticides against fruit borer during *Ambia bahar* 2018 & 2019 was pooled and presented in Table 4.13. It could be seen that all the insecticidal treatments were significantly superior over untreated control.

The pooled analysis of two years revealed that, the treatment with flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> consistently proved to be the most promising insecticide by recording least fruit borer damage (2.09 %) and found at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.33 %) as against 18.02 % in untreated control. The next treatments were, chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> (4.33 %), flubendiamide @ 72 g a.i. ha<sup>-1</sup> (4.39 %) and thiodicarb @ 750 g a.i. ha<sup>-1</sup> (5.22 %) being at par with each other were next to follow in the order of effectiveness.

### 4.2.1 Effect of newer insecticides on honey bees

In field experiment on bioefficacy of newer insecticides against pomegranate fruit borer, the effect of insecticides on honey bees was also studied simultaneously. The results from the mean number of honey bee/plant computed from 3 DAS to 15 DAS during each spray & pooled data have been presented under each sub-head.

#### 4.2.1.1 *Ambia bahar* – 2018

##### First spray

The data on the number of honey bee/plant recorded after first spray are presented in Table 4.14. The pre count of honey bees ranged from 11.25 to 13.11/plant and found to be non-significant. The data also indicated that, all the insecticidal treatments recorded significantly lower population of honey bees than untreated control.

At 3 DAS, untreated control recorded maximum number of honey bees (12.63/plant). It was, however at par with the treatment of chlorantraniliprole @ 40 g a.i./ha (12.45/plant) & flubendiamide @ 72 g a.i./ha (10.58/plant). The population of honey bees did not differ significantly in the rest of the treatments. Whereas, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha, which recorded lowest number of honey bees (7.74/plant).

At 7 DAS, the population of honey bees was maximum in untreated control (14.31/plant). Among the insecticidal treatments, highest number of honey bees were observed in the treatment of chlorantraniliprole @ 40 g a.i./ha (11.23/plant) & flubendiamide @ 72 g a.i./ha (9.89/plant). In the rest of the treatments, the population of honey bees was not significantly different, which ranged from 7.05 to 8.32/plant. However, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha, which recorded lowest number of honey bees (6.43/plant) indicating its toxicity. Similar trend of effect was observed on honey bees at 10 DAS & 15 DAS.

### **Second spray**

The data on the number of honey bee per plant recorded after second spray are presented in Table 4.14. The data also indicated that, all the insecticidal treatments recorded significantly lower population of honey bees than untreated control.

At 3 DAS, the population of honey bees was maximum in untreated control (12.73/plant). Among the insecticidal treatments, highest number of honey bees were observed in the treatment of chlorantraniliprole @ 40 g a.i./ha (9.53/plant), which was found at par with flubendiamide @ 72 g a.i./ha (9.33/plant). In the rest of the treatments, the population of honey bees was not significantly different, which is ranged from 7.41 to 6.62/plant. However, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha, which recorded lowest number of honey bees (5.29/plant). It was found at par with cyantraniliprole @ 75 g a.i./ha (5.89/plant) and thiodicarb @ 750 g a.i./ha (5.47/plant). Similar trend of effect was observed on honey bees at 7 DAS, 10 DAS & 15 DAS.

#### **4.2.1.2 *Ambia bahar* – 2019**

### **First spray**

The data on the number of honey bee per plant recorded after first spray are presented in Table 4.15. The pre count of honey bees ranged from 11.11 to 13.87/plant and found to be non-significant. The data also indicated that, all the insecticidal treatments recorded significantly lower population of honey bees than untreated control.

At 3 DAS, untreated control recorded maximum number of honey bees (12.89/plant). Which is found at par with the treatment of flubendiamide + thiacloprid @ 60+60 g a.i./ha (11.51/plant), flubendiamide @ 72 g a.i./ha (11.47/plant) & chlorantraniliprole @ 40 g a.i./ha

(11.32/plant). However, the population of honey bees was not significantly different in the rest of the treatments. Whereas, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha, which recorded lowest number of honey bees per plant (7.28/plant) and found at par with emamectin benzoate 5 SG @ 11 g a.i./ha (8.25/plant) and thiodicarb @ 750 g a.i./ha (7.41/plant).

At 7 DAS, the population of honey bees was maximum in untreated control (13.74/plant). Among the insecticidal treatments, highest number of honey bees were observed in the treatment of chlorantraniliprole @ 40 g a.i./ha (10.67/plant). It was at par with flubendiamide @ 72 g a.i./ha (10.54/plant) & flubendiamide + thiacloprid @ 60+60 g a.i./ha (9.89/plant). In the rest of the treatments, the population of honey bees was not significantly different, which ranged from 8.78 to 7.24/plant. However, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha, which recorded lowest number of honey bees (6.48/plant) indicating its toxicity. Which was at par with thiodicarb @ 750 g a.i./ha (6.52/plant). Similar trend of effect was observed on honey bees at 10 DAS & 15 DAS.

### **Second spray**

The data on the number of honey bee per plant recorded after second spray are presented in Table 4.15. The data also indicated that, all the insecticidal treatments recorded significantly lower population of honey bees than untreated control.

At 3 DAS, the population of honey bees was maximum in untreated control (12.69/plant). Among the insecticidal treatments, highest number of honey bees were observed in the treatment of flubendiamide @ 72 g a.i./ha (10.46/plant), which was found at par with chlorantraniliprole @ 40 g a.i./ha (9.36/plant) & flubendiamide + thiacloprid @ 60+60 g a.i./ha (8.89/plant). In the rest of the treatments, the population of honey bees was not significantly different, which was ranged from 7.34 to 6.32/plant. However, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha, which recorded lowest number of honey bees (6.32/plant). Similar trend of effect was observed on honey bees at 7 DAS, 10 DAS & 15 DAS.

#### **4.2.1.3 Pooled data (*Ambia bahar* - 2018 & 2019)**

The pooled data of *Ambia bahar* 2018 and 2019 presented in Table 4.16 revealed that, the treatment of chlorantraniliprole @ 40 g a.i./ha (10.57/plant) consistently proved to be the safer insecticidal treatment by recording highest number of honey bees. It was, however at par with flubendiamide @ 72 g a.i./ha (10.22/plant). Rest of the treatments appeared to be moderately toxic. Significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i./ha which recorded lowest population of honey bees (6.21/plant) and proved to be highly toxic.

**Table 4.13 Bioefficacy of newer insecticides against fruit borer**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Fruit borer damage (%)			Reduction over control (%)
			Ambia bahar 2018	Ambia bahar 2019	Pooled mean	
1.	Flubendiamide 39.35 % SC	72	4.68 <sup>b</sup> (12.24)	4.09 <sup>b</sup> (11.45)	4.39 <sup>b</sup> (11.85)	75.66
2.	Flubendiamide 19.92 % + Thiacloprid 19.92 % SC	60+60	2.30 <sup>a</sup> (8.59)	1.88 <sup>a</sup> (7.76)	2.09 <sup>a</sup> (8.18)	88.40
3.	Lambda cyhalothrin 5 % EC	25	7.83 <sup>c</sup> (15.83)	6.61 <sup>c</sup> (14.55)	7.22 <sup>c</sup> (15.20)	59.96
4.	Spinosad 45 % SC	75	7.65 <sup>c</sup> (15.65)	6.48 <sup>c</sup> (14.40)	7.07 <sup>c</sup> (15.04)	60.81
5.	Emamectin benzoate 5 % SG	11	6.07 <sup>b</sup> (13.94)	4.96 <sup>b</sup> (12.60)	5.52 <sup>b</sup> (13.29)	69.42
6.	Chlorantraniliprole 18.50 % SC	40	4.64 <sup>b</sup> (12.19)	4.01 <sup>b</sup> (11.33)	4.33 <sup>b</sup> (11.77)	76.00
7.	Cyantraniliprole 10.26 % OD	75	2.61 <sup>a</sup> (9.15)	2.05 <sup>a</sup> (8.09)	2.33 <sup>a</sup> (8.64)	87.08
8.	Thiodicarb 75 % WP	750	5.58 <sup>b</sup> (13.36)	4.86 <sup>b</sup> (12.48)	5.22 <sup>b</sup> (12.93)	71.04
9.	Untreated control	-	18.13 <sup>d</sup> (24.10)	17.92 <sup>d</sup> (23.95)	18.02 <sup>d</sup> (24.02)	
	SeM		0.61	0.43	0.51	
	CD		1.82	1.30	1.54	

The data in parenthesis have been arc sin converted

At the 5% level, values in each column with identical alphabets do not differ significantly

Table 4.14 Effect of newer insecticides on honey bees (*Ambia bahar-2018*)

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of honey bees per plant								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Flubendiamide 39.35 % SC	72	11.36 (3.44)	10.58 <sup>a</sup> (3.33)	9.89 <sup>b</sup> (3.22)	10.56 <sup>b</sup> (3.33)	11.23 <sup>b</sup> (3.42)	9.33 <sup>b</sup> (3.14)	8.56 <sup>b</sup> (3.01)	9.71 <sup>b</sup> (3.20)	10.07 <sup>b</sup> (3.25)
T2	Flubendiamide 19.92 % + Thiacloprid 19.92 % SC	60+60	11.78 (3.50)	9.50 <sup>b</sup> (3.16)	8.32 <sup>c</sup> (2.97)	9.11 <sup>c</sup> (3.10)	11.58 <sup>b</sup> (3.48)	7.41 <sup>c</sup> (2.81)	6.68 <sup>c</sup> (2.68)	7.33 <sup>c</sup> (2.80)	8.47 <sup>c</sup> (2.99)
T3	Lambda cyhalothrin 5 % EC	25	12.32 (3.58)	7.74 <sup>b</sup> (2.87)	6.43 <sup>d</sup> (2.63)	6.25 <sup>d</sup> (2.60)	7.29 <sup>d</sup> (2.79)	5.29 <sup>d</sup> (2.41)	4.42 <sup>d</sup> (2.22)	7.21 <sup>d</sup> (2.39)	5.69 <sup>d</sup> (2.49)
T4	Spinosad 45 % SC	75	11.25 (3.43)	9.25 <sup>b</sup> (3.12)	7.21 <sup>c</sup> (2.78)	7.44 <sup>d</sup> (2.82)	9.87 <sup>c</sup> (3.22)	6.78 <sup>c</sup> (2.70)	5.56 <sup>c</sup> (2.46)	6.31 <sup>c</sup> (2.61)	7.36 <sup>c</sup> (2.80)
T5	Emamectin benzoate 5 % SG	11	12.44 (3.60)	8.32 <sup>b</sup> (2.97)	7.11 <sup>c</sup> (2.76)	7.36 <sup>d</sup> (2.80)	8.38 <sup>c</sup> (2.98)	6.62 <sup>c</sup> (2.67)	5.37 <sup>d</sup> (2.42)	5.78 <sup>d</sup> (2.51)	6.25 <sup>d</sup> (2.60)
T6	Chlorantraniliprole 18.50 % SC	40	13.11 (3.69)	12.45 <sup>a</sup> (3.60)	11.23 <sup>b</sup> (3.42)	11.89 <sup>b</sup> (3.52)	12.44 <sup>b</sup> (3.60)	9.53 <sup>b</sup> (3.17)	8.74 <sup>b</sup> (3.04)	9.55 <sup>b</sup> (3.17)	10.22 <sup>b</sup> (3.27)
T7	Cyantraniliprole 10.26 % OD	75	11.74 (3.50)	8.58 <sup>b</sup> (3.01)	7.45 <sup>c</sup> (2.82)	7.67 <sup>c</sup> (2.86)	8.83 <sup>c</sup> (3.05)	5.89 <sup>d</sup> (2.53)	5.49 <sup>c</sup> (2.45)	6.69 <sup>c</sup> (2.68)	6.42 <sup>d</sup> (2.63)
T8	Thiodicarb 75 % WP	750	12.56 (3.61)	8.23 <sup>b</sup> (2.95)	7.05 <sup>c</sup> (2.75)	7.30 <sup>d</sup> (2.79)	7.57 <sup>d</sup> (2.84)	5.47 <sup>d</sup> (2.44)	4.87 <sup>d</sup> (2.32)	5.45 <sup>d</sup> (2.44)	5.87 <sup>d</sup> (2.52)
T9	Untreated control	-	11.38 (3.45)	12.63 <sup>a</sup> (3.60)	14.31 <sup>a</sup> (3.85)	14.88 <sup>a</sup> (3.82)	15.13 <sup>a</sup> (3.95)	12.73 <sup>a</sup> (3.64)	14.25 <sup>a</sup> (3.84)	14.55 <sup>a</sup> (3.88)	14.78 <sup>a</sup> (3.91)
	SeM		-	0.10	0.09	0.09	0.10	0.08	0.08	0.09	0.09
	CD		NS	0.29	0.27	0.27	0.30	0.25	0.24	0.26	0.26

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

Table 4.15 Effect of newer insecticides on honey bees (*Ambia bahar-2019*)

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of honey bees per plant								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Flubendiamide 39.35 % SC	72	12.71 (3.63)	11.47 <sup>a</sup> (3.46)	10.54 <sup>b</sup> (3.32)	10.76 <sup>b</sup> (3.36)	11.35 <sup>b</sup> (3.44)	10.46 <sup>b</sup> (3.31)	9.38 <sup>b</sup> (3.14)	9.52 <sup>b</sup> (3.17)	10.11 <sup>b</sup> (3.26)
T2	Flubendiamide 19.92 % + Thiocloprid 19.92 % SC	60+60	12.36 (3.59)	11.51 <sup>a</sup> (3.47)	9.89 <sup>b</sup> (3.22)	10.22 <sup>b</sup> (3.27)	11.05 <sup>b</sup> (3.40)	8.89 <sup>b</sup> (3.06)	8.11 <sup>b</sup> (2.93)	9.65 <sup>b</sup> (3.19)	10.36 <sup>b</sup> (3.30)
T3	Lambda cyhalothrin 5 % EC	25	13.54 (3.75)	7.28 <sup>c</sup> (2.79)	6.48 <sup>d</sup> (2.64)	6.73 <sup>c</sup> (2.69)	7.29 <sup>c</sup> (2.79)	6.32 <sup>c</sup> (2.61)	5.31 <sup>c</sup> (2.41)	5.42 <sup>d</sup> (2.43)	6.27 <sup>d</sup> (2.60)
T4	Spinosad 45 % SC	75	13.87 (3.79)	10.12 <sup>b</sup> (3.26)	8.78 <sup>c</sup> (3.05)	9.11 <sup>b</sup> (3.10)	9.43 <sup>b</sup> (3.15)	7.34 <sup>c</sup> (2.80)	6.37 <sup>c</sup> (2.62)	7.82 <sup>c</sup> (2.88)	7.91 <sup>c</sup> (2.90)
T5	Emamectin benzoate 5 % SG	11	11.73 (3.50)	8.25 <sup>c</sup> (2.96)	7.24 <sup>c</sup> (2.78)	7.58 <sup>c</sup> (2.84)	7.78 <sup>c</sup> (2.88)	5.48 <sup>d</sup> (2.45)	5.29 <sup>c</sup> (2.41)	5.88 <sup>d</sup> (2.53)	6.74 <sup>c</sup> (2.69)
T6	Chlorantraniliprole 18.50 % SC	40	12.84 (3.65)	11.32 <sup>a</sup> (3.44)	10.67 <sup>b</sup> (3.34)	10.89 <sup>b</sup> (3.37)	11.28 <sup>b</sup> (3.43)	9.36 <sup>b</sup> (3.14)	9.24 <sup>b</sup> (3.12)	9.84 <sup>b</sup> (3.22)	10.25 <sup>b</sup> (3.28)
T7	Cyantraniliprole 10.26 % OD	75	11.11 (3.41)	8.67 <sup>b</sup> (3.03)	7.35 <sup>c</sup> (2.80)	7.74 <sup>c</sup> (2.87)	8.26 <sup>c</sup> (2.96)	7.12 <sup>c</sup> (2.76)	6.5 <sup>c</sup> (2.66)	6.41 <sup>c</sup> (2.62)	6.35 <sup>d</sup> (2.62)
T8	Thiodicarb 75 % WP	750	11.78 (3.50)	7.41 <sup>c</sup> (2.81)	6.52 <sup>d</sup> (2.65)	6.81 <sup>c</sup> (2.70)	7.71 <sup>c</sup> (2.86)	6.85 <sup>c</sup> (2.71)	5.74 <sup>c</sup> (2.59)	5.94 <sup>d</sup> (2.54)	6.68 <sup>c</sup> (2.68)
T9	Untreated control	-	12.56 (3.61)	12.89 <sup>a</sup> (3.66)	13.74 <sup>a</sup> (3.77)	13.87 <sup>a</sup> (3.79)	14.55 <sup>a</sup> (3.88)	12.69 <sup>a</sup> (3.63)	12.86 <sup>a</sup> (3.66)	13.55 <sup>a</sup> (3.75)	13.73 <sup>a</sup> (3.77)
	SeM		-	0.10	0.09	0.09	0.10	0.09	0.08	0.09	0.09
	CD		NS	0.29	0.28	0.28	0.29	0.27	0.25	0.26	0.27

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.16 Effect of newer insecticides on honey bees (Pooled mean, Ambia bahar- 2018 & 2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Number of honey bees per plant				Mean	Reduction (%)
			2018		2019			
			1 <sup>st</sup> spray	2 <sup>nd</sup> spray	1 <sup>st</sup> spray	2 <sup>nd</sup> spray		
T1	Flubendiamide 39.35 % SC	72	10.57 <sup>b</sup> (3.33)	9.42 <sup>b</sup> (3.15)	11.03 <sup>b</sup> (3.40)	9.87 <sup>b</sup> (3.22)	10.22 <sup>b</sup> (3.27)	10.90
T2	Flubendiamide 19.92 % + Thiacloprid 19.92 % SC	60+60	9.63 <sup>c</sup> (3.18)	7.47 <sup>c</sup> (2.82)	10.67 <sup>b</sup> (3.34)	9.25 <sup>b</sup> (3.12)	9.26 <sup>c</sup> (3.12)	19.99
T3	Lambda cyhalothrin 5 % EC	25	6.93 <sup>d</sup> (2.73)	5.15 <sup>d</sup> (2.38)	6.95 <sup>c</sup> (2.73)	5.83 <sup>d</sup> (2.52)	6.21 <sup>c</sup> (2.59)	43.19
T4	Spinosad 45 % SC	75	8.44 <sup>c</sup> (2.99)	6.50 <sup>c</sup> (2.65)	9.36 <sup>b</sup> (3.14)	7.36 <sup>c</sup> (2.80)	7.92 <sup>d</sup> (2.90)	27.85
T5	Emamectin benzoate 5 % SG	11	7.79 <sup>d</sup> (2.88)	6.01 <sup>d</sup> (2.55)	7.71 <sup>c</sup> (2.84)	5.85 <sup>d</sup> (2.52)	6.84 <sup>e</sup> (2.71)	35.67
T6	Chlorantraniliprole 18.50 % SC	40	12.05 <sup>b</sup> (3.54)	9.51 <sup>b</sup> (3.16)	11.04 <sup>b</sup> (3.40)	9.6 <sup>b</sup> (3.19)	10.57 <sup>b</sup> (3.33)	10.08
T7	Cyantraniliprole 10.26 % OD	75	8.13 <sup>c</sup> (2.94)	6.12 <sup>c</sup> (2.57)	8.01 <sup>c</sup> (2.92)	6.62 <sup>c</sup> (2.67)	7.22 <sup>d</sup> (2.78)	32.92
T8	Thiodicarb 75 % WP	750	7.54 <sup>d</sup> (2.84)	5.42 <sup>d</sup> (2.43)	7.11 <sup>c</sup> (2.76)	6.30 <sup>c</sup> (2.61)	6.59 <sup>e</sup> (2.66)	37.87
T9	Untreated control	-	14.19 <sup>a</sup> (3.83)	14.07 <sup>a</sup> (3.82)	13.76 <sup>a</sup> (3.78)	13.20 <sup>a</sup> (3.70)	13.81 <sup>a</sup> (3.78)	
	SeM	-	0.09	0.08	0.10	0.09	0.04	
	CD	-	0.28	0.25	0.29	0.26	0.12	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

#### 4.2.2 Yield

The cost economics was worked out based on the pooled yield data of pomegranate fruits per tree obtained in experiment conducted during *Ambia bahar*, 2018 & 2019 (Table 4.17).

The data revealed that, the treatment with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded highest mean fruit yield per tree (23.78 kg/tree). It was followed by flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> (22.54 kg/tree), chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> (20.93 kg/tree), flubendiamide @ 72 g a.i. ha<sup>-1</sup> (20.29 kg/tree), spinosad @ 75 g a.i. ha<sup>-1</sup> (15.21 kg/tree), lambda cyhalothrin @ 25 g a.i. ha<sup>-1</sup> (14.70 kg/tree), emamectin benzoate 5 SG @ 11 g a.i. ha<sup>-1</sup> (14.49 kg/tree), thiodicarb @ 750 g a.i. ha<sup>-1</sup> (14.47 kg/tree) and untreated control (11.89 kg/tree).

The data further indicated that, the treatment cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> recorded highest mean fruit yield per hectare (17.74 t ha<sup>-1</sup>). It was followed by flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> (16.81 t ha<sup>-1</sup>), chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> (15.61 t ha<sup>-1</sup>), flubendiamide @ 72 g a.i. ha<sup>-1</sup> (15.14 t ha<sup>-1</sup>), spinosad @ 75 g a.i. ha<sup>-1</sup> (11.35 t ha<sup>-1</sup>), lambda cyhalothrin @ 25 g a.i. ha<sup>-1</sup> (10.97 t ha<sup>-1</sup>), emamectin benzoate 5 SG @ 11 g a.i. ha<sup>-1</sup> (10.81 t ha<sup>-1</sup>), thiodicarb @ 750 g a.i. ha<sup>-1</sup> (10.79 t ha<sup>-1</sup>) and untreated control (8.87 t ha<sup>-1</sup>).

#### 4.2.3 Cost effectiveness of newer insecticides

The cost effectiveness of tested insecticides used in present study was assessed. The ICBR of treatments ranged between 1: 10.74 and 1: 81.76. The highest ICBR of 1: 81.76 was recorded in the treatment of flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup>. It was followed by chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> (1: 37.91), flubendiamide @ 72 g a.i. ha<sup>-1</sup> (1: 33.06), lambda cyhalothrin @ 25 g a.i. ha<sup>-1</sup> (1: 28.95), emamectin benzoate 5 SG @ 11 g a.i. ha<sup>-1</sup> (1: 24.52) cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (1: 22.97), spinosad @ 75 g a.i. ha<sup>-1</sup> (1: 12.86), and thiodicarb @ 750 g a.i. ha<sup>-1</sup> (1: 10.74) (Table 4.18).

In the present investigation, among all the tested insecticides, flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> was the best treatment against fruit borer by recording least fruit borer damage (2.09 %) & highest per cent reduction over control (88.40 %). It was, however at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.33 % fruit borer damage & 87.08 % reduction over control) (Fig. 4.5 & 4.6).

Flubendiamide acts as a ryanodine receptor disruptor of cellular calcium movement, important for muscle contractions. It causes lethargy, paralysis, rapid feeding cessation and death. Thiacloprid acts as an agonist on the postsynaptic nicotinic acetylcholine receptors of motor neurons in insects. This causes an over-stimulation of the nervous system and ultimately kills the insect (IRAC Mode of Action Classification Scheme, 2020). Flubendiamide + thiacloprid 480 SC @ 84 + 84 g a.i./ha exhibited incredible reduction of brinjal shoot and fruit borer with 98.25 % reduction over control (Sangamithra *et al.*, 2018). Guru and Patil (2018) revealed that, flubendiamide + thiacloprid 480 SC recorded least larval population of

**Table 4.17 Effect of newer insecticides tested against fruit borer on yield of pomegranate (Pooled data, *Ambia bahar* - 2018 & 2019)**

<b>Tr. No.</b>	<b>Treatment</b>	<b>Dose (g a.i. ha<sup>-1</sup>)</b>	<b>Yield (kg/tree)</b>	<b>Yield (t/ha)</b>	<b>Yield increased over control (t/ha)</b>
T1	Flubendiamide 39.35 % SC	72	20.29	15.14	6.27
T2	Flubendiamide 19.92 % + Thiacloprid 19.92 % SC	60+60	22.54	16.81	7.94
T3	Lambda cyhalothrin 5 % EC	25	14.70	10.97	2.10
T4	Spinosad 45 % SC	75	15.21	11.35	2.48
T5	Emamectin benzoate 5 % SG	11	14.49	10.81	1.94
T6	Chlorantraniliprole 18.50 % SC	40	20.93	15.61	6.74
T7	Cyantraniliprole 10.26 % OD	75	23.78	17.74	8.87
T8	Thiodicarb 75 % WP	750	14.47	10.79	1.92
T9	Untreated control	--	11.89	8.87	--

**Table 4.18 Yield & cost effectiveness of newer insecticides tested against fruit borer (Pooled mean, *Ambia bahar* - 2018 & 2019)**

Tr. No.	Treatment	Dose (g a.i. ha <sup>-1</sup> )	Yield (t/ha) (B)	Gross returns (Rs./ha) (D)	Additional income over control (E)	Plant protection cost/ha (F)	Net gains over control (Rs./ha) (G)	ICBR (G/F)
T1	Flubendiamide 39.35 % SC	72	15.14	756817	313320	9200	304120	1 : 33.06
T2	Flubendiamide 19.92 % + Thiacloprid 19.92 % SC	60+60	16.81	840742	397245	4800	392445	1 : 81.76
T3	Lambda cyhalothrin 5 % EC	25	10.97	548310	104813	3500	101313	1 : 28.95
T4	Spinosad 45 % SC	75	11.35	567333	123836	8933	114903	1 : 12.86
T5	Emamectin benzoate 5 % SG	11	10.81	540477	96980	3800	93180	1 : 24.52
T6	Chlorantraniliprole 18.50 % SC	40	15.61	780689	337192	8667	328525	1 : 37.91
T7	Cyantraniliprole 10.26 % OD	75	17.74	886994	443497	18500	424997	1 : 22.97
T8	Thiodicarb 75 % WP	750	10.79	539731	96234	8200	88034	1 : 10.74
T9	Untreated control	--	8.87	443497	--	--	--	--

Flubendiamide 480 SC : Rs 18000/L  
 Spinosad 480 SC: Rs 21333/L  
 Cyantraniliprole 10.26 OD : Rs 9166/L  
 Cost of spraying : Rs. 2000 (1000x2)

Flubendiamide + Thiacloprid 480 SC : Rs 7000/L  
 Emamectin benzoate 5 SG: Rs 4500/kg  
 Thiodicarb 75 WP: Rs 3100/kg  
 Pomegranate : Rs 50000/tonne

Lambda cyhalothrin 5 EC : Rs 800/L  
 Chlorantraniliprole 18.5 SC : Rs 16000/L  
 Cost of cultivation: Rs. 275000

*Helicoverpa armigera* (0.13 larvae/plant) and *Spodoptera* spp. (0.33 larvae/meter row length) in chilli. Rohokale *et al.* (2018) confirmed the efficacy of flubendiamide + thiacloprid @ 0.020 % on brinjal shoot & fruit borer. Flubendiamide + thiacloprid 480 % SC @ 96 g a.i ha<sup>-1</sup> showed significantly least fruit borer damage (2.70 %) in tomato as reported by Vinoth Kumar *et al.*, (2010). All these reports lend support to the present finding.

Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> was the next best treatment against fruit borer as observed in the present investigation is in agreement with many earlier reports. Cyantraniliprole is a second generation anthranilic diamide label claimed insecticide for the control of insect pest complex in pomegranate which is having a novel mode of action as it collapses the ryanodine receptors in insect muscle cells leading to impairment of insect muscle function, rapid cessation of feeding cell sap and death of insects (IRAC Mode of Action Classification Scheme, 2020). Combination of cyantraniliprole 10.26 % OD (0.3 ml) + propineb 50 % WP (1 g) with soluble fertilizer (0:52:34) (5 g/L) was found most effective for the control of pomegranate fruit borer with lowest fruit borer damage of 1.17 % (Lad *et al.*, (2018). Cyantraniliprole 10.26 % OD @ 1.5 ml/L recorded highest pomegranate fruit yield (12.16 t/ha) and lowest fruit borer damage (2.51 %) (Vanitha *et al.*, 2017). Cyantraniliprole 10.26 % OD @ 90 g a.i/ha recorded lowest per cent of shoot and fruit borer damage (1.09 %) and highest yield of 49.70 t/ha in brinjal (Yaligar *et al.*, 2016). Likewise, Kodandaram *et al.*, (2015) also confirmed the efficacy of cyantraniliprole @ 105 g a.i. ha against brinjal shoot & fruit borer damage (8.92 and 8.25 %). Cyantraniliprole 10.26 % OD afforded highest protection (90.70 % of reduction over control) against cucumber fruit borer (Balikai and Mallapur, 2015). All these reports lend support to the present finding.

In the present investigation, the treatment of chlorantraniliprole @ 40 g a.i./ha recorded highest number (10.57/plant) & lowest per cent of reduction (10.08 %) of honey bees indicating safety. It was, however at par with flubendiamide @ 72 g a.i. ha<sup>-1</sup> (10.22/plant and 10.90 %) (Fig. 4.7).

The present finding in respect of, safety of chlorantraniliprole @ 40 g a.i./ha against honey bees in pomegranate is in conformity with many earlier reports. Chlorantraniliprole recorded highest LD<sub>50</sub> value (107.12 µg/bee) and LC<sub>50</sub> values (0.026 mg L<sup>-1</sup>) of *Apis mellifera* (Abbassy *et al.*, 2020). Dinter *et al.* (2010) demonstrated lower intrinsic toxicity of chlorantraniliprole to honey bees. Neither the technical grade nor the formulated products of chlorantraniliprole were acutely toxic to honey bees following 4 or 72 hours treatments at the tested concentrations. Four hours treatment of technical grade and formulated chlorantraniliprole did not significantly affect the 30 day's survivorship (Williams *et al.*, 2020). Ratnakar *et al.*, (2017) studied contact toxicity of different insecticides at half of the recommended dose on *Apis mellifera* and found that chlorantraniliprole was relatively safer than other insecticides. No

adverse effects were recorded in bumble bee colonies exposed to residues of chlorantraniliprole (Larson *et al.*, 2013). Cumulative mortality of *A. mellifera* at 24 hours after treatment indicated that, chlorantraniliprole 18.5 SC was found to be safe as it recorded 77.76 % mortality in comparison to 100 % mortality in other treatments (Hasanaba *et al.*, 2013). All these earlier reports lend support to the present finding.

On the contrary, the locomotion activity or total walking distance of bees exposed to chlorantraniliprole for 4 hours was significantly reduced. Lethargic behavior was observed and significantly reduced walking distances for bees provided a 72 h treatment of chlorantraniliprole. Long term exposure of chlorantraniliprole affected the survivorship and locomotor activity of honey bees (Williams *et al.*, 2020). Chlorantraniliprole activates ryanodine receptors and disturbs calcium homeostasis in the honey bee muscle. This molecule was also more toxic when applied on antennae. Honey bee antennae's are extremely sensitive to diamides (Kadala *et al.*, 2019).

Lincy *et al.*, (2019) worked on contact toxicity of flubendiamide 20 WG to *Apis cerana indica*, *A. florea*, *A. dorsata*, and *Trigona iridipennis* @ 70, 60, 50 and 40 g a.i./ha and reported that flubendiamide recorded the lowest mortality (< 40 %) when compared to standard checks at 24 hours after treatment. Cumulative mortality of *A. mellifera* at 24 hours after treatment indicated that, flubendiamide 20 WG was found to be safe as it recorded 88.86 % mortality in comparison to 100 % mortality in other treatments (Hasanaba *et al.*, 2013). Cheng *et al.*, (2015) studied spray toxicity & risk potential of 42 commonly used insecticides to honey bees and found that flubendiamide caused potential honey bee mortality of 1 % only. Flubendiamide caused less mortality to *Apis cerana* and *A. mellifera* through filter paper contamination than other insecticides (Stanely *et al.*, 2015). Flubendiamide (23.99-62.43 % mortality immediately after dry film formation) was found safer to *A. mellifera* when compared to rest of the insecticides (Ranjitha *et al.*, 2020). All these reports lend support to the present finding.

On the contrary, flubendiamide is known to bind ryanodine receptors and also have insecticidal properties. The ability of flubendiamide to disturb neuronal calcium homeostasis in the honey bee antennae was explored by Kadala *et al.* 2020. Further, they revealed that, calcium signals in the honey bee antennal neurons are altered by the insecticide flubendiamide.

The toxicity analysis of newer insecticide molecules on indian bee, *Apis cerana indica* revealed that, thiamethoxam, emamectin benzoate, fipronil, spinosad, and cyantraniliprole exhibited acute toxicity with LC<sub>50</sub> of 0.0003, 0.0006, 0.003, 0.277 and 4.864 µg a.i./ml, respectively. The experiment indicated that none of the insecticides were safer for honey bees (Dhivya *et al.*, 2017).

Application of cyantraniliprole during flowering, causes negative effects on honey bee survival, flight activity and behavior as well as negative effects on bumble bee queen survival (European Food Safety Authority, 2014).

Bocksch (2011) studied translocation of cyantraniliprole and its metabolites in nectar and pollen of different crops. Cyantraniliprole was detected at very high concentration (more than 100 µg/kg in pollen and nectar of citrus, more than 1400 µg/kg in pollen of apple). High quantities were also found in nectar and pollen of canola, sunflower, tomato, melons and grapes.

Cyantraniliprole and its metabolite (IN-HGW87) were toxic for honey bees and also found in guttation water. As well as it contaminated wax, pollen and honey (Kleinhenz 2011).

In the present investigation, significant reduction of honey bee population was observed in the treatment of lambda cyhalothrin @ 25 g a.i. ha<sup>-1</sup> which recorded lowest population of honey bees (6.21/plant) and proved to be highly toxic (Fig. 4.7).

The toxicity of lambda cyhalothrin @ 25 g a.i. ha<sup>-1</sup> against honey bees in pomegranate is in conformity with many earlier reports. Lambda cyhalothrin was the most toxic pesticide to *A. mellifera*, which recorded lowest LC<sub>50</sub> and LC<sub>90</sub> values at all tested periods and the lowest LT<sub>50</sub> and LT<sub>90</sub> at all tested concentrations (Manal *et al.*, 2019). Short term exposure to lambda cyhalothrin in worker bees reduced life span, affected learning and memory performance, reduced the homing ability and influenced the expression levels of two learning and memory related genes of *A. mellifera* (Liao *et al.*, 2018). Significant reduction in plant pollinators (honey bees, bumble bees, butterflies & syrphid fly) was observed after application of lambda cyhalothrin @ 0.093 g/ml on marigold plants. Lambda cyhalothrin also caused significant mortality (75 %) in honey bees (Hafiz *et al.*, 2017). Lambda cyhalothrin treated plot recorded lowest number of honey bees and highest honey bee death at 3 & 4 hours after spraying in onion crop (Melisie & Damte 2017). All these reports lend support to the present finding.

### **4.3 Bioefficacy of Biorationals Against Pomegranate Aphids & Thrips**

#### **4.3.1 Aphids, *Aphis punicae***

The results from the mean population of aphids/shoot computed from 3 DAS to 15 DAS from each spray along with pooled data have been presented under each sub-head.

##### **4.3.1.1 *Ambia bahar* – 2018**

###### **First spray**

The data pertaining to efficacy of biorationals against aphids after first spray are presented in Table 4.19. The pre count of aphids registered in the range of 21.86 to 22.54/shoot and found to be non significant, indicating homogenous population of aphids in the field. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of aphids.

At 3 DAS, results indicated that, neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment by recording minimum population of aphids (11.14/shoot). Which is at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (11.78/shoot) and *B. bassiana* @ 5 g L<sup>-1</sup> (13.20/shoot) as against 23.73 aphids/shoot recorded in untreated control. However, the rest of the treatments viz., *L. lecanii* @ 5 g L<sup>-1</sup> (14.07/shoot) and *M. anisopliae* @ 5 g L<sup>-1</sup> (16.54/shoot) being at par with each other, next to follow in the order of effectiveness. The next treatments N.S.E 5 % (17.96/shoot) and silicon @ 1000 ppm (18.71/shoot) were found less effective against pomegranate aphids. Almost a similar trend in effectiveness was observed at 7 DAS and 10 DAS.

It was evident that, the treatment spray with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (3.84/shoot). This was followed by azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (3.96/shoot), N.S.E @ 5 % (4.23 shoot), *L. lecanii* @ 5 g L<sup>-1</sup> (5.25 shoot), *B. bassiana* @ 5 g L<sup>-1</sup> (5.74 shoot) & *M. anisopliae* @ 5 g L<sup>-1</sup> (8.10 shoot). Whereas, highest population of aphids (23.45/shoot) was recorded in untreated control.

### **Second spray**

The data pertaining to efficacy of biorationals against aphids after second spray are presented in Table 4.19. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of aphids.

At 3 DAS, results indicated that, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> was the most effective treatment by recording minimum population of aphids (6.50/shoot). It was, however at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (7.41/shoot). *B. bassiana* @ 5 g L<sup>-1</sup> (8.78/shoot) and *L. lecanii* @ 5 g L<sup>-1</sup> (9.50/shoot) being at par, with each other next to follow in the order of effectiveness. Highest population of aphids (14.01/shoot) was recorded in untreated control. Almost a similar trend in effectiveness was observed at 7 DAS & 10 DAS.

Neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (3.10/shoot). This was followed by azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (3.45/shoot), N.S.E @ 5 % (6.17/shoot) & *L. lecanii* @ 5 g L<sup>-1</sup> (4.33/shoot). Highest population of aphids (14.28/shoot) was recorded in untreated control.

### **4.3.1.2 Ambia bahar – 2019**

#### **First spray**

The data pertaining to efficacy of biorationals against aphids after first spray are presented in Table 4.20. The pre count of aphids ranged between 11.23 and 12.54/shoot & found to be non significant, indicating homogenous population of aphids in the field. The data indicated, that all the biorational treatments were significantly superior over untreated control in reducing the population of aphids.

At 3 DAS, results indicated that, the treatment with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment in recording minimum population of aphids (5.13/shoot). It was, however at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (5.76/shoot). *B. bassiana* @ 5 g L<sup>-1</sup> (7.12/shoot) and *L. lecanii* @ 5 g L<sup>-1</sup> (7.98/shoot) being at par with each other, were next to follow in the order of effectiveness. Highest population of aphids (12.03/shoot) was recorded in untreated control. Similar trend was observed at 7 DAS & 10 DAS.

Neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (3.51/shoot). It was, however at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (3.67/shoot) as against untreated control (13.79/shoot). This was followed by *B. bassiana* @ 5 g L<sup>-1</sup> (4.57/shoot) & *L. lecanii* @ 5 g L<sup>-1</sup> (4.86/shoot).

### Second spray

The data pertaining to efficacy of biorationals against aphids after second spray are presented in Table 4.20. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of aphids.

At 3 DAS, results indicated that the treatment with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment by recording minimum population of aphids (4.43/shoot) as against 10.02/shoot in untreated control. However, it was at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (4.97/shoot). *B. bassiana* @ 5 g L<sup>-1</sup> (6.10/shoot), *L. lecanii* @ 5 g L<sup>-1</sup> (6.17/shoot) and *M. anisopliae* @ 5 g L<sup>-1</sup> (7.41/shoot) being at par, with each other next to follow in the order of effectiveness. Allmost similar trend was observed at 7 DAS and 10 DAS.

Neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> retained its superiority even at 15 DAS by recording least population of aphids (3.21/shoot). However, it was at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (3.40/shoot). This was followed by *L. lecanii* @ 5 g L<sup>-1</sup> (4.06/shoot), *B. bassiana* @ 5 g L<sup>-1</sup> (4.44/shoot), N.S.E @ 5 % (4.98/shoot), *M. anisopliae* @ 5 g L<sup>-1</sup> (5.08/shoot) & silicon @ 1000 ppm (6.02/shoot). Highest population of aphids (11.49/shoot) was recorded in untreated control.

#### 4.3.1.3. Pooled data

The data pertaining to efficacy of biorationals against aphids during *Ambia bahar* 2018 & 2019 was pooled and presented in Table 4.21. It could be seen that, all the biorational treatments were significantly superior over untreated control. The pooled analysis of two years revealed that, the treatment with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> consistently proved to be the most promising biorational by recording lowest population of aphids (4.13/shoot). It was at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (4.15/shoot). This was followed by *B. bassiana* @ 5 g L<sup>-1</sup> (5.55) & *L. lecanii* @ 5 g L<sup>-1</sup> (5.72).

**Table 4.19 Bioefficacy of biorationals against aphids (*Ambia bahar*-2018)**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Number of aphids per shoot (nymphs and adults)								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Silicon	1000 ppm	21.86 (4.73)	18.71 <sup>c</sup> (4.38)	10.78 <sup>c</sup> (3.36)	7.21 <sup>c</sup> (2.78)	9.40 <sup>c</sup> (3.15)	11.96 <sup>c</sup> (3.52)	8.91 <sup>c</sup> (3.07)	5.12 <sup>c</sup> (2.31)	6.35 <sup>c</sup> (2.62)
T2	<i>L. lecanii</i>	5 g	22.01 (4.74)	14.07 <sup>b</sup> (3.82)	7.81 <sup>b</sup> (2.88)	4.75 <sup>b</sup> (2.29)	5.25 <sup>b</sup> (2.40)	9.50 <sup>b</sup> (3.16)	5.10 <sup>b</sup> (2.37)	3.07 <sup>b</sup> (1.89)	4.33 <sup>b</sup> (2.20)
T3	Azadirachtin 10000 ppm	3 ml	22.43 (4.79)	11.78 <sup>a</sup> (3.50)	5.47 <sup>a</sup> (2.44)	3.41 <sup>a</sup> (1.98)	3.96 <sup>a</sup> (2.11)	6.50 <sup>a</sup> (2.65)	3.37 <sup>a</sup> (1.97)	2.01 <sup>a</sup> (1.58)	3.45 <sup>a</sup> (1.99)
T4	<i>M. anisopliae</i>	5 g	21.97 (4.74)	16.54 <sup>b</sup> (4.13)	8.40 <sup>b</sup> (2.98)	6.70 <sup>c</sup> (2.68)	8.10 <sup>c</sup> (2.93)	10.81 <sup>c</sup> (3.36)	6.54 <sup>c</sup> (2.65)	4.21 <sup>c</sup> (2.17)	5.78 <sup>c</sup> (2.51)
T5	<i>B. bassiana</i>	5 g	22.24 (4.77)	13.20 <sup>a</sup> (3.70)	6.74 <sup>b</sup> (2.69)	4.29 <sup>a</sup> (2.19)	5.74 <sup>b</sup> (2.50)	8.78 <sup>b</sup> (3.05)	5.70 <sup>b</sup> (2.49)	3.24 <sup>b</sup> (1.93)	4.18 <sup>b</sup> (2.16)
T6	Neem oil + Karanja oil	2 ml+2 ml	22.54 (4.80)	11.14 <sup>a</sup> (3.41)	5.18 <sup>a</sup> (2.38)	3.78 <sup>a</sup> (2.07)	3.84 <sup>a</sup> (2.08)	7.41 <sup>a</sup> (2.81)	3.90 <sup>a</sup> (2.10)	2.11 <sup>a</sup> (1.62)	3.10 <sup>a</sup> (1.90)
T7	N.S.E	5 %	21.92 (4.73)	17.96 <sup>c</sup> (4.30)	9.86 <sup>c</sup> (3.22)	7.18 <sup>c</sup> (2.77)	4.23 <sup>a</sup> (2.17)	11.73 <sup>c</sup> (3.50)	7.41 <sup>c</sup> (2.81)	5.43 <sup>c</sup> (2.44)	6.17 <sup>c</sup> (2.58)
T8	Untreated control	--	22.13 (4.76)	23.73 <sup>d</sup> (4.92)	21.78 <sup>d</sup> (4.72)	23.15 <sup>d</sup> (4.86)	23.45 <sup>d</sup> (4.89)	14.01 <sup>d</sup> (3.81)	14.25 <sup>d</sup> (3.84)	14.17 <sup>d</sup> (3.83)	14.28 <sup>d</sup> (3.84)
	SeM		-	0.13	0.09	0.08	0.08	0.10	0.08	0.06	0.07
	CD		NS	0.38	0.28	0.24	0.25	0.30	0.24	0.19	0.22

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.20 Bioefficacy of biorationals against aphids (*Ambia bahar*-2019)**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Number of aphids per shoot (nymphs and adults)								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Silicon	1000 ppm	11.27 (3.43)	10.25 <sup>c</sup> (3.28)	7.47 <sup>c</sup> (2.82)	5.80 <sup>c</sup> (2.51)	6.42 <sup>c</sup> (2.63)	8.10 <sup>c</sup> (2.93)	6.41 <sup>d</sup> (2.63)	5.45 <sup>d</sup> (2.44)	6.02 <sup>c</sup> (2.55)
T2	<i>L. lecanii</i>	5 g	11.44 (3.46)	7.98 <sup>b</sup> (2.91)	4.28 <sup>b</sup> (2.19)	3.80 <sup>b</sup> (2.07)	4.86 <sup>b</sup> (2.32)	6.17 <sup>b</sup> (2.58)	3.45 <sup>b</sup> (1.99)	2.97 <sup>b</sup> (1.86)	4.06 <sup>a</sup> (2.14)
T3	Azadirachtin 10000 ppm	3 ml	11.23 (3.42)	5.76 <sup>a</sup> (2.50)	2.18 <sup>a</sup> (1.64)	2.04 <sup>a</sup> (1.59)	3.67 <sup>a</sup> (2.04)	4.97 <sup>a</sup> (2.34)	2.11 <sup>a</sup> (1.62)	2.01 <sup>a</sup> (1.58)	3.40 <sup>a</sup> (1.97)
T4	<i>M. anisopliae</i>	5 g	11.37 (3.45)	9.55 <sup>c</sup> (3.17)	5.41 <sup>c</sup> (2.43)	4.17 <sup>b</sup> (2.16)	5.42 <sup>b</sup> (2.43)	7.41 <sup>b</sup> (2.81)	4.73 <sup>c</sup> (2.29)	3.81 <sup>c</sup> (2.08)	5.08 <sup>b</sup> (2.36)
T5	<i>B. bassiana</i>	5 g	12.07 (3.55)	7.12 <sup>b</sup> (2.76)	4.06 <sup>b</sup> (2.14)	3.96 <sup>b</sup> (2.11)	4.57 <sup>b</sup> (2.25)	6.10 <sup>b</sup> (2.57)	3.87 <sup>b</sup> (2.09)	2.86 <sup>b</sup> (1.83)	4.44 <sup>b</sup> (2.22)
T6	Neem oil + Karanja oil	2 ml+2 ml	11.78 (3.50)	5.13 <sup>a</sup> (2.37)	2.87 <sup>a</sup> (1.84)	2.10 <sup>a</sup> (1.61)	3.51 <sup>a</sup> (2.00)	4.43 <sup>a</sup> (2.22)	2.54 <sup>a</sup> (1.74)	2.08 <sup>a</sup> (1.61)	3.21 <sup>a</sup> (1.93)
T7	N.S.E	5 %	12.54 (3.61)	9.16 <sup>c</sup> (3.11)	6.32 <sup>c</sup> (2.61)	5.20 <sup>c</sup> (2.39)	5.81 <sup>c</sup> (2.51)	7.86 <sup>c</sup> (2.89)	4.64 <sup>c</sup> (2.27)	3.50 <sup>c</sup> (2.00)	4.98 <sup>b</sup> (2.34)
T8	Untreated control	--	11.39 (3.45)	12.03 <sup>d</sup> (3.54)	12.42 <sup>d</sup> (3.59)	12.37 <sup>d</sup> (3.59)	13.79 <sup>d</sup> (3.78)	10.02 <sup>d</sup> (3.24)	11.06 <sup>e</sup> (3.40)	11.27 <sup>e</sup> (3.43)	11.49 <sup>d</sup> (3.46)
	SeM		-	0.09	0.07	0.06	0.07	0.08	0.06	0.06	0.07
	CD		NS	0.27	0.21	0.19	0.22	0.25	0.20	0.18	0.21

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.21 Bioefficacy of biorationals against aphids (Pooled mean, *Ambia bahar*- 2018 & 2019)**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Number of aphids per shoot (nymphs and adults)				Mean	Reduction over control (%)
			2018		2019			
			1 <sup>st</sup> spray	2 <sup>nd</sup> spray	1 <sup>st</sup> spray	2 <sup>nd</sup> spray		
T1	Silicon	1000 ppm	11.52 <sup>c</sup> (3.47)	8.09 <sup>c</sup> (2.93)	7.49 <sup>d</sup> (2.83)	6.50 <sup>d</sup> (2.65)	8.40 <sup>d</sup> (2.98)	44.77
T2	<i>L. lecanii</i>	5 g	7.97 <sup>b</sup> (2.91)	5.50 <sup>b</sup> (2.45)	5.23 <sup>b</sup> (2.39)	4.16 <sup>b</sup> (2.16)	5.72 <sup>b</sup> (2.49)	62.41
T3	Azadirachtin 10000 ppm	3 ml	6.15 <sup>a</sup> (2.58)	3.83 <sup>a</sup> (2.08)	3.41 <sup>a</sup> (1.98)	3.12 <sup>a</sup> (1.90)	4.13 <sup>a</sup> (2.15)	72.83
T4	<i>M. anisopliae</i>	5 g	9.93 <sup>c</sup> (3.23)	6.84 <sup>c</sup> (2.71)	6.14 <sup>c</sup> (2.58)	5.26 <sup>c</sup> (2.40)	7.04 <sup>c</sup> (2.75)	53.69
T5	<i>B. bassiana</i>	5 g	7.49 <sup>a</sup> (2.83)	5.48 <sup>b</sup> (2.45)	4.93 <sup>b</sup> (2.33)	4.32 <sup>b</sup> (2.20)	5.55 <sup>b</sup> (2.46)	63.48
T6	Neem oil + Karanja oil	2 ml+2 ml	5.98 <sup>a</sup> (2.55)	4.13 <sup>a</sup> (2.15)	3.40 <sup>a</sup> (1.97)	3.07 <sup>a</sup> (1.89)	4.15 <sup>a</sup> (2.16)	72.73
T7	N.S.E	5 %	9.80 <sup>c</sup> (3.21)	7.69 <sup>c</sup> (2.86)	6.62 <sup>c</sup> (2.67)	5.25 <sup>c</sup> (2.40)	7.34 <sup>c</sup> (2.80)	51.72
T8	Untreated control	--	23.02 <sup>d</sup> (4.85)	14.18 <sup>d</sup> (3.83)	12.65 <sup>c</sup> (3.63)	10.96 <sup>c</sup> (3.39)	15.20 <sup>c</sup> (3.96)	
	SeM		0.10	0.08	0.07	0.07	0.06	
	CD		0.29	0.24	0.23	0.21	0.19	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

### 4.3.2 Thrips, *Scirtothrips dorsalis*

The results from the mean population of thrips/shoot computed from 3 DAS to 15 DAS from each spray along with pooled data have been presented under each sub-head.

#### 4.3.2.1 *Ambia bahar* – 2018

##### First spray

The data pertaining to efficacy of biorationals against thrips after first spray are presented in Table 4.22. The pre count of thrips ranged from 8.91 to 9.86/shoot and found to be non significant, indicating homogenous population of thrips in the field. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS, results indicated that, the treatment with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> was the most effective treatment in recording minimum population of thrips (3.40/shoot). However, it was at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (3.59/shoot) and *L. lecanii* @ 5 g L<sup>-1</sup> (4.18/shoot). *M. anisopliae* @ 5 g L<sup>-1</sup> (4.50/shoot) and N.S.E 5 % (5.10/shoot) being at par with each other, were next to follow in the order of effectiveness. The next treatments were, silicon @ 1000 ppm (5.70/shoot) and *B. bassiana* @ 5 g L<sup>-1</sup> (5.89/shoot). Highest population of thrips (9.87/shoot) was recorded in untreated control.

At 7 DAS, the treatment with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment with lowest population of thrips (2.25/shoot) and found at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (2.51) as against 9.81 thrips/shoot in untreated control. However, *L. lecanii* @ 5 g L<sup>-1</sup> (3.18), N.S.E @ 5 % (4.06), silicon @ 1000 ppm (4.80), *B. bassiana* @ 5 g L<sup>-1</sup> (4.95) and *M. anisopliae* @ 5 g L<sup>-1</sup> (5.75) were next to follow in the order of effectiveness. Similar trend of effectiveness was observed at 10 DAS & 15 DAS.

##### Second spray

The data pertaining to efficacy of biorationals against thrips after second spray are presented in Table 4.22. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS, results indicated that, neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment by recording minimum population of thrips (3.53/shoot). It was, however at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (3.94/shoot), *M. anisopliae* @ 5 g L<sup>-1</sup> (4.10/shoot) and *L. lecanii* @ 5 g L<sup>-1</sup> (4.25/shoot). N.S.E @ 5 % (5.10/shoot), silicon @ 1000 ppm (5.80/shoot) and *B. bassiana* @ 5 g L<sup>-1</sup> (5.97/shoot), being at par with each other, were next to follow in the order of effectiveness. Similar trend of effectiveness was observed at 7 DAS and 10 DAS.

Neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> retained its superiority at 15 DAS by recording least population of thrips (2.21/shoot). It was, however at par with azadirachtin 10000 ppm @ 3

ml L<sup>-1</sup> (2.30/shoot) and *M. anisopliae* @ 5 g L<sup>-1</sup> (2.84/shoot). *L. lecanii* @ 5 g L<sup>-1</sup> (2.96/shoot), N.S.E @ 5 % (4.12/shoot), silicon @ 1000 ppm (5.10/shoot) and *B. bassiana* @ 5 g L<sup>-1</sup> (5.20/shoot) were next to follow in the order of effectiveness. However, maximum population of thrips (8.50/shoot) was recorded in untreated control.

#### 4.3.2.2 *Ambia bahar*, 2019

##### First spray

The data pertaining to efficacy of biorationals against thrips after first spray are presented in Table 4.23. The pre count of thrips registered in the range of 8.18 to 9.25/shoot and found to be non significant, indicating homogenous population of thrips in the field. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS results indicated that, the treatment with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment by recording minimum population of thrips (4.02/shoot). However, it was at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (4.29/shoot). *M. anisopliae* @ 5 g L<sup>-1</sup> (5.31/shoot), N.S.E @ 5 % (5.50/shoot), *L. lecanii* @ 5 g L<sup>-1</sup> (5.60/shoot) and silicon @ 1000 ppm (6.10/shoot) were next to follow in the order of effectiveness. However, highest population of thrips (10.18/shoot) was recorded in untreated control. Similar trend of effectiveness was observed at 7 DAS and 10 DAS.

At 15 DAS, neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> retained its superiority by recording least population of thrips (2.20/shoot). However, it was at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (2.38/shoot). The treatment with *L. lecanii* @ 5 g L<sup>-1</sup> (2.86/shoot), *M. anisopliae* @ 5 g L<sup>-1</sup> (3.60/shoot) & N.S.E @ 5 % (3.95/shoot) were next to follow in the order of effectiveness. Maximum population of thrips (11.01/shoot) was recorded in untreated control.

##### Second spray

The data pertaining to efficacy of biorationals against thrips after second spray are presented in Table 4.23. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the population of thrips.

At 3 DAS, results indicated that, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> was the most effective treatment by recording minimum population of thrips (3.10/shoot). It was, however at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (3.20/shoot), *L. lecanii* @ 5 g L<sup>-1</sup> (3.65/shoot) and *M. anisopliae* @ 5 g L<sup>-1</sup> (3.86/shoot). N.S.E @ 5 % (4.12/shoot) and silicon @ 1000 ppm (4.68/shoot) were next to follow in the order of effectiveness. Highest population of thrips (8.51/shoot) was recorded in untreated control.

At 7 DAS, neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> was the most effective treatment by recording least population of thrips (2.15/shoot). It was, however at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (2.34/shoot). *M. anisopliae* @ 5 g L<sup>-1</sup> (2.89/shoot), *L. lecanii* @ 5 g L<sup>-1</sup>

(2.91/shoot) and N.S.E @ 5 % (3.48/shoot) were next in the order, but were at par with each other. Maximum population of thrips (8.90/shoot) was recorded in untreated control. Similar trend of effectiveness was observed at 10 DAS and 15 DAS.

#### 4.3.2.3 Pooled data

The data pertaining to efficacy of biorationals against thrips during *Ambia bahar* 2018 & 2019 was pooled and presented in Table 4.24. It could be seen that all the biorational treatments were significantly superior over untreated control.

The pooled analysis of two years revealed that, the treatment with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> consistently proved to be the most promising biorational treatment by recording lowest population of thrips (2.57/shoot). However, it was at par with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (2.68/shoot). *L. lecanii* @ 5 g L<sup>-1</sup> (3.31) & *M. anisopliae* @ 5 g L<sup>-1</sup> (3.59) were next in the order, but were at par with each other.

In the present investigation, among the tested biorationals, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (4.13 aphids & 2.68 thrips/shoot) and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (4.15 aphids & 2.57 thrips/shoot) were most promising biorational treatments by recording least population aphids and thrips (Fig. 4.8 & 4.9).

Neem oil, a product of the indian neem tree, *Azadirachta indica* possesses different insecticidal properties, such as repellency, antifeedancy, toxicity and growth disruption. The main active ingredient is azadirachtin, which was isolated from the seeds is known to disrupt metamorphosis of insects. Neem oil, a contact insecticide, but even has systemic activity.

Karanja oil is a product of the seeds of *Pongamia pinnata*. The oil and extract of karanja act as repellent, antifeedant, and growth regulators and even oviposition deterrent (Katerina and Pavela 2019). The effect of neem-based pesticides on the reproductive potential of aphids & thrips has been attributed to blocking the neurosecretory cells by the active ingredient, azadirachtin, which disrupts adult maturation and egg production (Vimala *et al.*, 2010).

Akhtar *et al.* (2020) recorded highest apple aphid mortality of 68.91 % in the treatment of azadirachtin @ 0.3 % which strongly supports the present finding. Katesiya *et al.* (2020) also mentioned that spraying of *L. lecanii* (1×10<sup>9</sup> cfu/gm) @ 4 g L<sup>-1</sup> followed by azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> is effective against chilli aphids, *A. gossypii* (1.26 aphids /plant). Saicharan *et al.* (2017) also found that two sprays of azadirachtin @ 5 ml L<sup>-1</sup> was significantly effective with higher cumulative efficacy (68.49 %) against aphids. Similar to the present investigations, Shannag *et al.* (2014) also reported that, 1.2 % of azadirachtin A and B decreased 50 % feeding activity of peach aphid. These earlier reports support the present finding.

Table 4.22 Bioefficacy of biorationals against thrips (*Ambia bahar-2018*)

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Number of thrips per shoot (nymphs and adults)								
			First spray				Second spray				
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Silicon	1000 ppm	9.48 (3.16)	5.70 <sup>c</sup> (2.49)	4.80 <sup>c</sup> (2.30)	3.90 <sup>c</sup> (2.10)	4.10 <sup>b</sup> (2.14)	5.97 <sup>b</sup> (2.54)	5.18 <sup>c</sup> (2.33)	4.93 <sup>d</sup> (2.38)	5.10 <sup>d</sup> (2.37)
T2	<i>L. lecanii</i>	5 g	8.96 (3.08)	4.18 <sup>a</sup> (2.16)	3.18 <sup>b</sup> (1.92)	2.87 <sup>b</sup> (1.84)	3.20 <sup>a</sup> (1.92)	4.25 <sup>a</sup> (2.18)	3.10 <sup>b</sup> (1.90)	2.85 <sup>b</sup> (1.83)	2.96 <sup>b</sup> (1.86)
T3	Azadirachtin 10000 ppm	3 ml	9.35 (3.14)	3.40 <sup>a</sup> (1.97)	2.51 <sup>a</sup> (1.73)	2.11 <sup>a</sup> (1.62)	2.80 <sup>a</sup> (1.82)	3.94 <sup>a</sup> (2.11)	2.54 <sup>a</sup> (1.74)	2.15 <sup>a</sup> (1.63)	2.30 <sup>a</sup> (1.67)
T4	<i>M. anisopliae</i>	5 g	8.91 (3.07)	4.50 <sup>b</sup> (2.24)	5.75 <sup>d</sup> (2.50)	3.10 <sup>b</sup> (1.90)	3.60 <sup>b</sup> (2.02)	4.10 <sup>a</sup> (2.14)	3.45 <sup>b</sup> (1.99)	2.96 <sup>b</sup> (1.86)	2.84 <sup>a</sup> (1.83)
T5	<i>B. bassiana</i>	5 g	9.15 (3.11)	5.89 <sup>c</sup> (2.53)	4.95 <sup>c</sup> (2.33)	5.21 <sup>d</sup> (2.39)	6.18 <sup>d</sup> (2.58)	5.80 <sup>b</sup> (2.51)	5.25 <sup>d</sup> (2.40)	5.10 <sup>d</sup> (2.37)	5.20 <sup>d</sup> (2.39)
T6	Neem oil + Karanja oil	2 ml+2 ml	9.20 (3.11)	3.59 <sup>a</sup> (2.02)	2.25 <sup>a</sup> (1.66)	2.18 <sup>a</sup> (1.64)	2.96 <sup>a</sup> (1.86)	3.53 <sup>a</sup> (2.01)	2.37 <sup>a</sup> (1.69)	2.01 <sup>a</sup> (1.58)	2.21 <sup>a</sup> (1.65)
T7	N.S.E	5 %	9.86 (3.22)	5.10 <sup>b</sup> (2.37)	4.06 <sup>c</sup> (2.14)	4.17 <sup>c</sup> (2.16)	4.50 <sup>c</sup> (2.24)	5.10 <sup>b</sup> (2.37)	4.37 <sup>c</sup> (2.21)	3.90 <sup>c</sup> (2.10)	4.12 <sup>c</sup> (2.15)
T8	Untreated control	--	9.45 (3.15)	9.87 <sup>d</sup> (3.22)	9.81 <sup>e</sup> (3.21)	9.90 <sup>e</sup> (3.22)	9.83 <sup>e</sup> (3.21)	7.81 <sup>c</sup> (2.88)	8.11 <sup>e</sup> (2.93)	8.34 <sup>e</sup> (2.97)	8.50 <sup>e</sup> (3.0)
	SeM		-	0.07	0.06	0.06	0.06	0.07	0.06	0.06	0.06
	CD		NS	0.21	0.19	0.17	0.19	0.21	0.18	0.17	0.18

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

Table 4.23 Bioefficacy of biorationals against thrips (*Ambia bahar-2019*)

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Number of thrips per shoot (nymphs and adults)								
			First spray					Second spray			
			Pre count	3 DAS	7 DAS	10 DAS	15 DAS	3 DAS	7 DAS	10 DAS	15 DAS
T1	Silicon	1000 ppm	8.76 (3.04)	6.10 <sup>b</sup> (2.57)	5.18 <sup>c</sup> (2.38)	4.56 <sup>c</sup> (2.25)	4.90 <sup>d</sup> (2.32)	4.68 <sup>b</sup> (2.28)	3.80 <sup>c</sup> (2.07)	3.10 <sup>b</sup> (1.90)	4.11 <sup>c</sup> (2.15)
T2	<i>L. lecanii</i>	5 g	8.18 (2.95)	5.60 <sup>b</sup> (2.47)	3.48 <sup>b</sup> (1.99)	2.90 <sup>b</sup> (1.84)	2.86 <sup>b</sup> (1.83)	3.65 <sup>a</sup> (2.04)	2.91 <sup>b</sup> (1.85)	2.24 <sup>a</sup> (1.66)	2.70 <sup>a</sup> (1.79)
T3	Azadirachtin 10000 ppm	3 ml	8.48 (3.00)	4.29 <sup>a</sup> (2.19)	2.57 <sup>a</sup> (1.75)	2.10 <sup>a</sup> (1.61)	2.38 <sup>a</sup> (1.70)	3.10 <sup>a</sup> (1.90)	2.34 <sup>a</sup> (1.69)	2.10 <sup>a</sup> (1.61)	2.30 <sup>a</sup> (1.67)
T4	<i>M. anisopliae</i>	5 g	8.50 (3.00)	5.31 <sup>b</sup> (2.41)	3.15 <sup>b</sup> (1.91)	3.44 <sup>b</sup> (1.98)	3.60 <sup>c</sup> (2.02)	3.86 <sup>a</sup> (2.09)	2.89 <sup>b</sup> (1.84)	2.30 <sup>a</sup> (1.67)	2.60 <sup>a</sup> (1.76)
T5	<i>B. bassiana</i>	5 g	8.25 (2.96)	6.92 <sup>c</sup> (2.72)	5.40 <sup>c</sup> (2.43)	4.90 <sup>d</sup> (2.32)	5.10 <sup>d</sup> (2.37)	5.51 <sup>c</sup> (2.45)	4.90 <sup>d</sup> (2.32)	3.75 <sup>c</sup> (2.06)	4.46 <sup>c</sup> (2.23)
T6	Neem oil + Karanja oil	2 ml+2 ml	9.10 (3.10)	4.02 <sup>a</sup> (2.13)	2.18 <sup>a</sup> (1.64)	2.04 <sup>a</sup> (1.59)	2.20 <sup>a</sup> (1.64)	3.20 <sup>a</sup> (1.92)	2.15 <sup>a</sup> (1.63)	2.10 <sup>a</sup> (1.61)	2.25 <sup>a</sup> (1.66)
T7	N.S.E	5 %	8.81 (3.05)	5.50 <sup>b</sup> (2.45)	4.02 <sup>c</sup> (2.13)	3.86 <sup>c</sup> (2.09)	3.95 <sup>c</sup> (2.11)	4.12 <sup>b</sup> (2.15)	3.48 <sup>b</sup> (1.99)	2.89 <sup>b</sup> (1.84)	3.23 <sup>b</sup> (1.93)
T8	Untreated control	--	9.25 (3.12)	10.18 <sup>d</sup> (3.27)	11.12 <sup>d</sup> (3.41)	10.86 <sup>e</sup> (3.37)	11.01 <sup>e</sup> (3.39)	8.51 <sup>d</sup> (3.00)	8.90 <sup>e</sup> (3.07)	9.01 <sup>d</sup> (3.08)	4.20 <sup>c</sup> (2.17)
	SeM		-	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05
	CD		NS	0.22	0.18	0.18	0.18	0.18	0.19	0.17	0.16

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.24 Bioefficacy of biorationals against thrips (Pooled mean, *Ambia bahar*- 2018 & 2019)**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Number of thrips per shoot (nymphs and adults)				Mean	Reduction over control (%)
			2018		2019			
			1 <sup>st</sup> spray	2 <sup>nd</sup> spray	1 <sup>st</sup> spray	2 <sup>nd</sup> spray		
T1	Silicon	1000 ppm	4.63 <sup>b</sup> (2.26)	5.30 <sup>d</sup> (2.41)	5.19 <sup>c</sup> (2.39)	3.92 <sup>b</sup> (2.10)	4.76 <sup>d</sup> (2.29)	47.86
T2	<i>L. lecanii</i>	5 g	3.36 <sup>a</sup> (1.96)	3.29 <sup>b</sup> (1.95)	3.71 <sup>b</sup> (2.05)	2.88 <sup>a</sup> (1.84)	3.31 <sup>b</sup> (1.95)	63.74
T3	Azadirachtin 10000 ppm	3 ml	2.71 <sup>a</sup> (1.79)	2.73 <sup>a</sup> (1.80)	2.84 <sup>a</sup> (1.83)	2.46 <sup>a</sup> (1.72)	2.68 <sup>a</sup> (1.78)	70.59
T4	<i>M. anisopliae</i>	5 g	4.24 <sup>b</sup> (2.18)	3.34 <sup>b</sup> (1.96)	3.88 <sup>b</sup> (2.09)	2.91 <sup>a</sup> (1.85)	3.59 <sup>b</sup> (2.02)	60.64
T5	<i>B. bassiana</i>	5 g	5.56 <sup>c</sup> (2.46)	5.34 <sup>d</sup> (2.42)	5.58 <sup>c</sup> (2.47)	4.66 <sup>c</sup> (2.27)	5.28 <sup>d</sup> (2.40)	42.09
T6	Neem oil + Karanja oil	2 ml+2 ml	2.71 <sup>a</sup> (1.79)	2.53 <sup>a</sup> (1.74)	2.61 <sup>a</sup> (1.76)	2.43 <sup>a</sup> (1.71)	2.57 <sup>a</sup> (1.75)	71.85
T7	N.S.E	5 %	4.46 <sup>b</sup> (2.23)	4.37 <sup>c</sup> (2.21)	4.33 <sup>b</sup> (2.20)	3.43 <sup>b</sup> (1.98)	4.15 <sup>c</sup> (2.16)	54.53
T8	Untreated control	--	9.85 <sup>d</sup> (3.22)	8.19 <sup>c</sup> (2.95)	10.79 <sup>d</sup> (3.36)	7.66 <sup>d</sup> (2.86)	9.12 <sup>e</sup> (3.10)	-
	SeM		0.06	0.06	0.06	0.06	0.04	
	CD		0.19	0.18	0.19	0.17	0.12	

Figures in parentheses represent converted values of  $\sqrt{x+0.5}$

At the 5 % level, values in each column with identical alphabets do not vary significantly

Lowest brinjal aphid population (13.25/15 leaves) & highest fruit yield (20.54 q/ha) was recorded in the treatment of neem oil @ 1 % (Dehariya *et al.*, 2018). Methanolic extract of neem + karanja oil was highly effective against aphids which exhibited 100 % protection (Vishal *et al.*, 2007). A study conducted by Shannag *et al.*, (2014) revealed that, 70 % neem oil and 100 % neem oil were highly effective in suppressing the peach aphid. Likewise in okra, Gaikwad *et al.*, (2020) also observed that neem oil @ 0.2 % exhibited significant control against aphids (11.75/3 leaves). Results of present investigations were in accordance with the finding of Jayakumar and Uthamasamy (1997) who reported that, neem oil @ 3 % caused 93.30 % mortality of peach aphid, *Myzus persicae*. These earlier reports lend support to the present finding.

Two sprays of neem oil+karanja oil @ 2 ml+2ml L<sup>-1</sup> at 15 days interval was recommended for the control of pomegranate thrips (Anonymous, 2018). Venkateswarlu *et al.*, (2021) also confirmed the efficacy of neem oil @ 2.5 ml L<sup>-1</sup> (1.56 thrips/ 3 leaves) and karanja oil @ 6 ml L<sup>-1</sup> (1.86 thrips/ 3 leaves) in chilli, which strongly supports the present finding. Similarly, Bhojane *et al.*, (2019) revealed that, neem oil @ 1 ml L<sup>-1</sup> (54 % reduction over control) and karanja oil @ 1 ml L<sup>-1</sup> (44 %) are best biorational components in managing cucumber thrips. The seed treatment with karanja oil at @ 10 and 20 ml/kg seed was the most effective treatment in controlling thrip population in tomato (Asmita and Ukey, 2014). According to Rakesh (2017), karanja oil (population reduction of 55.78 %) proved to be most effective treatment against *Scirtothrips dorsalis* in chilli and it was followed by neem oil (55.64 %). All these reports lend support to the present finding.

#### **4.4 Bioefficacy of Biorationals Against Fruit Borer, *Deudorix isocrates***

The results from the fruit borer damage per cent/tree computed at the time of harvesting along with pooled data have been presented under each sub-head.

##### **4.4.1 *Ambia bahar* – 2018**

The data on per cent fruit borer damage per tree at the time of harvesting was presented in Table 4.25. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the fruit borer damage.

At the time of harvesting, the treatment with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> proved to be the most effective treatment by recording lowest fruit borer damage (6.21 %). Which is also found at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> and N.S.E @ 5 % and recorded 6.33 & 7.44 % fruit borer damage, respectively as against 19.32 % in untreated control. The next treatments were, *M. anisopliae* @ 5 g L<sup>-1</sup> (8.59 %), *B. bassiana* @ 5 g L<sup>-1</sup> (9.55 %) and silicon @ 1000 ppm (9.80 %) were next in the order, but were at par with each other. This was followed by *L. lecanii* @ 5 g L<sup>-1</sup> (11.12 %).

#### 4.4.2 *Ambia bahar* – 2019

The data on fruit borer damage (%) per tree at the time of harvesting was presented in Table 4.25. The data indicated that, all the biorational treatments were significantly superior over untreated control in reducing the fruit borer damage.

At the time of harvesting, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> proved to be the most effective treatment by recording lowest fruit borer damage (7.39 %). It was, however at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> which recorded 7.70 per cent fruit borer damage. The next treatments were, N.S.E @ 5 % (8.90 %) and *M. anisopliae* @ 5 g L<sup>-1</sup> (9.58 %) were next in the order, but were at par with each other. This was followed by *B. bassiana* @ 5 g L<sup>-1</sup> (10.54 %), silicon @ 1000 ppm (10.85 %) and *L. lecanii* @ 5 g L<sup>-1</sup> (11.32 %). However, highest fruit borer damage (19.00 %) was recorded in untreated control.

#### 4.4.3 Pooled data (*Ambia bahar* 2018 and 2019)

The data pertaining to efficacy of biorationals against fruit borer during *Ambia bahar* 2018 & 2019 was pooled and presented in Table 4.25. It could be seen that all the biorationals were significantly superior over untreated control.

The pooled analysis of two years revealed that, the treatment azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> consistently proved to be the most promising biorational by recording least fruit borer damage (6.80 %). It was at par with neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (7.01 %). N.S.E @ 5 % (8.17 %) and *M. anisopliae* @ 5 g L<sup>-1</sup> (9.08 %) were next in the order, but were at par with each other. This was followed by *B. bassiana* @ 5 g L<sup>-1</sup> (10.05 %), silicon @ 1000 ppm (10.32 %) and *L. lecanii* @ 5 g L<sup>-1</sup> (11.22 %), which were found less effective. However, highest fruit borer damage (19.16 %) was recorded in untreated control.

#### 4.4.4 Yield

The cost economics was worked out based on the pooled yield data of pomegranate fruits/tree obtained in experiment conducted during *Ambia bahar*, 2018 & 2019. Different economical parameters were worked out and presented in Table 4.26.

The data revealed that, the treatment with azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> recorded highest mean fruit yield per tree (15.07 kg). It was followed by neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (14.95 kg), N.S.E @ 5 % (13.62 kg), *M. anisopliae* @ 5 g L<sup>-1</sup> (12.80 kg), *L. lecanii* @ 5 g L<sup>-1</sup> (12.71 kg), *B. bassiana* @ 5 g L<sup>-1</sup> (12.18 kg), silicon @ 1000 ppm (11.95 kg) and untreated control (10.38 kg).

Mean fruit yield per hectare was worked out on the basis of mean fruit yield per tree. The data indicated that, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> treated trees recorded highest mean fruit yield per hectare (11.24 t ha<sup>-1</sup>).

**Table 4.25 Bioefficacy of biorationals against fruit borer**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Fruit borer damage (%)			Reduction over control (%)
			<i>Ambia bahar</i> 2018	<i>Ambia bahar</i> 2019	Pooled mean	
1.	Silicon	1000 ppm	9.80 <sup>b</sup> (17.71)	10.85 <sup>d</sup> (18.64)	10.32 <sup>c</sup> (18.18)	46.09
2.	<i>L. lecanii</i>	5 g	11.12 <sup>c</sup> (18.87)	11.32 <sup>d</sup> (19.04)	11.22 <sup>c</sup> (18.95)	41.42
3.	Azadirachtin 10000 ppm	3 ml	6.21 <sup>a</sup> (14.10)	7.39 <sup>a</sup> (15.38)	6.80 <sup>a</sup> (14.76)	64.46
4.	<i>M. anisopliae</i>	5 g	8.59 <sup>b</sup> (16.58)	9.58 <sup>b</sup> (17.51)	9.08 <sup>b</sup> (17.05)	52.57
5.	<i>B. bassiana</i>	5 g	9.55 <sup>b</sup> (17.49)	10.54 <sup>c</sup> (18.37)	10.05 <sup>c</sup> (17.93)	47.55
6.	Neem oil + Karanja oil	2 ml+2 ml	6.33 <sup>a</sup> (14.23)	7.70 <sup>a</sup> (15.70)	7.01 <sup>a</sup> (14.98)	63.36
7.	N.S.E	5 %	7.44 <sup>a</sup> (15.44)	8.90 <sup>b</sup> (16.88)	8.17 <sup>b</sup> (16.18)	57.31
8.	Untreated control	--	19.32 <sup>d</sup> (24.87)	19.00 <sup>e</sup> (24.67)	19.16 <sup>d</sup> (24.77)	
	SeM		0.46	0.34	0.35	
	CD		1.38	1.04	1.18	

The data in parenthesis have been arc sin converted

At the 5% level, values in each column with identical alphabets do not differ significantly

**Table 4.26 Effect of biorationals tested against fruit borer on yield of pomegranate (Pooled data, *Ambia bahar* - 2018 & 2019)**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Yield (kg/tree) (A)	Yield (t/ha) (B)	Yield increased over control (t/ha) (C)
T1	Silicon	1000 ppm	11.95	8.91	1.17
T2	<i>L. lecanii</i>	5 g	12.71	9.48	1.74
T3	Azadirachtin 10000 ppm	3 ml	15.07	11.24	3.50
T4	<i>M. anisopliae</i>	5 g	12.80	9.55	1.81
T5	<i>B. bassiana</i>	5 g	12.18	9.09	1.34
T6	Neem oil + Karanja oil	2 ml+2 ml	14.95	11.15	3.41
T7	N.S.E 5%	5 %	13.62	10.16	2.42
T8	Untreated control	--	10.38	7.74	--

**Table 4.27 Yield & cost effectiveness of biorational insecticides tested against fruit borer (Pooled mean, *Ambia bahar* – 2018 & 2019)**

Tr. No.	Treatment	Dose (g or ml L <sup>-1</sup> )	Yield (t/ha) (B)	Gross returns (Rs./ha) (D)	Additional income over control (E)	Plant protection cost (Rs/ha) (F)	Net gains over control (Rs./ha) (G)	ICBR (G/F)
T1	Silicon	1000 ppm	8.91	445735	58561	2880	55681	1 : 19.33
T2	<i>L. lecanii</i>	5 g	9.48	474083	86909	4000	82909	1 : 20.73
T3	Azadirachtin 10000 ppm	3 ml	11.24	562111	174937	11000	163937	1 : 14.90
T4	<i>M. anisopliae</i>	5 g	9.55	477440	90266	4000	86266	1 : 21.57
T5	<i>B. bassiana</i>	5 g	9.09	454314	67140	4000	63140	1 : 15.79
T6	Neem oil + Karanja oil	2 ml+2 ml	11.15	557635	170461	6000	164461	1 : 27.41
T7	N.S.E	5 %	10.16	508026	120852	2150	118702	1 : 55.21
T8	Untreated control	--	7.74	387174	--	--	--	--

Silicon : Rs 500/kg  
*M. anisopliae* : Rs 200/kg  
 N.S.E. 5% : Rs 150

*L. lecanii* : Rs 200/kg  
*B. bassiana* : Rs 200/kg  
 Cost of spraying : Rs. 2000 (1000x2)

Azadirachtin : Rs 1500/L  
 Neem oil + Karanja oil : Rs 1000/L  
 Cost of cultivation: Rs. 275000  
 Pomegranate : Rs 50/kg

This was followed by neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (11.15 t ha<sup>-1</sup>), N.S.E @ 5 % (10.16 t ha<sup>-1</sup>), *M. anisopliae* @ 5 g L<sup>-1</sup> (9.55 t ha<sup>-1</sup>), *L. lecanii* @ 5 g L<sup>-1</sup> (9.48 t ha<sup>-1</sup>), *B. bassiana* @ 5 g L<sup>-1</sup> (9.09 t ha<sup>-1</sup>), silicon @ 1000 ppm (8.91 t ha<sup>-1</sup>) and untreated control (7.74 t ha<sup>-1</sup>).

#### 4.4.5 Cost effectiveness of biorationals

The cost effectiveness of different biorationals used in present study was assessed. The ICBR of different treatments ranged between 1: 55.21 and 1: 14.90. The highest ICBR of 1 : 55.21 was recorded in the treatment of N.S.E @ 5 %. It was followed by neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (1: 27.41), *M. anisopliae* @ 5 g L<sup>-1</sup> (1: 21.57), *L. lecanii* @ 5 g L<sup>-1</sup> (1: 20.73), *B. bassiana* @ 5 g L<sup>-1</sup> (1: 15.79), silicon @ 1000 ppm (1: 19.33) and azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (1: 14.90). Although azadirachtin 10000 ppm has great reduction of fruit borer damage, but has less cost benefit ratio due to high cost of the insecticide (Table 4.27).

In the present investigation, among the tested biorationals, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (6.80 % fruit borer damage) and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (7.01 % fruit borer damage) were found as most promising biorational treatments by recording lowest fruit borer damage % (Fig. 4.10 & 4.11).

The findings of several researchers about efficacy of neem plant products against fruit borers are very close to the present results. Bhut *et al.* (2013) reported that neem oil @ 0.5 % was found more effective against anar butterfly, *Virachola isocrates* in pomegranate, which strongly supports the present finding. Raja *et al.* (1999) also found that neem oil @ 4 % was effective in managing of brinjal shoot and fruit borer. Suraj *et al.* (2015) confirmed that karanjin 2 % EC @ 2 ml/L provided effective control against fruit borer (12.81 % fruit damage) in okra. Nawale *et al.*, (2018) also mentioned that, neem oil @ 2 ml/L (13.55 % shoot & 10 % fruit infestation) found effective against brinjal shoot & fruit borer.

Singh (2003) reported that the neem oil and karanja oil were found effective botanicals against brinjal shoot and fruit borer (49.10 % reduction over control). Lowest number of okra fruit borer larvae, least fruit damage % and highest marketable yield was observed in the treatment of neem oil @ 0.3 % (Subbireddy *et al.*, 2018). Sahana and Anoorag (2017) also confirmed the efficacy of neem oil @ 3 % & karanja oil @ 3 % with lowest shoot and fruit infestation (8.47 % & 9.68 % ; 9.85 % & 10.28 %) against brinjal shoot and fruit borer.

According to Abdur *et al.* (2021), okra fruit borer infestation reduction was highest (56.45 %) in the plots treated with azadirachtin 1000 ppm. Among the different biorationals, azadirachtin 10000 ppm found effective against tomato fruit borer, with lowest larval population (1.12), least fruit borer damage % (15.54) & also recorded highest yield (330 q/ha) (Patil *et al.*, 2018). Like wise, Suraj *et al.*, (2015) demonstrated effective control of fruit borer (8.74 % fruit damage) with azadirachtin 1 % EC @ 2 ml/L in okra & also recorded higher yield (37.92 q/ha). Lowest number of okra fruit borer larvae, least fruit damage % and highest marketable yield was

observed in the treatment of azadirachtin 0.15 EC @ 0.0006 % (Subbireddy *et al.*, 2018). These earlier reports lend support to the present finding.

#### **4.5 Studies on Residues & Dissipation of Insecticides in Pomegranate Fruits & Cropped Soil**

Two sprays each of flubendiamide + thiacloprid 480 SC (60+60 g a.i. ha<sup>-1</sup> & 120+120 g a.i. ha<sup>-1</sup>) and thiacloprid 240 SC (60 g a.i. ha<sup>-1</sup> & 120 g a.i. ha<sup>-1</sup>) were given at an interval of 10 days, first being at the fruit initiation stage. The fruits were collected at 0, 1, 3, 5, 7, 10 and 15 days after the second spray and subjected to QuEChERS method of analysis to determine the residues as explained under chapter 3 (Material and Methods).

##### **4.5.1 Method validation**

Method validation refers to the process used to confirm the suitability of analytical method employed for specific test and is an integral part of any good analytical procedure. Results of method validation can be used to judge the quality, reliability and consistency of analytical results. Validation parameters *viz.* Linearity, LOD and LOQ, accuracy and precision were determined before analysis of pomegranate fruit samples.

For the linearity study, a graph of detector response versus concentration of insecticide was plotted and correlation equation and coefficient were determined.

##### **4.5.1.1 Linearity**

For the linearity studies, a graph of detector response versus concentration of insecticide was plotted; correlation equation and coefficient were determined. Six linear concentrations *i.e.* 0.05, 0.10, 0.25, 0.40, 0.50 and 1 µg g<sup>-1</sup> of flubendiamide, des-iodo flubendiamide (metabolite) and thiacloprid were injected in triplicate and the linearity lines were drawn. The response was linear over the range tested and R<sup>2</sup> values were 0.992, 0.994 and 0.998 respectively. These results indicated that method of analysis was valid method for residue determination of the tested insecticides in pomegranate (Fig. 4.12).

##### **4.5.1.2 Limit of Detection (LOD) and Limit of Quantification (LOQ)**

Limit of Detection (LOD) of flubendiamide, des-iodo flubendiamide (metabolite) and thiacloprid was 0.015 µg g<sup>-1</sup> and obtained by considering a signal-to-noise ratio of compound with reference to background noise for the blank sample. The limits of quantification (LOQ) determined as the lowest concentration in pomegranate of a given compound giving a response that could be quantified with relative standard deviation (RSD) lower than 20 per cent that was 0.05 µg g<sup>-1</sup> for tested insecticide.

##### **4.5.1.3 Specificity**

Specificity studies were performed by spiking the pomegranate fruit sample and reagent blank with working standards of tested insecticides at the concentration of 0.05 µg g<sup>-1</sup>. The area

of sample and reagent blank were compared with spiked matrix match area. The acceptable range was  $\leq 30$  per cent.

#### **4.5.1.4 Recovery (Accuracy)**

Accuracy of the analytical method was determined by recovery studies. Mean recovery obtained from the studies reflected the accuracy of the method. Precision of the method was reflected in relative standard deviation (RSD).

Recovery study was performed with untreated pomegranate fruit samples fortified with three concentrations of flubendiamide, des-iodo flubendiamide (metabolite) and thiacloprid *i.e.* 0.05, 0.25 and 0.50  $\mu\text{g g}^{-1}$ . The extraction and clean-up was performed as described earlier. Recovery of flubendiamide, des-iodo flubendiamide (metabolite) and thiacloprid was determined in triplicate to confirm the validity of method.

The recovery percentages are presented in Table 4.28 & 4.29. The data revealed that the recovery of flubendiamide (80.82 % to 96.59 % ; 86.63 % to 95.09 %), des-iodo flubendiamide (98.10 % to 100.17 % ; 94.28 % to 101.60 %) & thiacloprid (98.37 to 99.66 % ; 97.75 % to 101.47 %) in pomegranate fruit and soil ranged in acceptable range, respectively.

#### **4.5.1.5 Repeatability and Reproducibility**

Repeatability or retest reliability was performed to check the variation in measurements taken by the same person on same instrument on the same item under the same conditions. Standards of tested insecticides were separately spiked into the control samples of pomegranate at the required fortification levels *i.e.* LOQ, 5 x LOQ and 10 x LOQ. The results of repeatability studies showed that the recovery ranged between 70-120 per cent and the method was found valid.

These results indicated that the QuEChERS method is valid method for residue determination of flubendiamide + thiacloprid 480 % SC, des-iodo flubendiamide (metabolite) and thiacloprid 240 % SC in pomegranate fruits and soil.

The analytical method employed for the extraction and clean-up of pomegranate fruits was found accurate as mean recovery percentage and relative standard deviation (RSD) were within the limits prescribed by SANTE/11813/2017 guidelines. Analytical method which records mean recovery in the range of 70-120 per cent and relative standard deviation (RSD) below 20 per cent is accurate and precise.

Table 4.28 Recovery of flubendiamide &amp; des-iodo flubendamide (metabolite) in pomegranate fruits and soil

Substrate	Fortification level ( $\mu\text{g g}^{-1}$ )	Recovery (%)							
		Flubendiamide				Des-iodo flubendamide (Flubendamide metabolite)			
		R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean
Pomegranate fruit	0.05	103.99	83.28	102.49	96.59 ( $\pm 11.55$ )	98.70	102.44	99.36	100.17 ( $\pm 2.00$ )
	0.25	78.76	87.78	75.91	80.82 ( $\pm 6.20$ )	99.30	98.59	96.42	98.10 ( $\pm 1.50$ )
	0.50	94.29	91.78	87.60	91.22 ( $\pm 3.38$ )	97.29	98.52	99.33	98.38 ( $\pm 1.03$ )
Soil	0.05	94.07	87.17	87.29	89.51 ( $\pm 3.95$ )	96.73	103.94	104.14	101.60 ( $\pm 4.22$ )
	0.25	89.04	88.64	82.22	86.63 ( $\pm 3.83$ )	88.89	97.63	96.34	94.28 ( $\pm 4.72$ )
	0.50	103.23	92.39	89.65	95.09 ( $\pm 7.18$ )	99.73	94.16	93.79	95.89 ( $\pm 3.33$ )

**Table 4.29 Recovery of thiacloprid in pomegranate fruits and soil**

Substrate	Fortification level ( $\mu\text{g g}^{-1}$ )	Recovery (%)			
		R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean
Pomegranate fruit	0.05	95.72	99.12	100.27	98.37 ( $\pm 2.36$ )
	0.25	99.45	99.64	99.89	99.66 ( $\pm 0.22$ )
	0.50	97.30	100.25	101.44	99.66 ( $\pm 2.13$ )
Soil	0.05	93.30	99.67	100.29	97.75 ( $\pm 3.87$ )
	0.25	100.35	98.07	99.21	99.21 ( $\pm 1.14$ )
	0.50	101.32	100.52	102.58	101.47 ( $\pm 1.03$ )

#### **4.5.2 Residues and dissipation of flubendiamide + thiacloprid 480 % SC in pomegranate fruits and soil**

##### **i) Flubendiamide**

Dissipation of flubendiamide was studied at the recommended dose (60 g a.i. ha<sup>-1</sup>) and double the recommended dose (120 g a.i. ha<sup>-1</sup>) on pomegranate. The results obtained indicated that flubendiamide residues decreased with different day intervals after the application. The results pertaining to the study are described hereunder (Table 4.30).

In the present studies, flubendiamide recorded mean initial residues of 0.55 and 0.98 µg g<sup>-1</sup>, which reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. Initial residues dissipated to maximum of 85.45 % and 91.84 % after 5<sup>th</sup> and 7<sup>th</sup> day, respectively in recommended and double the recommended dose. The half-life (RL<sub>50</sub>) values of flubendiamide in pomegranate were 1.79 and 2.01 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively. Whereas, the matured fruits & soil collected at harvest, did not record any residues of flubendiamide at both the doses. No residues of des-iodo flubendiamide (metabolite of flubendiamide) were detected in any of the samples (Fig. 4.13).

##### **ii) Thiacloprid**

Dissipation of thiacloprid was studied at the recommended dose (60 g a.i. ha<sup>-1</sup>) and double the recommended dose (120 g a.i. ha<sup>-1</sup>) on pomegranate crop. The results obtained indicated that thiacloprid residues decreased with different day intervals after the application. The results pertaining to the study are described hereunder (Table 4.31).

Studies on dissipation of thiacloprid in pomegranate revealed that, thiacloprid recorded mean initial residues of 0.59 and 0.95 µg g<sup>-1</sup>, which reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. Initial residues dissipated to maximum of 89.83 % and 92.63 % after 5<sup>th</sup> and 7<sup>th</sup> day, respectively in recommended and double the recommended dose. The half-life (RL<sub>50</sub>) values of thiacloprid in pomegranate were 1.53 and 2.07 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively. Whereas, the matured fruits & soil collected at harvest, did not record any residues of thiacloprid at both the doses (Fig. 4.14).

#### **4.5.3 Residues and dissipation of thiacloprid 240 % SC in pomegranate fruits and cropped soil**

Dissipation of thiacloprid 240 SC was studied at the recommended dose (60 g a.i. ha<sup>-1</sup>) and double the recommended dose (120 g a.i. ha<sup>-1</sup>) on pomegranate crop. The results obtained indicated that thiacloprid residues decreased with different day intervals after the application. The results pertaining to the study are described hereunder (Table 4.32).

Table 4.30 Dissipation of flubendiamide in/on pomegranate fruits and cropped soil

Sampling days after second application	Residues ( $\mu\text{g g}^{-1}$ )														
	Untreated control				Flubendiamide + thiocloprid 480 SC @ 60+60 g a.i./ha					Flubendiamide + thiocloprid 480 SC @ 120+120 g a.i./ha					
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	Dissipation (%)	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	Dissipation (%)	
<b>0</b>	ND	ND	ND	ND	0.50	0.56	0.57	0.55 ( $\pm 0.038$ )	--	0.99	0.99	0.96	0.98 ( $\pm 0.016$ )	--	
<b>1</b>	ND	ND	ND	ND	0.23	0.24	0.37	0.29 ( $\pm 0.079$ )	47.27	0.50	0.55	0.83	0.63 ( $\pm 0.179$ )	35.71	
<b>3</b>	ND	ND	ND	ND	0.11	0.10	0.11	0.11 ( $\pm 0.004$ )	80.00	0.24	0.39	0.38	0.34 ( $\pm 0.082$ )	65.31	
<b>5</b>	ND	ND	ND	ND	0.06	0.08	0.09	0.08 ( $\pm 0.014$ )	85.45	0.15	0.20	0.22	0.19 ( $\pm 0.037$ )	80.61	
<b>7</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	0.05	0.07	0.11	0.08 ( $\pm 0.038$ )	91.84	
<b>10</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>15</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>Mature fruits</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>Soil</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>RL<sub>50</sub> (Days)</b>								<b>1.79</b>						<b>2.01</b>	

ND- Not Detected, BQL- Below Quatification Limit & RL<sub>50</sub>- Residual Life 50

Table 4.31 Dissipation of thiacloprid in/on pomegranate fruits and cropped soil

Sampling days after second application	Residues ( $\mu\text{g g}^{-1}$ )														
	Untreated control				Flubendiamide + thiacloprid 480 SC @ 60+60 g a.i./ha					Flubendiamide + thiacloprid 480 SC @ 120+120 g a.i./ha					
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	Dissipation (%)	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	Dissipation (%)	
<b>0</b>	ND	ND	ND	ND	0.62	0.51	0.65	0.59 ( $\pm 0.07$ )	--	1.00	0.81	1.04	0.95 ( $\pm 0.12$ )	--	
<b>1</b>	ND	ND	ND	ND	0.28	0.35	0.31	0.31 ( $\pm 0.04$ )	47.46	0.47	0.58	0.51	0.52 ( $\pm 0.06$ )	45.26	
<b>3</b>	ND	ND	ND	ND	0.12	0.10	0.14	0.12 ( $\pm 0.02$ )	79.66	0.35	0.32	0.43	0.37 ( $\pm 0.06$ )	61.05	
<b>5</b>	ND	ND	ND	ND	0.06	0.06	0.07	0.06 ( $\pm 0.01$ )	89.83	0.21	0.22	0.26	0.23 ( $\pm 0.03$ )	75.79	
<b>7</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	0.07	0.07	0.08	0.07 ( $\pm 0.01$ )	92.63	
<b>10</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>15</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>Mature fruits</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>Soil</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>RL<sub>50</sub> (Days)</b>									<b>1.53</b>						<b>2.07</b>

ND- Not Detected, BQL- Below Quatification Limit & RL<sub>50</sub>- Residual Life 50

Table 4.32 Dissipation of thiacloprid in/on pomegranate fruits and cropped soil

Sampling days after second application	Residues ( $\mu\text{g g}^{-1}$ )														
	Untreated control				Thiacloprid 240 SC @ 60 g a.i./ha					Thiacloprid 240 SC @ 120 g a.i./ha					
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	Dissipation (%)	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Mean	Dissipation (%)	
<b>0</b>	ND	ND	ND	ND	0.66	0.54	0.69	0.63 ( $\pm 0.08$ )	--	0.96	0.96	0.99	0.98 ( $\pm 0.01$ )	--	
<b>1</b>	ND	ND	ND	ND	0.24	0.39	0.38	0.35 ( $\pm 0.08$ )	44.44	0.56	0.69	0.61	0.62 ( $\pm 0.07$ )	36.73	
<b>3</b>	ND	ND	ND	ND	0.10	0.15	0.14	0.13 ( $\pm 0.03$ )	79.37	0.24	0.39	0.38	0.34 ( $\pm 0.08$ )	65.31	
<b>5</b>	ND	ND	ND	ND	0.05	0.10	0.05	0.07 ( $\pm 0.03$ )	88.89	0.14	0.25	0.25	0.22 ( $\pm 0.06$ )	77.55	
<b>7</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	0.10	0.05	0.05	0.07 ( $\pm 0.03$ )	92.86	
<b>10</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>15</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>Mature fruits</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>Soil</b>	ND	ND	ND	ND	BQL	BQL	BQL	BQL	--	BQL	BQL	BQL	BQL	--	
<b>RL<sub>50</sub> (Days)</b>									<b>1.57</b>						<b>1.97</b>

ND- Not Detected, BQL- Below Quatification Limit & RL<sub>50</sub>- Residual Life 50

In the present studies on dissipation of thiacloprid @ 60 g a.i. ha<sup>-1</sup> & 120 g a.i. ha<sup>-1</sup> recorded mean initial residues of 0.63 and 0.98 µg g<sup>-1</sup>, which reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. Initial residues dissipated to maximum of 88.89 % and 92.86 % after 5<sup>th</sup> and 7<sup>th</sup> day, respectively in recommended and double the recommended dose. The half-life (RL<sub>50</sub>) values of thiacloprid in pomegranate were 1.57 and 1.97 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively. Whereas, the matured fruits & soil collected at harvest, did not record any residues of thiacloprid at both the doses (Fig. 4.15).

Since, the literature is scanty on dissipation of flubendiamide and thiacloprid in pomegranate crop, similar studies in other crops are discussed.

The dissipation of pesticide residues in/on crops depends on climatic condition, type of application, plant species, dosage interval between application and time of harvest (Khay *et al.*, 2008).

The present finding on dissipation behaviour of flubendiamide & thiacloprid is in agreement with several earlier reports (Sahoo *et al.*, 2009, Mohapatra *et al.*, 2010 & Parmar *et al.*, 2012). Application of flubendiamide 480 SC @ 60 and 120 g a.i. ha<sup>-1</sup> in chilli led to initial residues of 1.06 and 2.00 µg g<sup>-1</sup> and were dissipated to below quantification limit of 0.01 µg g<sup>-1</sup> at 7 and 10 days, respectively (Sahoo *et al.*, 2009).

Application of flubendiamide @ 60 g and 120 g a.i. ha<sup>-1</sup> in chilli led to initial residues of 0.22 and 0.31 µg g<sup>-1</sup>, respectively. These levels gradually declined and reached below quantification limit after 3 and 5 days, respectively. Half-life of flubendiamide was observed to be 1.12 and 1.76 days, at single and double dose, respectively (Parmar *et al.*, 2012).

In cabbage, flubendiamide 480 SC @ 24 and 48 g a.i./ha recorded initial residues of 0.33 and 0.49 µg g<sup>-1</sup> which persisted for 10 days from the both the treatments and dissipated with the half-life of 3.9 and 4.45 days, respectively. Des-iodo flubendiamide was not detected in any cabbage and soil samples during the study period (Mohapatra *et al.*, 2010).

Flubendiamide @ 0.72 g a.i. 10 L<sup>-1</sup> and 1.44 g a.i. 10 L<sup>-1</sup> recorded initial residue of 0.42 and 0.60 µg g<sup>-1</sup> in cardamom capsules, respectively with a half-life of 1.25 and 2.53 days. No residues of des-iodo flubendiamide were detected in any of the samples up to 15 days (George *et al.*, 2015).

Flubendiamide 480 SC @ 150 ml a.i. ha<sup>-1</sup> recorded initial residues of 0.220 µg g<sup>-1</sup> in tomato (Kanwar *et al.*, 2011). More than 85 % of flubendiamide residues dissipated within 5 days of the last application. Residues of flubendiamide dissipated below quantification limit within 7 days.

Flubendiamide @ 48 g a.i./ha and 96 g a.i./ha declined to below detectable level of  $0.01 \mu\text{g g}^{-1}$  after 5 and 7 days of with  $\text{RL}_{50}$  of 0.72 and 1.32 days, respectively in tomato (Sharma and Parihar, 2013).

A faster dissipation of flubendiamide & thiacloprid observed at the lower rate of application maybe attributed to the exposure of a lower concentration of the chemical to various biotic and abiotic factors. Flubendiamide & thiacloprid persisted for longer period are more when applied at a higher rate, presumably due to a higher concentration of the chemical, resulting in a slower degradation. Further, no residues of the flubendiamide metabolite was detected in the samples, presumably due to the higher polarity of the des-iodo flubendiamide with high water solubility which would have resulted in a faster elimination of the compound either through cell sap or formation of conjugates with different glycone moieties in the system (George *et al.*, 2015). All these reports lend support to the present finding.

On the contrary, flubendiamide @ 18.24 and 36.48 g a.i.  $\text{ha}^{-1}$  persisted for 10 and 15 days in cabbage with half life of 3.7 to 3.9 days in Nilgiris, Tamil Nadu (Preethi *et al.*, 2019). Similarly, flubendiamide dissipated at the half-life of 3.9 and 4.4 days and persisted for more than 15 days from both the treatments as reported by Mohapatra *et al.*, (2011). Flubendiamide (at 48 g a.i.  $\text{ha}^{-1}$  and 96 g a.i.  $\text{ha}^{-1}$ ) residues persisted for 15 days in field grown and for 25 days in poly house grown capsicum. These residues were degraded with the half lives of 4.3 - 4.7 and 5.6 - 6.6 days in field and poly-house, respectively (Radhika *et al.*, 2016).

Initial residues of thiacloprid @ 180 and 360 g a.i./ha, were observed to be 0.48 and  $1.05 \mu\text{g g}^{-1}$  on the brinjal, respectively. Half life periods for thiacloprid were found to be 0.47 and 0.50 days at single and double the application rates. Residues of thiacloprid declined below its limit of quantification of  $0.05 \mu\text{g g}^{-1}$  after 3 and 5 days, respectively (Sanjay Kumar *et al.*, 2013).

Thiacloprid 48 @ g a.i./ha and 96 g a.i./ha residues reached below quantification limit of  $0.01 \mu\text{g g}^{-1}$  after 5 and 7 days at with  $\text{RL}_{50}$  of 0.83 and 1.79 days, respectively in tomato (Sharma and Parihar, 2013). Parmar *et al.* (2012) also studied persistence of thiacloprid at 60 and 120 g a.i./ha, initial residues recorded were 0.15 and  $0.21 \mu\text{g g}^{-1}$  respectively, one hour after application. The levels gradually declined and reached below quantification limit at 5 and 7 days after application in recommended and double the recommended dose, respectively. Half life of thiacloprid on chilli was observed to be 2.17 and 2.13 days, respectively. Bikramjit and Dikshit (2011) studied the persistence of thiacloprid 240 SC on tomato @ 48 and 96 g ai  $\text{ha}^{-1}$ . Initial residues of thiacloprid ranged from 0.76 to  $1.38 \mu\text{g g}^{-1}$ . However, residues were short lived and attained the below quantification limit by around 10 days. All these reports lend support to the present finding.

However, present findings contradict many reports, initial residues of thiacloprid 240 SC @ 0.0096 and 0.0192 % on apples persisted for 15 days & 30 days, respectively in Kashmir. The Lower concentration (0.0096 %) dissipated with half-life value of 4.70 days, while the higher concentration (0.0192 %) degraded with half-life value of 6.57 days (Khan *et al.*, 2018). Dong *et al.* (2014) studied dissipation pattern of thiacloprid 36 % WG @ 15 & 30 kg/ha in tomato leaves and revealed that, thiacloprid was present in the tomato leaves upto 25 days in both doses, then its amount was less than  $0.005 \mu\text{g g}^{-1}$  and could not be detected. Initial residues ( $3.72$  and  $6.77 \mu\text{g g}^{-1}$ ) of thiacloprid @ 90 and 180 a.i. g ha<sup>-1</sup> on green tea leaves persisted up to 14 days with half-life values of 3.34 and 3.58 days at single and double doses, respectively (Paramasivam *et al.*, 2012).

The persistence and rate of degradation of pesticides varies with the crop and also with the agroclimatic conditions of the place (Teotia and Dham, 1950 and Gupta 1980). The pesticides generally dissipate rapidly in situations where high temperatures are experienced but degrade very slowly in situations where low temperatures exist (Verma and Lal, 1976).

#### **4.6 Evaluation of IPM Module for the Management of Insect Pests in Pomegranate**

The field experiment was conducted during *Ambia bahar* - 2020 in the orchard of All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar. The results obtained during the studies have been presented and discussed.

##### **4.6.1 Aphids, *A. punicae***

###### **Up to 40 days after bahar**

The data pertaining to evaluation of IPM module against aphids during *Ambia bahar* - 2020 are presented in Table 4.33. The pre count of aphids/shoot ranged from 26.35 to 27.05 and found to be non significant, indicating homogenous population of aphids in the field.

At 1<sup>st</sup> week, the results indicated that farmer's practice was the most effective treatment by recording least population of aphids (11.62/shoot). It was followed by IPM module (14.64/shoot). However, highest population of aphids was recorded in untreated control (29.14/shoot).

Almost a similar trend was observed at 2<sup>nd</sup> week & 3<sup>rd</sup> week.

At 4<sup>th</sup> week, lowest population of aphids was recorded in farmer's practice (2.78/shoot). It was followed by IPM module (5.91). However, highest population of aphids was recorded in untreated control (31.59).

###### **At 40 to 90 days after bahar**

The data pertaining to evaluation of IPM module against aphids at 40 to 90 days during *Ambia bahar* - 2020 are presented in Table 4.33. The pre count of aphids ranged between 18.06

and 18.31/shoot and found to be non significant, indicating homogenous population of aphids in the field.

At 1<sup>st</sup> week, the results indicated that IPM module was the most effective treatment by recording least population of aphids (8.88/shoot). It was followed by farmer's practice (12.14/shoot). However, highest population of aphids was recorded in untreated control (19.17/shoot).

Almost a similar trend was observed at 2<sup>nd</sup> week & 3<sup>rd</sup> week.

At 4<sup>th</sup> week, lowest population of aphids was recorded in IPM module (1.64/shoot). It was followed by farmer's practice (5.21/shoot). However, highest population of aphids was recorded in untreated control (23.11/shoot).

#### **4.6.2 Thrips, *S. dorsalis***

##### **At 40-90 days after bahar**

The data pertaining to evaluation of IPM module against thrips at 40 to 90 days during *Ambia bahar* - 2020 are presented in Table 4.34. The pre count of thrips ranged between 10.65 and 10.75/shoot and found to be non significant, indicating homogenous population of thrips in the field.

At 1<sup>st</sup> week, IPM module was the most effective treatment by recording least population of thrips (5.39/shoot). It was followed by farmer's practice (7.99/shoot). However, highest population of thrips was recorded in untreated control (11.30/shoot).

Almost a similar trend was observed at 2<sup>nd</sup> week & 3<sup>rd</sup> week.

At 4<sup>th</sup> week, lowest population of thrips was recorded in IPM module (1.64/shoot). It was followed by farmer's practice (3.41/shoot). However, highest population of thrips was recorded in untreated control (13.42/shoot).

##### **At 90-120 days after bahar**

The data pertaining to evaluation of IPM module against thrips at 90 to 120 days during *Ambia bahar* - 2020 are presented in Table 4.34. The pre count of thrips ranged between 6.37 to 6.89/shoot and found to be non significant, indicating homogenous population of thrips in the field.

At 1<sup>st</sup> week, the results indicated that, IPM module was the most effective treatment by recording least population of thrips per shoot (3.90/shoot). It was followed by farmer's practice (4.62/shoot). However, highest population of thrips was recorded in untreated control (8.20/shoot).

Almost a similar trend was observed at 2<sup>nd</sup> week & 3<sup>rd</sup> week.

At 4<sup>th</sup> week, lowest population of thrips was recorded in IPM module (1.28/shoot). It was followed by farmer's practice (1.70/shoot). However, highest population of thrips was recorded in untreated control (11.65/shoot).

### 4.6.3 Fruit borer, *D. isocrates*

#### At 90-120 days after bahar

The data on fruit borer damage (%) per tree at each picking are presented in Table 4.35. The data indicated that IPM module recorded lowest fruit borer damage per cent than other treatments.

At first picking, IPM module was the most effective treatment by recording least fruit borer damage (3.77 %). It was followed by farmer's practice (6.89 %). However, highest fruit borer damage (13.02 %) was recorded in untreated control.

Almost a similar trend was observed in second picking.

IPM module recorded minimum fruit borer damage (2.19 %) in third picking also. It was followed by farmer's practice (6.13 %). However, maximum fruit borer damage (17.76 %) was recorded in untreated control.

### 4.6.4 Yield

The pomegranate trees treated with IPM module registered highest fruit yield per tree (19.98 Kg). It was followed by farmer's practice (16.81 Kg). However, lowest mean fruit yield per tree (9.02 Kg) was recorded in untreated control (Table 4.36).

Mean fruit yield per hectare was worked out on the basis of mean fruit yield per tree. IPM module registered highest mean fruit yield per hectare (14.91 t/ha). It was followed by farmer's practice (12.54 t/ha). However, lowest mean fruit yield per hectare (6.73 t/ha) was recorded in untreated control.

### 4.6.5 Cost economics

The cost economics of IPM module and farmers practice was worked out based on yield of pomegranate fruits per tree obtained in experiment conducted during *Ambia bahar*, 2020. Different economical parameters were worked out and are presented in Table 4.37. Cost economics results indicated that, IPM module recorded highest Incremental Cost Benefit Ratio (ICBR) (1 : 10.72) followed by farmer's practice (1 : 2.31).

In the present investigation, IPM module comprising of i) up to 40 days, one spray of *L. lecanii* @ 5 g L<sup>-1</sup> followed by one spray of *M. anisopliae* @ 5 g L<sup>-1</sup> at 7 days interval and need based application of imidacloprid 17.8 SL @ 50 g a.i. ha<sup>-1</sup> ii) at 40-90 days, one spray of *L. lecanii* @ 5 g L<sup>-1</sup>, one spray of *M. anisopliae* @ 5 g L<sup>-1</sup> followed by one spray of azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> at 10 days of interval and two sprays of neem oil+ karanja oil @ 2 ml L<sup>-1</sup> + 2 ml L<sup>-1</sup> at an interval of 10 days iii) at 90-120 days, two sprays of NSE @ 5 % at 10 days of interval and need based application of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> proved significantly superior in suppressing the population of sucking pests and fruit borer & registered highest yield (14.91 t/ha) & ICBR (1 : 10.72) (Fig. 4.16).

Since, the literature is scanty on evaluation of IPM module in pomegranate crop, similar studies in other crops are discussed. Karuppuchamy *et al.* (2001) developed IPM module against the pomegranate fruit borer which reduced the incidence of the pest to a greater extent. Similar to the present investigation Bhut *et al.* (2013) found that neem oil @ 0.5 % (22.71 % fruit damage), NSE @ 5 % (23.01 %) and *Bacillus thuringiensis* @ 0.15% (23.87 %) were found more effective against anar butterfly.

Present results are in accordance with the studies of several workers who evaluated the efficacy of different IPM modules against aphids, thrips & fruit borer in other crops. Pawar *et al.* (2020) revealed that sequential strategy (application of lambda cyhalothrin 5 EC @ 15 g a.i./ha followed by *M. anisopliae* 1.15 wp @ 5 g/l. followed by NSE 5 %) was found most effective for the control of thrips in onion.

Agro Ecosystem Analysis based Integrated Pest Management module (Divya *et al.*, 2019) recorded minimum brinjal shoot & fruit borer damage (8.90 %), highest abundance of parasitoids (5.82) and least population of aphids & whiteflies (2.16 and 1.19/three leaves). Whereas farmer's practice recorded maximum population of aphids and whiteflies (16.5 & 14.58), respectively.

Integrated Pest Management Module comprising *M. anisopliae* @ 5 g/l at 30 DAS, installation of yellow sticky traps @ 25/ha, spraying of spinosad 45 SC @ 0.3 ml/l at 45 DAS, *L. lecanii* @ 5g/l @ 60 DAS, neem oil (300 ppm) @ 5 ml/l at 75 DAS was found to be the most effective on thrips & aphids in cucumber with highest yield (230 q/ha) & ICBR (1: 13.86) as reported by Pawar *et al.*, (2019).

IPM module (Application of neem cake @ 2.5 q/ha at the time of sowing + root dip with imidacloprid 17.8 SL @ 0.5 ml/l for 30 min. at the time of transplanting + azadirachtin 10000 ppm @ 1.0 ml/l.+ *L. lecanii* ( $1 \times 10^8$  cfu/g) @ 5 g/l + chlorantraniliprole 18.5 SC @ 0.2 ml/l) was the most effective module against chilli aphids, thrips & fruit borer and recorded 33.78 % increase in yield (Akshata Kurbett *et al.* 2018).

Sruthi *et al.*, (2018) confirmed that biointensive module comprising of i) neemcake application at 50 g per plant ii) three sprays of azadirachtin 10000 ppm @ 1 ml/L + *Lecanicillium lecani* @ 5 g/L vi) cyantraniliprole 10.26 % OD @ 1.5 ml/L were quite effective against capsicum aphids & thrips and obtained higher yield ( $54.53 \text{ t ha}^{-1}$ ), higher net returns (Rs. 21,71,810  $\text{ha}^{-1}$ ) and B:C ratio (2.97),

All these reports lend support to the present finding.

Table 4.33 Influence of Integrated Pest Management module on aphids, *A. punicae*

	Number of aphids per shoot (nymphs & adults)					
Up to 40 days after bahar	Pre count	1 <sup>st</sup> week	2 <sup>nd</sup> week	3 <sup>rd</sup> week	4 <sup>th</sup> week	MEAN
<b>IPM module</b>	26.37 (5.18)	14.64 <sup>b</sup> (3.89)	10.89 <sup>b</sup> (3.37)	8.02 <sup>b</sup> (2.92)	5.91 <sup>b</sup> (2.53)	9.68 <sup>b</sup> (3.19)
<b>Farmer's practice</b>	27.05 (5.25)	11.62 <sup>a</sup> (3.48)	6.93 <sup>a</sup> (2.73)	4.93 <sup>a</sup> (2.33)	2.78 <sup>a</sup> (1.81)	6.56 <sup>a</sup> (2.66)
<b>Untreated control</b>	26.86 (5.23)	29.14 <sup>c</sup> (5.44)	28.83 <sup>c</sup> (5.42)	30.33 <sup>c</sup> (5.55)	31.59 <sup>c</sup> (5.67)	29.97 <sup>c</sup> (5.52)
<b>SeM</b>	NS	0.05	0.03	0.03	0.03	0.03
<b>CD</b>	NS	0.16	0.09	0.10	0.09	0.10
40 to 90 days after bahar						
<b>IPM module</b>	18.17 (4.32)	8.88 <sup>a</sup> (3.06)	5.88 <sup>a</sup> (2.52)	3.57 <sup>a</sup> (2.02)	1.64 <sup>a</sup> (1.46)	4.99 <sup>a</sup> (2.34)
<b>Farmer's practice</b>	18.06 (4.31)	12.14 <sup>b</sup> (3.55)	8.91 <sup>b</sup> (3.06)	7.39 <sup>b</sup> (2.81)	5.21 <sup>b</sup> (2.39)	8.41 <sup>b</sup> (2.98)
<b>Untreated control</b>	18.31 (4.34)	19.17 <sup>c</sup> (4.44)	21.23 <sup>c</sup> (4.66)	22.60 <sup>c</sup> (4.81)	23.11 <sup>c</sup> (4.86)	21.53 <sup>c</sup> (4.69)
<b>SeM</b>	NS	0.05	0.03	0.04	0.07	0.03
<b>CD</b>	NS	0.15	0.09	0.12	0.21	0.09

Figures in parentheses are  $\sqrt{x+0.5}$  transformed values

NS- Non Significant

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.34 Influence of Integrated Pest Management module on thrips, *S. dorsalis***

	Number of thrips per shoot (nymphs & adults)					
40 to 90 days after bahar	Pre count	1 <sup>st</sup> week	2 <sup>nd</sup> week	3 <sup>rd</sup> week	4 <sup>th</sup> week	MEAN
<b>IPM module</b>	10.65 (3.34)	5.39 <sup>a</sup> (2.43)	3.23 <sup>a</sup> (1.93)	2.55 <sup>a</sup> (1.75)	1.64 <sup>a</sup> (1.46)	3.20 <sup>a</sup> (1.92)
<b>Farmer's practice</b>	10.66 (3.35)	7.99 <sup>b</sup> (2.91)	6.18 <sup>b</sup> (2.58)	5.03 <sup>b</sup> (2.35)	3.41 <sup>b</sup> (1.98)	5.65 <sup>b</sup> (2.48)
<b>Untreated control</b>	10.75 (3.36)	11.30 <sup>c</sup> (3.44)	12.93 <sup>c</sup> (3.67)	12.99 <sup>c</sup> (3.67)	13.12 <sup>c</sup> (3.69)	12.59 <sup>c</sup> (3.62)
<b>SeM</b>	NS	0.04	0.04	0.07	0.05	0.03
<b>CD</b>	NS	0.11	0.13	0.22	0.16	0.10
90 to 120 days after bahar						
<b>IPM module</b>	6.37 (2.62)	3.90 <sup>a</sup> (2.10)	2.71 <sup>a</sup> (1.79)	1.79 <sup>a</sup> (1.51)	1.28 <sup>a</sup> (1.33)	2.42 <sup>a</sup> (1.71)
<b>Farmer's practice</b>	6.75 (2.69)	4.62 <sup>b</sup> (2.26)	3.28 <sup>a</sup> (1.94)	2.32 <sup>b</sup> (1.68)	1.70 <sup>a</sup> (1.48)	2.98 <sup>b</sup> (1.87)
<b>Untreated control</b>	6.89 (2.72)	8.20 <sup>c</sup> (2.95)	8.34 <sup>b</sup> (2.97)	10.50 <sup>c</sup> (3.32)	11.65 <sup>b</sup> (3.49)	9.67 <sup>c</sup> (3.19)
<b>SeM</b>	NS	0.04	0.05	0.05	0.05	0.03
<b>CD</b>	NS	0.12	0.16	0.16	0.15	0.10

Figures in parentheses are  $\sqrt{x+0.5}$  transformed values

NS- Non Significant

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.35 Influence of Integrated Pest Management module on fruit borer, *D. isocrates***

90-120 days	Fruit borer damage (%)			
	1 <sup>st</sup> Picking	2 <sup>nd</sup> Picking	3 <sup>rd</sup> Picking	MEAN
<b>IPM module</b>	3.77 <sup>a</sup> (10.99)	2.73 <sup>a</sup> (9.35)	2.19 <sup>a</sup> (8.38)	2.89 <sup>a</sup> (9.63)
<b>Farmer's practice</b>	6.89 <sup>b</sup> (14.85)	5.90 <sup>b</sup> (13.74)	6.23 <sup>b</sup> (14.12)	6.34 <sup>b</sup> (14.24)
<b>Untreated control</b>	13.02 <sup>c</sup> (20.41)	16.34 <sup>c</sup> (22.87)	17.76 <sup>c</sup> (23.84)	15.70 <sup>c</sup> (22.42)
<b>SeM</b>	0.17	0.23	0.15	0.12
<b>CD</b>	0.51	0.71	0.46	0.37

Figures in the parentheses are arc sine transformed values

At the 5 % level, values in each column with identical alphabets do not vary significantly

**Table 4.36 Impact and influence of Integrated Pest Management module on the yield of pomegranate**

<b>Tr. No.</b>	<b>Treatment</b>	<b>Yield (Kg/tree)</b>	<b>Yield (t/ha)</b>	<b>Increased yield over control (t/ha)</b>
1	<b>IPM module</b>	19.98	14.91	5.89
2	<b>Farmer's practice</b>	16.81	12.54	3.52
3	<b>Untreated control</b>	9.02	6.73	--

**Table 4.37 Cost effectiveness of IPM module for the management of insect pests in pomegranate**

Tr. No.	Treatment	Yield (t/ha) (A)	Gross returns (Rs./ha) (B)	Additional income over control (C)	Plant protection cost/ha (D)	Net gains over control (Rs./ha) (E)	ICBR (E/D)
1	<b>IPM module</b>	14.91	745254	294254	25100	269154	10.72
2	<b>Farmer's practice</b>	12.54	627013	176013	53150	122863	2.31
3	<b>Untreated control</b>	6.73	336446	0	0	0	--

Cyantraniliprole 10.26 OD : Rs 9166/L  
 Spinosad 480 SC: Rs 21333/L,  
*M. anisopliae* : Rs 200/kg,  
 Cost of cultivation: Rs. 275000  
 Pomegranate : Rs 50000/tonne

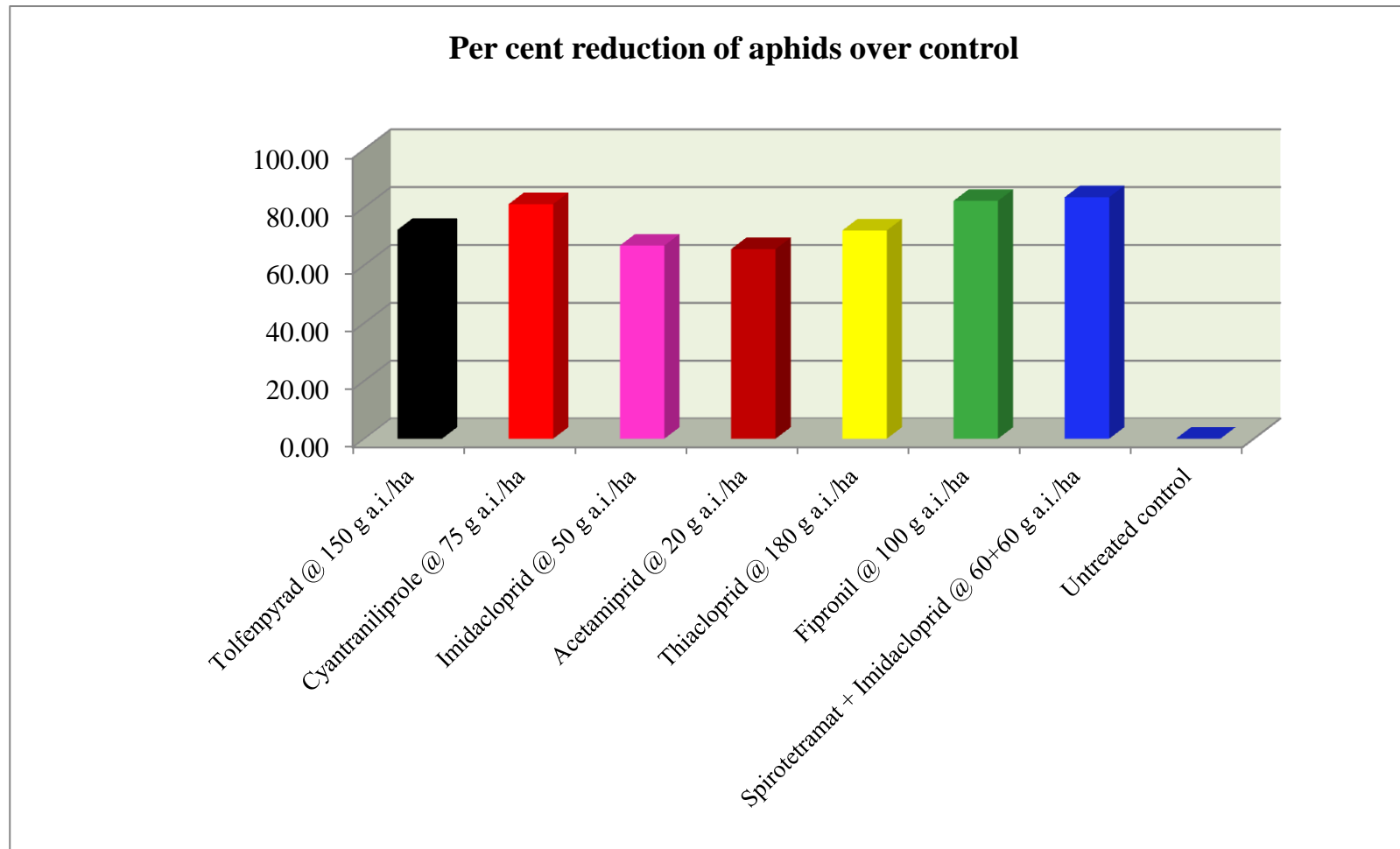
Emamectin benzoate 5 SG: Rs 4500/kg,  
*L. lecanii* : Rs 200/kg,  
 Neem oil + Karanja oil : Rs 1000/L,  
 Cost of spraying : Rs. 1000/spray

Imidacloprid 200 SL : Rs 2500/L  
 Azadirachtin : Rs 1500/L,  
 NSE 5 % : Rs 150

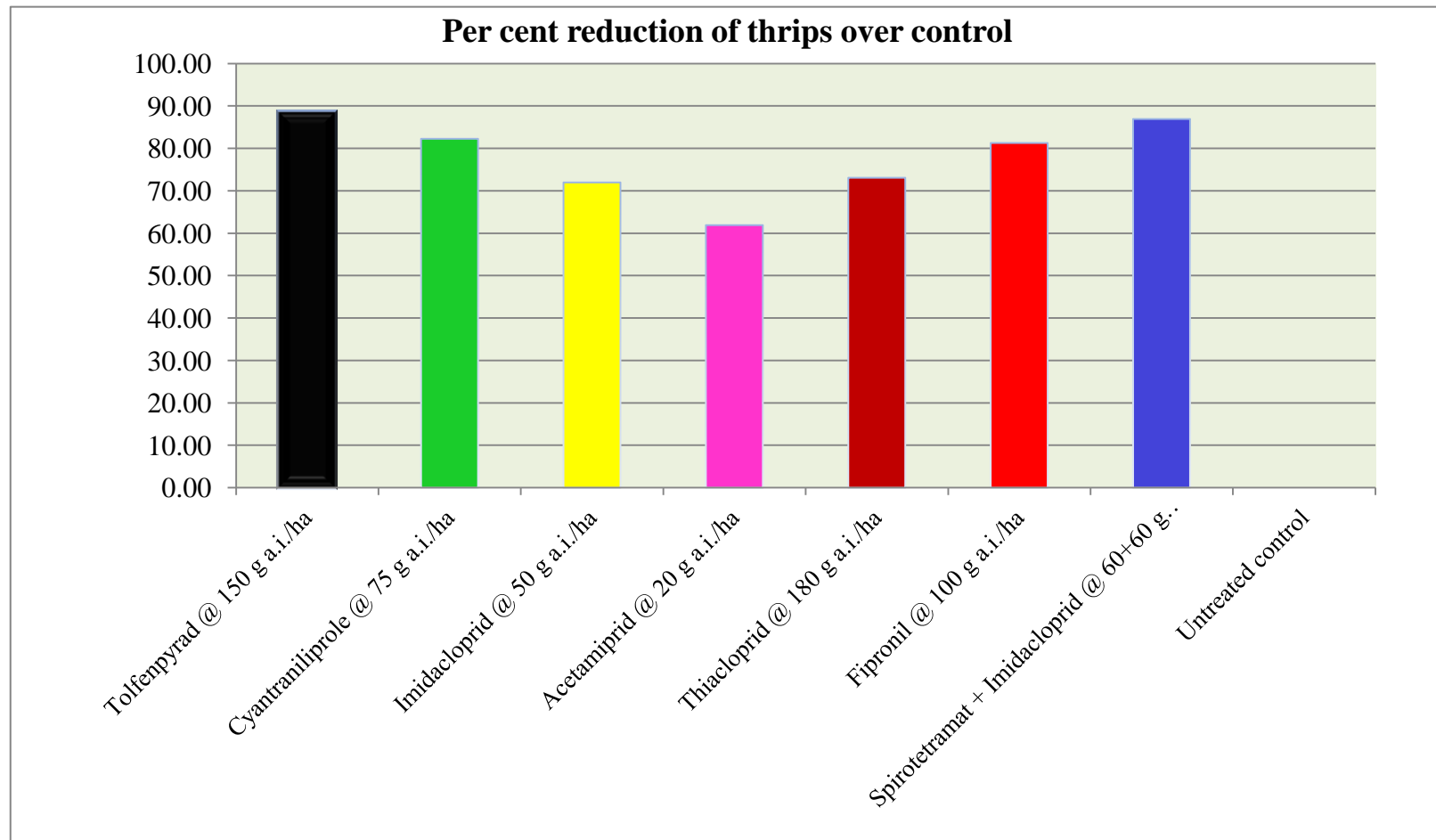
**FUTURE LINES OF WORK:**

- Identification of natural enemies of major insect pests of pomegranate and their conservation
- Studies on toxicity of newer insecticides to different stages of natural enemies and honey bees in pomegranate ecosystem
- Studies on dissipation of newer insecticides to determine safe waiting period for the expansion of label claim
- Formulation, refinement and validation of IPM modules for ecofriendly and cost economic pest management

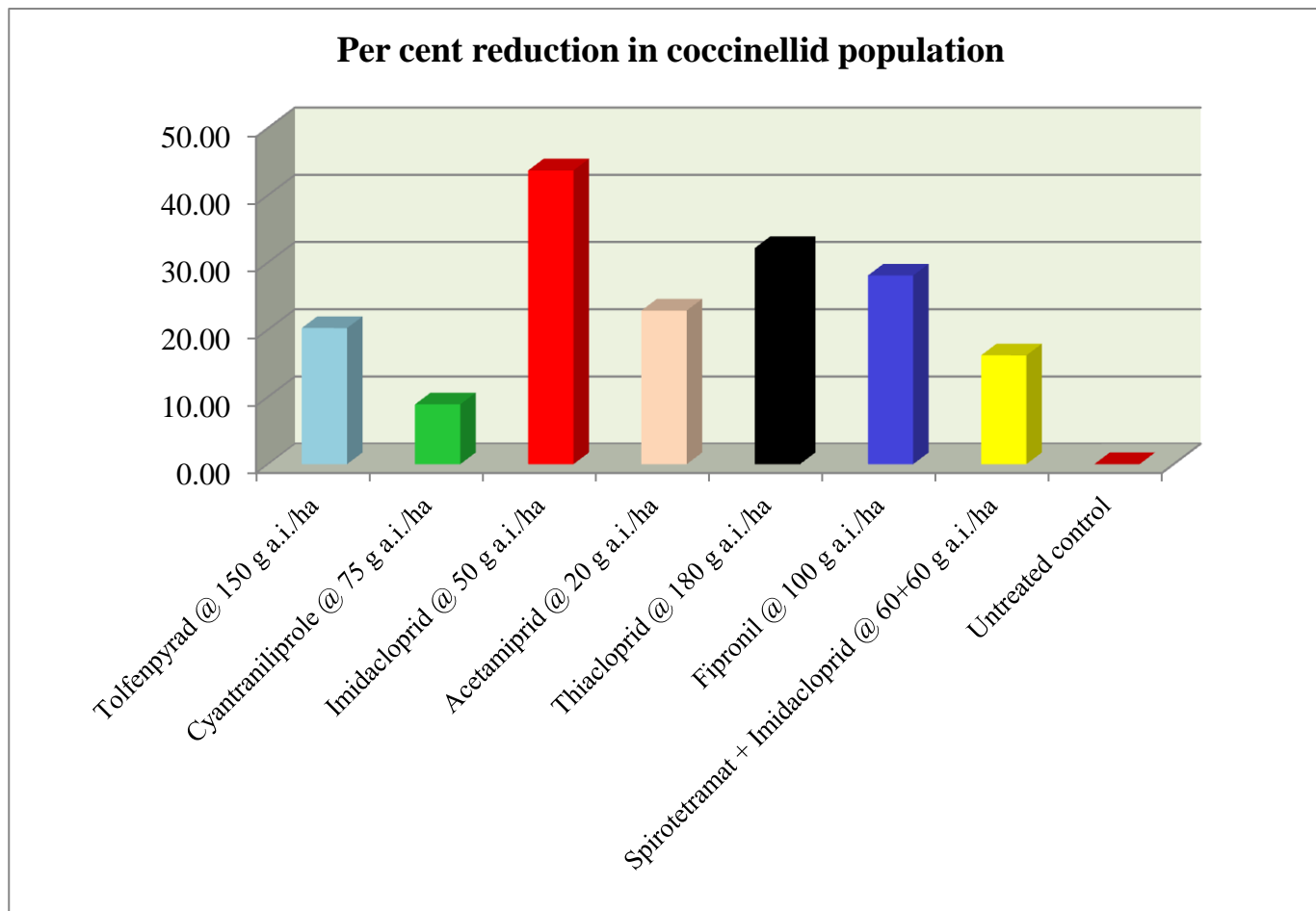




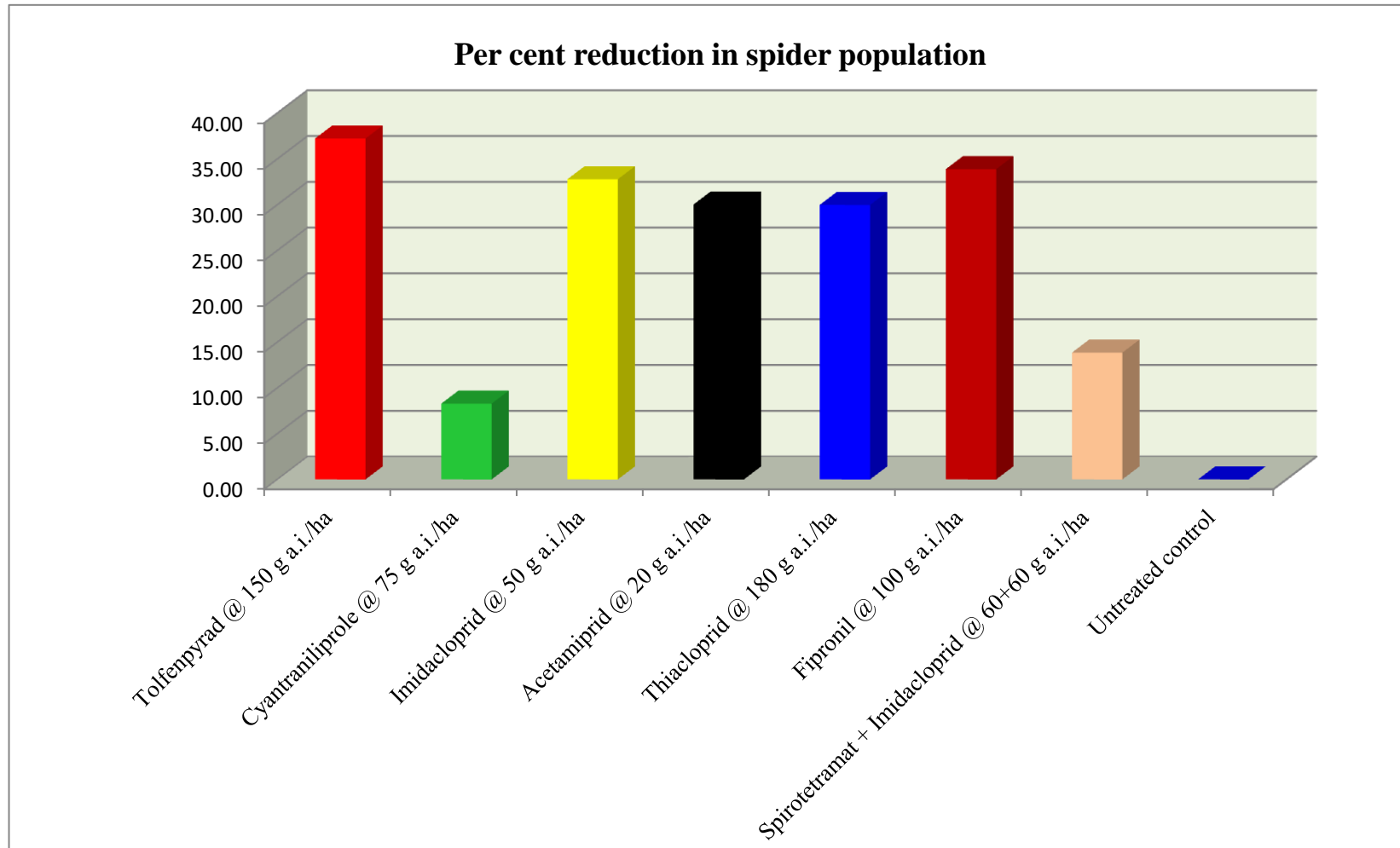
**Fig. 4.1 Bioefficacy of newer insecticides against aphids (Per cent reduction over control, *Ambia bahar*- 2018 & 2019)**



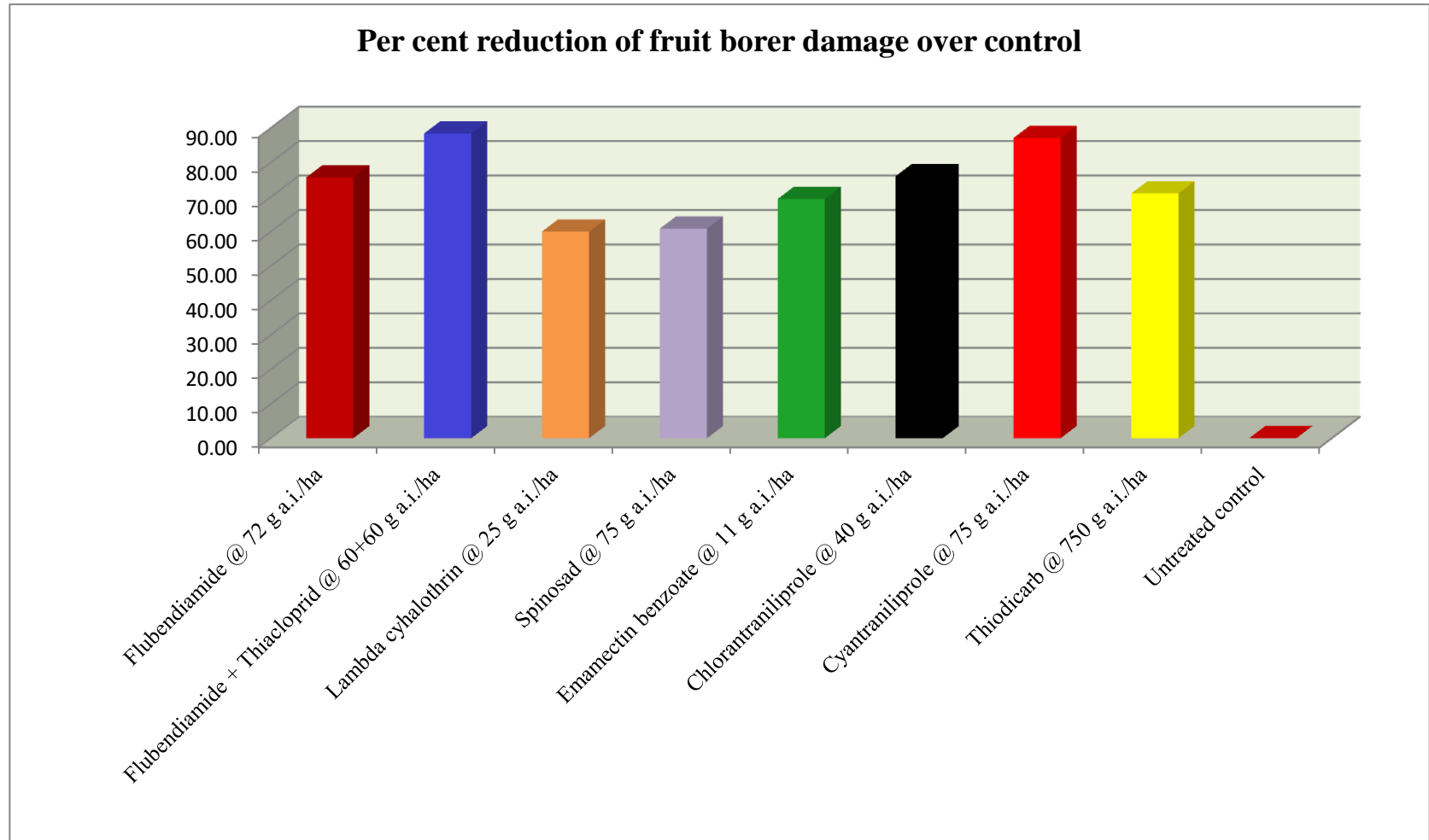
**Fig. 4.2 Bioefficacy of newer insecticides against thrips (Per cent reduction over control, *Ambia bahar*- 2018 & 2019)**



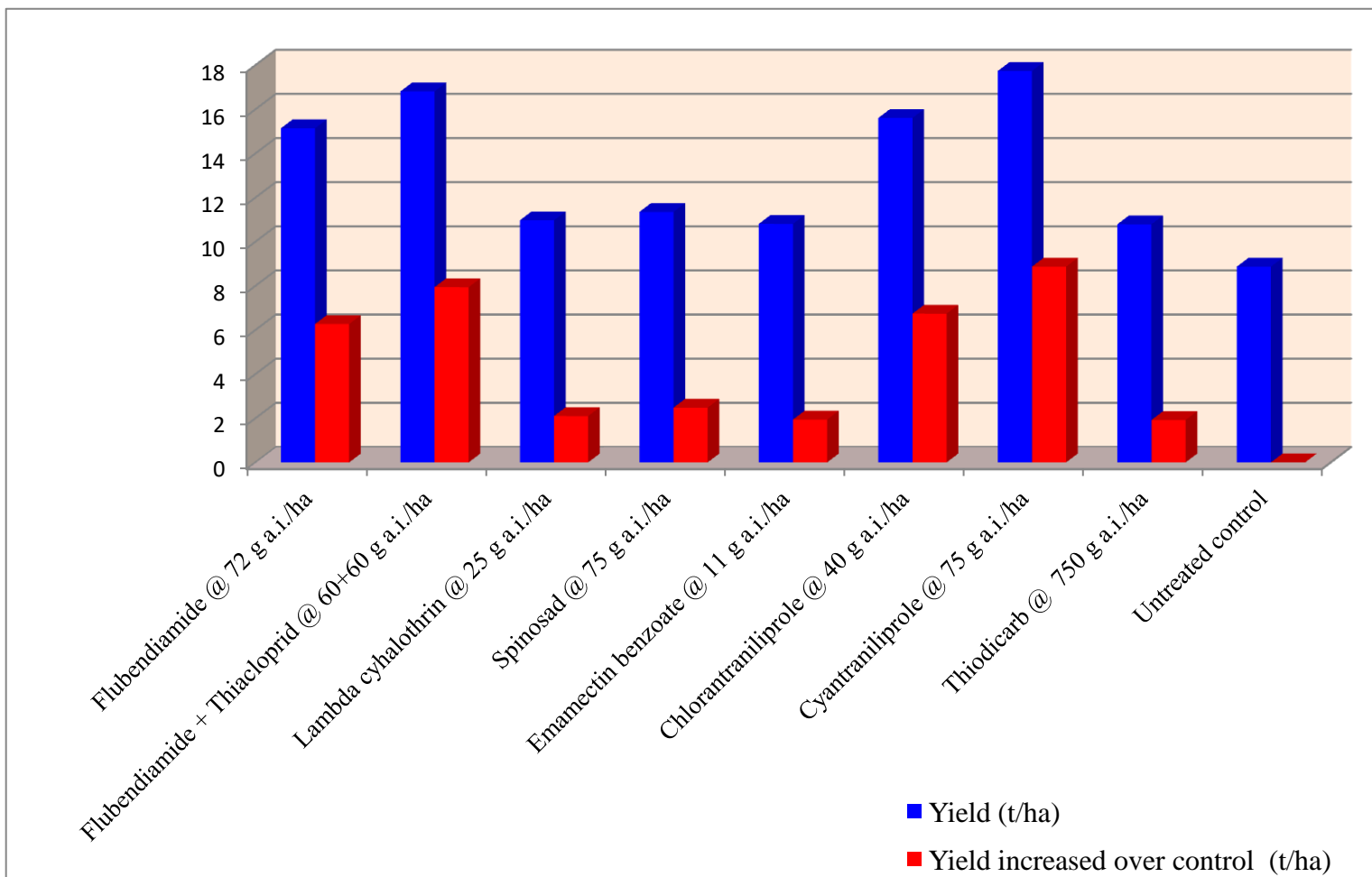
**Fig. 4.3** Effect of newer insecticides on coccinellids (Per cent reduction, *Ambia bahar*- 2018 & 2019)



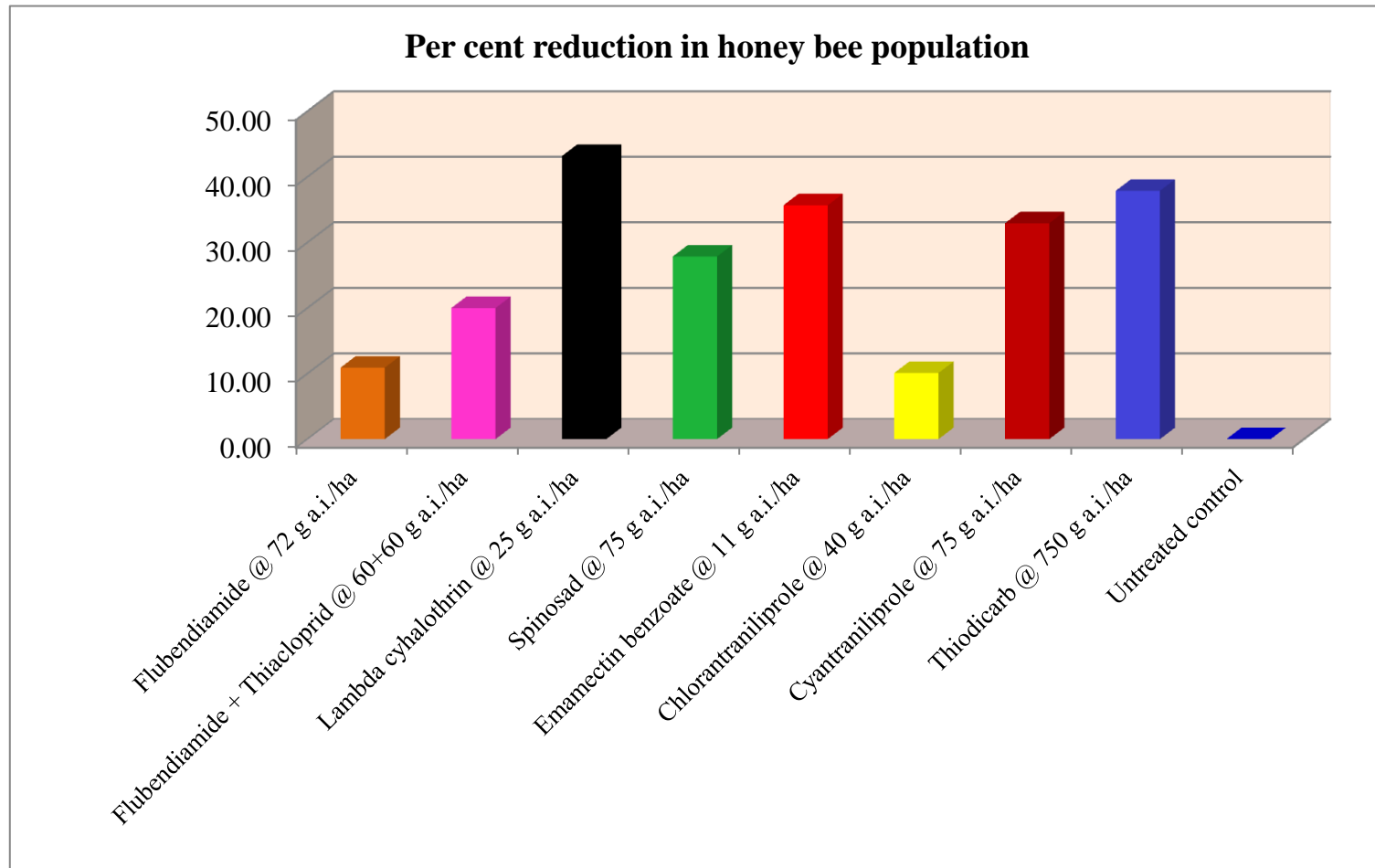
**Fig. 4.4** Effect of newer insecticides on spiders (Per cent reduction, *Ambia bahar*- 2018 & 2019)



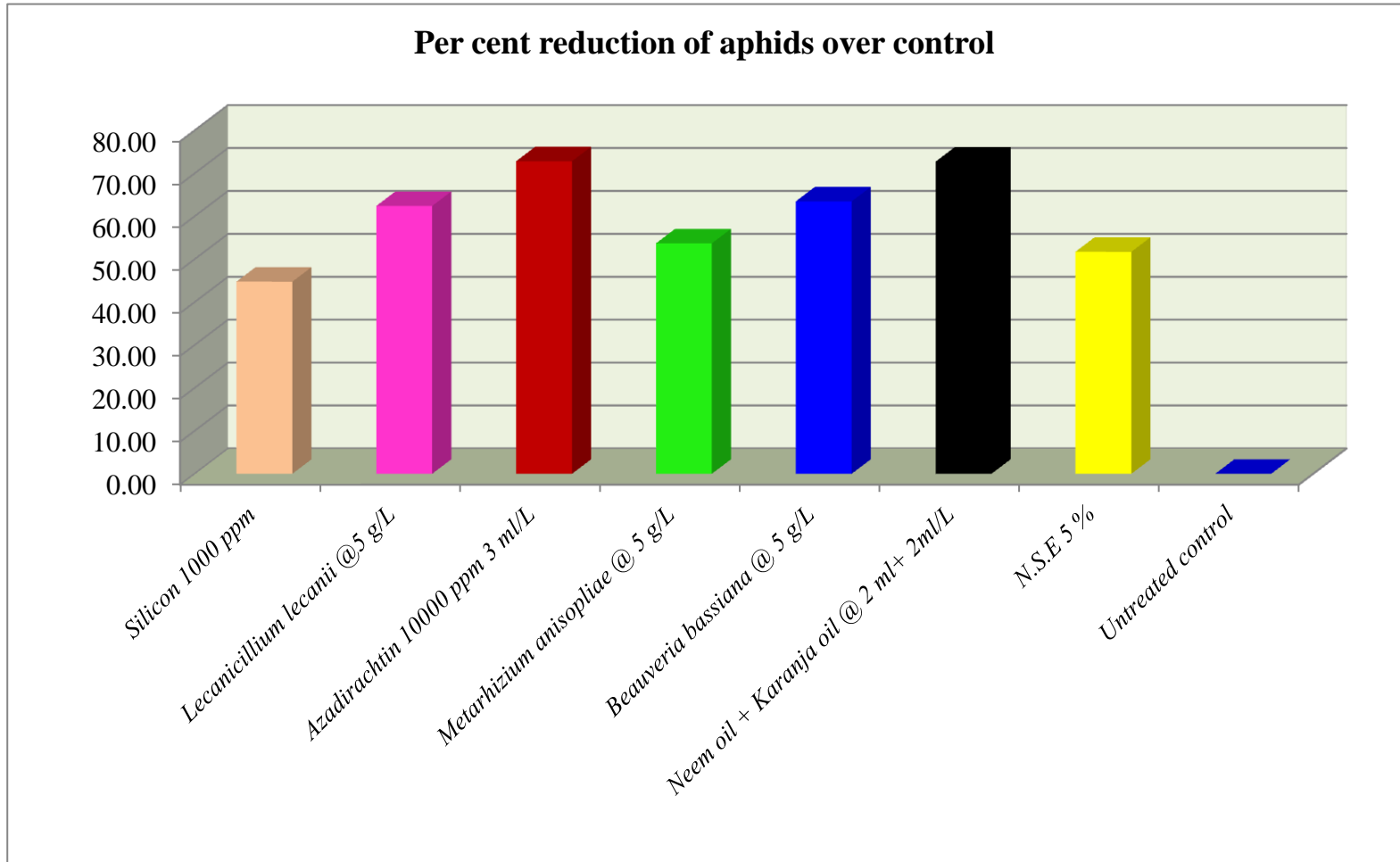
**Fig. 4.5 Bioefficacy of newer insecticides against fruit borer (Per cent reduction over control, *Ambia bahar*- 2018 & 2019)**



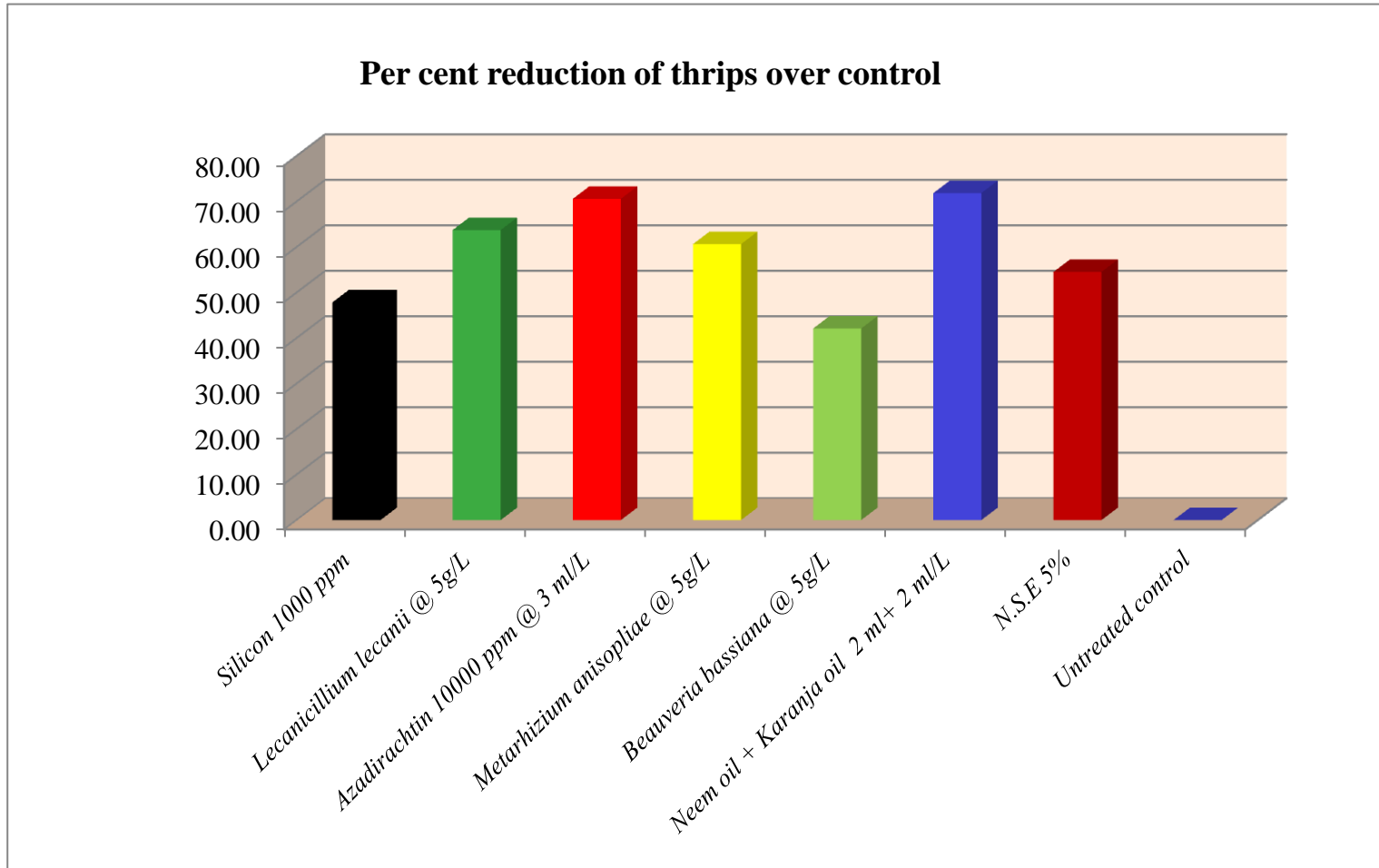
**Fig. 4.6 Effect of newer insecticides tested against fruit borer on yield of pomegranate**



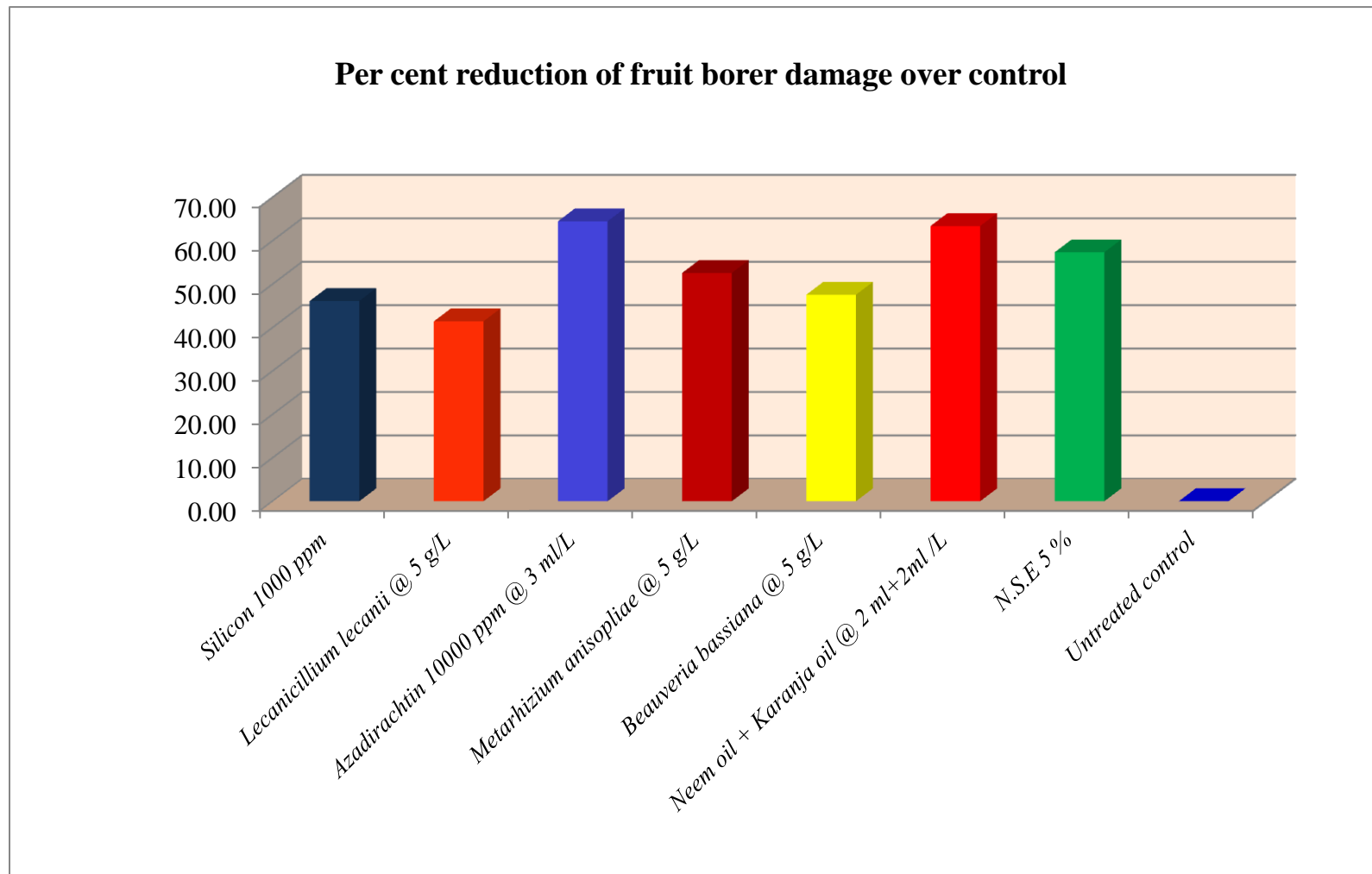
**Fig. 4.7** Effect of newer insecticides on honey bees (Per cent reduction, *Ambia bahar*- 2018 & 2019)



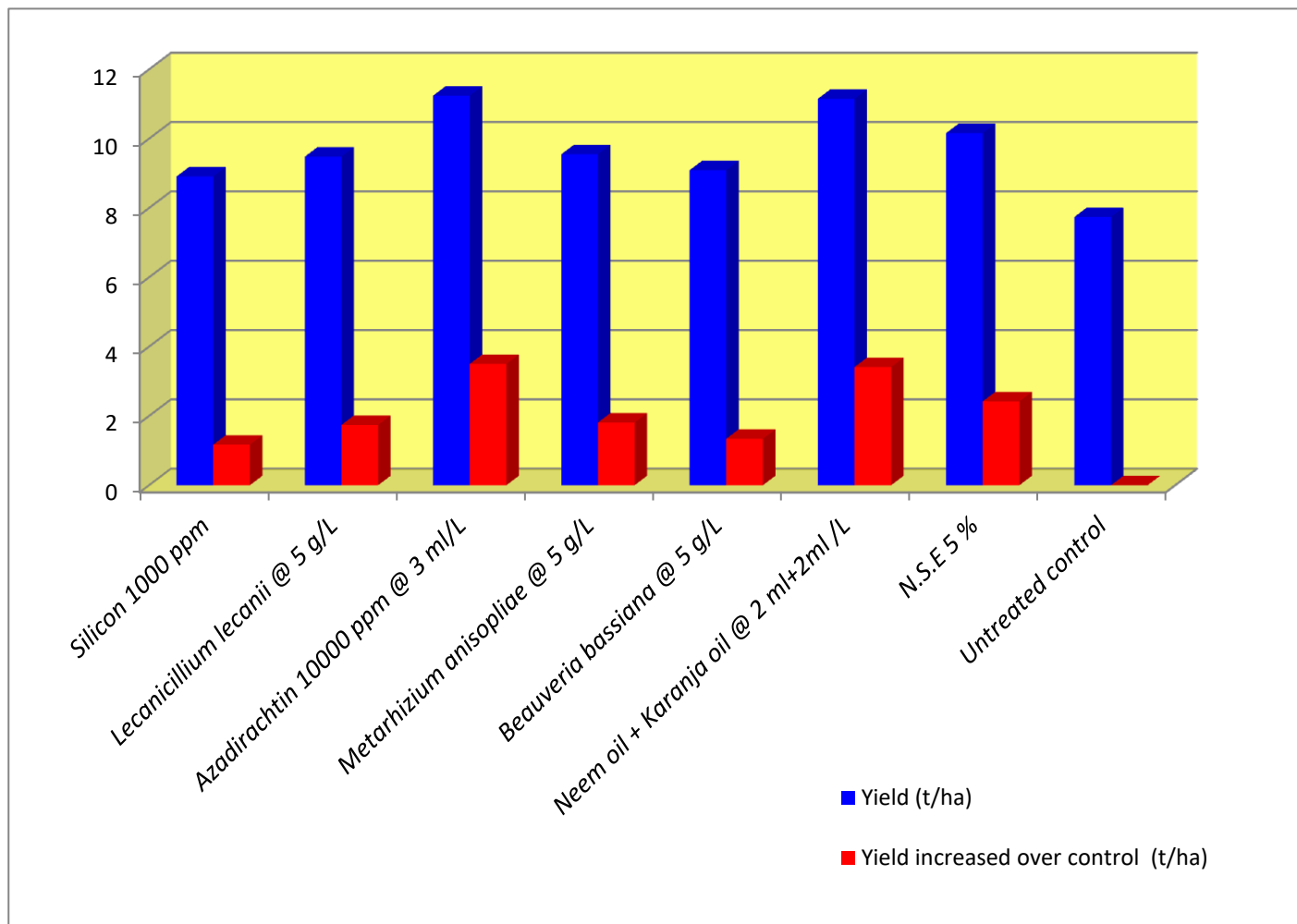
**Fig. 4.8 Bioefficacy of biorationals against aphids (Per cent reduction over control, *Ambia bahar*- 2018 & 2019)**



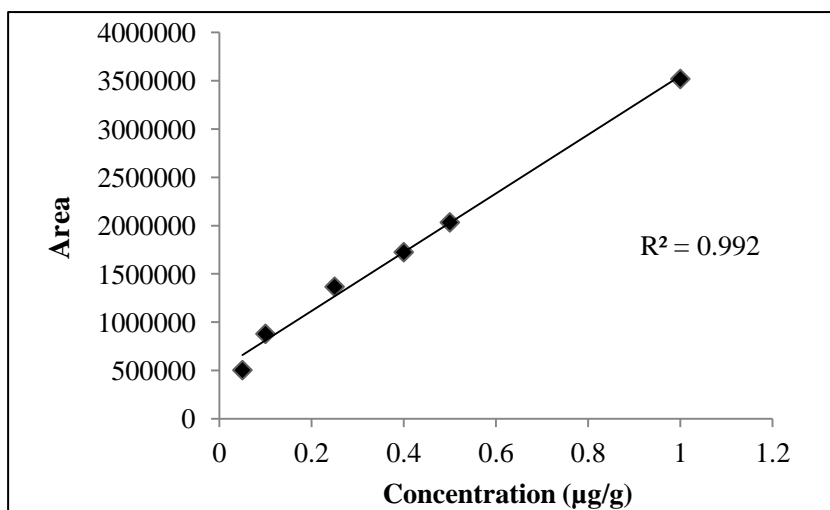
**Fig. 4.9 Bioefficacy of biorationals against thrips (Per cent reduction over control, *Ambia bahar*- 2018 & 2019)**



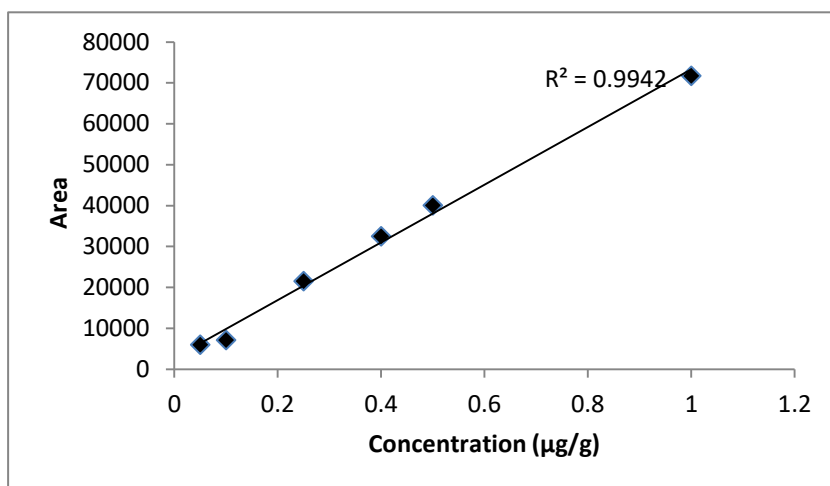
**Fig. 4.10 Bioefficacy of biorationals against fruit borer (Per cent reduction over control, *Ambia bahar*- 2018 & 2019)**



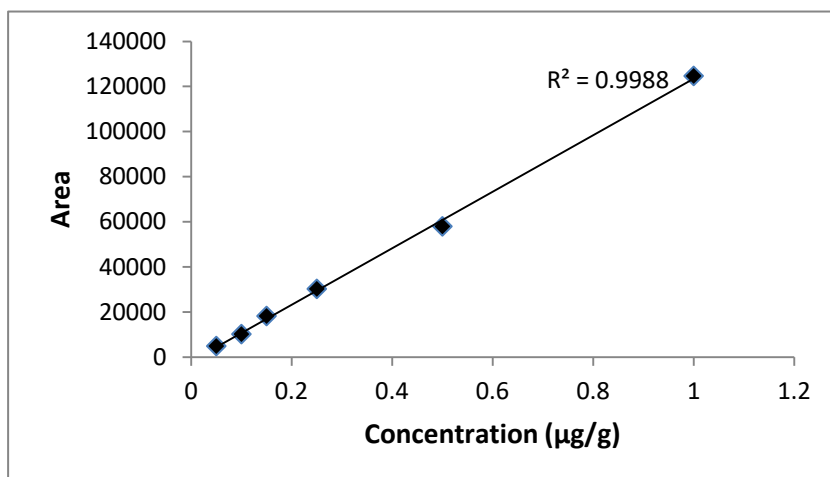
**Fig. 4.11 Effect of biorationals tested against fruit borer on yield of pomegranate**



**a. Flubendiamide**

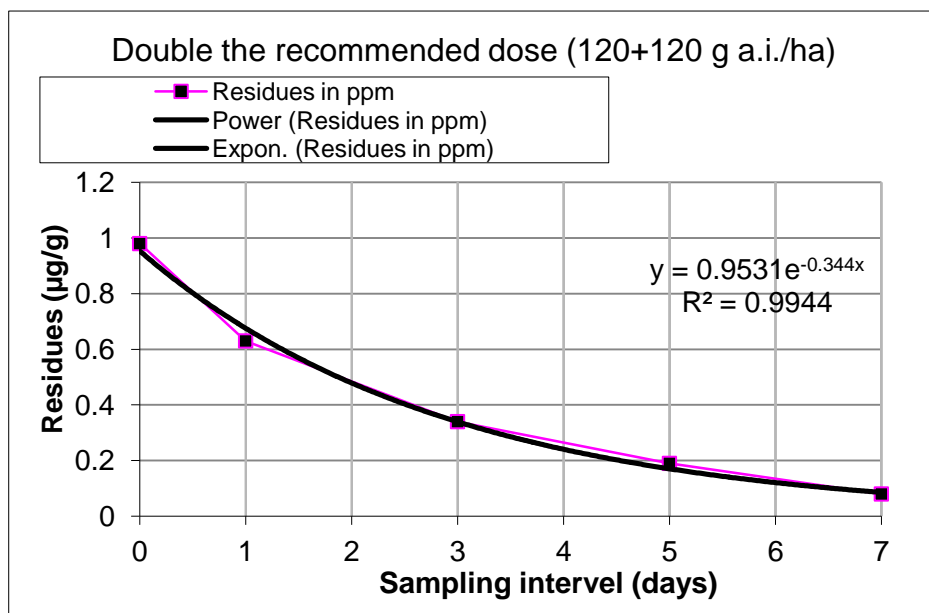
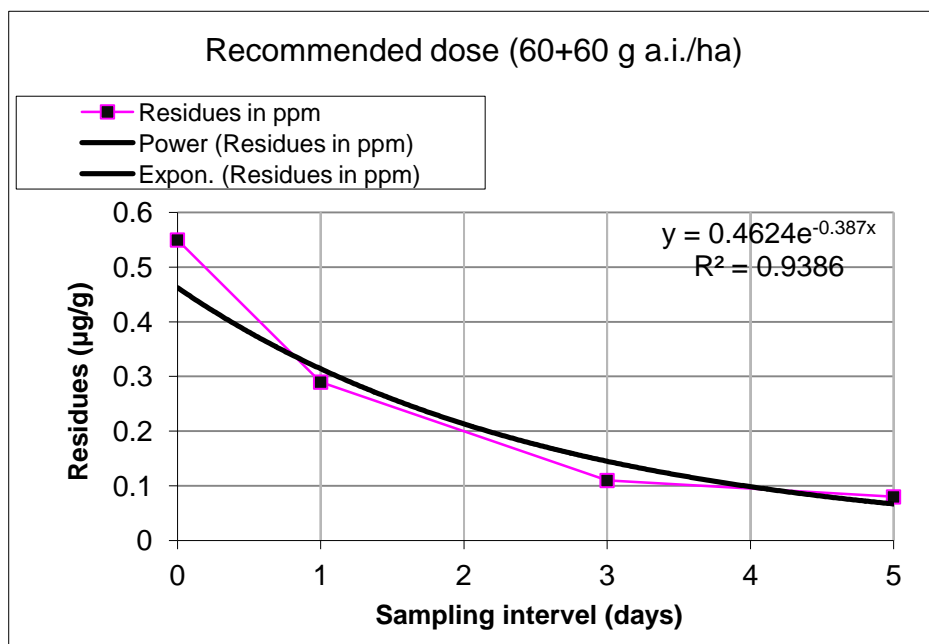


**b. Des-iodo flubendiamide**

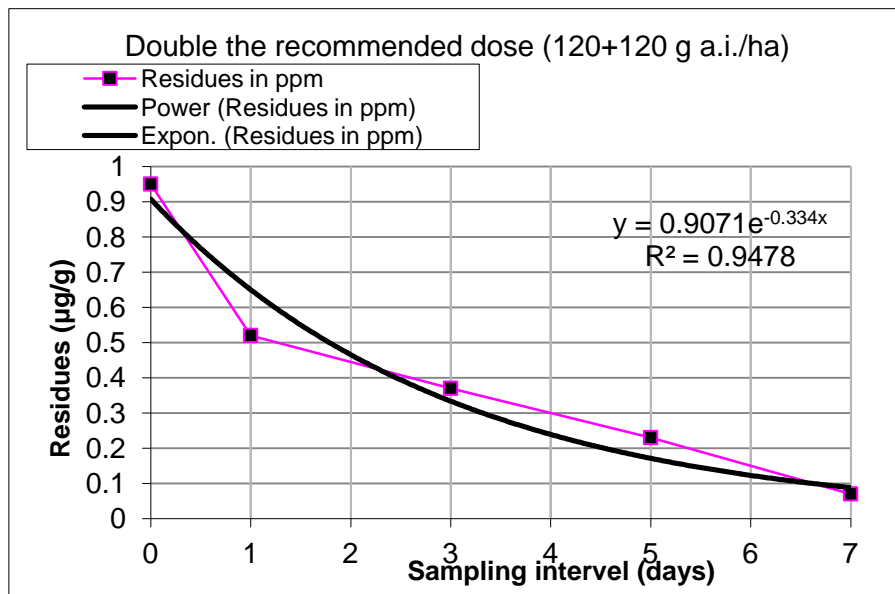
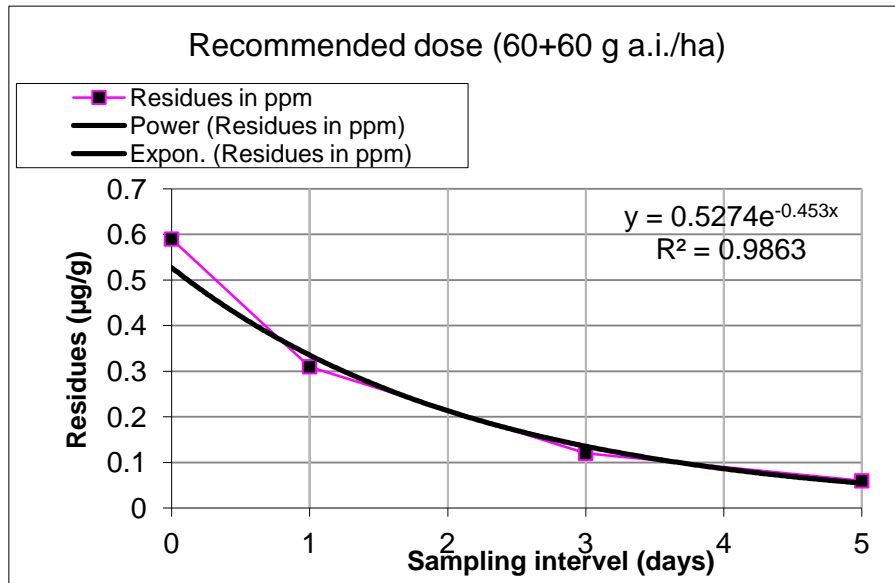


**c. Thiacloprid**

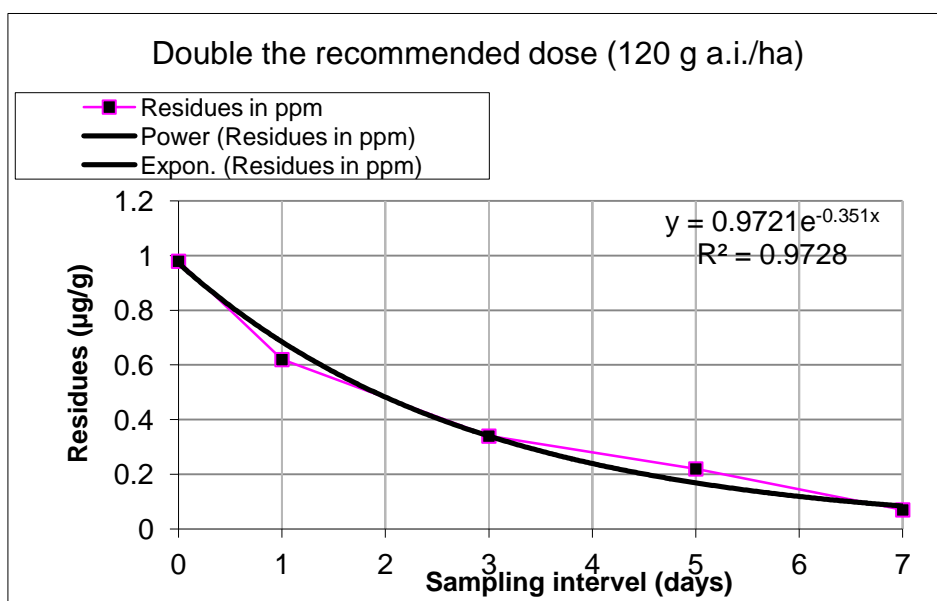
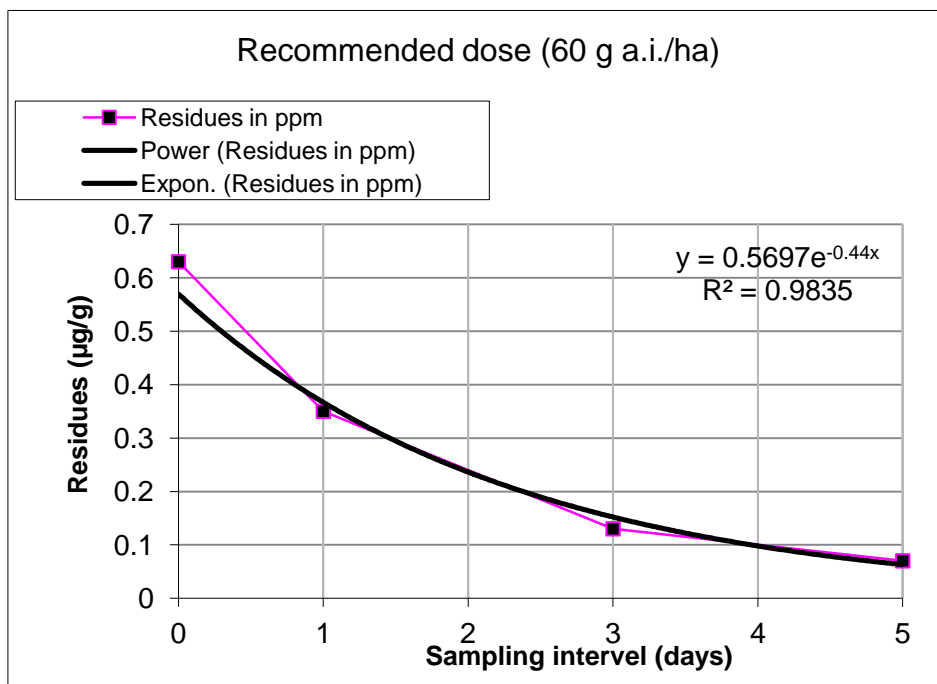
**Fig. 4.12 Linearity graphs of tested insecticides (flubendiamide, des-iodo flubendiamide & thiacloprid)**



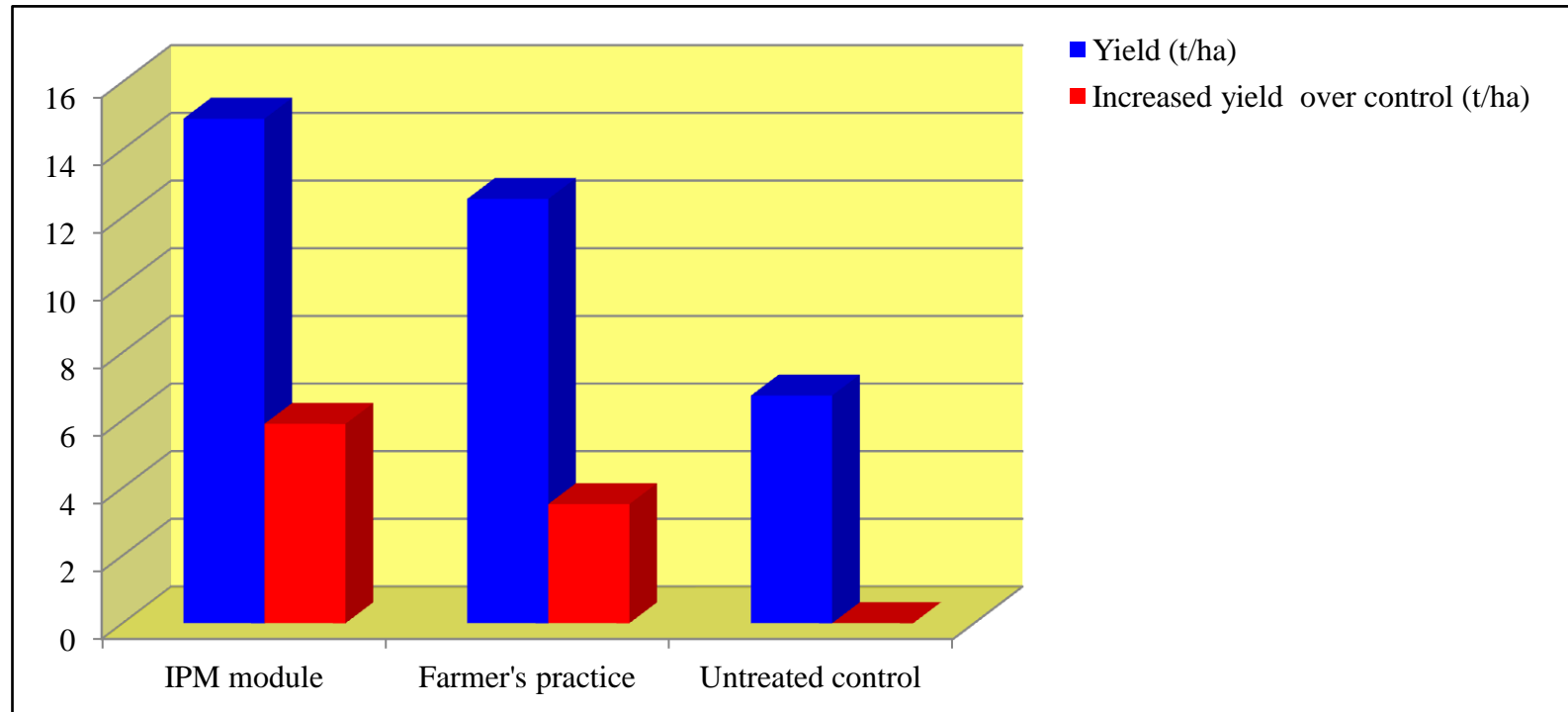
**Fig. 4.13** Semi-logarithmic graph showing dissipation kinetics of flubendiamide after application of flubendiamide + thiacloprid 480 SC



**Fig. 4.14 Semi-logarithmic graph showing dissipation kinetics of thiocloprid after application of flubedniamide + thiocloprid 480 SC**



**Fig. 4.15** Semi-logarithmic graph showing dissipation kinetics of thiacloprid after application of thiacloprid 240 SC



**Fig. 4.16 Influence of Integrated Pest Management module on the yield of pomegranate**

## 5. SUMMARY AND CONCLUSIONS

The present investigations entitled “Studies on insecticide management of pests infesting pomegranate (*Punica granatum* L.)” were carried out during the *Ambia bahar*, 2018 to 2020 at Post Graduate Institute (P.G.I), Mahatma Phule Krishi Vidyapeeth (M.P.K.V.), Rahuri, Maharashtra (19.3491° N, 74.6461° E). The field experiments on bioefficacy, estimation of residues & dissipation and integrated pest management studies were conducted at All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, M.P.K.V., Rahuri, Maharashtra. The laboratory studies on residues and dissipation of insecticides were carried out at All India Network Project on Pesticide Residues, Department of Agricultural Entomology, M.P.K.V., Rahuri. In this chapter, results obtained are summarized with concluding statements.

### 5.1 Bioefficacy of Newer Insecticides Against Pomegranate Aphids & Thrips

Studies on bioefficacy of newer insecticides against aphids revealed that, spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (3.31/shoot, 83.49 % reduction over control) was consistently proved to be the most promising insecticide by recording least population of aphids. It was, however at par with fipronil @ 100 g a.i. ha<sup>-1</sup> (3.79/shoot, 82.22 % reduction over control) & cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (3.78/shoot, 81.11 % reduction over control).

As regard thrips, tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (1.35/shoot, 88.62 % reduction over control) was found most effective. It was, however at par with spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (1.55/shoot, 86.96 % reduction over control). This was followed by cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.10/shoot, 82.29 % reduction over control) & fipronil @ 100 g a.i. ha<sup>-1</sup> (2.22/shoot, 81.30 % reduction over control).

Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (5.70/plant), spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (5.50/plant) and tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> (5.00/plant) were safer to coccinellid predators. Whereas, imidacloprid @ 50 g a.i. ha<sup>-1</sup> (3.77/plant) proved to be highly toxic by recording least coccinellid population (3.77/plant).

Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (4.65/plant) and spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> (4.50/plant) recorded higher number of spiders and can be considered as safe. Whereas, tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> proved to be highly toxic by recording least number of spiders (3.04/plant).

### 5.2 Bioefficacy of Newer Insecticides Against Fruit Borer

It was observed that, flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> (2.09 % fruit borer damage and 88.40 % reduction over control) recorded least fruit borer damage & found effective against pomegranate fruit borer. It was, however at par with cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (2.33 % fruit borer damage and 87.08 % reduction over control). The efficacy of flubendiamide +

thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> also reflected in recording higher yield (16.81 t/ha) & high Incremental Cost Benefit Ratio (1 : 81.76). Cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> (17.74 t/ha) was next in the order but registered cost benefit ratio of 1 : 22.97 due to high cost of the insecticide.

Chlorantraniliprole @ 40 g a.i./ha (10.57/plant) and flubendiamide @ 72 g a.i./ha (10.22/plant) recorded higher number of honey bees and can be considered safe. Whereas, lambda cyhalothrin @ 25 g a.i./ha proved to be toxic by recording lowest population of honey bees (6.21/plant).

### 5.3 Bioefficacy of Biorationals Against Aphids & Thrips

Among the biorational treatments, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (4.13 aphids & 2.68 thrips/shoot) and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (4.15 aphids & 2.57 thrips/shoot) were found effective against pomegranate sucking pests.

### 5.4 Bioefficacy of Biorationals Against Fruit Borer

Among the tested biorationals, azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (6.80 % fruit borer damage, 64.46 % reduction over control) and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> (7.01 % fruit borer damage, 63.36 % reduction over control) were most promising in controlling the fruit borer.

The efficacy of neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> also reflected in recording higher yield (11.15 t/ha) & high Incremental Cost Benefit Ratio (1 : 27.41). This was followed by azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> (11.24 t/ha) which registered cost benefit ratio of 1 : 14.90, due to high cost of the insecticide.

### 5.5 Studies on Residues & Dissipation of Insecticides in Pomegranate Fruits & Cropped Soil

#### Flubendiamide + thiacloprid 480 SC

In the present studies on dissipation, flubendiamide @ 60 g a.i. ha<sup>-1</sup> & 120 g a.i. ha<sup>-1</sup> recorded mean initial residues of 0.55 and 0.98 µg g<sup>-1</sup>, which dissipated to maximum of 85.45 % and 91.84 % after 5<sup>th</sup> and 7<sup>th</sup> day, respectively in recommended and double the recommended dose. Initial residues (0.55 and 0.98 µg g<sup>-1</sup>) reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. The half-life (RL<sub>50</sub>) values of flubendiamide in pomegranate were 1.79 and 2.01 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively. Whereas, the matured fruits & soil collected at harvest, did not record any residues of flubendiamide at both the doses. No residues of des-iodo flubendiamide, metabolite of flubendiamide, were detected in any of the samples.

Whereas, thiacloprid @ 60 g a.i. ha<sup>-1</sup> & 120 g a.i. ha<sup>-1</sup> recorded mean initial residues of 0.59 and 0.95 µg g<sup>-1</sup>, which dissipated to maximum of 89.83 % and 92.63 % after 5<sup>th</sup> and 7<sup>th</sup> day, respectively in recommended and double the recommended dose. Initial residues (0.59 and 0.95 µg g<sup>-1</sup>) reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. The half-life (RL<sub>50</sub>)

values of thiacloprid in pomegranate were 1.53 and 2.07 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively. Whereas, the matured fruits & soil collected at harvest, did not record any residues of thiacloprid at both the doses.

### **Thiacloprid 240 SC**

Studies on dissipation of thiacloprid @ 60 g a.i. ha<sup>-1</sup> & 120 g a.i. ha<sup>-1</sup> recorded mean initial residues of 0.63 and 0.98 µg g<sup>-1</sup>, which were dissipated to maximum of 88.89 % and 92.86 % after 5<sup>th</sup> and 7<sup>th</sup> day, respectively in recommended and double the recommended dose. Initial residues (0.63 and 0.98 µg g<sup>-1</sup>) reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day, respectively. The half-life (RL<sub>50</sub>) values of thiacloprid in pomegranate were 1.57 and 1.97 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively. Whereas, the matured fruits & soil collected at harvest, did not record any residues of thiacloprid at both the doses.

### **5.6 Evaluation of IPM Module For The Management of Insect Pests in Pomegranate**

In the present investigation, IPM module comprising i) up to 40 days, one spray of *Lecanicillium lecanii* @ 5 g L<sup>-1</sup> followed by one spray of *Metarhizium anisopliae* @ 5 g L<sup>-1</sup> at 7 days interval and need based application of imidacloprid 17.8 SL @ 50 g a.i. ha<sup>-1</sup> ii) at 40-90 days, one spray of *Lecanicillium lecanii* @ 5 g L<sup>-1</sup>, one spray of *Metarhizium anisopliae* @ 5 g L<sup>-1</sup> followed by one spray of azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> at 10 days of interval and two sprays of neem oil+ karanja oil @ 2 ml L<sup>-1</sup> + 2 ml L<sup>-1</sup> at an interval of 10 days iii) at 90-120 days, two sprays of NSE @ 5 % at 10 days of interval and need based application of cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> was the most effective treatment by recording minimum population of aphids, thrips and least fruit borer damage than farmer's practice. The pomegranate plants in IPM module registered highest fruit yield (14.91 t/ha) than farmer's practice (12.54 t/ha) & untreated control (6.73 t/ha). Cost economics assessment indicated that, IPM module recorded highest Incremental Cost Benefit Ratio (1 : 10.72) than farmer's practice (1 : 2.31).

### **Conclusions**

- Spirotetramat + imidacloprid @ 60+60 g a.i. ha<sup>-1</sup> & cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> were proved to be highly effective against pomegranate aphids & thrips and also found to be safe to coccinellids & spiders
- Fipronil @ 100 g a.i. ha<sup>-1</sup> was found effective against pomegranate aphids but moderately toxic to coccinellids
- Tolfenpyrad @ 150 g a.i. ha<sup>-1</sup> was effective against pomegranate thrips but was toxic to spiders
- Flubendiamide + thiacloprid @ 60+60 g a.i. ha<sup>-1</sup> and cyantraniliprole @ 75 g a.i. ha<sup>-1</sup> were highly effective against pomegranate fruit borer but were toxic to honey bees

- Chlorantraniliprole @ 40 g a.i. ha<sup>-1</sup> & flubendiamide @ 72 g a.i. ha<sup>-1</sup> consistently proved to be the safer insecticidal treatments by recording higher number of honey bees.
- Azadirachtin 10000 ppm @ 3 ml L<sup>-1</sup> and neem oil + karanja oil @ 2 ml + 2 ml L<sup>-1</sup> were found most effective biorationals against pomegranate aphids, thrips and fruit borer
- Initial residues of flubendiamide reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day with half-life (RL<sub>50</sub>) values of 1.79 and 2.01 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively.
- Initial residues of thiacloprid reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day with half-life (RL<sub>50</sub>) values of 1.53 and 2.07 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively.
- Initial residues of thiacloprid 240 SC reached below quantification limit (BQL) on 7<sup>th</sup> and 10<sup>th</sup> day with half-life (RL<sub>50</sub>) values of 1.57 and 1.97 days for recommended dose (60 g a.i ha<sup>-1</sup>) and double dose (120 g a.i ha<sup>-1</sup>), respectively.
- Considering the values of BQL, farmers may be advised to observe a pre-harvest interval of 7 days for flubendiamide + thiacloprid 480 SC and thiacloprid 240 SC for the production of residue free pomegranate fruits.
- IPM module suppressed the population of sucking pests (aphids & thrips) and fruit borer damage, also recorded higher yield (14.91 t/ha) and high Incremental Cost Benefit Ratio (1 : 10.72) than farmer's practice in pomegranate.

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**\*Note:** Literature cited chapter was written as per the guide lines of “Journal of Maharashtra Agricultural Universities”

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**\*Note:** Literature cited chapter was written as per the guide lines of “Journal of Maharashtra Agricultural Universities”

## 7. APPENDICES

### 1. Meteorological data during experimental period (2018)

Month and Year	SMW	Temperature		Relative Humidity		Rainfall	No of rainy days
				Morning	Evening		
		2018	Max 0C	Min 0C	RH-I (%)	RH-II (%)	(mm)
01-07 January	1	29.3	8.8	42	23	0	0
08-14 January	2	28.5	8.9	57	28	0	0
15-21 January	3	29.4	11.3	58	31	0	0
22-28 January	4	27.2	10.3	60	42	0	0
29-04 February	5	30.3	10.6	59	21	0	0
05-11 February	6	31.2	13.8	53	23	0	0
12-18 February	7	30.4	13.5	66	34	0	0
19-25 February	8	33.7	15	53	24	0	0
26-04 March	9	34.6	17	49	20	0	0
05-11 March	10	34.6	18.2	44	20	0	0
12-18 March	11	33.1	18.9	48	25	0	0
19-25 March	12	35	16.4	44	19	0	0
26-01 April	13	37.6	18	40	15	0	0
02-08 April	14	37.5	19.8	40	19	0	0
09-15 April	15	37.2	20	44	19	0	0
16-22 April	16	39.3	22.3	41	21	1	0
23-29 April	17	39.4	19.7	30	13	0	0
30-06 May	18	40.6	21	36	17	0	0
07-13 May	19	40.2	24.2	32	18	3	0
14-20 May	20	39.8	24.3	36	19	0	0
21-27 May	21	38.8	25	40	20	0	0
28-03 June	22	38.8	24.7	64	34	34.6	1
04-10 June	23	34.2	24.6	72	47	11	2
11-17 June	24	35.3	25	62	42	0	0
18-24 June	25	34.1	23.4	72	54	43	3
25-01 July	26	32.1	23	73	53	63.8	1
02-08 July	27	31.7	23.3	76	59	26.2	1
09-15 July	28	28.2	22.8	80	70	13.8	2
16-22 July	29	29.4	23	77	65	4.4	1
23-29 July	30	28.6	22.7	75	62	0	0
30-05 August	31	31.3	23.3	72	53	0	0
06-12 August	32	30	23	75	62	0	0
13-19 August	33	27.8	22.5	81	73	58.4	1
20-26 August	34	27.9	21.5	80	70	24.2	2
27-02 September	35	29.6	21.1	75	61	6.4	1
03-09 September	36	30.1	19.6	70	53	0	0
10-16 September	37	32.4	19.5	69	49	0	0
17-23 September	38	31.9	22.1	71	45	3.8	1

24-30 September	39	33.8	22.3	71	44	0	0
01-07 October	40	34	21.5	67	43	0	0
08-14 October	41	34	18.4	55	30	0	0
15-21 October	42	33.5	18.6	50	30	0	0
22-28 October	43	34.4	16.8	46	30	0	0
29-04 November	44	31.7	14.4	58	39	2	0
05-11 November	45	33.1	16.8	59	37	0	0
12-18 November	46	32.5	12.9	43	23	0	0
19-25 November	47	31.7	16.3	61	46	0	0
26-02 December	48	30.1	11.3	58	32	0	0
03-09 December	49	30.3	15	60	35	0	0
10-16 December	50	28.1	11.3	55	35	0	0
17-29 December	51	26.5	9	64	36	0	0
24-31 December	52	27.8	8.9	51	30	0	0

## 2. Meteorological data during experimental period (2019)

Month and Year	SMW	Temperature		Relative Humidity		Rainfall (mm)	No of rainy days
		Max	Min	Morning RH-I	Evening RH-II		
		0C	0C	(%)	(%)	days	
2019							
01-07 January	1	27	12	81	49	0	0
08-14 January	2	25.9	13.8	82	47	0	0
15-21 January	3	25.1	11.9	83	43	0	0
22-28 January	4	30.2	15.3	83	33	0	0
29-04 February	5	27.7	10.4	53	29	0	0
05-11 February	6	27.8	9	54	29	0	0
12-18 February	7	31.8	14.1	55	28	0	0
19-25 February	8	34.6	15.9	50	24	0	0
26-04 March	9	31.9	13	47	20	0	0
05-11 March	10	33.3	14.1	45	20	0	0
12-18 March	11	35.5	15.1	51	16	1	0
19-25 March	12	36.4	16.1	46	15	0	0
26-01 April	13	39.3	18.8	40	13	0	0
02-08 April	14	39.7	19.9	38	14	3	0
09-15 April	15	40.4	21.2	35	13	0	0
16-22 April	16	37.1	19.2	45	19	4.4	1
23-29 April	17	41.2	24	32	12	0	0
30-06 May	18	39.1	20.7	37	16	0	0
07-13 May	19	39.3	21.7	44	17	0	0
14-20 May	20	40	21.8	34	14	0	0
21-27 May	21	41.2	25.6	35	16	0	0
28-03 June	22	41.1	23.5	39	19	0	0
04-10 June	23	39.1	26.1	51	30	7	1
11-17 June	24	37	24.9	59	35	0.4	0
18-24 June	25	36.1	24.3	70	40	18.2	1
25-01 July	26	31.4	23.8	81	60	51.4	2
02-08 July	27	30.6	23.5	79	63	37	2
09-15 July	28	32.1	23.6	76	56	3.8	1
16-22 July	29	33.8	23.2	71	51	32	2
23-29 July	30	30.5	23.6	78	68	18.4	2
30-05 August	31	27	22.8	88	77	47.8	5
06-12 August	32	28	23.3	80	68	3.6	0
13-19 August	33	31	22.5	75	59	1.4	0
20-26 August	34	32.5	21.3	72	47	0	0
27-02 September	35	32	23	75	56	87.2	4
03-09 September	36	30	23.3	77	71	3	0
10-16 September	37	28.8	22.5	78	68	21.6	2
17-23 September	38	29.8	21.7	89	71	84.2	4
24-30 September	39	30.2	21.9	83	67	36.6	3
01-07 October	40	31.1	21.1	80	59	7.8	1

08-14 October	41	31.7	24.1	77	50	2.8	0
15-21 October	42	28.2	18.6	81	68	52.4	3
22-28 October	43	25.7	20.8	87	79	141.8	6
29-04 November	44	30.4	21	84	58	4	1
05-11 November	45	31.1	18.4	76	46	23.4	1
12-18 November	46	29.7	16.7	73	48	0	0
19-25 November	47	30	15.2	74	45	0	0
26-02 December	48	30.5	15.9	74	44	0	0
03-09 December	49	28.8	16.4	71	47	0	0
10-16 December	50	29.6	16.3	74	42	2.8	1
17-29 December	51	28	15.8	78	47	0	0
24-31 December	52	27.1	16.6	77	48	1.4	0

### 3. Meteorological data during experimental period (2020)

Month	MW	Temperature		Humidity %		Rainfall (mm)	Rainy days
		Max	Min	Morn. (I)	Even.(II)		
Jan.	1	19.20	8.10	54.17	28.67	0.0	0.0
	2	25.20	13.30	82.30	47.80	0.0	0.0
	3	25.70	11.80	83.30	41.30	0.0	0.0
	4	28.10	15.20	81.50	36.20	0.0	0.0
	5	28.00	12.50	81.20	37.70	0.0	0.0
February	6	29.20	14.60	79.00	36.70	0.0	0.0
	7	28.20	16.00	83.30	42.20	0.0	0.0
	8	33.20	16.70	76.80	27.80	0.0	0.0
	9	31.90	13.90	72.70	22.80	0.0	0.0
March	10	32.00	14.10	77.70	24.30	0.0	0.0
	11	31.80	14.90	70.30	28.20	0.0	0.0
	12	35.00	16.70	68.00	29.00	0.0	0.0
	13	33.60	20.20	73.20	34.30	0.0	0.0
April	14	35.77	19.69	78.00	24.71	0.0	0.00
	15	36.80	16.69	70.29	17.29	0.0	0.00
	16	39.51	22.83	67.86	18.29	0.0	0.00
	17	38.63	21.13	73.00	20.71	0.0	0.00
May	18	38.61	22.04	70.14	19.86	0.00	0.00
	19	40.19	25.26	53.00	16.14	0.00	0.00
	20	39.29	27.27	59.14	24.29	0.00	0.00
	21	39.29	25.13	64.14	19.71	0.00	0.00
	22	40.49	26.04	63.86	20.14	0.00	0.00
June	23	31.11	23.41	87.14	57.00	93.20	5.00
	24	33.40	24.96	82.86	45.29	18.40	4.00
	25	32.43	24.07	86.71	51.57	75.40	3.00
	26	32.97	24.86	86.14	47.86	78.20	3.00
July	27	31.94	24.36	89.00	57.00	67.60	4.00
	28	31.69	24.87	81.43	54.43	2.00	1.00
	29	31.09	24.03	85.57	60.57	81.00	3.00
	30	30.23	23.51	90.86	65.86	109.30	4.00
August	31	30.14	20.36	91.43	56.43	107.80	6.00
	32	30.43	24.16	83.43	60.71	0.00	0.00
	33	27.51	23.20	89.29	74.86	60.20	5.00
	34	27.49	23.26	88.86	71.57	25.80	4.00
Sept.	35	29.57	23.33	86.14	60.57	0.80	0.00
	36	30.59	23.40	87.00	56.00	4.70	1.00
	37	32.06	23.67	92.43	59.43	82.60	4.00
	38	29.20	23.19	93.00	69.86	209.00	4.00
	39	27.94	23.76	90.29	69.71	68.20	5.00
October	40	30.66	22.93	87.71	56.71	1.00	0.00
	41	32.31	23.61	86.00	43.71	8.40	1.00
	42	29.80	23.43	91.71	62.86	49.00	3.00
	43	30.86	22.76	93.14	58.57	97.60	0.00
November	44	30.09	19.80	86.86	52.14	0.00	0.00
	45	30.51	16.94	85.86	35.86	0.00	0.00
	46	28.41	14.33	83.00	35.57	0.00	0.00

	47	31.29	19.84	85.71	43.29	0.00	0.00
	48	29.00	17.26	84.43	42.00	0.00	0.00
December	49	28.77	16.23	86.29	37.71	0.00	0.00
	50	29.54	14.99	78.43	33.29	0.00	0.00
	51	27.43	16.80	90.71	49.43	0.00	0.00
	52	27.34	10.80	86.00	33.00	0.00	0.00
	53	28.08	13.50	85.20	44.20	0.00	0.00

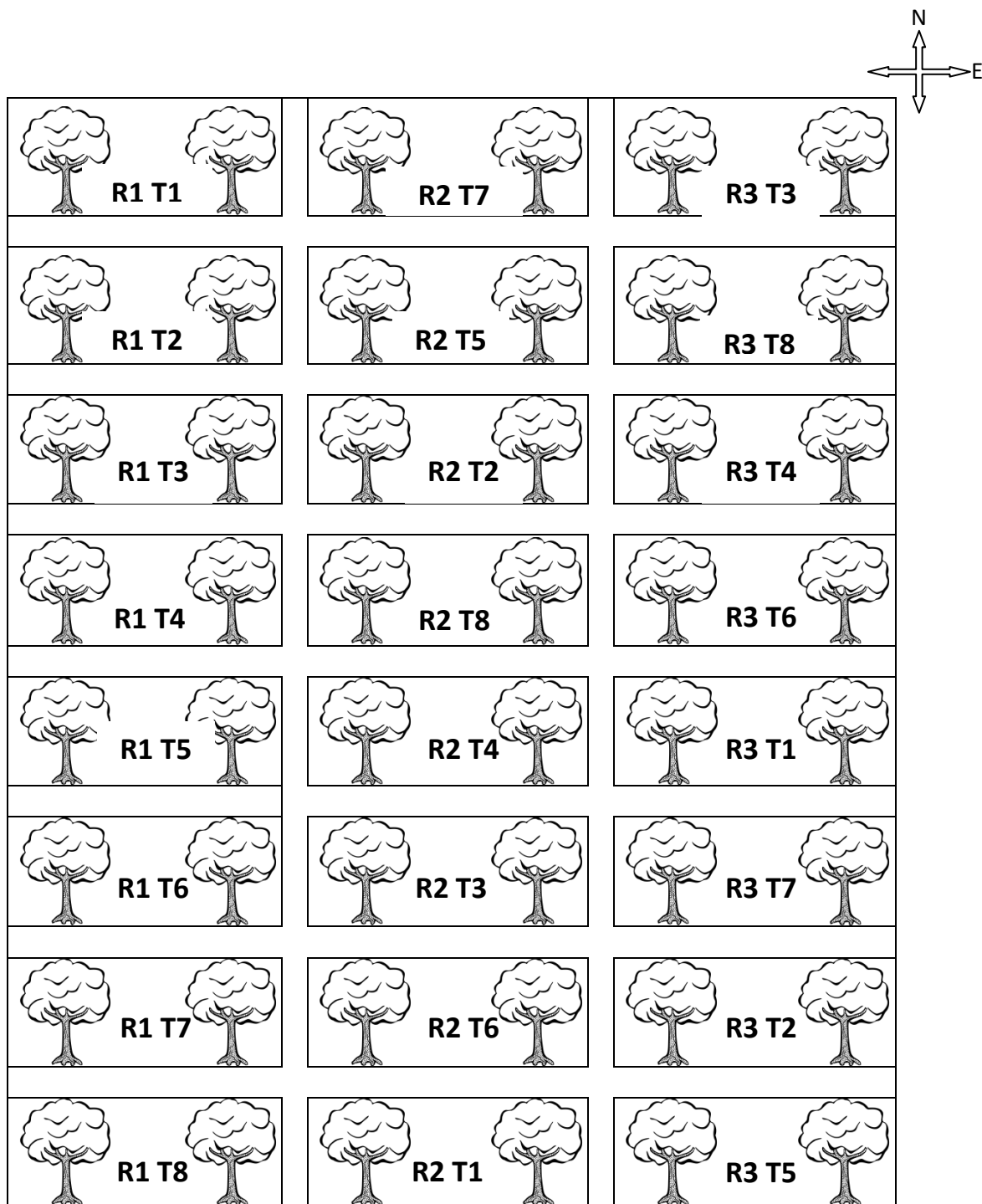
## 8. VITAE

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**KONNI APPALA RAJU**  
**DOCTOR OF PHILOSOPHY (AGRICULTURE)**  
**IN**  
**AGRICULTURAL ENTOMOLOGY**  
**2022**

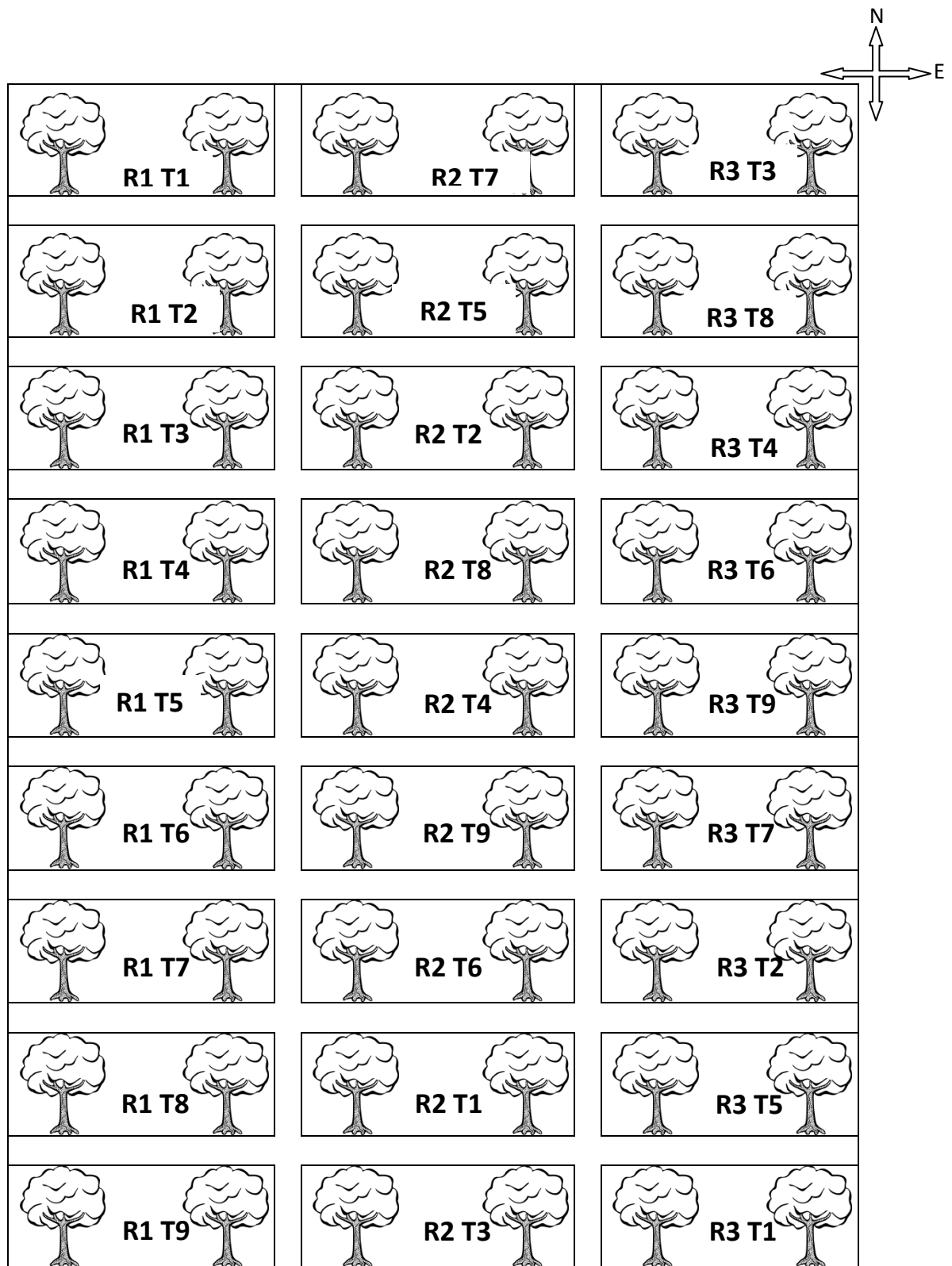
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<b>Title of Thesis</b>		:	“Studies on Insecticide Management of Pests Infesting Pomegranate ( <i>Punica granatum</i> L.)”
<b>Major field</b>		:	Agricultural Entomology
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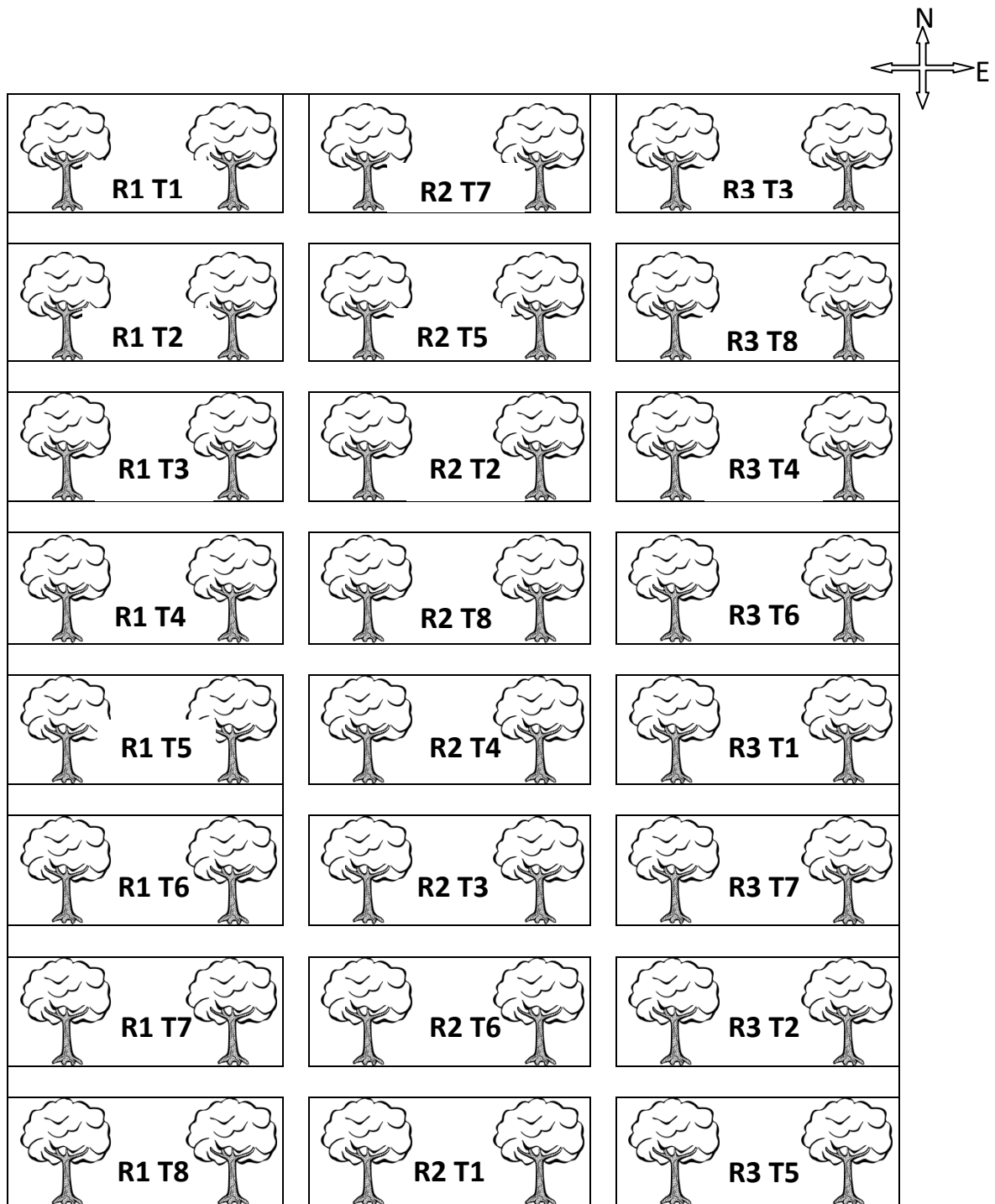
**Plate 3.1 Plan and layout of the experimental field for evaluating newer insecticides against pomegranate aphids and thrips**

- |  |   |
|--|---|
| T1 : Tolfenpyrad @ 150 g a.i. ha <sup>-1</sup>     | T5 : Thiacloprid @ 180 g a.i. ha <sup>-1</sup>                    |
| T2 : Cyantraniliprole @ 75 g a.i. ha <sup>-1</sup> | T6 : Fipronil @ 100 g a.i. ha <sup>-1</sup>                       |
| T3 : Imidacloprid @ 50 g a.i. ha <sup>-1</sup>     | T7 : Spirotetramat + Imidacloprid @ 60+60 g a.i. ha <sup>-1</sup> |
| T4 : Acetamiprid @ 20 g a.i. ha <sup>-1</sup>      | T8 : Untreated control  |



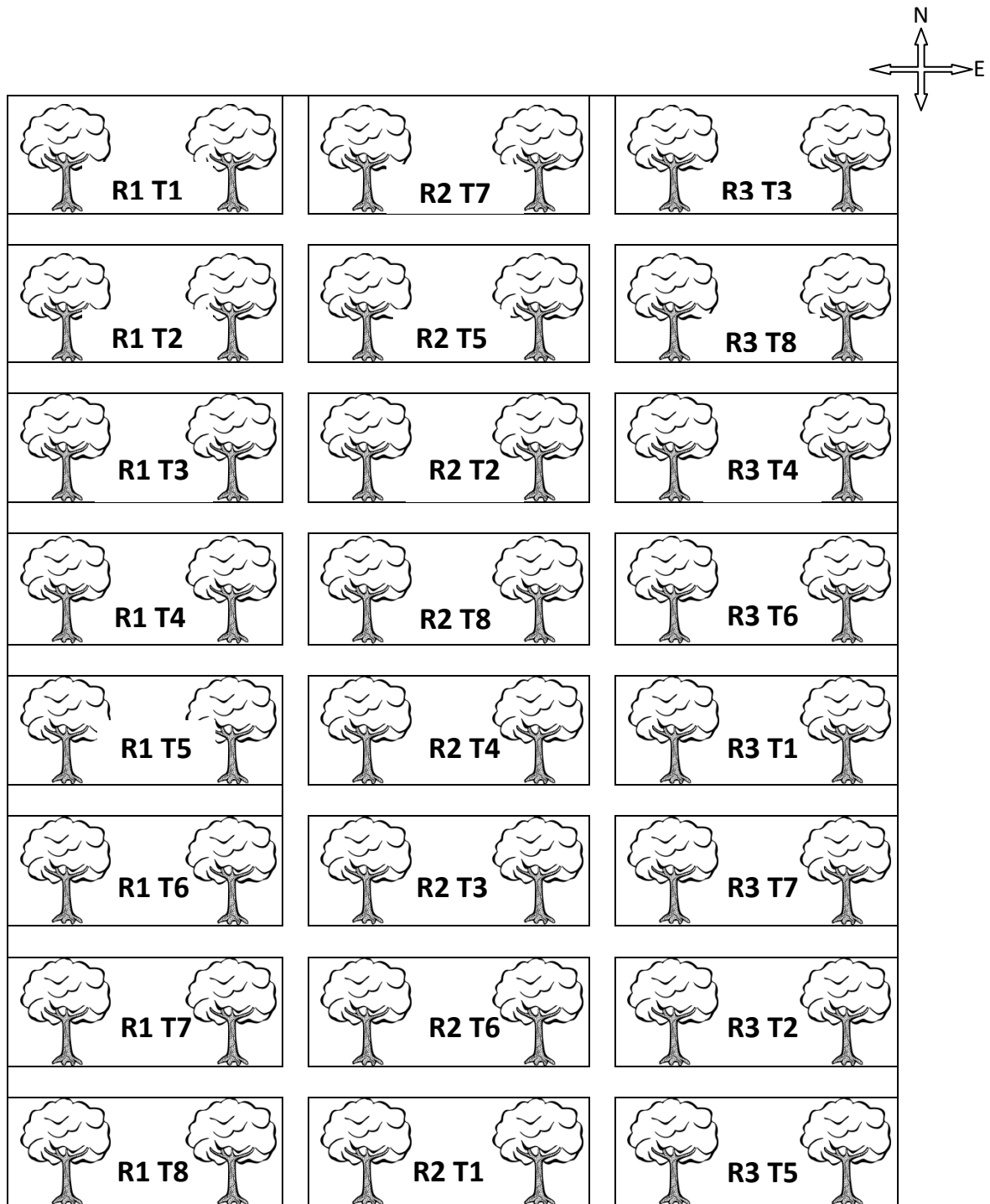
**Plate 3.2 Plan and layout of the experimental field for evaluating newer insecticides against pomegranate fruit borer**

- |  |   |
|--|---|
| T1 : Flubendiamide @ 72 g a.i. ha <sup>-1</sup>                  | T6 : Chlorantraniliprole @ 40 g a.i. ha <sup>-1</sup> |
| T2 : Flubendiamide + Thiocloprid @ 60+60 g a.i. ha <sup>-1</sup> | T7 : Cyantraniliprole @ 75 g a.i. ha <sup>-1</sup>    |
| T3 : Lambda cyhalothrin @ 25 g a.i. ha <sup>-1</sup>             | T8 : Thiodicarb @ 750 g a.i. ha <sup>-1</sup>         |
| T4 : Spinosad @ 75 g a.i. ha <sup>-1</sup>                       | T9 : Untreated control                                |
| T5 : Emamectin benzoate @ 11 g a.i. ha <sup>-1</sup>             |   |



**Plate 3.3 Plan and layout of the experimental field for evaluating biorationals against pomegranate aphids & thrips**

- |  |  |
|--|--|
| T1 : Silicon @ 1000 ppm                                  | T5 : <i>Beauveria bassiana</i> @ 5 g L <sup>-1</sup>     |
| T2 : <i>Lecanicillium lecanii</i> @ 5 g L <sup>-1</sup>  | T6 : Neem oil + Karanja oil @ 2 ml+ 2 ml L <sup>-1</sup> |
| T3 : Azadirachtin 10000 ppm @ 3 ml L <sup>-1</sup>       | T7 : N.S.E 5 %   |
| T4 : <i>Metarhizium anisopliae</i> @ 5 g L <sup>-1</sup> | T8 : Untreated control                                   |



**Plate 3.4 Plan and layout of the experimental field for evaluating biorationals against pomegranate fruit borer**

- |  |  |
|--|--|
| T1 : Silicon @ 1000 ppm                                  | T5 : <i>Beauveria bassiana</i> @ 5 g L <sup>-1</sup>     |
| T2 : <i>Lecanicillium lecanii</i> @ 5 g L <sup>-1</sup>  | T6 : Neem oil + Karanja oil @ 2 ml+ 2 ml L <sup>-1</sup> |
| T3 : Azadirachtin 10000 ppm @ 3 ml L <sup>-1</sup>       | T7 : N.S.E 5 %   |
| T4 : <i>Metarhizium anisopliae</i> @ 5 g L <sup>-1</sup> | T8 : Untreated control                                   |