

**“EFFICACY OF INSECTICIDES AND SOME BIORATIONALS AGAINST
THRIPS AND MITES IN/ON CHILLI (*Capsicum annum* L.)”**

by

Mr. SIDDESHA M.

(Reg. No.017/162)

A Thesis submitted to the

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

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY



DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH

RAHURI-413722, DIST- AHMEDNAGAR

MAHARASHTRA, INDIA

2019

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2019**

CANDIDATE'S DECLARATION

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

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

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LIST OF ABBREVIATIONS AND SYMBOLS

@	:	At the rate of
a.i	:	Active ingredient
AINP	:	All India Network Project
BDL	:	Below Determination Limit
BQL	:	Below Quantification Limit
⁰ C	:	Degree Celsius
CAC	:	Codex Alimentarius Commission
CD	;	Critical Difference
Cm	:	Centimetre
CRMs	:	Certified Reference Materials
DAT	:	Days After Treatment
DBT	:	Days Before Treatment
DT ₅₀	:	Dissipation Time 50
EC	:	Emulsifiable Concentrate
<i>etc.</i>	:	Extra
<i>et al</i>	:	and others
FSSAI	:	Food Safety and Standard Authority of India
FYM	:	Farm Yard Manure
g a.i/ha	:	gram active ingredient per hectare
G	:	gram
Ha	:	hectare
Hrs	:	hours
HAS	:	Hours After Spray
i.e	:	that is
IPM	:	Integrated Pest Management
K cal	:	Kilo calories
Kg ha ⁻¹	:	Kilogram per hectare
Kg	:	Kilogram
L	:	Litre
l ha ⁻¹	:	Litre per hectare

LOD	:	Limit Of Detection
LOQ	:	Limit Of Quantification
M	:	Metre
m ²	:	Metre square
mg kg ⁻¹	:	Milligram per kilogram
mg	:	Milligram
min	:	Minute
ml ha ⁻¹	:	Millilitre per hectare
ml l ⁻¹	:	Millilitre per litre
ml	:	Millilitre
mm	:	Millimetre
MRL	:	Maximum Residue Limit
nm	:	nanometre
No.	:	Number
%	:	Per cent
±	:	Plus or minus
ppm	:	Parts per million
QuEChERS	:	Quick Easy Cheap Effective Rugged Safe
RBD	:	Randomized Block Design
RL ₅₀	:	Half-life
RSD	:	Replicated Standard Deviation
rpm	:	rotations per minute
SD	:	Standard Deviation
SC	:	Soluble Concentrate
S. Em	:	Standard Error of mean
t ha ⁻¹	:	tonne per hectare
µl	:	Micro litre
µg kg ⁻¹	:	Microgram per kilogram
viz.,	:	namely

ABSTRACT

“EFFICACY OF INSECTICIDES AND SOME BIORATIONALS AGAINST THRIPS AND MITES IN/ON CHILLI (*Capsicum annuum* L.)”**by****Mr. Siddesha M**

A candidate for the degree

of

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Research guide : Dr. C. S. Patil**Discipline : Agricultural Entomology**

The experiment on ‘Efficacy of insecticides and some bio-rationals against thrips and mites in/on chilli (*Capsicum annuum* L.)’ were carried out during the year 2018-2019 at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The field experiment on bio-efficacy and dissipation studies were conducted at Post Graduate Institute instruction farm, M.P.K.V., Rahuri, Maharashtra. The laboratory study on dissipation of insecticide was carried out at Pesticide Residue Laboratory, Department of Agricultural Entomology, M.P.K.V., Rahuri.

In the present studies, some pesticides were evaluated for their efficacy against thrips and mites on chilli. The result revealed that spirotetramat + imidacloprid 240 SC was the effective insecticide against thrips with 90.73 % reduction in population followed by fipronil 5 SC (86.22%) and ethion 50 EC (81.60%). Whereas, mites were effectively controlled by spirotetramat + imidacloprid 240 SC (86.80%) followed by spiromesifen 22.9 SC (82.89%) which it was on par. Among biorationals nimbecidine was proved more effective by recording the highest reduction in thrips and mites. The yield and cost economics data showed that spirotetramat + imidacloprid 240 SC (2.10t/ha), fipronil 5 SC (2.02t/ha), spiromesifen 22.9 SC (1.92t/ha) and ethion 50 EC (1.78t/ha) against thrips and mites. Spirotetramat + imidacloprid 240 SC recorded the highest C:B ratio of 1:4.66.

The spiromesifen 22.9 SC was studied for dissipation in chilli at recommended and double the recommended dose. The mean initial residues of spiromesifen 22.9 SC @ 96 and 192 g a.i/ha in chilli fruits were 0.69 mg kg⁻¹ and 1.58 mg kg⁻¹ which dissipated Below Detection Limit (BDL) on 10th and 15th days after 2nd spray. The half-life values were 2.06 and 2.18 days. The residues of spiromesifen 22.9 SC were found BDL in soil at harvest at both the doses, respectively. Considering this, Pre-Harvest interval (PHI) of 10 days can be suggested for spiromesifen 22.9 SC in chilli.

1. INTRODUCTION:

Chilli (*Capsicum annuum* L.) is one of the important vegetable and condiment crop grown throughout the year. It is also known as the 'hot pepper', 'red pepper' etc. Chilli belongs to Solanaceae family and originated from Mexico. It is widely cultivated as spice in temperate and tropical countries of the world.

Chilli fruit is mainly used as green or dried to impart pungency to food. The fruit is rich in vitamin 'A' and 'C' and the seeds contain traces of starch, which has medicinal significance in dyspepsia and prevent blood cancer. Capsaicin and essential oils of chillies are active constituents for providing characteristic pungency, flavor and aroma and have number of uses in capsaicin industries (Zamski *et al.*, 1987).

Chilli can be grown in almost all the states of India. Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, Orissa, West Bengal, Rajasthan and Tamil Nadu are the major chilli growing states in the country. In India, the chilli was grown in 2,92,000 ha area, producing 33,90,000 tonnes with an average productivity of 1.16 tonnes per ha (Anon., 2017). In Maharashtra, chilli crop is grown over an area of 30,990 ha with production of 3,59,770 tonnes.

Chilli cultivation is facing biotic and abiotic stress that causes severe yield loss (Zhani *et al.*, 2013). As many as, 51 insects and one mite pest species have been reported to infest chilli crop (Jadhav *et al.*, 2004) Of these, thrips (*Scirtothrips dorsalis* Hood), mites (*Polyphagotarsonemus latus* Banks) and aphids (*Aphis gossypii* Glover) are responsible for approximately 50 percent reduction in yield (Ahmed *et al.*, 1987). Thrips and mites cause "Murda" disease in chilli in association with virus. Thrips cause upward curling of leaves and mites cause downward curling of leaves and petiole elongation. The white fly act as vectors of disease. i.e chilli leaf curl disease.

The pest severity of chilli crop is changing day-by-day due to variations in climate and also introduction of high yielding genotypes, vulnerable to attack of thrips and mites, most potential pests of this crop. These can be controlled mainly by the chemical methods. As per the insecticide Act 1968, 37 insecticide formulations are registered and recommended for use on chilli targeting various pests.

Today, farmers are using insecticides in much higher amounts than that of recommended. So for quick and better result in controlling pest population and avoidable losses in yield caused by them. This attitude towards application of insecticides in field to control pest population irrespective of their density parameters gives hazardous effects *viz.*, resistance, resurgence and residues. Pesticide use has created concern regarding environmental quality and the potentially

toxic or carcinogenic residues remaining in the food chain. In recent years, occurrence of pesticide residues have been reported in fruits and vegetables (Samira Mebdoua *et al.*, 2017).

Now a days, application of bio-pesticides on chilli is practiced by farmers and these bio-pesticides are safer to natural enemies of pests. Presently, bio-pesticides cover only 2% of the plant protectants used globally. However, its growth rate shows an increasing trend in the past two decades.

Development of resistance and resurgence has limited the application of single pesticide. In order to overcome these problems, insecticide combinations were sprayed. Insect pests that are resistant to one or more insecticides may be susceptible to a combination of toxicants.

There has been increasing awareness on hazards of pesticides to consumers. Farmers use pesticides indiscriminately to control the insect pest in chilli resulting in the occurrence of pesticide residues in chilli fruits. There are frequent reports indicating occurrence of pesticides in green chilli and red chilli. India is dominating world market in chilli as a spice crop. There is great scope for its export. In view of this, it is necessary to produce residue free chilli fruits by adapting good agricultural practices.

The insecticides applied for the management of insect pests were degraded in the environment by different processes. Whereas, quantity of insecticide is dissipated gradually in the plant products and soil and can be the need of study. The dissipation of the chemical insecticides after their application depends on various factors, like plant, chemical formulation and application method (Ebert *et al.*, 1999), climatic conditions, physical phenomena (mainly volatilization) and chemical degradation, in which sunlight plays a prominent role (Garau *et al.*, 2002;). Therefore, dissipation studies for a given crop in the specific condition of each growing area are necessary to determine pre-harvest interval (PHI) which ensures that residue levels are below the maximum residue limit (MRL).

Keeping this in mind the investigation was undertaken with the following objectives

1. To study the bio-efficacy of newer insecticides and some bio-rationals against Chilli thrips and mites.
2. To study the dissipation of spiromesifen in/on chilli fruits and cropped soil.

2. REVIEW OF LITERATURE

Chilli being relatively short duration crop, the plant parts (vegetative, floral and fruit) are usually exposed to pests, which affects the yield, quality and market value of the produce. Hence, pest identification and management at right stage of the crop is very important. Sucking pests viz., thrips and mites are the major pests of chilli and cause severe curling of leaves resulting significant losses in the fruit yield. Hence, the pest control strategy using chemical insecticides is still the front line of defense against insect pests of chilli

2.1 Bio-efficacy of insecticides and some bio-rationals against thrips and mites on chilli and other crops

Chilli thrips, *Scirtothrips dorsalis* is a polyphagous pest with a wide range of host plants. Both nymphs and adults lacerate the leaf tissues and suck the oozing juice, sometimes even the buds and flowers are attacked. Tender leaves and growing shoots are preferred, older leaves are seldom attacked. The infested leaves start curling upwards, crumple where as buds become brittle and drop down. Pest infestation increases in dry weather. If there are no rains or sufficient irrigation systems, the entire plant may wither and dry away (Butani, 1976). The yield losses attributed to *S. dorsalis* in chilli have ranged from 20% (Ahmed et al., 1987) to nearly 50% (Sanap and Nawale, 1987).

Though several workers have tested different chemicals against these pests, still the problem continues. Considering the economic importance of these pests, the study was conducted to test the bio-efficacy of newer insecticide molecules and select bio-rationals against major sucking pests of chilli. The available review related to bio-efficacy of insecticides and bio-rationals against thrips and mites and persistence of spiromesifen has been reviewed and presented in this chapter.

2.1.1 Bio-efficacy of insecticides against thrips on chilli

Kumar *et al.* (2001) studied the efficacy of four insecticides against major pests of chilli (*Capsicum annuum*). Imidacloprid at 70 g a.i.ha⁻¹ was found to be the most effective treatment for controlling aphids. Acephate (1500 g a.i. ha⁻¹) was effective in controlling chilli thrips, while cypermethrin (300 g a.i. ha⁻¹) was determined to be the most effective insecticide against borers.

Kadam and Dethe (2002) reported that crop sprayed with fipronil 5% SC @ 60 g.a.i ha⁻¹ recorded green chilli yield of 51.7 q ha⁻¹.

Misra (2003) recorded that efficacy of five insecticides i.e., Naclfmoa 1.9 EC (fermentation metabolite) at 15, 20 and 25 mL ha⁻¹, abamectin (Vertimec) 1.9 EC at 20 mL ha⁻¹, dimethoate (Rogar) 30% at 300 mL ha⁻¹, dicofol (Hilfol) 18.5% EC at 500 mL ha⁻¹ and ethion

(Phosmite) 50% EC at 250 mL ha⁻¹ were evaluated in a field at Bhubaneswar. Ethion proved superior in controlling the leaf curl disease of chilli.

Fipronil was found effective at 50 g a.i. ha⁻¹ against chilli thrips (Jadhav *et al.*, 2004). They evaluated the efficacy of fipronil 5 SC at different concentrations against sucking pests of chilli. On comparison with imidacloprid 17.8 SL @ 20 g a.i. ha⁻¹, phosalone 35 EC @ 500 g a.i.ha⁻¹. Fipronil 5 SC @ 100 g a.i. ha⁻¹ recorded lowest population of sucking pests and registered highest yield.

Reddy *et al.* (2005) studied the bio-efficacy of new insecticides with traditional insecticides as foliar sprays against chilli thrips (*S.dorsalis*) and mites (*P.latus*) during 2001 and 2002. Seventeen insecticides were sprayed 3 times at an interval of 10 days. Fipronil 5 SC (0.01%) followed by thiamethoxam 25 WG (0.005%), acetamiprid 20 SP (0.002%) and dimethoate 30 EC (0.06%) were the most effective treatments against thrips.

Reddy *et al.* (2007) evaluated the bioefficacy of certain newer insecticides with traditional insecticides as foliar spray against chilli thrips and mites. Results indicated that among 17 insecticides tested, fipronil 5% SC at 0.01% followed by triazophos 40 EC at 0.06%, phosalone 50 EC at 0.075 and carbaryl 50 WDP at 0.15% found effective against thrips.

Application of phosphamidon 40% + imidacloprid 2% SP at 700 g ha⁻¹ was the most effective treatment for suppression of thrips population and also increased the yield of green chilli (Bhede *et al.*, 2008).

Mahalingappa *et al.* (2008) studied the bio-efficacy of insecticides against chilli thrips (*S. dorsalis*) and mites (*P. latus*) at Students Farm, College of Agriculture, Rajendranagar, Hyderabad. The results indicated that fipronil 0.01 and triazophos 0.08 per cent were the most effective against chilli thrips followed by profenofos 0.10%, ethion 0.10% and cypermethrin 0.0012 per cent . Chlorpyriphos 0.0012 % was the least effective against thrips (*S. dorsalis*). Profenofos 0.10 % was most effective against mite (*P latus*). The next best treatments were triazophos 0,08% and ethion 0.1 %. Cypermethrin 0.0012% was the least effective against mites.

Reddy and Sreehari (2009) studied the bioefficacy and phytotoxicity of new formulation along with other insecticides against thrips in chilli. Treatments included the new formulation, fipronil 80 WG in three doses @ 30 g a.i ha⁻¹ , @ 40 g a.i ha⁻¹ , @ 50 g a.i ha⁻¹ , fipronil (Regent) 5% SC @ 40 g a.i ha⁻¹ , acephate 75% SP @ 468.75 g a.i ha⁻¹ , imidacloprid (Confidor) 200 SL @ 30 g a.i ha⁻¹ and untreated control. The results revealed that the fipronil 80 WG @ 50 g a.i ha⁻¹ recorded lowest number of thrips and is on par with fipronil 80 WG @ 40 g a.i ha⁻¹ fiproni 5% SC @ 40 g a.i ha⁻¹ and acephate 75% SP @ 468.75 g a.i ha⁻¹, whereas

imidacloprid 200 SL and fipronil 80 WG @ 30 g a.i ha⁻¹ were found least effective against thrips.

Hosamania *et al.* (2012) evaluated the new formulation of fipronil against thrips. On the basis of pooled data of two consecutive years it was concluded that fipronil 80 WG at 60 g a.i. ha⁻¹ was effective in reducing the thrips populations with increased yield of onion.

Tatagar *et al.* (2014) conducted studies on the bio-efficacy of new molecule, flubendiamide 24% + Thiacloprid 24% - 48% SC against chilli thrips, *S. dorsalis* at Horticulture Research Station, Haveri, University of Horticultural Sciences, Karnataka, during 2007 and 2008. Different dosages of flubendiamide 24% + thiacloprid 24% - 48% SC viz., @ 36 + 36, 48 + 48 and 60 + 60 g a.i. ha⁻¹, were evaluated with checks. Flubendiamide 24% + thiacloprid 24% - 48% SC @ 48 + 48 g a.i. ha⁻¹ recorded the least number of thrips and least leaf curl damage of 0.46 LCI (Leaf curl index) per plant compared with recommended insecticide, profenophos 50 EC @ 500 g a.i. ha⁻¹. The dry chilli yield was also found better in flubendiamide 24% + thiacloprid 24% - 48% SC @ 48 + 48 g a.i. ha⁻¹ (7.18 q ha⁻¹) than profenofos 50 EC @ 500g a.i. ha⁻¹ (5.77 q ha⁻¹).

Samota *et al.* (2017) conducted investigations on “Efficacy of newer insecticides and biopesticides against thrips, *Scirtothrips dorsalis* Hood on chilli.” at Horticulture farm, S.K.N. College of Agriculture, Jobner during *Zaid*, 2014 and 2015. Ten treatments including untreated control were evaluated for their efficacy. On the basis of mean per cent reduction in thrips population in all the three sprays, the treatment of acetamiprid (82.62%) was found to be the most effective, followed by thiamethoxam (80.79%), imidacloprid (77.90%), fipronil (76.38%) and standard check (71.92%), former three treatments were statistically at par with each other.

2.1.2 Bio-efficacy of insecticides against thrips and other pests on different crops

Mallikarjuna *et al.* (2009) found that flubendiamide 24 SC + thiacloprid 24-48 SC at 2 ml l⁻¹ recorded the highest percentage larval reduction of pod borers of dolichus bean.

Patel *et al.* (2009) evaluated the efficacy of some inorganic insecticides and botanicals for the control of chilli thrips, *Scirtothrips dorsalis* Hood conducted at the Main Vegetable Research Station, Anand Agricultural University during 2002-03 and 2003-04. It was revealed that among the 10 different insecticidal treatments, ethion + cypermethrin (0.045%), methomyl (0.04%) and difenthiuron (0.05%) proved most effective treatment followed by imidacloprid (0.005%), lufenuron (0.005%) and triazophos (0.04%).

Patil *et al.* (2009) evaluated the efficacy of fipronil 5% SC @ 800 g ha⁻¹, fipronil 40% + imidacloprid 200 SL @ 200 ml ha⁻¹, acetamiprid 20SP @ 100 g ha⁻¹ and triazophos 40 EC @

1500 ml ha⁻¹ (standard checks) against sucking pests of cotton. All the insecticides showed effective control of leafhoppers, aphids and thrips. Fipronil 5% SC @ 800 g ha⁻¹ registered least number of thrips i.e., 8.47/three leaves and found to be on par with acetamiprid 20 SP @ 100 g ha⁻¹ i.e., 7.80/three leaves. Fipronil 40% + imidacloprid 40% 80 WG was the next best and followed by imidacloprid 200 SL. Significantly highest seed cotton yield of 27.23 q ha⁻¹ (2007) and 27.50 q ha⁻¹ (2008) was obtained with higher dosage of fipronil 5% SC @ 800 g ha⁻¹, respectively.

According to Kumar *et al.* (2010) flubendiamide + thiacloprid 480 SC at 120 g a.i. ha⁻¹ was effective against the aphids, whitefly, leafhopper and bollworms on cotton compared to the standard checks. It also did not show any phytotoxicity at concentration of 120, 240 and 480 g a.i. ha⁻¹ on the plant.

Shivaraju *et al.* (2011) reported that among the new insecticide molecules flubendiamide 24 + thiacloprid 24 - 48 SC recorded high larval reduction (76.56 and 84.45%) followed by emamectin benzoate (66.50 and 80.88%) and then indoxacarb (61.55 and 77.94%) in the first and second sprays, respectively against *Maruca testulalis* G.

Field efficacy of different insecticidal and botanical formulations was evaluated for the management of sucking pests on Capsicum under net house conditions at Vegetable Research Farm, Punjab Agricultural University, Punjab. Result revealed that Imidacloprid 17.8% SL @ 0.025% and 0.05%, acephate @ 0.05%, deltamethrin 2.8 EC @ 0.025%, and neem soap @ 1.0% were effective for the control of aphid and thrips (Kaur & Singh, 2013).

Kumar *et al.* (2013) studied the bioefficacy of fipronil (Jump 80 WG) against thrips, *Thrips tabaci* on cotton. Experiment revealed that population of thrips per three leaves was significantly lower in fipronil @ 50 g a.i. ha⁻¹ and 60 g.a.i. ha⁻¹ (5.13 and 3.63) compared to all other treatments after 3 days of spray. However, after 5 and 7 days of spray all the treatments gave better control of *Thrips tabaci* except imidacloprid. After 12 days of spray, thrips population per three leaves was significantly lower in fipronil @ 60 g.a.i. ha⁻¹ (2.49), on par with its lower dose, fipronil @ 50 g.a.i. ha⁻¹ (5.06).

Studies conducted by Pandey *et al.* (2013) revealed that the lowest mean thrips (*Thrips tabaci* L.) population (8.0 nymphs/plant) and the highest marketable yield (362 q ha⁻¹) were achieved by applying fipronil @ 1.5 ml lt⁻¹, resulting in the highest cost benefit ratio (1:11.55) leading to an arbitration of spraying fipronil @ 1.5 ml/lit. at 15 days interval minimize the thrips population and increase the yield of rabi onion. Neem based formulations were found less effective.

Singh *et al.* (2013) conducted the field experiment to assess the thrips population. The maximum mean values ranged between 15.30 and 153.45 thrips / plant. The seven treatments of insecticides i.e. fipronil 5% SC, lambda-cyhalothrin 5% EC, lambda - cyhalothrin 4.9% CS, thiacloprid 21.7% SC, deltamethrin 11% w/w EC, malathion 50% EC were applied at 30, 45 and 60 days after transplanting of onion crop for management of onion thrips. Among all the insecticides applied, fipronil 5% SC and lambda-cyhalothrin 4.9% CS were the most effective insecticides in reducing the thrips population and increasing the weight of exportable bulb and yield of onion compared to control. Fipronil 5% reduced the thrips population by 98.56 per cent over control and increased the bulb yield by 124.90 per cent compared to control.

Badgujar *et al.* (2014) documented that spraying fipronil 5 SC was significantly superior over other treatments followed by acetamiprid 20 SP and thiamethoxam 25 WG. The data on yield revealed that fipronil 5 SC recorded the highest seed cotton yield (2087 kg ha⁻¹) followed by acetamiprid 20 SP and thiamethoxam 25 WG. The highest C:B ratio was obtained from fipronil 5 SC followed by acetamiprid 20 SP and thiamethoxam 25 WG.

Roy *et al.* (2016) studied the comparative efficacy, non-target toxicity and economics of seven novel pre-mixed formulations against *Maruca testulalis* G. and *Aphis crassivora* K. infesting cowpea and resulted revealed that the chlorantraniliprole + thiamethaxam showed maximum mortality (60.68%) than emamectin benzoate + fipronil (60.66%) and flubendamide + thiacloprid (60.35%) considering the mean per cent reduction of pod borer damage and the highest green pod and seed yield was recorded from flubendamide + thiacloprid.

Wagh *et al.* (2016) conducted the field experiment at the All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, MPKV, Rahuri, Ahmednagar during Rabi, 2013 - 14. It revealed that fipronil @ 0.0075 % was the most effective as it recorded least (4.00-6.00 thrips/plant) and maximum (25.67 t ha⁻¹) yield of onion bulbs followed by spinosad @ 0.018%, acetamiprid @ 0.005 % and clothianidin @ 0.0075 per cent, among different insecticides tested. Carbosulfan @ 0.025 %, thiamethoxam @ 0.0075 % and lambda cyhalothrin @ 0.005% were equally effective and recorded less number of thrips and better yields.

2.1.3 Bio-efficacy of insecticides / acaricides against mites on chilli.

Chilli mite, *P. latus* is a tiny spider like creature found in large numbers on the underside of leaves, covered with fine webs. Both nymphs and adults suck the cell sap and devitalize the plants (Butani, 1976). Feeding of *P. latus* caused different types of physical deformities like thickening, brittleness and shortening, twisting, downward curling and crumpling of young leaves. Midrib of young infested leaves bent in a zigzag fashion, ventral surface become silvery, petiole of mature leaves elongated and the plant become stunted with rosette symptoms.

Infestation at flowering stage caused falling of flower bud (Karmakar, 1997). It caused about 60 per cent crop loss and may even cause 100 per cent loss under glass house conditions (Liu *et al.* 1991).

Investigatoion in field trial conducted in farmer's holdings to evaluate the efficacy of spiromesifen 240 SC against chilli mite revealed that, spiromesifen @ 72, 96 and 120g a.i. ha⁻¹ recorded 83.8, 86.6 and 91.7% mean reduction of chilli mite population, respectively. Where as in the second trial, mortality was 82.0, 88.0 and 92.3%, respectively (Kavitha *et al.*, 2006). Spiromesifen 240 SC showed better efficacy than Dicofol 18.5 EC. Spiromesifen @ 120 g a.i. ha⁻¹ was superior in controlling of chilli mites. But the lower dose of spiromesifen 240 SC @ 72 g a.i. ha⁻¹ was economically viable, if applied at early stage of mite infestation. Spiromesifen was found to have long lasting efficacy on chilli and @ 120g a.i ha⁻¹, reduced the leaf curl damage from 41.8% to12.5%. Application of spiromesifen at 240 SC did not exhibit phytotoxic effect on chilli crop.

Nagaraju *et al.* (2007) reported the efficacy of spiromesifen 45 SC at 100 g a.i. ha⁻¹ in reducing chilli mite infestation in comparison to other insecticides. Spiromesifen 45 SC at 100 g a.i. ha⁻¹ recorded the lowest mite population and leaf curl index (LCI) (8.17 mites/leaf, 1.61 LCI) and highest dry chilli yield (926.53 q ha⁻¹) followed by vertimec 1.9 EC @ 125 ml ha⁻¹ (8.18 mites/leaf, 1.75 LCI, 926.27 q ha⁻¹) and fenazaquin @ 250 ml ha⁻¹ (8.78 mites/leaf, 1.69 LCI, 25.43 q ha⁻¹), respectively.

Field experiment was conducted during summer 2007 - 2008 to evaluate the effectiveness of acaricides *viz.*, abamectin, acephate, dicofol, ethion, gronim, lannate, magister, mitexs, polo [diafenthiuron] and propargite at recommended concentration and doses. The mortality data was recorded as pre-spray, and at 1, 3, 7 and 14th days as post-spray of acaricides / insecticides. Dicofol showed maximum mortality followed by abamectin, propargite and ethion *i.e.*, 91.56, 87.44, 81.66 and 72.94 per cent, respectively (Rai *et al.*, 2011).

Varghese and Mathew (2013) observed that spiromesifen 45 SC @ 100 g a.i. ha⁻¹ and propargite 57 EC @ 570 g a.i. ha⁻¹ were effective in reducing chilli mite population whereas acetamiprid 20 SP @ 20 g a.i. ha⁻¹ with spiromesifen were effective against chilli thrips. The leaf curling was due to the feeding of mites and thrips was the least in spiromesifen, propargite and acetamiprid sprayed plants.

Halder *et al.* (2015) reported from a field experiment conducted at ICAR- Institute of Vegetable Research, Varanasi during 2011-2014 to evaluate the different newer molecules against Yellow mite, *Polyphagotarsonemus latus* (Banks) and thrips *Scirtothrips dorsalis* Hood, infesting chilli. Result revealed that the maximum reduction in yellow mite population was obtained in the treatment with chlorfenapyr @ 1.5 ml/l (69.95%) followed by

spiromesifen @ 0.6 ml/l (57.43%) and fipronil @ 0.35 g/l (57.29%) . In case of thrips, maximum control was achieved with fipronil @ 0.35 g/l (75.41%) followed by spiromesifen (58.29%).

Vikrant kumar *et al* (2015) reported that, among the treatments tested, spirotetramat 120 + imidacloprid 120-240 SC @ 90 g + 90 g a.i ha⁻¹ caused high reduction of thrips , aphids, whiteflies, jassids and mites at 5 and 10 days after each spray. It also recorded the highest marketable yield of 133.08 q ha⁻¹. The ready mixture of spirotetramat 120 + imidacloprid 120 - 240 SC @ 90 g + 90 g a.i. ha⁻¹ and other six insecticides evaluated did not show phytotoxic effect on chillies.

2.1.4 Bio-efficacy of insecticides / acaricides against mites and pests on different crops

Spiromesifen (0.024%), difenthiuron (0.075%) and dicofol (0.046%) were highly effective against all stages of red spider mite. Dimethoate (0.05%), endosulfan (0.07%), monocrotophos (0.036%) and phosalone (0.07%) were found ineffective. Maximum fruit yields were recorded in spiromesifen and difenthiuron with yield of 240.74 and 248.97 q ha⁻¹ during second and 176.33 and 163.99 q ha⁻¹ during third trial, respectively (Roopa, 2005).

Sekh *et al.* (2007) conducted a field trial at Bidhan Chandra Krishi Vishwa vidyalaya, West Bengal, spiromesifen (Oberon 240 SC) 624 ml ha⁻¹ gave good control of red spider mite of brinjal along with significant increase in yield.

Bioefficacy of spiromesifen 240 SC conducted at instructional farm, RCA, MPUAT, Udaipur during summer and kharif, 2009 revealed that two sprays of spiromesifen 240 SC at 625 ml ha⁻¹ at 28 days interval was found the most effective (Ameta *et al.*, 2010).

Usha Chauhan *et al.* (2011) evaluated the efficacy of *V. lecanii*, predator *Neoseiulus longispinosus* and profenofos 50 EC against two spotted mite, *T. urticae* in carnation. Among the treatment combinations, *V. lecanii* showed significant reduction in mite population, 4.5 to 9.3 mites per leaf in comparison with 64.7 mites per leaf in the control.

Sood *et al.* (2015) conducted an experiment to control *T. urticae* on cucumber. Spiromesifen 240 SC @ 144 g a.i. ha⁻¹ application had significantly reduced mite infestation when sprayed at 21 days interval with mean mite population of 0.8 –1.3 mite/five leaves was most effective in reducing mite population and also resulted in highest yield plant⁻¹. Phytotoxicity observations of spiromesifen recorded upto 15 days after application revealed that there was no phytotoxicity symptoms at evaluated doses of 120, 144, 288 and 576 g a.i. ha⁻¹, respectively.

Syed Arif *et al.* (2015) conducted field studies for the control of cotton mealybug (*Phenacoccus solenopsis* Tinsley) during July 2015-16 at University of Agricultural Science, Peshawar - Pakistan. Results indicated that maximum mortalities was observed after 72 hours of application spirotetramat + imidacloprid 240 SC caused the highest mortality of 92.96% followed by imidacloprid 200 O-Teq, Thiamethaxam 25 WG, Tobacco Extract @ 2.00 % and Neem Extract @ 2.00 % 57.2%, 51.32% and 45.03% and 29.76 %, respectively.

Field investigations (Koushik sen *et al.*, 2017) were conducted on brinjal to evaluate the efficacy of new ready mix formulation of spirotetramat 120 + imidacloprid 120 - 240 SC against sucking pest complex during 2012 and 2013. The results revealed that spirotetramat 120 + imidacloprid 120 - 240 SC @ 75 + 75 g a.i. ha⁻¹ was found more effective than other treatments in the reduction of the population of jassids (99.21%), whiteflies (99.04%) and red spider mites (91.31%), respectively. The highest marketable fruit yield was recorded in the treatment with spirotetramat120 + imidacloprid 120 - 240 SC @ 75 + 75 g a.i. ha⁻¹ (72.77 q ha⁻¹).

2.1.5 Bio-efficacy of bio-rationals against thrips, mites and other pests on chilli and other crops

Halagatti (2006) conducted studies on the efficacy of entomopathogens against thrips of rose under polyhouse conditions *Verticillium lecanii* recorded the highest mortality of 82.5 and 80 per cent in pre-pupal and pupal stage at 60 DAT, followed by local strains of *B. bassiana*.

Halagatti (2006) conducted studies on the efficacy of botanicals against thrips, *S. dorsalis* of rose under polyhouse conditions and revealed that NSKE 5% recorded the highest mortality of thrips 82.6%.

Makadai *et al.* (2009) studied the effectiveness of *Verticilum lecanii* against *Maconellicoccus hirsutus* on custard apple and reported that, the mortality of 18.9 per cent was found in the treatment of *V.lecanii* @ 2.0 g l⁻¹ of water combined with ranipal 1ml l⁻¹ of water.

Roopa and Nandihalli (2009) reported that Neem oil (2%) and NSKE (5%) exhibited maximum toxicity against red spider mite (*T. macfarlanei*).They also recorded highest fruit yield of 189.3 and 187.24 q ha⁻¹, respectively, which were on par with standard acaricide i.e. dicofol (209.8) in brinjal ecosystem.

Ferria *et al.* (2011) reported that use of artificial silicon application has been observed in a wide variety of plant species. Deposition of silicon on leaf epidermis reduced the whitefly (*Bemisia tabaci*) population through increased development period and nymph mortality in both cucumber and soybean.

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

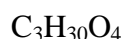
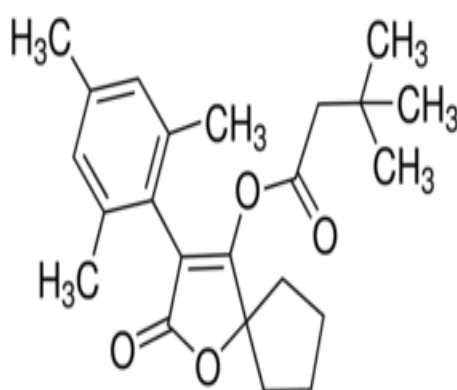
Sayeda *et al.* (2011) evaluated the efficacy of two biopesticides, neem (Nimbecidine) and *B. bassiana* (Bio-power) for control of onion thrips, *T. tabaci*. Results showed that nimbecidine exhibited highest control of thrips in flowering period.

Nitai (2012) reported the efficacy of silica nanoparticle as a insecticide agent against *Sitophilus oryzae*, *Liphaphispseudo brassicae* and *Spodoptera litura*. At higher concentration of silicon i.e, 500 ppm, 97.0, 96.0 and 95.0 percent of mortality was recorded respectively.

Augusto *et al.* (2018) conducted an experiment to evaluate the use of Calcium, Potassium and Silicon for the Management of *Diaphorina citri* Populations in Tahiti Lime trees. The results showed that differences were observed only in adults at 7 WAT, and the foliar calcium and silicon (at doses of 3mL and 2mL of the commercial compound used per liter of H₂O, respectively) applications resulted in the lowest number of individuals (i.e., 1.13 per flush) compared with untreated trees (i.e., 3.13 per flush).

Henk-Maarten Laane (2018) used the silicon for foliar spray to control different pest and result showed that foliar sprays with silicates were effective as pesticides, while (stabilized) silicic acid sprays increased growth and yield and decreased biotic and abiotic stresses.

2.2 Dissipation of spiromesifen in/on chilli, other crops and Soil



Molar mass: 370.489g. mol⁻¹

IUPAC name : [2-oxo-3-(2,4,6-trimethylephenyl)-1-oxaspiro[4.4] non en- 4-yl] 3,3-dimethylebutanoate.

Spiromesifen is a novel foliar contact insecticide/acaricide belonging to the chemical class of keto-enols. It has been developed world wide for the control of mites and whitefly on

vegetables, fruits, cotton and tea (Elbert *et al.*, 2005). It is active against all the developmental stages of mites and whiteflies resulting in long lasting control (Palumbo, 2004 and Ebert *et al.*, 2005). It is also reported to suppress some species of thrips such as chilli thrips, *Scirtothrips dorsalis* Hood, melon thrips, *Thrips palmi* Karny and *Thrips tabaci* in vegetables (Bielza *et al.*, 2009).

Spiromesifen is reported as safe on beneficial insects and with its new mode of action i.e., inhibition of lipid bio-synthesis, offers excellent management of resistant whiteflies and mites (Dekeyser, 2005).

The EU pesticides database indicated MRL of 0.5 mg kg⁻¹, whereas no standardized limits were fixed for spiromesifen in chilli in India. The review of literature pertaining to dissipation of spiromesifen in different crops is presented below.

2.2.1 Dissipation of spiromesifen in/on chilli

Sharma *et al.* (2007) studied the persistence and dissipation kinetics of spiromesifen in chilli and cotton and its dissipation time for 50 per cent (DT₅₀) and dissipation time for 99.00 per cent (DT₉₉) were estimated. After spraying on chilli at 96 and 192 g a.i. ha⁻¹ and cotton at 120 and 240 g a.i. ha⁻¹, the limit of quantification (LOQ) was observed to be 0.033 µg g⁻¹ with limit of detection (LOD) at 0.01 µg g⁻¹. The DT₅₀ of spiromesifen when applied at recommended doses on chilli was found to be 2.18–2.40 days. There was 99% degradation within 14.5–16.3 days after application. Residues of spiromesifen were not detected in cotton seed and lint samples at the first picking. In soil, no residues of spiromesifen were detected at 15 DAT.

Varghese *et al.* (2011) determined the dissipation of spiromesifen 240 SC @ 96 g a.i. ha⁻¹ in/on chilli fruits. Initial deposit was found to be 0.609 mg kg⁻¹ and reached below detection limit on 7th day and Half-life determined was 2.62 days.

Xavier and Chandran (2016) conducted an experiment to study the residue dynamics of spiromesifen 240 SC in chilli fruit using Ultra HPLC coupled with tandem mass spectrometer (UPLC - MS/MS). The initial deposits in chilli fruits after application at 96 and 192 g ai ha⁻¹, were found to be 0.62 and 1.20 mg g⁻¹, which reached below quantification level after 21 and 27 days, respectively. Half-life of spiromesifen at single and double recommended dose were 3.65 and 3.19 days, respectively and the corresponding waiting period calculated was 0.74 and 4.49 days.

Susheel *et al.* (2018) reported the persistence and dissipation behavior of spiromesifen in chilli (*Capsicum annuum*) and the initial deposit was 1.982 mg kg⁻¹ which reached below detection level on 20th day. Half-life of spiromesifen 96 g a.i ha⁻¹ was found to be 3.20 days.

2.2.2 Dissipation of spiromesifen

Sharma *et al.* (2005a) determined the maximum residue limit (MRL) of spiromesifen @ 96 g a.i. ha⁻¹ as on tea and the initial deposits were 6.22 -7.04, 10.36-11.71 and 19.99 -23.01 µg g⁻¹, respectively.

Sharma *et al.* (2005b) studied the persistence of spiromesifen @ 96 g a.i. ha⁻¹ in apple in four locations and recorded initial deposits of spiromesifen as 0.91, 0.99, 0.99 and 0.88 µg kg⁻¹ at recommended dose in Solan, Mashobra, Matiana and Thanedhar in Himachal Pradesh, respectively and the half - life at different locations ranged between 5 to 6 days at the recommended dose.

Sharma *et al.* (2006) reported the residue behaviour and risk assessment of spiromesifen on egg plants from different agro climatic zones in India. The initial deposits of spiromesifen were determined as 0.592 and 0.91 µg kg⁻¹ at Solan, 0.692 and 0.822 µg kg⁻¹ at Ludhiana, 0.682 and 0.809 µg kg⁻¹ at Jaipur and 0.688 and 0.842 µg kg⁻¹ at New Delhi at recommended (96 g a.i. ha⁻¹) and double the recommended doses (192 g a.i. ha⁻¹), respectively. Half - life in fruits ranged between 2.52 to 2.88 days at the recommended dose and between 2.32 to 2.70 days at double the recommended dose. Maximum permissible intake (MPI) was calculated as 1.21 mg per day.

Half- life (T_{1/2}) of spiromesifen applied on tea @ 96 g a.i. ha⁻¹ was found to be 5.0-5.8 days. Degradation was found to occur more than 99 per cent within 33-57 days after application (Sharma *et al.*, 2006a).

The average half -life of spiromesifen residues in nectar and pollen of mustard (*Brassica juncea* L) were 19.99 and 9.69 hr, respectively. It was concluded that waiting period of 5 days should be observed on crops sprayed during blooms to avoid accidental hazards to honey bees (Choudary and Sharma, 2008).

Raj *et al.* (2012) reported the dissipation of spiromesifen on okra under middle Gujarat conditions and the initial deposits were recorded as 0.964 and 1.819 µg g⁻¹ at standard (48 g a.i. ha⁻¹) and double (96 g a.i. ha⁻¹) the dose of application, respectively. Gradually residues declined and persisted up to 3rd and 5th day at lower and higher doses. The residues reached below quantification limit of 0.01 µg g⁻¹ on the fifth and seventh day at standard and double the dose. Half-life of the insecticides on okra fruits was 1.68 and 1.65 days for standard and higher doses.

Sharma *et al.* (2014a) reported the residues of spiromesifen 240 SC in tomato from 4 different agro-climatic locations of India. Residues were found below the limit of quantification

of $0.05 \mu\text{g kg}^{-1}$ at both the doses of application in all the locations. Spiromesifen dissipated with a half-life of 0.93-1.38 days at the recommended dose and 1.04 -1.34 days at the double dose.

Lekha *et al.* (2017) reported the residues of spiromesifen 23.4 EC @ 125 and 250 g a.i. ha^{-1} on tomato for the two years (2013 and 2014). The half-life of spiromesifen was 3.5 and 3.8 days in 2013 and 4.0 and 4.2 days in 2014 for two doses (48 and 96 g a.i. ha^{-1}), respectively. The pre-harvest interval (PHI) was 20 and 25 days in 2013 and 24 and 28 days in 2014 at both doses, respectively.

Lekha and Mohapatra (2016) reported the residues of spiromesifen @ 125 and 250 g a.i. ha^{-1} on cabbage crop. The initial deposits ranged between 0.640-0.723 and 1.438-1.549 with half-life of 2.9-3.2 and 3.9-4.5 days for single and double dose, respectively. No residue was found in soil sample collected from field at harvest.

Pathipati *et al.* (2017) studied the dissipation of spiromesifen against mites *Polyphagotarsonemus latus* Banks on capsicum under field conditions. Initial deposits of 1.61 mg kg^{-1} of spiromesifen detected at 2 hours after last spray, dissipated to BDL at 10th day after spray. The half-life and safe waiting period for harvest was 2.09 and 10.00 days, respectively.

Chauhan *et al.* (2018) studied the persistence of spiromesifen 22.9 SC in/on Cucumber (*Cucumis sativus*) under field conditions and reported that the initial deposits on cucumber fruits after two applications @ 96 and 192 g a.i. ha^{-1} were 0.47 and 0.79 mg kg^{-1} respectively, which declined and reached below determination level on the 10th day at both the doses of application. The half-lives of spiromesifen in cucumber were found 5.6 and 4.8 d at the standard and the double doses, respectively.

3. MATERIALS AND METHODS

Investigation on “Efficacy of insecticides and some biorationals against thrips and mites in/on chilli” was carried out during the year 2017-19 at Mahatma Phule Krishi Vidyapeeth (19.3491° N, 74.6461° E), Rahuri, Maharashtra. The field experiments on bio-efficacy and dissipation were conducted at MPKV, Rahuri, Ahmednagar (Dist) of Maharashtra. The laboratory studies on dissipation of insecticides were carried out at AINP on Pesticide Residues Laboratory, Department of Agricultural Entomology, M.P.K.V., Rahuri. The detailed materials used and methods followed during the experimentation are described here under.

3.1. Bio-efficacy of newer insecticides and some bio-rationals against thrips and mites on chilli

3.1.1 Preliminary lab experiment to fix the silicon dose

A preliminary laboratory experiment was conducted to determine the effective dose of silicon against chilli thrips and mites. The healthy chilli leaves were collected from the field and were used for bioassay studies. The leaves were dipped in silicon formulations of concentrations 250, 500, 750 and 1000 ppm, respectively as four treatments in two replications. The leaves were shade dried and kept in petriplate formulated as rearing chamber (Plate. 1). The known number of field collected thrips and mites were released in the treated plates separately and were observed for the effect of silicon on them. The per cent mortality was calculated based on the recorded population at 24, 48 and 72 hrs after treatment. The two concentrations with higher per cent mortality were selected for the studies on bio-efficacy in field condition.

3.1.2. Experimental details

The field experiments on ‘Efficacy of insecticides and some bio-rationals against thrips and mites in/on chilli’ were conducted during 2018-19. The soil of the experimental site was sandy loam mixed with black soil. The field was ploughed thoroughly and soil was evenly leveled. Broad bed and furrow were prepared for planting with a bed width of 1 feet and furrows of 20 cm deep and 30 cm broad. Across the furrows, irrigation water drains were formed at a spacing of 3 - 4 m and connected with main water channels. Individual lines of plants were considered as treatment with triplicates across lines. The experiment was laid out in a Randomized Block Design (RBD) (Plate. 2), with three replications. The chilli variety “*Teja-4*” was raised as per standard package of practices except the plant protection measures.

3.1.3 Insect pests

The sucking pests like thrips and mites were the major pests observed during the experimental period and since, they co-existed with spatial and temporal distributions, the trials

of bio-efficacy were conducted for thrips and mites. The details of field layout and experimentation are described below.

Insect pests of chilli selected for the study were,

1. Chilli thrips – *Scirtothrips dorsalis* (Hood)
2. Chilli yellow mite – *Polyphagotarsonemus latus* (Banks)

The first spray was applied when the insect population reached economic threshold levels (ETL) (Thrips, – 2 no./leaf, mite –1 no./cm² as given by Kumar *et al.*, 2007) and second and third sprays were given at when pest pressure develops. A total of three sprays were applied during the entire experimentation against thrips and mites. The details of trial and treatments were described in Table 1.

3.1.4 Preparation of spray solution

The measured quantity of test insecticide was mixed with small quantity of water and remaining quantity of water added was to it subsequently to make up the spray volume required for the plot. The spray solution was evenly mixed with a stick before spraying. The insecticidal requirement per litre of water was calculated by the following formula.

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

3.1.5 Insecticidal application

Test insecticides were applied using a high volume knapsack sprayer. Sprayings were undertaken during morning hours. The sprayer and the container used for preparing spray fluid were thoroughly cleaned with water before changing the insecticide and rinsed with the water.

3.1.6 Observations

Observations on insect populations *viz.*, thrips, *S. dorsalis* were recorded in five randomly tagged plants, from 3 leaves (1 from top, 1 from middle and 1 from bottom) per plant. For mites, *P. latus*, numbers of mites present in cm² on under surface of leaf were recorded. Pre count (1 day before spray) and post count (1, 3, 5, 7 and 10 days after spray) of the insects was recorded by counting the numbers and analysed as number per leaf for thrips and number of mites per cm² of leaf. Per cent reduction over control was calculated for the mean population count of 1, 3, 5, 7 and 10 DAT readings using the following formula (Flemming and Retnakaran, 1985).

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

Pre-count (1 DBT) and post-count (mean of 1, 3, 5, 7 and 10 DAT) population and per cent reduction over control (ROC) were calculated after each spray. Cumulative mean of three sprays in trial with pooled mean are presented and discussed for each recorded pests.

3.1.7. Statistical Analysis.

The observations recorded from the different treatments about studied insects were subjected to statistical analysis (RBD) to know the significance of difference among different treatments at 0.05 level of significance. The values in number were transformed into square root values ($\sqrt{x+0.5}$). The DMRT (Duncan's Multiple Range Test) was applied for the population per cent reduction values to determine the level of effectiveness of the treatments (Gomez and Gomez, 1984).

3.2 Dissipation pattern of spiromesifen in/on chilli.

The Dissipation of novel insecticide *viz.*, spiromesifen was studied in open field. The chilli var. *Teja-4* was raised using standard package of practices except insecticides application. Two foliar sprays of insecticides were given at an interval of 10 days starting from fruit initiation stage with the help of knapsack sprayer. Quantity of spray fluid required per plot was calculated by spraying untreated control plot with water. 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 below.

3.2.1 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.

3.2.2 Chemicals and Reagents

- a. Acetonitrile gradient (HPLC Grade), Avantor Performance Material Ltd., Mumbai (M.S.).
- b. Sodium sulphate anhydrous purified, SDFCL, Mumbai.
- c. Magnesium sulphate (Analytical reagent grade), Avantor Performance Material Ltd., Mumbai (M.S.).
- d. Primary Secondary Amine (PSA), Agilent Technology, Bengaluru.

Table 1: Details of trial and experimentation for the studies of bioefficacy of insecticides and biorationals against thrips and mites**a) Details of field experimentation.**

1. Year and Season	:	<i>Summer - 2018 and Rabi -2018</i>
2. Crop and Variety	:	Chilli –“ <i>Teja-4</i> ”.
3. Design	:	RBD
4. Treatment	:	Eleven
5. Replication	:	Three
6. Plot Size	:	3.6m×2.75m
7. Spacing	:	60 cm× 45cm

b) Details of insecticides and bio-rationals used in the experiment on bio-efficacy.

Sr. no.	Insecticides	Trade name	Active ingredient (g a.i. ha ⁻¹)	Formulations
1.	Fipronil 5 SC	Regent	50	800
2.	Spiromesifen 22.9 SC	Oberon	96	400
3.	Ethion 50 EC	Fosmite	750	1500
4.	Acephate 75 SP	Asataf	584	780
5.	Spirotetramat + Imidacloprid 240 SC	Movento energy	60 + 60	500
6.	Flubendamide + Thiacloprid 240 SC	Belt expert	48 + 48	500
7.	Silicon	Prosilica	1000 ppm	500
8.	Silicon	Prosilica	750 ppm	500
9.	Nimbecidine	Neemazol 10000 ppm	5ml/l	500
10.	<i>Lecanicillium lecanii</i>	Phule bugicide	2g/l (1× 10 ⁸ cfu)	500
11.	Untreated control	----	-----	----

- e. Acetone (Analytical Reagent grade), Avantor Performance Material Ltd., Mumbai (M.S.).
- f. Sodium chloride (Analytical Reagent grade), Avantor Performance Material Ltd., Mumbai (M.S.).
- g. Pesticides: Certified Reference Materials (CRMs) of pesticides were purchased from Dr. Ehrenstorfer GmbH (Augsburg, Germany) and Sigma Aldrich.

Apparatus, Equipments and Instruments used during the course of study. (Plate 4).

Apparatus/Equipment	Make	Model	Range and Accuracy
Weighing balance	Citizen	Cy-204	0.0001 to 220 gm
Weighing balance	Citizen	CTG 302-300	Min 0.02 to 300 mg
Grinder	Robot Coupe	Blixer 6 v.v.	7 L
Centrifuge	Remi	R-8-CHDLC-10151	5000 RPM
Vortex	Spinix	--	--
Deep Freezer	Sanyo	MDF-U5411	Ambient to - 40 ⁰ C
Micro Pipette	Eppendorf	--	100 to 1000 µL
Micro Pipette	Eppendorf	--	10 to 100 µL

3.2.2a Instrumental analysis.

The residue estimation of spiromesifen was carried out using high performance liquid chromatography.

3.2.2b Liquid chromatographic conditions.

Residue estimation of spiromesifen was performed using high performance liquid chromatography with auto sampler and Photo Diode Array (PDA) (Shimadzu/HPLC-LC-20AT). LC-solution was used as data analysis software. The operating parameters of the instrument are given below.

Parameters	Spiromesifen
Mobile phase	Acetonitrile : Water (90:10)
Wavelength	225nm
Flow rate	0.8ml/min
Column	RP-18, 150×4.6mm i.d 5µm
Injection volume	20µl
Retention time	5.89 min

3.2.3 Standard preparation.

a. Primary stock solution- An accurately weighed 10 mg of an individual analytical grade pesticide was dissolved in 1ml acetonitrile and the volume made to 10 ml in volumetric flask using acetonitrile as solvent to prepare the stock solution of $1000 \mu\text{g mL}^{-1}$. The expiry for stock solution is 1 year.

b. Intermediate stock solution- The stock solution of each insecticide was diluted to obtain intermediate lower concentration of $100 \mu\text{g mL}^{-1}$. They were stored in a refrigerator at -30°C . The intermediate solutions can be stored up to 6 months for their usage to proper results.

c. Working standards- From the intermediate standards, working standards of concentrations *viz.*, 0.05, 0.10, 0.25, 0.40 and 0.50 ppm were prepared. 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.

3.2.4 Method validation

Prior to pesticide application and field sample analysis, the residue analysis method was validated following the SANTE/11945/2015. Method validation is the process used to confirm that the analytical procedure employed for a specific test is suitable for its intended use. 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 in order 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) determined as three times of LOD.

b. Specificity

Specificity studies were performed by spiking the capsicum sample and reagent blank with working standards of spiromesifen at the concentration of 0.05 mg Kg^{-1} . The area of sample and reagent blank was compared with spiked matrix match area.

c. Linearity studies

Five linear concentrations ($0.05, 0.10, 0.25, 0.40$ and 0.50 mg Kg^{-1}) of working standards *i.e.*, spiromesifen 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 spiromesifen in chilli was validated by conducting recovery studies using chilli samples from control plots (insecticide free samples).

Fifteen gram of homogenized chilli samples from untreated plot was taken in 50 ml centrifuge tube in three replicates. Sample was spiked with spiromesifen at required fortification levels *i.e.* LOQ, 5×LOQ and 10×LOQ, as per method. This mixture was then shaken, in order 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 per cent recovery was calculated by using following 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 under 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.

Table 2: Treatment details for dissipation studies of insecticides.

Sr. no.	Insecticide	Dose (gm a.i. ha ⁻¹)	Formulation (gm or ml ha ⁻¹)
1	Spiromesifen 22.9 SC single dose	96	400
	Spiromesifen 22.9 SC double dose	192	800
2	Untreated control	-	-

3.2.5 Residue analysis

a. Sample collection and preparation.

Samples of chilli were collected from field from individual treatments in all the replications after second spray, in labeled polybags. Care was taken to avoid contamination by wearing hand gloves. Good marketable quality chilli fruits were collected and brought to

laboratory at regular intervals *i.e.* 0 (2 hr after spraying), 1, 3, 5, 7, 10 and 15 days after last spray from field and soil samples were collected at harvest. The chilli and soil samples collected from field were processed for extraction and clean-up using QuEChERS method (Anastassiades *et al.*, 2003) (Plate. 5).

b. Extraction and clean up procedure (QuEChERS method) for analyzing under HPLC.

For Chilli :

A representative 15 g of homogenized sample was taken in a clean 50 ml polypropylene tube and tube was kept in deep freezer for 10 min. 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 300 mg Primary Secondary Amine + 900 mg Magnesium Sulphate. Shaked vigorously for 30 Sec and centrifuged at 3500 rpm for 1.0 min to separate the solid material. 2 ml of supernatant was taken and evaporated to dryness and made up to 2.0 ml with acetonitrile for analysis (HPLC).

For Soil:

A representative of 10g soil sample was taken in a clean 50ml polypropylene tube. To this added 20ml of acetonitrile, shaken vigorously and for this added 4g of MgSO₄ and 1g 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 MgSO₄ and sonicated for 1minute. Centrifuged for 10minutes at 4000 rpm and collected 4ml supernatant from that and evaporated to nearly dryness and reconstituted residues to 1ml with cyclohexane.

c. Residue Determination

Residue estimation of spiromesifen 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,

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

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

4. RESULTS AND DISCUSSION

4.1 Bio-efficacy of insecticides and some bio-rationals against thrips and mites in/on chilli

4.1.1 Preliminary lab experiment to fix the silicon dose.

A preliminary lab experiment was conducted to fix the doses of silicon for including in the field experiment on bioefficacy. The healthy chilli leaves were dipped in different silicon concentrations *viz.*, 250, 500, 750 and 1000 ppm and used for bioassay studies. The leaves treated with silicon were shade dried and kept in petriplates which were formulated as rearing chambers in two replications. The known number of field collected thrips and mites were released into the petriplates with rearing chamber separately and observed for mortality of thrips and mites after 24, 48 and 72 hours of treatments.

The results revealed that the petriplates with 750 and 1000 ppm concentrations recorded maximum mortality of 70 and 85 per cent for thrips and 65 and 75 per cent for mites, respectively, after 72 hrs of treatment (Fig.1). The above two doses were selected for spraying in the field as treatments.

4.1.2 Bio-efficacy of insecticides and some bio-rationals against thrips.

Thrips were observed as serious pest on chilli with maximum damage which severely affected the yield of chilli. Several workers have recorded thrips, *S. dorsalis* on chillies in India (Ramakrishna ayyar, 1932; Ramakrishna ayyar and Subbiah, 1935). Thrips were mainly responsible for leaf curling (Ananthakrishnan, 1971). The losses caused by thrips and mites were estimated to the tune of 50% (Ahmed *et al.*, 1987). Patel and Gupta (1998) reported 60 to 74 per cent loss in yield of green chillies due to thrips infestation.

In the present investigation, fipronil 5 SC @ 40-50 g a.i ha⁻¹, spiromesifen 22.9 SC @ 96 g a.i. ha⁻¹, ethion 50 EC @ 750 g a.i. ha⁻¹, acephate 75 SP @ 584 g a.i. ha⁻¹, spirotetramat + imidacloprid 240 SC @ 60 + 60 g a.i. ha⁻¹, flubendamide + thiacloprid 240 SC @ 48 + 48 g a.i. ha⁻¹) and biorationals (nimbecidine @ 5 ml/l and *Lecanicillium lecanii* @ 2 g/l, and silicon with concentrations of 1000 ppm and 750 ppm) were used as treatments in three replications and evaluated for efficacy against thrips on chilli.

The sprays were given at when the pest pressure developed. Pre-count was recorded a day before treatment (DBT) and observations were recorded 1, 3, 5, 7 and 10 days after treatment (DAT) to know the efficacy of insecticides. The mean surviving population was worked out to determine the effectiveness of chemical and it is also used to calculate the per cent reduction over control. The treatment which recorded lowest number of thrips or highest per cent of thrips control was recorded as the most effective treatment.

4.1.2.1 First season

First spray

The data pertaining to efficacy of insecticides and some bio-rationals against thrips are presented in the Table 3. The thrips population recorded at a day before treatment (DBT) ranged between 5.78 to 6.18 thrips per leaf and there was no significant difference between the treatments.

It could be seen that all the insecticidal treatments were significantly superior over untreated control (6.18/leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was superior among the tested insecticides with the least population (2.02/leaf) followed by fipronil @ 50 g a.i. ha⁻¹ (2.27/leaf) and ethion @ 750 g a.i. ha⁻¹ (2.40/leaf) to which it was on par. Among biopesticides, nimbecidine @ 5ml/l (3.87/leaf) followed by *Lecanicillium lecanii* @ 2g/l (4.62/leaf) and among silicon treatments, silicon @ 1000 ppm (4.09/leaf) was found effective against thrips.

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ recorded least (1.07/leaf) thrips population. It was followed by fipronil @ 50 g a.i. ha⁻¹ (1.53/leaf). Next in the order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (1.71/leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹, spiromesifen @ 96 g a.i. ha⁻¹ and acephate @ 584 g a.i. ha⁻¹. Highest (6.33/leaf) population of thrips was recorded in untreated control.

Almost a similar trend of effectiveness was observed at 7DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT also by recording least (1.14/leaf) population of thrips. This was followed by fipronil @ 50 g a.i. ha⁻¹ and ethion @ 750 g a.i. ha⁻¹ which recorded 1.36 and 1.51 thrips per leaf, respectively. Untreated plots recorded higher (7.09/leaf) population of thrips.

Considering the mean population of thrips after first spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective treatment by recording least population (1.14/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ (1.44/leaf) and ethion @ 750 g a.i. ha⁻¹ (1.61/leaf). Among the biopesticides, nimbecidine @ 5ml/l recorded lowest population (3.16/leaf). Silicon @ 1000 ppm (3.64/leaf) was more effective than silicon @ 750 ppm (4.14/leaf).

The data also indicated that the higher per cent reduction over control of population was observed in plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (82.72%) followed by fipronil @ 50 g a.i. ha⁻¹ (78.18%) and ethion @ 750 g a.i. ha⁻¹ (75.60%). Among biopesticides, nimbecidine @ 5 ml/l (52.12%) was found to be effective followed by *L. lecanii*

Table 3: Evaluation of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli (summer, 2018 – 1st spray)

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of thrips per leaf (nymphs and adult)					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	6.02 (2.55)	2.27 (1.66)	1.53 (1.43)	0.60 (1.05)	1.36 (1.36)	1.44 (1.39)	78.18 ^b
T ₂	Spiromesifen 22.9 SC	96	5.87 (2.52)	3.38 (1.97)	2.40 (1.70)	1.64 (1.46)	2.40 (1.70)	2.45 (1.72)	62.87 ^d
T ₃	Ethion 50 EC	750	5.80 (2.51)	2.40 (1.70)	1.71 (1.49)	0.84 (1.16)	1.51 (1.42)	1.61 (1.45)	75.60 ^{bc}
T ₄	Acephate 75 SP	584	6.00 (2.55)	3.60 (2.02)	2.73 (1.80)	2.16 (1.58)	2.62 (1.77)	2.77 (1.80)	58.48 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	6.13 (2.58)	2.02 (1.59)	1.07 (1.25)	0.33 (0.91)	1.14 (1.25)	1.14 (1.28)	82.72 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	5.93 (2.54)	2.78 (1.81)	1.93 (1.56)	1.20 (1.30)	1.76 (1.50)	1.92 (1.56)	70.90 ^c
T ₇	Silicon	1000ppm	5.78 (2.51)	4.09 (2.14)	3.64 (2.04)	3.20 (1.95)	3.53 (2.01)	3.64 (2.03)	44.84 ^g
T ₈	Silicon	750 ppm	6.18 (2.58)	4.67 (2.27)	4.20 (2.17)	3.78 (2.07)	3.93 (2.11)	4.14 (2.15)	37.27 ^h
T ₉	Nimbecidine	5ml/l	6.02 (2.55)	3.87 (2.09)	3.20 (1.92)	2.67 (1.78)	2.91 (1.85)	3.16 (1.91)	52.12 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	6.00 (2.55)	4.62 (2.26)	4.18 (2.16)	3.68 (2.04)	3.60 (2.02)	4.02 (2.13)	39.09 ^h
T ₁₁	Untreated control	---	5.96 (2.54)	6.11 (2.57)	6.33 (2.61)	6.87 (2.71)	7.09 (2.73)	6.6 (2.66)	-----
S.Em ±			NS	0.058	0.046	0.028	0.036	0.027	1.409
CD @ 5%			NS	0.170	0.135	0.146	0.107	0.079	4.156

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

(39.09%). Silicon @ 1000 ppm (44.84%) was found to be effective followed by silicon @ 750 ppm (37.27%).

Second spray

After second spray (Table 4), it could be seen that population of thrips recorded, at a day before treatment (DBT) ranged between 2.31 to 7.22 thrips per leaf. All the insecticidal treatments were significantly superior over untreated control (7.53/leaf) at 1DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective among tested insecticides by recording least population of thrips (1.03/leaf). It was followed by fipronil @ 50 g a.i. ha⁻¹ (1.28/leaf) to which it was on par. Next in order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (1.76/leaf) and flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (1.93/leaf).

Almost a similar trend of effectiveness was observed at 3 and 7 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT by recording least population (0.52/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ (1.00/leaf) and ethion @ 750 g a.i. ha⁻¹ (1.23/leaf). Among biopesticides, nimbecidine @ 5ml/l found effective as compared to *L. lecanii* @ 2g/l. untreated plots recorded higher (7.96/leaf) population of thrips.

Considering the mean population of thrips after second spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective insecticide followed by fipronil @ 50 g a.i. ha⁻¹. Ethion @ 750 g a.i. ha⁻¹, flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹, spiromesifen @ 96 g a.i. ha⁻¹ and acephate @ 584 g a.i. ha⁻¹ were next to follow in the order of effectiveness. Among biopesticides, nimbecidine @ 5ml/l has found effective by recording less population (2.32/leaf) followed by silicon @ 1000 ppm (2.39/leaf).

The data also indicated that the higher per cent reduction over control of thrips population was observed in spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (93.12%). This was followed by fipronil @ 50 g a.i. ha⁻¹ (89.09%) and ethion @ 750 g a.i. ha⁻¹ (84.19%). Next in the order of effectiveness were flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (80.96%) and spiromesifen @ 96 g a.i. ha⁻¹ (78.19%). Among biorationals nimbecidine @ 5ml/l (70.00%) and silicon @ 1000 ppm (69.16%) were performed better.

Third spray

The data pertaining to efficacy of insecticides and some bio-rationals against thrips are presented in the Table 5. The thrips population recorded, at a day before treatment (DBT) ranged

Table 4: Evaluation of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli (summer, 2018 - 2nd spray)

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of thrips per leaf (Nymphs and adults)					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	2.53 (1.74)	1.28 (1.33)	0.66 (1.08)	0.44 (0.97)	1.00 (1.22)	0.84 (1.16)	89.09 ^b
T ₂	Spiromesifen 22.9 SC	96	3.24 (1.94)	2.09 (1.61)	1.56 (1.43)	1.38 (1.37)	1.73 (1.49)	1.69 (1.48)	78.19 ^{de}
T ₃	Ethion 50 EC	750	2.89 (1.84)	1.76 (1.50)	1.07 (1.25)	0.84 (1.16)	1.23 (1.32)	1.23 (1.32)	84.19 ^c
T ₄	Acephate 75 SP	584	3.51 (2.00)	2.56 (1.75)	1.88 (1.54)	1.62 (1.46)	2.00 (1.58)	2.01 (1.58)	74.00 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	2.31 (1.68)	1.03 (1.24)	0.42 (0.96)	0.16 (0.81)	0.52 (1.01)	0.53 (1.01)	93.12 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	3.00 (1.87)	1.93 (1.56)	1.33 (1.35)	1.04 (1.24)	1.60 (1.45)	1.47 (1.40)	80.96 ^{cd}
T ₇	Silicon	1000ppm	3.98 (2.12)	2.91 (1.85)	2.24 (1.66)	2.07 (1.60)	2.33 (1.68)	2.39 (1.70)	69.16 ^f
T ₈	Silicon	750 ppm	4.24 (2.18)	3.44 (1.99)	3.18 (1.92)	2.76 (1.80)	2.96 (1.86)	3.08 (1.89)	60.26 ^h
T ₉	Nimbecidine	5ml/l	3.78 (2.07)	2.84 (1.83)	2.20 (1.64)	1.98 (1.57)	2.26 (1.66)	2.32 (1.68)	70.00 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	4.09 (2.12)	3.82 (2.08)	3.60 (2.02)	3.42 (1.98)	3.74 (2.06)	3.64 (2.03)	52.96 ⁱ
T ₁₁	Untreated control	---	7.22 (2.79)	7.53 (2.83)	7.69 (2.86)	7.78 (2.88)	7.96 (2.91)	7.75 (2.87)	-----
S.Em ±			0.104	0.040	0.049	0.053	0.045	0.091	1.140
CD @ 5%			0.307	0.114	0.145	0.157	0.133	0.270	3.363

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

Between 1.24 to 7.80 thrips per leaf.

It could be seen that all the insecticidal treatments were significantly superior over untreated control (7.76/leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was significantly superior among the tested insecticides with least population (0.36/leaf) followed by fipronil @ 50 g a.i. ha⁻¹ (1.06/leaf) and ethion @ 750 g a.i. ha⁻¹ (1.80/leaf). Among biorationals, nimbecidine @ 5ml/l was promising (2.52/leaf) followed by *L. lecanii* @ 2g/l (3.60/leaf) and silicon @ 1000 ppm (2.46/leaf) was found effective against thrips.

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ recorded least (0.20/leaf) thrips population followed by fipronil @ 50 g a.i. ha⁻¹ (0.52/leaf). Next in order of effectiveness was ethion @ 750 g a.i. ha⁻¹ (0.80/leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and spiromesifen @ 96 g a.i. ha⁻¹. Highest (7.84/leaf) population of thrips was recorded in control.

Almost a similar trend of effectiveness was observed at 7 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT also by recording least population of thrips (0.26/leaf). This was followed by fipronil 50 g a.i. ha⁻¹ and ethion @ 750 g a.i. ha⁻¹ which recorded 0.40 and 1.00 thrips per leaf, respectively. Untreated plots recorded higher (8.11/leaf) population of thrips.

Considering the mean population of thrips after first spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective treatment by recording least population (0.22/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ (0.54/leaf) and ethion @ 750 g a.i. ha⁻¹ (0.99/leaf). Among the biorationals, nimbecidine @ 5ml/l recorded lowest population (2.22/leaf) followed by *L. lecanii* @ 2g/l (3.31/leaf) and silicon @ 1000 ppm (2.21/leaf).

The data indicated that the higher per cent reduction over control of population was observed in plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (97.15%) followed by fipronil @ 50 g a.i. ha⁻¹ (93.11%) and ethion @ 750 g a.i. ha⁻¹ (89.07%). Among biorationals, nimbecidine @ 5ml/l (71.96%) was found effective followed by *L. lecanii* @ 2g/l (58.17%) and silicon @ 1000 ppm (72.09%).

4.1.2.2. Second season

First spray

The data pertaining to efficacy of insecticides and some bio-rationals against thrips are presented in the Table 6. The thrips population recorded, at a day before treatment (DBT) ranged

Table 5: Evaluation of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli (summer, 2018 - 3rd spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of thrips per leaf (Nymphs and adults)					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	1.47 (1.40)	1.06 (1.25)	0.52 (1.01)	0.20 (0.84)	0.40 (0.95)	0.54 (1.12)	93.11 ^b
T ₂	Spiromesifen 22.9 SC	96	2.20 (1.64)	1.80 (1.52)	1.52 (1.42)	1.26 (1.33)	1.72 (1.49)	1.50 (1.41)	80.11 ^c
T ₃	Ethion 50 EC	750	1.69 (1.48)	1.18 (1.30)	0.80 (1.14)	0.48 (0.99)	1.00 (1.22)	0.99 (1.22)	89.07 ^c
T ₄	Acephate 75 SP	584	2.60 (1.76)	2.20 (1.64)	1.80 (1.52)	1.48 (1.41)	1.82 (1.52)	1.82 (1.52)	76.95 ^{ef}
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	1.24 (1.32)	0.36 (0.93)	0.20 (0.84)	0.08 (0.76)	0.26 (0.87)	0.22 (0.85)	97.15 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	1.87 (1.54)	1.40 (1.38)	1.18 (1.30)	0.86 (1.17)	1.32 (1.35)	1.19 (1.30)	84.96 ^d
T ₇	Silicon	1000ppm	2.80 (1.82)	2.46 (1.72)	2.12 (1.62)	1.88 (1.54)	2.38 (1.70)	2.21 (1.65)	72.09 ^f
T ₈	Silicon	750 ppm	3.33 (1.96)	2.96 (1.86)	2.60 (1.76)	2.31 (1.68)	2.64 (1.77)	2.63 (1.77)	66.80 ^g
T ₉	Nimbecidine	5ml/l	2.72 (1.79)	2.52 (1.74)	2.26 (1.66)	2.00 (1.58)	2.10 (1.61)	2.22 (1.66)	71.96 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	3.88 (2.09)	3.60 (2.02)	3.42 (1.98)	3.20 (1.92)	3.03 (1.88)	3.31 (1.95)	58.17 ^h
T ₁₁	Untreated control	---	7.80 (2.88)	7.76 (2.87)	7.84 (2.89)	7.96 (2.91)	8.11 (2.93)	7.92 (2.90)	-----
S.Em ±			0.046	0.056	0.040	0.042	0.051	0.027	1.285
CD @ 5%			0.136	0.164	0.118	0.123	0.150	0.078	3.790

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

from 5.31 to 5.98 thrips per leaf and there was no significant difference between the treatments.

It could be seen that all the insecticidal treatments were significantly superior over untreated control (6.00/leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was significantly superior among the tested insecticides with least population (1.80/leaf) followed by fipronil @ 50 g a.i. ha⁻¹ (2.40/leaf) and ethion @ 750 g a.i. ha⁻¹ (2.80/leaf). Among biorationals, nimbecidine @ 5ml/l (3.96/leaf) was superior followed by *L. lecanii* @ 2g/l (4.00/leaf) and silicon @ 1000 ppm (4.00/leaf).

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ recorded least (1.00/leaf) thrips population followed by fipronil @ 50 g a.i. ha⁻¹ (1.40/leaf) to which it was on par. Next in the order of effectiveness was ethion @ 750 g a.i. ha⁻¹ (1.84/leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and spiromesifen @ 96 g a.i. ha⁻¹. Highest (6.35/leaf) population of thrips was recorded in untreated control.

Almost a similar trend of effectiveness was observed at 7 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained superiority even at 10 DAT by recording least (1.44/leaf) population of thrips. This was followed by fipronil @ 50 g a.i. ha⁻¹ and ethion @ 750 g a.i. ha⁻¹ recorded 1.80 and 2.27 thrips per leaf, respectively. Untreated plots recorded higher (7.11/leaf) population of thrips.

Considering the mean population of thrips after first spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ combination was the most effective treatment by recording the least population (1.21/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ (1.60/leaf) and ethion @ 750 g a.i. ha⁻¹ (2.06/leaf). Nimbecidine @ 5ml/l (3.32/leaf) and silicon @ 1000 ppm (3.59/leaf) proved more effective among the biorationals.

The data also indicated that the higher per cent reduction over control of population was observed in plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (81.49 %) followed by fipronil @ 50 g a.i. ha⁻¹ (74.92%) and ethion @ 750 g a.i. ha⁻¹ (68.50%). Among biorationals, nimbecidine @ 5ml/l (49.23%) was found effective followed by *L. lecanii* @ 2g/l (46.48%), silicon @ 1000 ppm (45.10 %).

Second spray

It could be seen that (Table 7) population of thrips recorded, at a day before treatment (DBT) ranged from 3.22 to 7.40 thrips per leaf. All the insecticidal treatments were significantly superior over untreated control (7.62/leaf) at 1DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective treatment among tested insecticides by recording least population (1.20/leaf). It

Table 6: Evaluation of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli (Rabi, 2018- 1st spray).

Treatment details		Dose (g or ml a.i.ha ⁻¹)	Number of thrips per leaf (Nymphs and adults)					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	5.56 (2.46)	2.40 (1.70)	1.40 (1.38)	0.98 (1.22)	1.80 (1.52)	1.64 (1.46)	74.92 ^b
T ₂	Spiromesifen 22.9 SC	96	5.89 (2.53)	3.51 (2.00)	2.76 (1.80)	2.00 (1.58)	2.71 (1.79)	2.74 (1.80)	58.10 ^{de}
T ₃	Ethion 50 EC	750	5.96 (2.54)	2.80 (1.82)	1.84 (1.53)	1.31 (1.35)	2.27 (1.66)	2.06 (1.60)	68.50 ^{bc}
T ₄	Acephate 75 SP	584	5.82 (2.51)	3.60 (2.02)	2.98 (1.86)	2.42 (1.71)	3.07 (1.89)	3.02 (1.88)	53.82 ^{ef}
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	5.47 (2.44)	1.80 (1.52)	1.00 (1.22)	0.60 (1.05)	1.44 (1.39)	1.21 (1.31)	81.49 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	5.71 (2.49)	3.11 (1.90)	2.31 (1.68)	1.76 (1.50)	2.51 (1.74)	2.42 (1.71)	62.99 ^{cd}
T ₇	Silicon	1000 ppm	5.31 (2.41)	4.00 (2.12)	3.80 (2.07)	3.13 (1.91)	3.44 (1.99)	3.59 (2.02)	45.10 ^g
T ₈	Silicon	750 ppm	5.69 (2.49)	4.80 (2.30)	4.40 (2.21)	4.00 (2.12)	3.84 (2.08)	4.26 (2.18)	34.86 ^h
T ₉	Nimbecidine	5ml/l	5.96 (2.54)	3.96 (2.11)	3.38 (1.97)	2.80 (1.82)	3.16 (1.91)	3.32 (1.96)	49.23 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	5.98 (2.55)	4.00 (2.22)	3.80 (2.14)	3.13 (2.04)	3.07 (1.89)	3.50 (2.00)	46.48 ^h
T ₁₁	Untreated control	---	5.80 (2.51)	6.00 (2.55)	6.35 (2.62)	6.71 (2.69)	7.11 (2.76)	6.54 (2.65)	-----
S.Em ±			NS	0.082	0.064	0.083	0.068	0.037	2.14
CD @ 5%			NS	0.242	0.190	0.224	0.179	0.109	6.35

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

Table 7: Evaluation of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli (Rabi, 2018- 2nd spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of thrips per leaf (Nymphs and adults)					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	3.29 (1.95)	1.51 (1.42)	1.09 (1.26)	.67 (1.08)	1.33 (1.35)	1.15 (1.28)	85.88 ^b
T ₂	Spiromesifen 22.9 SC	96	3.67 (2.04)	2.20 (1.64)	1.96 (1.57)	1.58 (1.44)	2.42 (1.71)	2.04 (1.59)	74.97 ^{de}
T ₃	Ethion 50 EC	750	3.44 (1.99)	1.76 (1.50)	1.42 (1.39)	0.98 (1.22)	1.73 (1.49)	1.47 (1.40)	81.96 ^{bc}
T ₄	Acephate 75 SP	584	3.91 (2.10)	2.62 (1.77)	2.33 (1.68)	1.98 (1.57)	2.67 (1.78)	2.40 (1.70)	70.55 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	3.22 (1.93)	1.20 (1.30)	0.60 (1.05)	0.27 (0.88)	1.00 (1.22)	0.77 (1.13)	90.55 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	3.98 (2.12)	1.98 (1.57)	1.67 (1.47)	1.20 (1.30)	2.00 (1.58)	1.71 (1.49)	79.01 ^{cd}
T ₇	Silicon	1000 ppm	4.00 (2.12)	3.27 (1.94)	2.91 (1.85)	2.69 (1.79)	3.60 (2.02)	3.12 (1.90)	61.71 ^{fg}
T ₈	Silicon	750 ppm	4.16 (2.16)	3.44 (1.99)	3.20 (1.92)	2.84 (1.83)	3.76 (2.06)	3.31 (1.95)	59.38 ^g
T ₉	Nimbecidine	5ml/l	3.98 (2.12)	2.98 (1.86)	2.67 (1.78)	2.27 (1.66)	2.93 (1.85)	2.71 (1.79)	66.74 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	4.20 (2.17)	3.89 (2.09)	3.56 (2.01)	3.18 (1.92)	2.84 (1.83)	3.37 (1.97)	58.65 ^g
T ₁₁	Untreated control	---	7.40 (2.81)	7.62 (2.85)	8.11 (2.93)	8.27 (2.96)	8.60 (3.02)	8.15 (2.94)	----
S.Em ±			0.081	0.067	0.065	0.044	0.052	0.034	1.51
CD @ 5%			0.239	0.198	0.191	0.130	0.154	0.101	4.48

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

was followed by fipronil @ 50 g a.i. ha⁻¹ (1.51/leaf), which was on par. Next in order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (1.76/leaf) and flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (1.98/leaf).

Almost similar trend of effectiveness was observed at 3 and 7 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT by recording least thrips population (1.00/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ (1.33/leaf) and ethion @ 750 g a.i. ha⁻¹ (1.73/leaf). Among biorationals, *L. lecanii* @ 2g/l was found effective compared to nimbecidine @ 5ml/l. However, untreated plots recorded higher (8.60/leaf) population of thrips.

Considering the mean population of thrips after second spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ combination was the most effective followed by fipronil @ 50 g a.i. ha⁻¹. Ethion @ 750 g a.i. ha⁻¹, flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and spiromesifen @ 96 g a.i. ha⁻¹ were the next to follow in the order of effectiveness. Among the biorationals, nimbecidine @ 5ml/l was found effective by recording less population (2.71/leaf) and among silicon treatments, silicon @ 1000 ppm was found effective (3.12/leaf) followed by silicon @ 750 ppm (3.31/leaf).

The data also indicated that the higher per cent reduction over control of thrips population was observed in spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (90.55%). This was followed by fipronil @ 50 g a.i. ha⁻¹ (85.88%) and ethion @ 750 g a.i. ha⁻¹ (81.96%). Next in the order of effectiveness were flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (79.01%) and spiromesifen @ 96 g a.i. ha⁻¹ (74.97%). Nimbecidine @ 5ml/l (66.74%) and silicon @ 1000 ppm (61.71%) were effective among biorationals.

Third spray

The data pertaining to efficacy of insecticides and some bio-rationals against thrips are presented in the Table 8. The thrips population recorded, at a day before treatment (DBT) ranged between 1.47 to 8.58 thrips per leaf.

It could be seen that all the insecticidal treatments were significantly superior over untreated control (8.64/leaf) at one day after treatment (1DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was significantly superior among the tested insecticides with the least population (1.07/leaf) followed by fipronil @ 50 g a.i. ha⁻¹ (1.31/leaf) and ethion @ 750 g a.i. ha⁻¹ (21.67/leaf). Among the biorationals, nimbecidine 5ml/l (2.89/leaf) and silicon @ 1000 ppm (3.27/leaf) were found effective against thrips.

Table 8: Evaluation of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli. (Rabi, 2018 - 3rd spray).

Treatment details		Dose (g or ml a.i. ha ¹)	Number of thrips per leaf (Nymphs and adults)					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	1.87 (1.54)	1.31 (1.35)	0.87 (1.17)	0.40 (0.95)	0.69 (1.09)	0.82 (1.15)	90.64 ^b
T ₂	Spiromesifen 22.9 SC	96	2.78 (1.81)	2.24 (1.67)	1.56 (1.44)	1.22 (1.31)	1.64 (1.46)	1.66 (1.47)	80.86 ^d
T ₃	Ethion 50 EC	750	2.00 (1.58)	1.67 (1.47)	1.11 (1.27)	0.78 (1.13)	1.16 (1.29)	1.18 (1.30)	86.49 ^{bc}
T ₄	Acephate 75 SP	584	2.98 (1.86)	2.47 (1.72)	1.71 (1.49)	1.38 (1.37)	1.80 (1.52)	1.84 (1.53)	78.91 ^{de}
T ₅	Spirotetramate + Imidacloprid 240 SC	60 + 60	1.47 (1.40)	1.07 (1.25)	0.49 (0.99)	0.07 (0.75)	0.20 (0.84)	0.45 (0.97)	94.77 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	2.33 (1.68)	1.80 (1.52)	1.24 (1.32)	0.96 (1.21)	1.27 (1.33)	1.32 (1.35)	84.90 ^{cd}
T ₇	Silicon	1000 ppm	3.80 (2.07)	3.27 (1.94)	2.38 (1.70)	1.93 (1.56)	2.22 (1.65)	2.45 (1.72)	71.86 ^f
T ₈	Silicon	750 ppm	4.00 (2.12)	3.60 (2.02)	2.73 (1.80)	2.27 (1.66)	2.44 (1.72)	2.76 (1.81)	68.31 ^g
T ₉	Nimbecidine	5ml/l	3.20 (1.92)	2.89 (1.84)	2.16 (1.63)	1.67 (1.47)	2.07 (1.60)	2.19 (1.64)	74.84 ^e
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	3.47 (1.99)	3.07 (1.89)	2.62 (1.77)	2.13 (1.62)	2.07 (1.60)	2.47 (1.72)	68.62 ^f
T ₁₁	Untreated control	---	8.58 (3.01)	8.64 (3.02)	8.71 (3.03)	8.73 (3.04)	8.80 (3.05)	8.72 (3.04)	---
S.Em ±			0.058	0.043	0.046	0.041	0.040	0.017	0.640
CD @ 5%			0.170	0.126	0.135	0.122	0.119	0.051	1.887

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ biorationals, nimbecidine 5ml/l (2.89/leaf) and silicon @ 1000 ppm (3.27/leaf) were found effective against thrips recorded the least thrips population (0.49/leaf) followed by fipronil @ 50 g a.i. ha⁻¹ biorationals, nimbecidine 5ml/l (2.89/leaf) and silicon @ 1000 ppm (3.27/leaf) were found effective against thrips (0.87/leaf). Next in order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (1.11/leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and spiromesifen @ 96 g a.i. ha⁻¹. Highest (8.71/leaf) population of thrips was recorded in untreated control.

Almost a similar trend of effectiveness was observed at 7DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT by recording least population of thrips (0.20/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ and ethion @ 750 g a.i. ha⁻¹ which recorded 0.69 and 1.16 thrips per leaf, respectively. Untreated plots recorded higher (8.80/leaf) population of thrips.

Considering the mean population of thrips after first spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective by recording the least population (0.45/leaf). This was followed by fipronil @ 50 g a.i. ha⁻¹ (0.82/leaf) and ethion @ 750 g a.i. ha⁻¹ (1.18/leaf). Among the biorationals, nimbecidine @ 5ml/l and silicon @ 1000 ppm (2.45/leaf) proved more effective.

The data also indicated that the higher per cent reduction over control of population was observed in plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (94.77%) followed by fipronil @ 50 g a.i. ha⁻¹ (90.64%) and ethion @ 750 g a.i. ha⁻¹ (86.49%). Among biorationals, nimbecidine @ 5ml/l (74.84%), *L. lecanii* @ 2g/l (68.62%) and silicon @ 1000 ppm (71.86 %) were found to be effective.

4.2.1.3 Pooled data

The data pertaining to efficacy of insecticides and some bio-rationals against thrips during first and second seasons are pooled and presented in Table 9 (Fig. 2). It could be seen that all the insecticidal treatments were significantly superior over untreated control.

The pooled data of first and second seasons revealed that, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ consistently proved to be the most promising by recording the least population (0.72/leaf) of thrips. This was followed by fipronil @ 50 g a.i. ha⁻¹ (1.07/leaf) and ethion @ 750 g a.i. ha⁻¹ (1.43/leaf). Nimbecidine @ 5ml/l and silicon @ 1000 ppm were more effective among biorationals.

Superiority of spirotetramat + imidacloprid 240 SC as observed in the present investigation is

Table 9 : Efficacy of insecticides and some bio-rationals against thrips (*S. dorsalis*) on chilli (Pooled data).

Treatment details		Dose (g or ml a.i.ha-1)	Number of thrips per leaf (Nymphs and adults)								Mean	Percent reduction
			First season				Second season					
			1 st spray	2 nd spray	3 rd spray	Mean	1 st spray	2 nd spray	3 rd spray	Mean		
T ₁	Fipronil 5 SC	50	1.44 (1.39)	0.84 (1.16)	0.54 (1.12)	0.94 (1.22)	1.64 (1.46)	1.15 (1.28)	0.82 (1.15)	1.20 (1.30)	1.07 (1.26)	86.22 ^b
T ₂	Spiromesifen 22.9 SC	96	2.45 (1.72)	1.69 (1.48)	1.50 (1.41)	1.88 (1.54)	2.74 (1.80)	2.04 (1.59)	1.66 (1.47)	2.15 (1.62)	2.02 (1.58)	74.00 ^d
T ₃	Ethion 50 EC	750	1.61 (1.45)	1.23 (1.32)	0.99 (1.22)	1.28 (1.33)	2.06 (1.60)	1.47 (1.40)	1.18 (1.30)	1.57 (1.43)	1.43 (1.38)	81.60 ^c
T ₄	Acephate 75 SP	584	2.77 (1.80)	2.01 (1.58)	1.82 (1.48)	2.20 (1.62)	3.02 (1.88)	2.40 (1.70)	1.84 (1.53)	2.42 (1.70)	2.31 (1.66)	70.27 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	1.14 (1.28)	0.53 (1.01)	0.22 (0.99)	0.63 (1.09)	1.21 (1.31)	0.77 (1.13)	0.45 (0.97)	0.81 (1.14)	0.72 (1.12)	90.73 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	1.92 (1.56)	1.47 (1.40)	1.19 (1.31)	1.53 (1.42)	2.42 (1.71)	1.71 (1.49)	1.32 (1.35)	1.82 (1.52)	1.68 (1.47)	78.38 ^{cd}
T ₇	Silicon	1000 ppm	3.64 (2.03)	2.39 (1.70)	2.21 (1.61)	2.75 (1.78)	3.59 (2.02)	3.12 (1.90)	2.45 (1.72)	3.05 (1.88)	2.90 (1.83)	62.68 ^{fg}
T ₈	Silicon	750 ppm	4.14 (2.15)	3.08 (1.89)	2.63 (1.77)	3.28 (1.94)	4.26 (2.18)	3.31 (1.95)	2.76 (1.81)	3.44 (1.98)	3.36 (1.96)	56.76 ^h
T ₉	Nimbecidine	5ml/l	3.16 (1.91)	2.32 (1.68)	2.22 (1.57)	2.57 (1.72)	3.32 (1.96)	2.71 (1.79)	2.19 (1.64)	2.74 (1.80)	2.66 (1.76)	65.77 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1×10 ⁸ cfu)	4.02 (2.13)	3.64 (2.03)	3.31 (1.95)	3.65 (2.04)	3.50 (2.00)	3.37 (1.97)	2.47 (1.72)	3.11 (1.90)	3.38 (1.97)	56.47 ^h
T ₁₁	Untreated control	---	6.60 (2.66)	7.75 (2.87)	7.92 (2.90)	7.74 (2.81)	6.54 (2.65)	8.15 (2.94)	8.72 (3.04)	7.80 (2.88)	7.77 (2.85)	--
S. Em ±			0.027	0.091	0.027	0.05	0.037	0.034	0.017	0.090	0.070	0.271
CD @ 5%			0.079	0.270	0.078	0.14	0.109	0.101	0.051	0.287	0.214	0.796

Note : Figures in parentheses are $x+0.5$ transformed values,

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

due to different modes of action of both these compounds. Spirotetramat belongs to insecticide group tetrone acid derivatives which control insect pests by inhibiting lipid biosynthesis and ultimately causes the target pests to dry out and die. Imidacloprid kills the target pests by inhibiting the nicotinic acetylcholine by binding with nicotinic acetylcholine receptor.

Vikrant kumar *et al* (2015) reported that spirotetramat 120 + imidacloprid 120-240 SC @ 90 g + 90 g a.i. ha⁻¹ caused higher reduction of thrips on chilli. Similar type of studies were also conducted by Koushik *et al* (2017) who reported spirotetramat 120 + imidacloprid 120-240 SC @ 75 + 75 g a.i. ha⁻¹ as an effective insecticide against thrips.

The effectiveness of fipronil against thrips as observed in the present studies is in agreement with Kadam and Dethle (2002) at higher dose @ 60 g a.i. ha⁻¹. Fipronil is a new molecule which belongs to phenol-pyrazole group with a mode of action of blocking gamma-amino-butyric-acid (GABA) and regulating of chloride channels in insect neurons, thus antagonizing the “calming” effect of GABA. (Gavkare *et al.*,2013). Effectiveness of fipronil in controlling thrips on chilli was also reported by Vanisree *et al* (2013), Reddy *et al* (2007), Reddy and Sreehari (2009), Reddy *et al* (2007) and Mahalingappa *et al* (2008). All these reports lend support to the present findings.

In the present studies nimbecidine was effective in controlling thrips on chilli among biorationals. These findings are in corroboration with Jagdish and Purnima (2011) and Balasingam *et al* (2003). Silicon showed less effectiveness against thrips because pepper acts as a silicon neutral plant i.e., only a limited quantities of silicon was accumulated inside the leaf tissue from foliar application but it was not translocated through out the plants (Ma and Yamaji 2006).

L. lecanii @ 2g/l was found inferior in the present investigation. In contrast *L. lecanii* @ 3g/l was reported to be effective against thrips in chilli as reported by Ghatak *et al* (2009). Imidacloprid 200 SL @ 0.05 ml/l was found most effective against thrips on sunflower and recorded highest yield of 726 kg ha⁻¹ (Rathod *et al.*, 2010). All these reports lend support to the present findings.

4.1.2.3 Bioefficacy of insecticides and some bio-rationals against mites.

Among non-insect pests, the chilli mite/ broad mite/yellow mite *p. latus* is severe (Eshwar Reddy and Kumar 2006). It was reported to cause about 60% crop loss and even cause 100% loss under glass house condition (Liu *et al.*, 1991) The nymphs and adults actively feed on tender leaves causing elongation of leaf lamina, there by yield loss up to 34.14% in India (Ahmed *et al.*, 1987). Mites affected leaves become narrow and twisted resulting in downward curling (Eshwar Reddy and

Kumar, 2006) and even causing damage to reproductive buds resulting in substantial yield loss. It attacks the capsicum throughout the crop season. The annual yield loss inflicted by these mites was estimated to be around Rs. 60.69 lakh on chilli alone (Rao *et al.*, 1983).

Since, the mite pests are persistence and can buildup faster than the insects, there is a continual need for management. In this regard, application of new acaricides/insecticides with novel biochemical mode of action is needed as an option. But their use is to be optimized in order to prevent or delay the evolution of resistance and prolong the chemical life spans (Dekeyser, 2005).

4.2.2.1 First season

First spray

The data pertaining to efficacy of insecticides and some bio-rationals against mites are presented in the Table 10. The mites population recorded, at a day before treatment (DBT) ranged between 3.98 to 4.27 mites per cm^2 of leaf, which showed non-significant differences among the treatments indicating homogeneous distribution of mites in the experimental area.

It could be seen that all the insecticidal treatments were significantly superior over untreated control ($4.39/\text{cm}^2$ of leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} was superior among the tested insecticides with least population ($1.80/\text{cm}^2$ of leaf) followed by spiromesifen @ 96 g a.i. ha^{-1} ($2.09/\text{cm}^2$ of leaf) which it was on par. This was followed by ethion @ 750 g a.i. ha^{-1} ($2.36/\text{cm}^2$ of leaf). Among biorationals, nimbecidine @ 5ml/l ($3.44/\text{cm}^2$ of leaf) and silicon @ 1000 ppm ($3.67/\text{cm}^2$ of leaf) were found effective against mites.

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} recorded least mites population ($1.00/\text{cm}^2$ of leaf) followed by spiromesifen @ 96 g a.i. ha^{-1} ($1.36/\text{cm}^2$ of leaf). Next in order of effectiveness were ethion @ 750 g a.i. ha^{-1} ($1.60/\text{cm}^2$ of leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha^{-1} and fipronil @ 50g a.i. ha^{-1} . Highest population ($4.56/\text{cm}^2$ of leaf) of mites was recorded in untreated control.

Almost a similar trend of effectiveness was observed at 7DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} retained its superiority even at 10 DAT also by recording least population ($1.09/\text{cm}^2$ of leaf) of mites. This was followed by spiromesifen @ 96 g a.i. ha^{-1} and ethion @ 750 g a.i. ha^{-1} which recorded 1.22 and 1.44 mites per cm^2 of leaf, respectively. Untreated plots recorded higher population ($5.03/\text{cm}^2$ of leaf) of mites.

Considering the mean population of mites after first spray, it was revealed that spirotetramat

Table 10: Evaluation of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Summer, 2018 - 1st spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of mites per cm ²					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	4.22 (2.17)	2.91 (1.85)	2.00 (1.58)	1.40 (1.38)	1.80 (1.52)	2.03 (1.59)	56.90 ^{de}
T ₂	Spiromesifen 22.9 SC	96	4.07 (2.14)	2.09 (1.61)	1.36 (1.36)	0.64 (1.07)	1.22 (1.31)	1.33 (1.35)	71.76 ^b
T ₃	Ethion 50 EC	750	4.09 (2.14)	2.36 (1.69)	1.60 (1.45)	0.98 (1.22)	1.44 (1.39)	1.59 (1.45)	66.24 ^c
T ₄	Acephate 75 SP	584	4.20 (2.17)	3.27 (1.94)	2.44 (1.72)	1.67 (1.47)	2.00 (1.58)	2.34 (1.69)	50.31 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	3.98 (2.12)	1.80 (1.52)	1.00 (1.22)	0.47 (0.98)	1.09 (1.26)	1.09 (1.26)	76.85 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	4.27 (2.18)	2.64 (1.77)	1.84 (1.53)	1.20 (1.30)	1.67 (1.47)	1.84 (1.88)	60.93 ^d
T ₇	Silicon	1000 ppm	4.36 (2.20)	3.67 (2.04)	2.93 (1.85)	2.00 (1.58)	2.53 (1.74)	2.78 (1.81)	40.97 ^g
T ₈	Silicon	750 ppm	4.40 (2.21)	4.11 (2.15)	3.47 (1.99)	2.56 (1.75)	2.80 (1.82)	3.23 (2.24)	31.42 ^h
T ₉	Nimbecidine	5ml/l	4.20 (2.17)	3.44 (1.99)	2.87 (1.83)	1.80 (1.52)	2.07 (1.60)	2.54 (1.740)	46.07 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	4.38 (2.21)	3.93 (2.11)	3.47 (1.99)	2.87 (1.83)	2.40 (1.70)	3.17 (1.91)	32.69 ^h
T ₁₁	Untreated control	---	4.27 (2.18)	4.39 (2.21)	4.56 (2.25)	4.87 (2.30)	5.03 (2.35)	4.71 (2.28)	----
S.Em ±			NS	0.052	0.041	0.056	0.047	0.024	1.8
CD @ 5%			NS	0.152	0.121	0.166	0.125	0.072	5.35

Note: DBT: Days before treatment, DAT: Days after treatment, NS- Non-significant

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

+ imidacloprid @ 60 + 60 g a.i. ha⁻¹ was most effective treatment by recording least population (1.09/cm² of leaf) of mites. This was followed by spiromesifen @ 96 g a.i. ha⁻¹ (1.33/cm² of leaf) and ethion @ 750 g a.i. ha⁻¹ (1.59/cm² of leaf). Among the biorationals, nimbecidine @ 5ml/l (2.54/cm² of leaf) and silicon @ 1000 ppm (2.78/cm² of leaf) proved more effective.

The data also indicated that the higher per cent reduction over control of population of mites was observed in plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (76.85%) followed by spiromesifen @ 96 g a.i. ha⁻¹ (71.76%) and ethion @ 750 g a.i. ha⁻¹ (66.24%). Among biopesticides, nimbecidine @ 5ml/l (46.07%) and silicon @ 1000 ppm (40.97%) were found to be effective.

Second spray

After second spray (Table 11), it could be seen that population of mites recorded, at a day before treatment (DBT) ranged between 2.33 to 5.11 mites per cm² of leaf. All the insecticidal treatments were significantly superior over untreated control (5.24/cm² of leaf) at 1 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective among tested insecticides by recording the least population (1.27/cm² of leaf) and it was followed by spiromesifen @ 96 g a.i. ha⁻¹ (1.40/cm² of leaf) to which it was on par. Next in order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (1.67/cm² of leaf) and flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (1.98/cm² of leaf).

Almost a similar trend of effectiveness was observed at 3 and 7 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT by recording least population (0.78/cm² of leaf) of mites. This was followed by spiromesifen @ 96 g a.i. ha⁻¹ (1.00/cm² of leaf) and ethion @ 750 g a.i. ha⁻¹ (1.20/cm² of leaf). Among the biorationals, nimbecidine @ 5ml/l was found effective as compared to *L. lecanii* @ 2g/l. However, untreated plots recorded higher population (5.98/cm² of leaf) of mites.

Considering the mean population of mites after second spray, it was revealed that spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was the most effective insecticides followed by spiromesifen @ 96 g a.i. ha⁻¹. Ethion @ 750 g a.i. ha⁻¹, flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and fipronil @ 50 g a.i. ha⁻¹. were next to follow in the order of effectiveness. Nimbecidine @ 5ml/l (2.03/cm² of leaf) and silicon @ 1000 ppm (2.05/cm² of leaf) were effective among the biorationals.

The data also indicated that the higher per cent reduction over control of mites population was observed in spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (87.47%). This was followed by

Table 11: Evaluation of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Summer, 2018 – 2nd spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of mites per cm ²					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	2.82 (1.82)	2.09 (1.61)	1.67 (1.47)	1.13 (1.28)	1.60 (1.45)	1.62 (1.46)	71.42 ^{de}
T ₂	Spiromesifen 22.9 SC	96	2.40 (1.70)	1.40 (1.38)	1.02 (1.23)	0.44 (0.97)	1.00 (1.22)	0.97 (1.21)	82.89 ^b
T ₃	Ethion 50 EC	750	2.93 (1.85)	1.67 (1.47)	1.27 (1.33)	0.76 (1.12)	1.20 (1.30)	1.22 (1.31)	78.48 ^c
T ₄	Acephate 75 SP	584	3.11 (1.90)	2.27 (1.66)	1.82 (1.52)	1.33 (1.35)	1.73 (1.49)	1.79 (1.51)	68.43 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	2.33 (1.68)	1.27 (1.33)	0.80 (1.14)	0.27 (0.88)	0.78 (1.13)	0.78 (1.13)	87.47 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	3.00 (1.87)	1.98 (1.57)	1.44 (1.39)	0.98 (1.22)	1.36 (1.36)	1.44 (1.39)	74.60 ^d
T ₇	Silicon	1000 ppm	3.18 (1.92)	2.53 (1.74)	2.13 (1.39)	1.60 (1.22)	1.93 (1.36)	2.05 (1.39)	63.84 ^f
T ₈	Silicon	750 ppm	3.40 (1.97)	2.98 (1.87)	2.64 (1.77)	2.31 (1.68)	2.40 (1.70)	2.58 (1.75)	54.49 ^g
T ₉	Nimbecidine	5ml/l	3.36 (1.96)	2.80 (1.82)	2.07 (1.60)	1.44 (1.39)	1.82 (1.52)	2.03 (1.59)	64.15 ^{ef}
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	3.67 (2.04)	3.32 (1.95)	3.07 (1.89)	2.84 (1.83)	2.72 (1.79)	2.68 (1.78)	47.31 ^h
T ₁₁	Untreated control	---	5.11 (2.37)	5.24 (2.40)	5.67 (2.48)	5.80 (2.51)	5.98 (2.55)	5.67 (2.48)	---
S.Em ±			0.072	0.059	0.037	0.038	0.035	0.021	1.20
CD @ 5%			0.213	0.173	0.108	0.113	0.102	0.063	3.58

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

spiromesifen @ 96 g a.i. ha⁻¹ (82.89%) and ethion @ 750 g a.i. ha⁻¹ (78.48%). Next in the order of effectiveness were flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (74.60%) and fipronil @ 50 g a.i. ha⁻¹ (71.42%). Nimbecidine @ 5ml/l (64.15%) and silicon @ 1000 ppm (63.84%).

Third spray

The data pertaining to efficacy of insecticides and some bio-rationals against mites are presented in the Table 12. The mites population recorded, at a day before treatment (DBT) ranged between 1.20 to 6.00 mites per cm² of leaf.

It could be seen that all the insecticidal treatments were significantly superior over untreated control (5.98/cm² of leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was superior among the tested insecticides with least population (0.67/cm² of leaf) followed by spiromesifen @ 96 g a.i. ha⁻¹ (0.98/cm² of leaf) to which it was on par. This was followed by ethion @ 750 g a.i. ha⁻¹ (1.22/cm² of leaf). Among biorationals, nimbecidine @ 5ml/l (2.04/cm² of leaf) and silicon @ 1000 ppm (2.09/cm² of leaf) were found effective against mites.

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ recorded least (0.33/cm² of leaf) mites population followed by spiromesifen @ 96 g a.i. ha⁻¹ (0.47/cm² of leaf). Next in order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (0.73/cm² of leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and fipronil @ 50 g a.i. ha⁻¹. However, the highest population (6.04/cm² of leaf) of mites was recorded in control.

Almost a similar trend of effectiveness was observed at 7DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained its superiority even at 10 DAT also by recording least population of mites (0.42/cm² of leaf). This was followed by spiromesifen @ 96 g a.i. ha⁻¹ and ethion @ 750 g a.i. ha⁻¹ which recorded 0.69 and 0.93 mites per cm² of leaf, respectively. Untreated plots recorded higher population (6.20/ cm² of leaf) of mites.

Considering the mean population of mites after first spray, it was revealed that spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ was most effective treatment by recording least population (0.39/cm² of leaf). This was followed by spiromesifen @ 96 g a.i. ha⁻¹ (0.60/cm² of leaf) and ethion @ 750 g a.i. ha⁻¹ (0.84/cm² of leaf). Nimbecidine @ 5ml/l was (1.77/cm² of leaf) and silicon @ 1000 ppm (1.87/cm² of leaf) proved more effective among the biorationals. biorationals, nimbecidine @ 5ml/l (70.88%) and silicon @ 1000 ppm (69.34%) were found to be effective.

Table 12: Evaluation of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Summer, 2018 - 3rd spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of mites per cm ²					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	2.02 (1.59)	1.60 (1.45)	1.22 (1.31)	1.00 (1.22)	1.44 (1.39)	1.32 (1.35)	78.37 ^d
T ₂	Spiromesifen 22.9 SC	96	1.29 (1.34)	0.98 (1.22)	0.47 (0.98)	0.27 (0.88)	0.69 (1.09)	0.60 (1.05)	90.12 ^a
T ₃	Ethion 50 EC	750	1.56 (1.43)	1.22 (1.31)	0.73 (1.11)	0.49 (0.99)	0.93 (1.20)	0.84 (1.16)	86.10 ^b
T ₄	Acephate 75 SP	584	2.00 (1.58)	1.82 (1.52)	1.47 (1.40)	1.24 (1.32)	1.67 (1.47)	1.55 (1.43)	74.48 ^e
T ₅	Spirotetramate + Imidacloprid 240 SC	60 + 60	1.20 (1.30)	0.67 (1.08)	0.33 (0.91)	0.13 (0.80)	0.42 (0.96)	0.39 (0.94)	93.60 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	1.78 (1.51)	1.47 (1.40)	0.98 (1.22)	0.73 (1.11)	1.13 (1.28)	1.08 (1.26)	82.26 ^c
T ₇	Silicon	1000 ppm	2.33 (1.68)	2.09 (1.61)	1.87 (1.54)	1.51 (1.42)	2.00 (1.58)	1.87 (1.54)	69.34 ^f
T ₈	Silicon	750 ppm	2.78 (1.81)	2.44 (1.72)	2.18 (1.64)	1.91 (1.55)	2.36 (1.69)	2.22 (1.65)	63.51 ^g
T ₉	Nimbecidine	5ml/l	2.27 (1.66)	2.04 (1.60)	1.78 (1.51)	1.40 (1.38)	1.87 (1.54)	1.77 (1.51)	70.88 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	3.07 (1.89)	2.86 (1.83)	2.64 (1.77)	2.48 (1.73)	2.62 (1.77)	2.65 (1.77)	56.41 ^h
T ₁₁	Untreated control	---	6.00 (2.55)	5.98 (2.55)	6.04 (2.56)	6.11 (2.57)	6.20 (2.59)	6.08 (2.57)	---
S.Em ±			0.066	0.051	0.046	0.049	0.042	0.022	0.987
CD @ 5%			0.194	0.151	0.135	0.144	0.125	0.066	2.911

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

4.2.2.2 Second season

First spray

The data pertaining to efficacy of insecticides and some bio-rationals against mites are presented in the Table 13. The mites population recorded, at a day before treatment (DBT) ranged between 3.87 to 4.20 mites per cm^2 of leaf which showed non-significant difference among the treatments indicating homogeneous distribution of mites population in the experimental area.

It could be seen that all the insecticidal treatments were significantly superior over untreated control ($4.27/\text{cm}^2$ of leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} was superior among the tested insecticides with least population ($1.60/\text{cm}^2$ of leaf) followed by spiromesifen @ 96 g a.i. ha^{-1} ($1.68/\text{cm}^2$ of leaf) and ethion @ 750 g a.i. ha^{-1} ($1.98/\text{cm}^2$ of leaf). Among biorationals, nimbecidine @ 5ml/l ($2.89/\text{cm}^2$ of leaf) and silicon @ 1000 ppm ($3.07/\text{cm}^2$ of leaf) was found effective against mites.

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} recorded the least mites population ($0.98/\text{cm}^2$ of leaf) followed by spiromesifen @ 96 g a.i. ha^{-1} ($1.07/\text{cm}^2$ of leaf). Next in order of effectiveness were ethion @ 750 g a.i. ha^{-1} ($1.47/\text{cm}^2$ of leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha^{-1} , fipronil @ 50 g a.i. ha^{-1} and acephate @ 584 g a.i. ha^{-1} . However, highest population ($4.58/\text{cm}^2$ of leaf) of mites was recorded in untreated control.

Almost a similar trend of effectiveness was observed at 7DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} combination retained its superiority even at 10 DAT also by recording the least population ($1.02/\text{cm}^2$ of leaf) of mites. This was followed by spiromesifen @ 96 g a.i. ha^{-1} and ethion @ 750 g a.i. ha^{-1} which recorded 1.10 and 1.49 mites per cm^2 of leaf, respectively. However, untreated plots recorded higher population ($5.09/\text{cm}^2$ of leaf) of mites.

Considering the mean population of mites after first spray, it was revealed that spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} was the most effective treatment by recording least population ($1.01/\text{cm}^2$ of leaf). This was followed by spiromesifen @ 96 g a.i. ha^{-1} ($1.09/\text{cm}^2$ of leaf) and ethion @ 750 g a.i. ha^{-1} ($1.45/\text{cm}^2$ of leaf). Nimbecidine @ 5ml/l and silicon @ 1000 ppm were proved more effective among biorationals. by spiromesifen @ 96 g a.i. ha^{-1} (73.36%) and ethion @ 750 g a.i. ha^{-1} (69.27%). Among biorationals, nimbecidine @ 5ml/l (49.36%) and silicon @ 1000 ppm (45.76%) were effective.

Second spray

It could be seen (Table 14) that population of mites recorded, at a day before treatment (DBT)

Table 13: Evaluation of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Rabi,2018 - 1st spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of mites per cm ² of leaf					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	4.00 (2.12)	2.36 (1.69)	1.84 (1.53)	1.38 (1.37)	2.07 (1.60)	1.91 (1.55)	59.53 ^e
T ₂	Spiromesifen 22.9 SC	96	3.87 (2.09)	1.68 (1.48)	1.07 (1.25)	0.54 (1.02)	1.10 (1.26)	1.09 (1.26)	73.36 ^b
T ₃	Ethion 50 EC	750	4.16 (2.16)	1.98 (1.57)	1.47 (1.40)	0.89 (1.18)	1.49 (1.41)	1.45 (1.40)	69.27 ^c
T ₄	Acephate 75 SP	584	4.20 (2.17)	2.53 (1.74)	2.11 (1.62)	1.60 (1.45)	2.33 (1.68)	2.14 (1.62)	54.66 ^f
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	3.98 (2.12)	1.60 (1.45)	0.98 (1.22)	0.42 (0.96)	1.02 (1.23)	1.01 (1.23)	78.60 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	4.04 (2.13)	2.13 (1.62)	1.64 (1.46)	1.09 (1.26)	1.73 (1.49)	1.65 (1.47)	65.04 ^d
T ₇	Silicon	1000ppm	4.11 (2.15)	3.07 (1.89)	2.58 (1.75)	2.13 (1.62)	2.51 (1.74)	2.56 (1.75)	45.76 ^{gh}
T ₈	Silicon	750 ppm	3.89 (2.09)	3.56 (2.01)	3.20 (1.92)	2.89 (1.83)	3.00 (1.87)	3.16 (1.91)	33.05 ^h
T ₉	Nimbecidine	5ml/l	3.93 (2.11)	2.89 (1.84)	2.33 (1.68)	1.96 (1.57)	2.42 (1.71)	2.39 (1.70)	49.36 ^g
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	4.02 (2.13)	3.33 (1.96)	2.98 (1.86)	2.40 (1.70)	2.16 (1.63)	2.71 (1.79)	42.58 ^{gh}
T ₁₁	Untreated control	---	4.16 (2.16)	4.27 (2.18)	4.58 (2.25)	4.93 (2.33)	5.09 (2.36)	4.12 (2.17)	-----
S.Em ±			NS	0.036	0.046	0.047	0.050	0.022	1.572
CD @ 5%			NS	0.125	0.136	0.139	0.148	0.065	4.638

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

ranged between 1.31 to 5.20 mites per cm^2 of leaf. All the insecticidal treatments were significantly superior over untreated control ($5.36/\text{cm}^2$ of leaf) at 1 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} was the most effective among tested insecticides by recording least population ($0.93/\text{cm}^2$ of leaf). It was followed by spiromesifen @ 96 g a.i. ha^{-1} ($1.16/\text{cm}^2$ of leaf) to which it was on par. Next in order of effectiveness were ethion @ 750 g a.i. ha^{-1} ($1.42/\text{cm}^2$ of leaf) and flubendamide + thiacloprid @ 48 + 48 g a.i. ha^{-1} ($1.62/\text{cm}^2$ of leaf).

Almost a similar trend of effectiveness was observed at 3 and 7 DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} retained its superiority even at 10 DAT by recording least population ($0.64/\text{cm}^2$ of leaf). This was followed by spiromesifen @ 96 g a.i. ha^{-1} ($0.98/\text{cm}^2$ of leaf) and ethion @ 750 g a.i. ha^{-1} ($1.20/\text{cm}^2$ of leaf). Among biorationals, nimbecidine @ 5ml/l was found effective as compared to *Lecanicillium lecanii* @ 2g/l. However, untreated plots recorded higher ($5.80/\text{cm}^2$ of leaf) population of mites.

Considering the mean population of mites after second spray, it was revealed that spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} was the most effective insecticides followed by spiromesifen @ 96 g a.i. ha^{-1} . Ethion @ 750 g a.i. ha^{-1} and flubendamide + thiacloprid @ 48 + 48 g a.i. ha^{-1} were next to follow in the order of effectiveness. Among biorationals, nimbecidine @ 5ml/l was found effective by recording less population ($1.99/\text{cm}^2$ of leaf) and followed by silicon @ 1000 ppm ($2.22/\text{cm}^2$ of leaf).

The data also indicated that the higher per cent reduction over control of mites population was observed in spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} (89.24%). This was followed by spiromesifen @ 96 g a.i. ha^{-1} (84.95%) and ethion @ 750 g a.i. ha^{-1} (80.10%). Next in the order of effectiveness were flubendamide + thiacloprid @ 60 + 60 g a.i. ha^{-1} (76.16%) and fipronil @ 50 g a.i. ha^{-1} (72.40%), nimbecidine @ 5ml/l (64.53%) and silicon @ 1000 ppm (59.13%).

Third spray

The data pertaining to efficacy of insecticides and some bio-rationals against mites are presented in the Table 15. The mites population recorded, at a day before treatment (DBT) ranged between 1.00 to 5.82 mites per cm^2 of leaf.

It could be seen that all the insecticidal treatments were significantly superior over untreated control ($5.91/\text{cm}^2$ of leaf) at one day after treatment (1 DAT). Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha^{-1} was superior among the tested insecticides with least population ($0.66/\text{cm}^2$ of leaf) followed by spiromesifen @ 96 g a.i. ha^{-1} ($0.96/\text{cm}^2$ of leaf) to which it was on par. Among biorationals nimbecidine @ 5ml/l and silicon @ 1000 ppm ($2.33/\text{cm}^2$ of leaf) were found effective

Table 14: Evaluation of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Rabi, 2018 - 2nd spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of mites per cm ² leaf					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	2.33 (1.68)	1.87 (1.54)	1.47 (1.40)	1.18 (1.30)	1.67 (1.47)	1.54 (1.43)	72.40 ^{de}
T ₂	Spiromesifen 22.9 SC	96	1.51 (1.42)	1.16 (1.29)	0.84 (1.16)	0.40 (0.95)	0.98 (1.22)	0.84 (1.16)	84.95 ^b
T ₃	Ethion 50 EC	750	1.73 (1.49)	1.42 (1.39)	1.04 (1.24)	0.78 (1.13)	1.20 (1.30)	1.11 (1.27)	80.10 ^c
T ₄	Acephate 75 SP	584	2.56 (1.75)	2.02 (1.59)	1.73 (1.49)	1.33 (1.35)	1.84 (1.53)	1.73 (1.49)	69.00 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	1.31 (1.35)	0.93 (1.20)	0.58 (1.04)	0.24 (0.86)	0.64 (1.07)	0.60 (1.05)	89.24 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	2.00 (1.58)	1.62 (1.46)	1.27 (1.33)	1.00 (1.22)	1.44 (1.39)	1.33 (1.35)	76.16 ^d
T ₇	Silicon	1000ppm	2.93 (1.85)	2.60 (1.76)	2.24 (1.66)	1.87 (1.54)	2.20 (1.64)	2.22 (1.65)	59.13 ^g
T ₈	Silicon	750 ppm	3.33 (1.96)	3.02 (1.88)	2.73 (1.80)	2.40 (1.70)	2.62 (1.77)	2.69 (1.79)	51.80 ^h
T ₉	Nimbecidine	5ml/l	2.73 (1.80)	2.33 (1.68)	2.00 (1.58)	1.64 (1.46)	2.02 (1.59)	1.99 (1.58)	64.53 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	3.00 (1.87)	2.87 (1.83)	2.40 (1.70)	2.13 (1.62)	2.22 (1.67)	2.39 (1.70)	57.17 ^g
T ₁₁	Untreated control	---	5.20 (2.39)	5.36 (2.42)	5.47 (2.44)	5.69 (2.49)	5.80 (2.51)	5.58 (2.47)	-----
S.Em ±			0.054	0.063	0.041	0.034	0.056	0.022	1.285
CD @ 5%			0.159	0.184	0.120	0.102	0.164	0.069	3.790

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

against mites.

At 3 DAT, plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ recorded least (0.40/cm² of leaf) mites population followed by spiromesifen @ 96 g a.i. ha⁻¹ (0.64/cm² of leaf). Next in order of effectiveness were ethion @ 750 g a.i. ha⁻¹ (0.87/cm² of leaf), flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ and fipronil @ 50g a.i. ha⁻¹. However, highest population (6.02/cm² of leaf) of mites was recorded in control.

Almost a similar trend of effectiveness was observed at 7DAT. Spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ retained superiority even at 10 DAT by recording the least population of mites (0.40/cm² of leaf). This was followed by spiromesifen @ 96 g a.i. ha⁻¹ and ethion @ 750 g a.i. ha⁻¹ which recorded 0.76 and 0.98 mites per cm² of leaf, respectively. However, untreated plots recorded higher population (6.27/ cm² of leaf) of mites.

Considering the mean population of mites after first spray, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ combination was the most effective treatment by recording the least population (0.39/cm² of leaf). This was followed by spiromesifen @ 96 g a.i. ha⁻¹ (0.67/cm² of leaf) and ethion @ 750 g a.i. ha⁻¹ (0.91/cm² of leaf). Nimbecidine @ 5ml/l and silicon @ 1000 ppm (1.99/cm² of leaf) were proved more effective.

The data also indicated that the higher per cent reduction over control of population of mites was observed in plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ (93.51%) followed by spiromesifen @ 96 g a.i. ha⁻¹ (88.98%) and ethion @ 750 g a.i. ha⁻¹ (84.90%). Among biorationals, nimbecidine @ 5ml/l (69.57%) was found to be effective followed by *L. lecanii* @ 2g/l (64.30%) and silicon @ 1000 ppm (67.26%).

4.2.2.3 Pooled data

The data pertaining to efficacy of insecticides and some bio-rationals against mites during first and second seasons are pooled and presented in Table 16 (Fig. 3). It could be seen that all the insecticidal treatments were significantly superior over untreated control.

The pooled data of first and second seasons revealed that, spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ consistently proved the most promising by recording the least population (0.71/cm² of leaf). This was followed by spiromesifen @ 96 g a.i. ha⁻¹ (0.92/cm² of leaf) and ethion @ 750 g a.i. ha⁻¹ (1.19/cm² of leaf). Among biorationals, nimbecidine @ 5ml/l (2.10/cm² of leaf) and silicon @ 1000 ppm were effective.

Table 15: Evaluation of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Rabi, 2018 - 3rd spray).

Treatment details		Dose (g or ml a.i. ha ⁻¹)	Number of mites per cm ² leaf					Mean	Per cent reduction
			DBT	1 DAT	3 DAT	7 DAT	10 DAT		
T ₁	Fipronil 5 SC	50	2.07 (1.60)	1.64 (1.46)	1.38 (1.37)	1.13 (1.28)	1.38 (1.37)	1.38 (1.37)	77.30 ^{de}
T ₂	Spiromesifen 22.9 SC	96	1.47 (1.40)	0.96 (1.21)	0.64 (1.07)	0.31 (0.90)	0.76 (1.12)	0.67 (1.08)	88.98 ^b
T ₃	Ethion 50 EC	750	1.64 (1.46)	1.22 (1.31)	0.87 (1.17)	0.60 (1.05)	0.98 (1.22)	0.91 (1.19)	84.90 ^c
T ₄	Acephate 75 SP	584	2.29 (1.67)	1.93 (1.56)	1.56 (1.44)	1.29 (1.34)	1.60 (1.45)	1.59 (1.45)	73.76 ^e
T ₅	Spirotetramat + Imidacloprid 240 SC	60 + 60	1.00 (1.22)	0.66 (1.08)	0.40 (0.95)	0.12 (0.79)	0.40 (0.95)	0.39 (0.94)	93.51 ^a
T ₆	Flubendamide + Thiacloprid 240 SC	48 + 48	1.93 (1.56)	1.36 (1.36)	1.11 (1.27)	0.96 (1.21)	1.20 (1.30)	1.16 (1.29)	80.92 ^d
T ₇	Silicon	1000ppm	2.69 (1.79)	2.33 (1.68)	1.93 (1.56)	1.67 (1.47)	2.02 (1.59)	1.99 (1.58)	67.26 ^f
T ₈	Silicon	750 ppm	2.98 (1.86)	2.82 (1.82)	2.56 (1.75)	2.29 (1.67)	2.58 (1.75)	2.56 (1.75)	57.89 ^h
T ₉	Nimbecidine	5ml/l	2.56 (1.75)	2.20 (1.64)	1.80 (1.52)	1.58 (1.44)	1.82 (1.52)	1.85 (1.53)	69.57 ^f
T ₁₀	<i>Lecanicillium lecanii</i>	2g/l (1x10 ⁸ cfu)	2.60 (1.76)	2.46 (1.72)	2.24 (1.66)	1.96 (1.57)	2.12 (1.62)	2.19 (1.64)	64.30 ^g
T ₁₁	Untreated control	---	5.82 (2.51)	5.91 (2.53)	6.02 (2.55)	6.13 (2.57)	6.27 (2.60)	6.08 (2.57)	-----
S.Em ±			0.046	0.049	0.052	0.057	0.042	0.024	1.071
CD @ 5%			0.136	0.145	0.153	0.168	0.124	0.070	3.160

Note: DBT: Days before treatment, DAT: Days after treatment,

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

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

Vikrant kumar *et al* (2015) reported that spirotetramat 120 + imidacloprid 120-240 SC @ 90 g + 90 g a.i. ha⁻¹ caused higher reduction of mites on chilli. Similar type of studies were conducted by Koushik *et al* (2017) who reported that spirotetramat 120 + imidacloprid 120-240 SC @ 75 + 75 g a.i. ha⁻¹ was an effective insecticide against mites on brinjal. Targe and Kurtadikar (2003) reported that imidacloprid 17.8 SL @ 112 ml ha⁻¹ was effective in controlling chilli mites.

Spiromesifen, a tetrone acid derivative which blocks the fat synthesis and ultimately causes the target pest to dry out and die i.e., the active ingredient is a lipid biosynthesis inhibitor that prevents insect from maintaining necessary water balance (Gavkare *et al.*, 2013). It was found effective against numerous mites species and white flies (Bretschneider *et al.*, 2003). The effectiveness of spiromesifen in controlling mites was also endorsed by Kavitha *et al* (2006), Varghese and Mathew (2013) and Pathipati *et al* (2017). Nagaraju *et al* (2007) reported that spiromesifen 24 SC was the best acaricide by registering the highest dry chilli yield of 26.53q ha⁻¹. All the reports lend support to the present findings.

Table 16 : Efficacy of insecticides and some bio-rationals against mites (*P. latus*) on chilli (Pooled data).

Treatment details		Dose (g or ml a.i.ha-1)	Number of mites per cm ² of leaf								Mean	Percent reduction
			First season				Second season					
			1 st spray	2 nd spray	3 rd spray	Mean	1 st spray	2 nd spray	3 rd spray	Mean		
T₁	Fipronil 5 SC	50	2.03 (1.59)	1.62 (1.46)	1.32 (1.35)	1.66 (1.50)	1.91 (1.55)	1.54 (1.43)	1.38 (1.37)	1.61 (1.45)	1.64 (1.48)	69.51 ^d
T₂	Spiromesifen 22.9 SC	96	1.33 (1.35)	0.97 (1.21)	0.60 (1.05)	0.97 (1.46)	1.09 (1.26)	0.84 (1.16)	0.67 (1.08)	0.87 (1.17)	0.92 (1.32)	82.89 ^{ab}
T₃	Ethion 50 EC	750	1.59 (1.45)	1.22 (1.31)	0.84 (1.16)	1.22 (1.57)	1.45 (1.40)	1.11 (1.27)	0.91 (1.19)	1.16 (1.29)	1.19 (1.43)	77.88 ^b
T₄	Acephate 75 SP	584	2.34 (1.65)	1.79 (1.51)	1.55 (1.43)	1.89 (1.75)	2.14 (1.62)	1.73 (1.49)	1.59 (1.45)	1.82 (1.52)	1.86 (1.64)	65.42 ^c
T₅	Spirotetramat+ Imidacloprid 240 SC	60 + 60	1.09 (1.26)	0.78 (1.13)	0.39 (0.94)	0.75 (1.11)	1.01 (1.23)	0.60 (1.05)	0.39 (0.94)	0.67 (1.07)	0.71 (1.09)	86.80 ^a
T₆	Flubendamide + Thiacloprid 240 SC	48 + 48	1.84 (1.53)	1.44 (1.39)	1.08 (1.26)	1.45 (1.68)	1.65 (1.47)	1.33 (1.35)	1.16 (1.29)	1.38 (1.37)	1.42 (1.53)	73.60 ^c
T₇	Silicon	1000 ppm	2.78 (1.81)	2.05 (1.60)	1.87 (1.54)	2.23 (1.90)	2.56 (1.75)	2.22 (1.65)	1.99 (1.58)	2.26 (1.66)	2.25 (1.78)	58.17 ^{fg}
T₈	Silicon	750 ppm	3.23 (1.93)	2.58 (1.75)	2.22 (1.65)	2.68 (2.06)	3.16 (1.91)	2.69 (1.79)	2.56 (1.75)	2.80 (1.82)	2.74 (1.94)	49.07 ^h
T₉	Nimbecidine	5ml/l	2.54 (1.74)	2.03 (1.59)	1.77 (1.51)	2.11 (1.61)	2.39 (1.70)	1.99 (1.58)	1.85 (1.53)	2.08 (1.60)	2.10 (1.61)	60.96 ^f
T₁₀	<i>Lecanicillium lecanii</i>	2g/l (1×10 ⁸ cfu)	3.17 (1.91)	2.68 (1.78)	2.65 (1.77)	2.83 (1.82)	2.71 (1.79)	2.39 (1.70)	2.19 (1.64)	2.43 (1.71)	2.63 (1.77)	57.11 ^g
T₁₁	Untreated control	---	4.71 (2.28)	5.67 (2.48)	6.08 (2.57)	5.49 (2.44)	4.12 (2.17)	5.58 (2.47)	6.08 (2.57)	5.26 (2.40)	5.38 (2.42)	--
S. Em ±			0.024	0.021	0.022	0.022	0.022	0.020	0.028	0.020	0.028	0.021
CD @ 5%			0.072	0.063	0.066	0.067	0.065	0.070	0.076	0.070	0.076	0.070

Note : Figures in parentheses are $x+0.5$ transformed values,

In a column, per cent followed by the same alphabet do not differ significantly (P=0.05) by DMRT

4.3 Yield and cost economics of chilli (pooled)

The result pertaining to the capsicum yield and cost economics as influenced by different insecticides and biopesticides for thrips and mites management are presented in Table 17 and 18. The data indicated that yield in all the insecticides treatments were significantly higher than untreated control (1.16 t ha⁻¹).

The plots treated with spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹ registered highest yield of 2.10 t ha⁻¹ with maximum per cent increase over control (81.03%). This was followed by fipronil @ 50 g a.i. ha⁻¹ (2.02 t ha⁻¹ with 74.13% increase) and Spiromesifen @ 96 g a.i. ha⁻¹ (1.92 t ha⁻¹ with 65.51% increase), ethion @ 750 g a.i. ha⁻¹ (1.78 t ha⁻¹ with 53.44% increase). Flubendamide + thiacloprid @ 48 + 48 g a.i. ha⁻¹ (1.75 t ha⁻¹ with 50.86% increase), acephate @ 584 g a.i. ha⁻¹ (1.56 t ha⁻¹ with 34.44% increase) were next to follow in the order. Among biopesticides, the nimbecidine @ 5ml/l registered 1.53 t ha⁻¹ and (31.46% increase) followed by *L. lecanii* @ 2g/l (1.33 t ha⁻¹ with 10.34% increase) and Silicon @ 1000 ppm (1.47 t ha⁻¹ with 26.72% increase).

Table 17: Influence of synthetic insecticides and some bio-rationals on the yield of chilli (pooled)

Treatment details	Dose (g. or ml a.i. ha ⁻¹)	Yield (t ha ⁻¹)			Increase in yield over control (%)
		First season (2018)	Second season (2018)	pooled	
T ₁ Fipronil 5 SC	50	1.95	2.10	2.02	74.13
T ₂ Spiromesifen 22.9 SC	96	1.84	2.00	1.92	65.51
T ₃ Ethion 50 EC	750	1.77	1.79	1.78	53.44
T ₄ Acephate 75 SP	584	1.5	1.62	1.56	34.44
T ₅ Spirotetramat + Imidacloprid 240 SC	60 + 60	1.89	2.31	2.10	81.03
T ₆ Flubendamide + Thiacloprid 240 SC	48 + 48	1.62	1.88	1.75	50.86
T ₇ Silicon	1000 ppm	1.26	1.68	1.47	26.72
T ₈ Silicon	750 ppm	1.20	1.60	1.40	20.68
T ₉ Nimbecidine	5ml/l	1.32	1.73	1.53	31.46
T ₁₀ <i>Lecanicillium lecanii</i>	2g/l	1.06	1.50	1.33	10.34
T ₁₁ Untreated control	---	1.02	1.30	1.16	--
± S Em		0.189	0.324	0.171	1.01
CD @ 5%		0.557	0.956	0.503	2.99

Table 18 : Economics of thrips and mites control through insecticides and bio-rationals.

Sr. no.	Treatments	Quantity of insecticide required for 3 spray (g or ml ha ⁻¹)	Increased yield over control	Monetary value of the produce	Plant protection cost (Rs. ha ⁻¹)	Net profit over control	C : B Ratio
1	Fipronil 5 SC	2400	0.86	25800	7800	18000	1 : 3.30
2	Spiromesifen 22.9 SC	1200	0.76	22800	9288	13512	1 : 2.45
3	Ethion 50 EC	4500	0.62	18600	5730	12870	1 : 3.24
4	Acephate 75 SP	2340	0.40	12000	5165	6835	1 : 2.32
5	Spirotetramat + imidacloprid 240 SC	750	0.94	28200	6045	22155	1 : 4.66
6	Flubendamide + Thiacloprid 240 SC	600	0.59	17700	8880	8820	1 : 1.99
7	Silicon 1000 ppm	1800	0.31	9300	4272	5028	1 : 2.17
8	Silicon 750 ppm	1250	0.24	7200	4030	3170	1 : 1.78
9	Nimbecidine	3000	0.37	11100	7854	3246	1 : 1.41
10	<i>Lecanicillium lecanii</i>	3000	0.17	6300	4080	2220	1 : 1.32
11	Untreated control	---	---	---	---	----	-----

Fipronil 5 SC: Rs 180/100 ml , Spiromesifen 22.9 SC : Rs 484/100 ml, Ethion 50 EC: Rs 50/100 ml, Acephate 75 SP: Rs 72/100 g
 Spirotetramat + imidacloprid 240 SC: Rs 342/100 ml, Flubendamide + Thiacloprid 240 SC: Rs 450/ 50 ml, Silicon : Rs 44/100 g
 NSE 5%:Rs 1458 ltr, *Lecanicillium lecanii*: Rs.200/kg, Cost of labour: Rs.3000 (500×6), Chilli: Rs.30/kg, Sprayer rent: Rs.160/Spray.

The cost effectiveness of different insecticides and bio-rationals used during present study was assessed. The C:B ratio of different treatments ranged between 1.32 to 4.66. The highest C:B ratio of 1:4.66 was recorded in the treatment of spirotetramat + imidacloprid @ 60 + 60 g a.i. ha⁻¹. It was followed by fipronil @ 50 g a.i. ha⁻¹ (1:3.30) and ethion @ 750 g a.i. ha⁻¹ (1:3.24). Whereas, among biorational higher C:B ratio was recorded from silicon @ 1000 ppm (1:2.17) followed by silicon @ 750 ppm (1:1.78), nimbecidine @ 5ml/l (1:1.41) and *L. lecanii* @ 2g/l (1:1.32).

The present study revealed that spirotetramat + imidacloprid 240 SC and fipronil 5 SC are effective in controlling thrips. Spirotetramat + imidacloprid 240 SC and spiromesifen 22.9 SC are proved to be effective against mites. The result was probably because spirotetramat + imidacloprid 240 SC is a new molecule with two different mode of action. Vikrant kumar *et al* (2015) reported that spirotetramat 120 + imidacloprid 120-240 SC @ 90 g + 90 g a.i. ha⁻¹ caused high reduction of thrips and mites on chilli with highest marketable yield. Similar type of study conducted by Koushik *et al* (2017) reported spirotetramat 120 + imidacloprid 120-240 SC @ 75 + 75 g a.i. ha⁻¹ as an effective insecticide against thrips and mites with highest marketable yield on brinjal.

B S Rana *et al* (2016) reported that imidacloprid 350 SC @ 150 ml ha⁻¹ recorded maximum reduction of chilli thrips with highest marketable yield and ICBR (1:16.66) of chilli. The same result obtained by Sandeep kumar *et al.* (2017). Lacenta (imidacloprid + fipronil) recorded maximum reduction of thrips with highest marketable yield of chilli (Iftikhar ahmed *et al.*, 2018) and H Łabanowska (2017) reported that spirotetramat 100 SC causes maximum reduction of spider mites on apple with highest marketable yield.

4.4 Dissipation of spiromesifen 22.9 SC in chilli fruits and cropped soil

Dissipation of spiromesifen 22.9 SC was determined by conducting supervised field trial during 2018-2019, at the Instructional Farm, Post Graduate Institute, MPKV, Rahuri. Two sprays of spiromesifen 22.9 SC (@ 96 and 192 g a.i. ha⁻¹) 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 residue as explained under section 3.2.5 of the chapter 3 (material and method).

4.4.1 Method validation

Method validation refers to the process used to confirm the suitability of analytical method employed for specific test and an integral part of any good analytical procedure. Validation parameters *viz.* Linearity, LOD and LOQ, accuracy and precision were determined before analysis of chilli fruit samples.

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

4.4.1.1 Limit of Detection (LOD) and Limit of Quantification (LOQ)

Limit of Detection (LOD) of spiromesifen 22.9 SC was 0.05 mg kg^{-1} 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 chilli 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 mg kg^{-1} for tested insecticide.

4.4.1.2 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 mg kg^{-1} of spiromesifen 22.9 SC were injected in triplicate and the linearity lines were drawn (Fig. 4.). The response was linear over the range tested and R^2 value was 0.996 for spiromesifen 22.9 SC. These result indicated that method of analysis was valid method for residue determination of the tested insecticides in chilli.

4.4.1.3 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 chilli fruit samples fortified with three concentrations of spiromesifen *i.e.* 0.05, 0.25 and 0.50 mg kg^{-1} . The extraction and clean-up were performed as described earlier. Recovery of spiromesifen 22.9 SC was determined in triplicate to confirm the validity of method. The recovery percentages are presented in Table 19. The data revealed that the recovery of spiromesifen 22.9 SC on chilli and soil ranged between 89.06 to 95.86 and 86.00 to 93.96 per cent, respectively. These results indicated that the QuEChERS method is valid method for residue determination of the spiromesifen 22.9 SC in chilli fruits and soil.

The analytical method employed for the extraction and clean-up of chilli fruits was found accurate as mean recovery percentage and relative standard deviation (RSD) were within the limits prescribed by SANTE /11945/2015 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.

4.4.2 Residues of spiromesifen 22.9 SC in chilli fruits and soil

Dissipation of spiromesifen 22.9 SC was studied after two sprays at the recommended dose and doubles the recommended dose on chilli crop. The results obtained indicated that spiromesifen residue decreased with different day intervals after the application.

Table 19: Recovery of spiromesifen in chilli fruits and soil.

Substrate	Fortification level (mg/kg)	Recovery (%)				SD	RSD
		R1	R2	R3	Mean		
Chilli fruits	0.05	92.00	90.00	94.00	92.00	1.63	1.77
	0.25	86.80	89.20	91.20	89.06	1.80	2.02
	0.50	97.40	94.20	96.00	95.86	1.31	1.37
Soil	0.05	94.00	94.10	93.80	93.96	0.12	0.13
	0.25	86.00	86.40	85.60	86.00	0.33	0.38
	0.50	95.40	94.80	95.00	95.06	0.25	0.26

Note : R - Replication.

4.4.2.1 Dissipation and persistence of spiromesifen 22.9 SC in/on chilli fruits and cropped soil.

Use of insecticide for the management of insect pests in crops has become a vital strategy. The application of insecticides on crop leaves residues on food products which pose a potential risk to the health of consumers (Lindsay, 1997). The dissipation of a pesticide is the major behaviour in its environmental fate (Margi and Haith, 2009). The dissipation rate for given insecticide depends on several factors including the species cultivated (Phenology, plant characters, growth rate, pH dependency, etc.), climatic conditions (temperature, humidity, rainfall, etc.), application parameters (formulations, number of applications, penetration rate, volume of water, type of nozzle, pressure and height between the boom and the canopy, mode of action of insecticide. (Lin *et al.*, 2001; Rahman *et al.*, 2015, Minelli *et al.*, 1996; Ebert *et al.*, 1999; Fantke *et al.*, 2011;)

In the present studies on dissipation of spiromesifen 22.9 SC @ 92 and 192 g a.i. ha⁻¹, initial deposits recorded were 0.69 and 1.58 mg kg⁻¹ and were found to be below detection limit (BDL) on 10th and 15th day, respectively. The half-life (RL₅₀) values of spiromesifen 22.9 SC in chilli were 2.06 and 2.18 days,

Table 20: Dissipation of Spiromesifen in/on Chilli fruits and cropped soil.

Sampling days after second application	Untreated control				Residues (mg/kg) of Spiromesifen @ 92 gm a.i. ha ⁻¹				Residues (mg/kg) of Spiromesifen @ 192 gm a.i.ha ⁻¹			
	R1	R2	R3	Mean	R1	R2	R3	Mean	R1	R2	R3	Mean
0	ND	ND	ND	ND	0.73	0.62	0.72	0.69 (±0.061)	1.51	1.51	1.71	1.58 (±0.115)
1	ND	ND	ND	ND	0.34	0.41	0.40	0.38 (±0.038)	1.09	0.97	1.08	1.05 (±0.067)
3	ND	ND	ND	ND	0.23	0.21	0.24	0.22 (±0.015)	0.58	0.60	0.61	0.59 (±0.015)
5	ND	ND	ND	ND	0.11	0.13	0.11	0.11 (±0.012)	0.22	0.25	0.21	0.22 (±0.021)
7	ND	ND	ND	ND	0.07	0.08	0.05	0.06 (±0.015)	0.14	0.15	0.14	0.14 (±0.006)
10	ND	ND	ND	ND	BQL	BQL	BQL	BQL	0.08	0.06	0.05	0.07 (±0.012)
15	ND	ND	ND	ND	--	--	--	--	BQL	BQL	BQL	BQL
Soil	ND	ND	ND	ND	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
DT₅₀ (days)	--	--	--	--	2.06				2.18			
R²	--	--	--	--	0.987				0.985			

BQL – Below Quantification Limit i.e. , 0.05mg/kg, ND - Not Detected, DT₅₀ - Dissipation time

Table 21: Per-cent dissipation of spiromesifen in chilli fruits.

Sampling days after second application	Spiromesifen 22.9 SC		Spiromesifen 22.9 SC	
	96 g a.i. ha ⁻¹		192 g a.i. ha ⁻¹	
	Mean Residue (mg/kg)	Dissipation (%)	Mean Residue (mg/kg)	Dissipation (%)
0	0.69	--	1.58	--
1	0.38	44.00	1.05	33.54
3	0.22	68.11	0.59	62.65
5	0.11	84.00	0.22	86.07
7	0.06	91.30	0.14	91.00
10	BQL	≈100	0.07	95.50
15	--	--	BQL	≈100

*BQL – Below Quantification Limit

respectively (Table 20). The residues dissipated to 91.30 and 95.50 per cent at both the dosage of application (Table 21 and Fig. 6).

Similar types of studies were also conducted by Sharma *et al.* (2007). It was indicated that initial deposit of spiromesifen 22.9 SC were 0.69 mg kg^{-1} and 1.58 mg kg^{-1} which dissipated below detection limit on 10th and 15th day after application with half-life are 2.18 and 2.40 days for recommended and double the recommended dose, respectively. In soil, no residues were detectable 15 days after treatment. Varghese *et al.* (2011) studied the persistence of spiromesifen 22.9 SC in chilli and recorded initial deposit of 0.609 mg kg^{-1} which dissipated below detection limit on 7th day with a half-life of 2.62 days for recommended dose.

Xavier and Chandran (2016) reported initial deposits of 0.62 and 1.20 mg kg^{-1} at lower and higher doses of spiromesifen 22.9 SC on chilli and half-lives found to be 21 and 27 days, respectively. Raj *et al.* (2012) studied the dissipation and persistence of spiromesifen 22.9 SC on Okra and observed initial deposits of 0.964 and 1.819 mg kg^{-1} which dissipated below detection limit on 5th and 7th day, respectively

As reported earlier by Lekha and Mohapatra (2016) initial deposit of spiromesifen on cabbage were 0.640 and 1.549 mg kg^{-1} during 2013 and 0.723 and 1.438 mg kg^{-1} during 2014 from treatments of 125 and 250 g a.i. ha⁻¹, respectively. The soil sample analysed at harvest (30 days) was free from spiromesifen residues.

Sharma *et al.* (2007) studied the persistence and dissipation kinetics of spiromesifen in chilli @ 96 and 192 g a.i. ha⁻¹ and on cotton @ 120 and 240 g a.i. ha⁻¹. The soil samples were analysed after 15 days of treatment and no residues of spiromesifen were detected in both the soil samples. All these reports lend support to the present findings.

5. SUMMARY AND CONCLUSION

5.1 SUMMARY

5.1.1 Efficacy of insecticides and some biorationals against thrips and mites.

The experiment on 'Efficacy of insecticides and some bio-rationals against thrips and mites in/on chilli (*Capsicum annuum* L.)' were carried out during the year 2018-2019 at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The field experiment on bio-efficacy and dissipation studies were conducted at Post Graduate Institute instruction farm, M.P.K.V., Rahuri, Maharashtra. The laboratory study on dissipation of insecticide was carried out at Pesticide Residue Laboratory, Department of Agricultural Entomology, M.P.K.V., Rahuri. The obtained results are summarized in this chapter.

Bio-efficacy of insecticides and some bio-rationals revealed that spirotetramat + imidacloprid 240 SC was effective against thrips by recording least population (0.72/leaf) with higher per cent reduction (90.73%). This was followed by fipronil 5 SC (1.07/leaf with 86.22% reduction). Among biorationals, nimbecidine (2.66/leaf with 65.77% reduction) and Silicon 1000 ppm were proved effective against thrips (2.90/leaf with 62.68% reduction).

Spirotetramat + imidacloprid 240 SC was also proved effective against mites by recording least population (0.71/cm² of leaf) with per cent reduction of 86.80%. This was followed by spiromesifen 22.9 SC with a population of 0.92/cm² of leaf by recording 82.89 per cent of reduction. Among biorationals, nimbecidine (2.10/cm² of leaf with 60.96%) and silicon @ 1000 ppm was recorded lowest population (2.25/cm² of leaf with 58.17% reduction) were effective. The efficacy of spirotetramat + imidacloprid 240 SC also reflected in recording highest yield (2.10 t ha⁻¹) with highest C:B ratio of 1:4.66.

5.1.2 Dissipation of spiromesifen 22.9 SC

The most common acaricide, spiromesifen 22.9 SC is recommended on chilli to control mites. However, increased spraying of spiromesifen 22.9 SC for the control of mites which leaves the residue on crop and cropped soil. In view of this dissipation of Spiromesifen 22.9 SC was studied at recommended and double the recommended dose.

5.1.3 Recovery studies

In case of spiromesifen 22.9 SC in chilli and cropped soil the mean recovery per cent ranged between 89.06 to 95.86 and 86.00 to 95.06 per cent, respectively, which was within acceptable range (70-120%).

5.1.4 Persistence and dissipation of spiromesifen 22.9 SC

The mean initial residues of spiromesifen 22.9 SC @ 96 and 192 g a.i. ha⁻¹ in chilli fruits were 0.69 mg kg⁻¹ and 1.58 mg kg⁻¹ which dissipated to below detection limit (BDL) on 10th and 15th days after 2nd spray. The half-life values were 2.06 and 2.18 days. The residues of spiromesifen 22.9 SC were found BDL in soil at harvest at both the doses, respectively.

5.2 CONCLUSION

Spirotetramat + imidaclopid 240 SC @ 60 + 60 g a.i. ha⁻¹ was found to be the most effective and economical against thrips and mites. Next in the order of effectiveness were fipronil 5 SC @ 50 g a.i. ha⁻¹ for thrips and spiromesifen 22.9 SC @ 96 g a.i. ha⁻¹ for mites. Farmers may be advised to observe a pre-harvest interval of 7 days for spiromesifen for the production of residue free chilli.

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7. APPENDIX

Details of meteorological data during investigation period (2018).

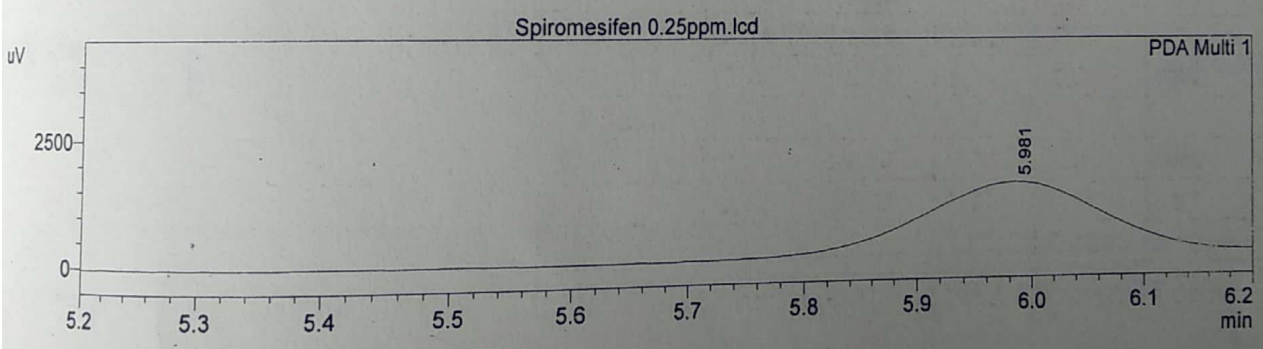
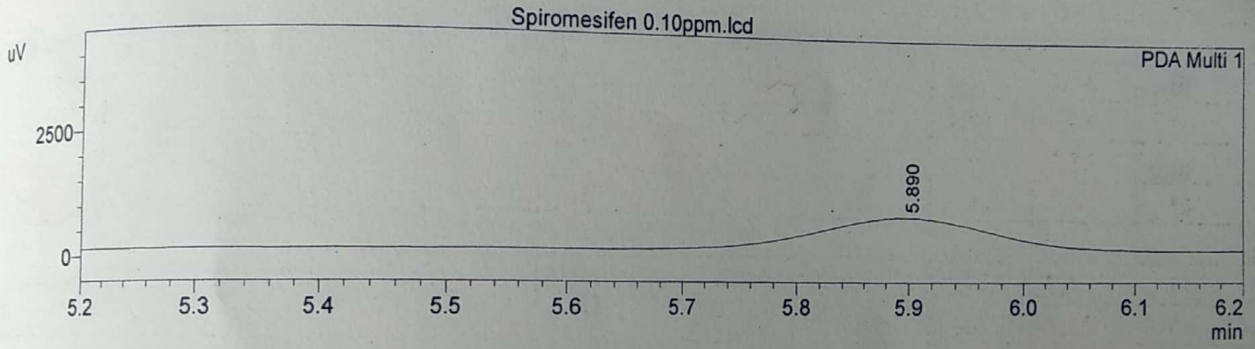
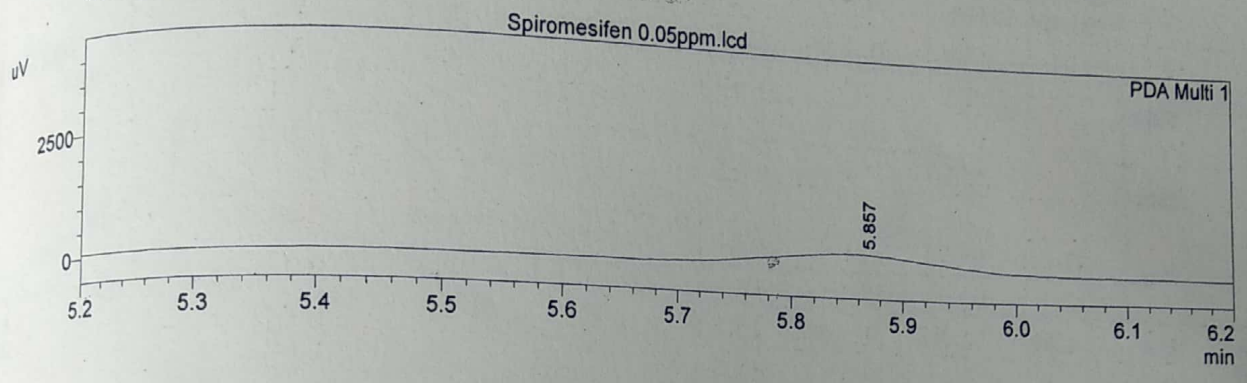
Met. Week	Temp. ($^{\circ}\text{C}$)		RH (%)		Wind velocity	Sunshine hours (hrs.)	Rain fall (mm)	Evaporati on (mm)	No. of rainy days
	Max.	Min.	Morn.	Even.	(km hr^{-1})				
Jan-18									
1	28.5	10.7	67.1	36.4	0.3	8.0	0.0	3.8	-
2	28.1	12.2	62.6	34.6	0.4	7.5	0.0	3.9	-
3	29.9	12.8	70.4	31.9	0.4	8.6	0.0	4.4	-
4	28.4	9.5	55.6	27.1	0.5	9.4	0.0	4.8	-
Feb-18									
5	30.3	10.7	59.4	21.6	0.8	9.5	0.0	5.0	-
6	31.2	13.9	53.4	22.9	1.3	7.4	0.0	5.1	-
7	30.5	13.5	66.4	33.9	0.9	9.0	0.0	5.3	-
8	33.7	15.0	53.6	24.0	0.7	8.8	0.0	6.0	-
Mar-18									
9.0	34.6	17.1	49.4	20.3	1.1	8.5	0.0	6.6	-
10.0	34.7	18.3	44.4	20.3	1.4	7.4	0.0	5.9	-
11	33.1	18.9	47.9	25.3	1.4	5.9	0.0	7.0	-
12	35.0	16.4	43.9	19.1	1.9	8.8	0.0	7.3	-
13	37.6	18.0	40.6	14.7	1.9	9.2	0.0	8.5	-
Apr-18									
14	37.5	19.9	40.1	19.4	1.8	7.9	0.0	7.5	-
15	37.3	20.0	44.0	19.6	1.6	8.8	0.0	8.5	-
16	39.3	22.3	41.3	21.3	3.6	10.0	0.1	10.5	-
17	39.4	19.7	30.1	13.6	2.2	10.8	0.0	13.0	-
May-18									
18	40.7	21.0	36.1	17.0	3.9	10.6	0.0	14.3	-
19	40.2	24.2	32.1	17.7	4.1	10.3	0.0	13.8	-
20	39.8	24.3	36.3	19.0	4.8	9.8	0.0	13.7	-
21	38.9	25.2	40.4	20.6	4.5	7.1	0.0	9.5	-
22	38.9	24.8	64.1	34.4	4.4	7.8	4.9	7.8	-
Jun-18									
23	34.2	24.6	71.9	47.3	3.7	3.8	1.6	4.8	-
24	35.3	25.0	61.9	41.7	11.6	7.8	0.0	6.1	-
25	34.1	23.4	72.4	54.1	5.5	4.8	6.1	5.3	-
26	32.1	23.0	72.7	53.3	7.7	4.8	9.1	5.0	-
Jul-18									
27	31.7	23.3	76.1	59.4	8.0	3.9	3.7	5.3	-
28	28.3	22.8	80.0	69.7	5.0	0.3	2.0	3.4	-
29	29.4	23.0	76.7	64.7	8.7	1.8	0.6	4.1	-

30	28.7	22.7	75.1	62.3	7.5	1.3	0.0	4.1	-
Aug-18									
31	31.3	23.3	71.7	53.3	7.9	4.0	0.0	5.4	-
32	30.0	23.0	75.1	62.6	6.8	1.5	0.0	5.1	-
33	27.9	22.5	80.7	72.9	4.8	0.6	8.3	3.6	-
34	27.9	21.5	80.0	70.6	5.0	3.1	3.5	3.7	-
35	29.7	21.1	74.7	61.1	3.5	5.0	0.9	4.4	-
Sep-18									
36	30.1	19.6	70.6	53.1	4.2	5.8	0.0	5.1	-
37	32.4	19.5	69.1	48.7	0.8	7.6	0.0	5.5	-
38	31.9	22.1	71.6	45.1	2.7	6.2	0.5	5.5	-
39	33.8	22.3	71.4	44.4	1.3	8.1	0.0	6.3	-
Oct-18									
40	34.0	21.5	67.3	42.9	1.3	7.8	0.0	6.3	-
41	34.0	18.4	54.7	30.1	1.6	8.8	0.0	7.1	-
42	33.5	18.6	50.0	30.3	1.3	8.2	0.0	6.6	-
43	34.4	16.8	46.0	31.1	1.0	8.5	0.0	6.7	-
Nov-18									
44	31.7	14.4	58.1	38.0	1.9	9.5	0.3	6.5	-
45	33.1	16.8	58.7	37.3	0.8	8.1	0.0	6.4	-
46	32.5	12.9	43.4	23.3	0.8	10.0	0.0	5.9	-
47	31.7	16.3	61.1	46.4	1.3	7.7	0.0	5.7	-
48	30.1	11.3	54.0	31.7	0.8	9.2	0.0	5.6	-
Dec-18									
49	30.3	15.0	60.4	35.0	0.4	6.6	0.0	4.8	-
50	28.1	11.3	54.7	31.1	0.7	8.0	0.0	4.9	-
51	26.5	9.1	64.0	36.0	0.5	9.1	0.0	4.4	-
52	27.8	9.0	51.4	29.4	0.6	8.8	0.0	4.6	-

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
Flow Rate: 0.8ml/min
Mobile Phase: ACN:Water(90:10)
Wavelength: 225nm

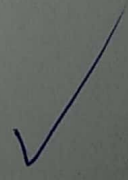
Linearity.



<< PDA >>

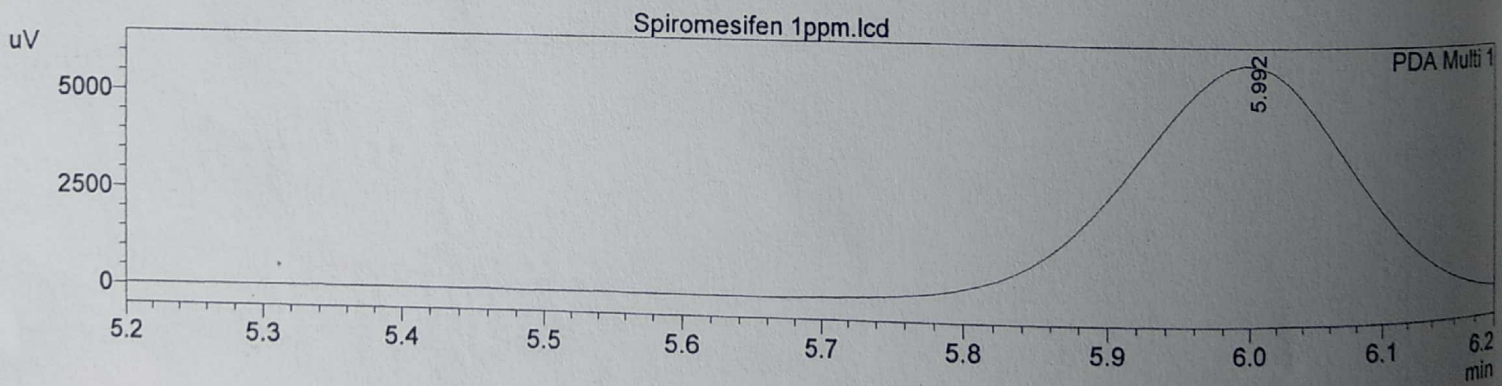
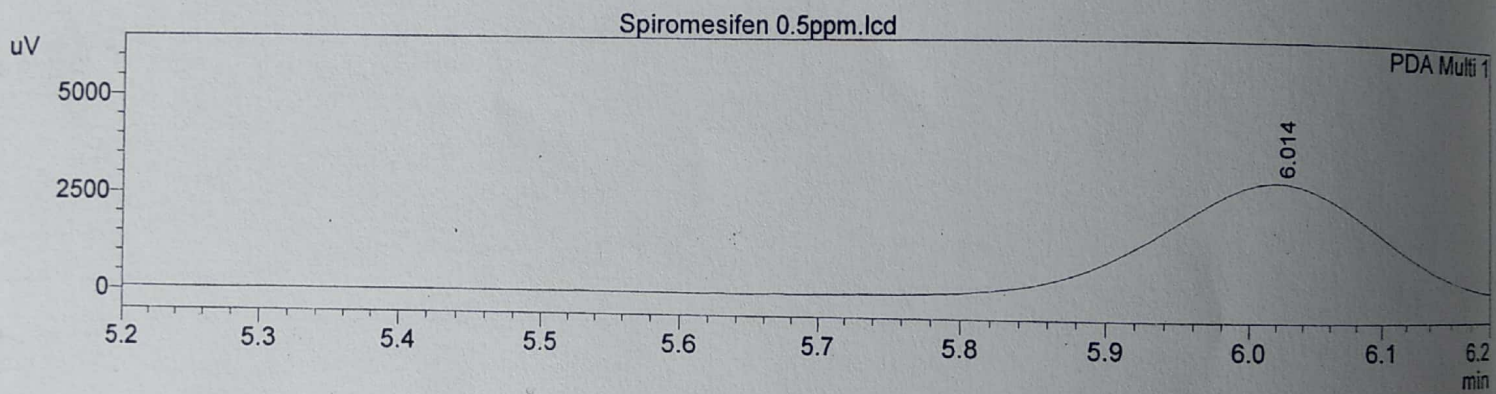
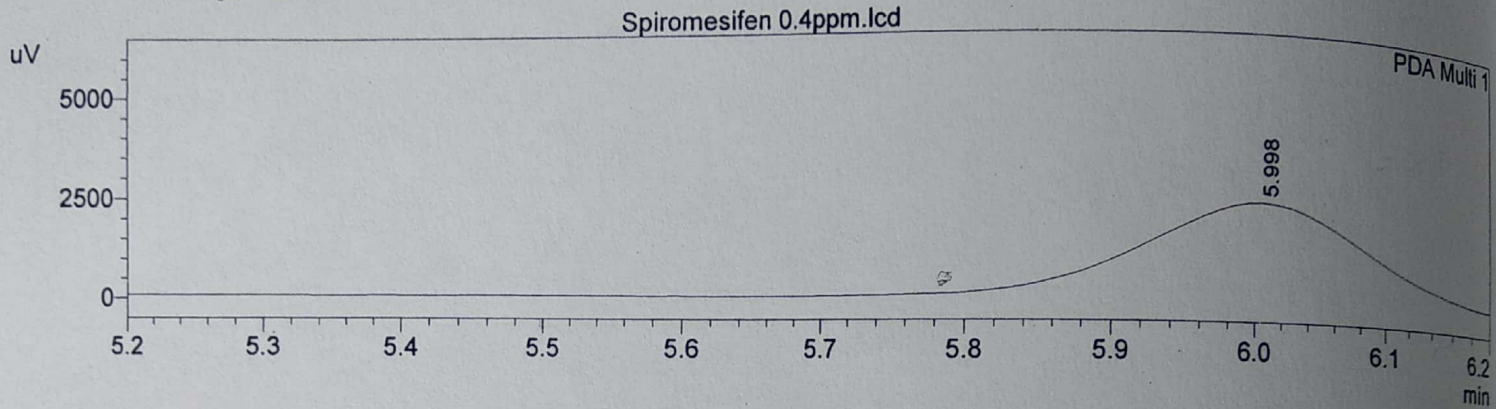
ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
Spiromesifen 0.05ppm.lcd	5.857	3743	350
Spiromesifen 0.10ppm.lcd	5.890	7401	686
Spiromesifen 0.25ppm.lcd	5.981	16755	1495



== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



<< PDA >>

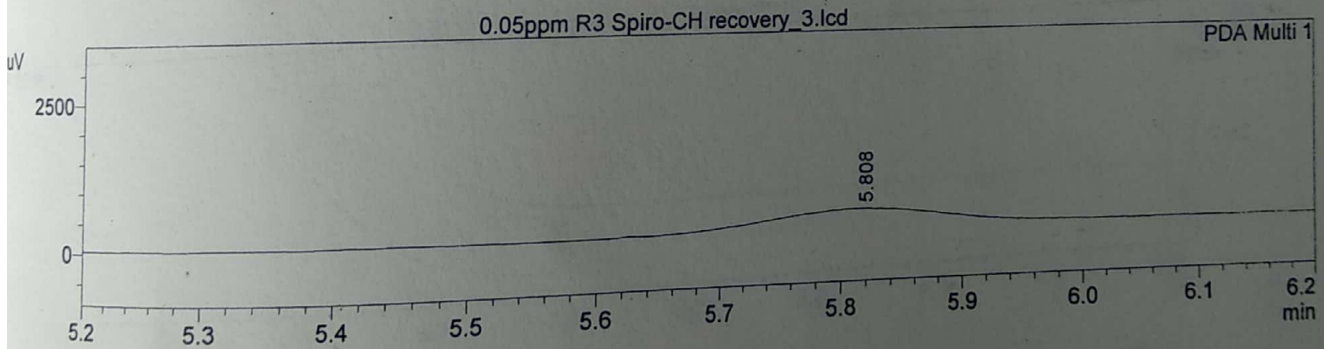
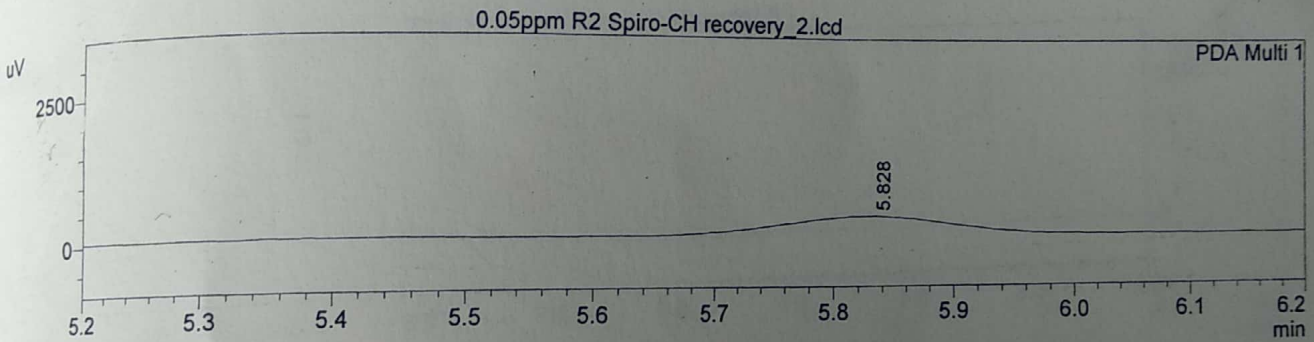
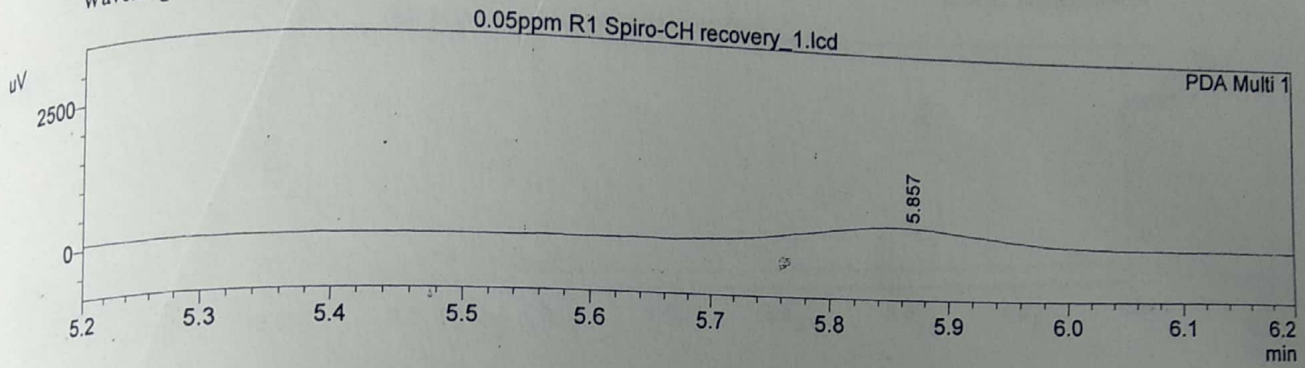
ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
Spiromesifen 0.4ppm.lcd	5.998	25874	2318
Spiromesifen 0.5ppm.lcd	6.014	33338	2935
Spiromesifen 1ppm.lcd	5.992	68352	6009



== AINP on Pesticide Residue, MPKV, Rahuri ==

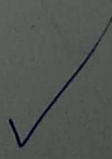
Sample Name: Spiromesifen
Flow Rate: 0.8ml/min
Mobile Phase: ACN:Water(90:10)
Wavelength: 225nm



<< PDA >>

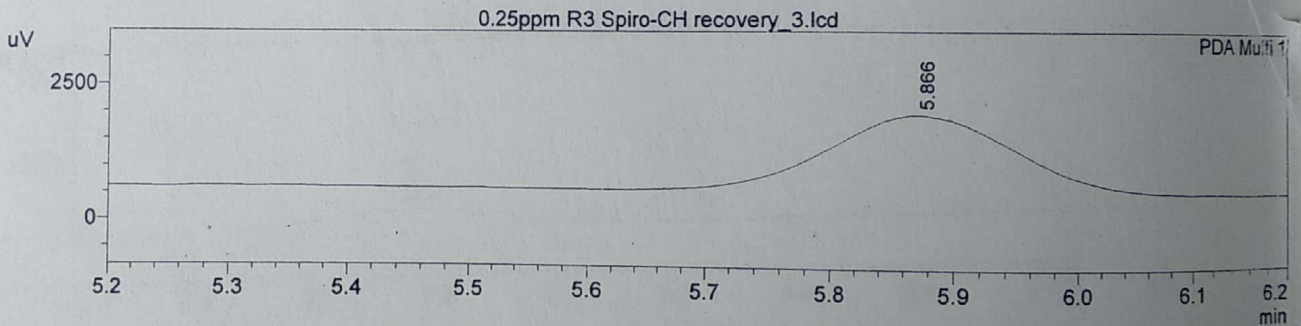
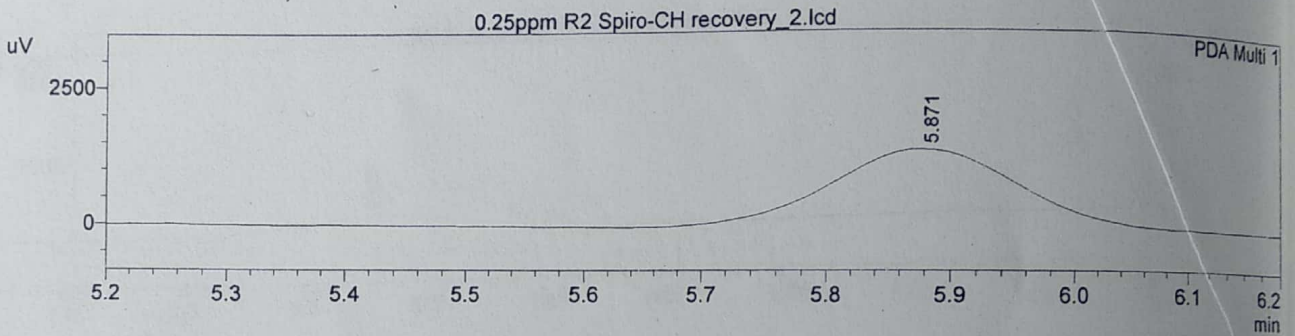
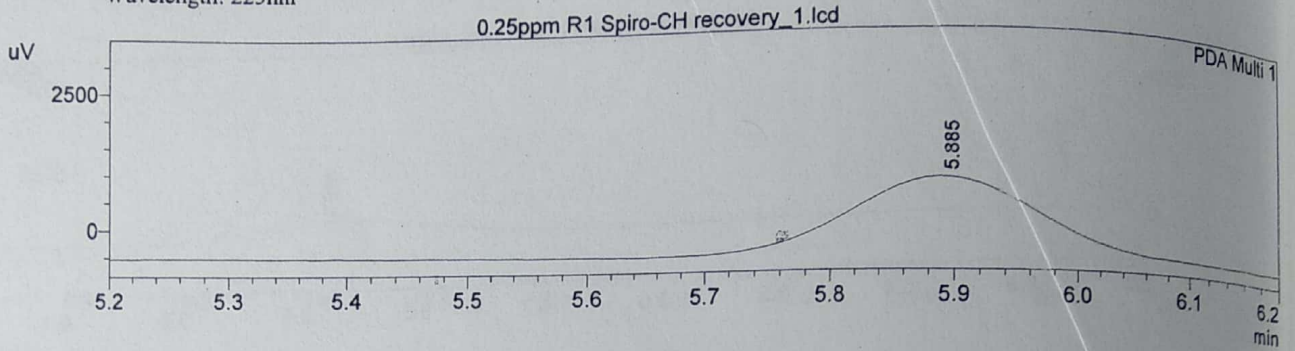
ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
0.05ppm R1 Spiro-CH recovery 1.l	5.857	4244	360
0.05ppm R2 Spiro-CH recovery 2.l	5.828	3349	332
0.05ppm R3 Spiro-CH recovery 3.l	5.808	3484	330



== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



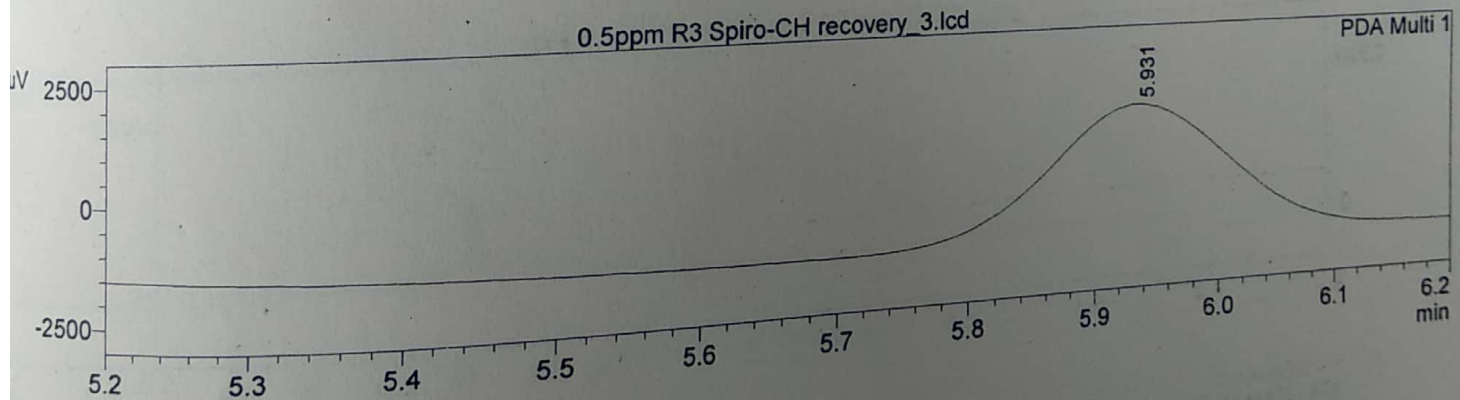
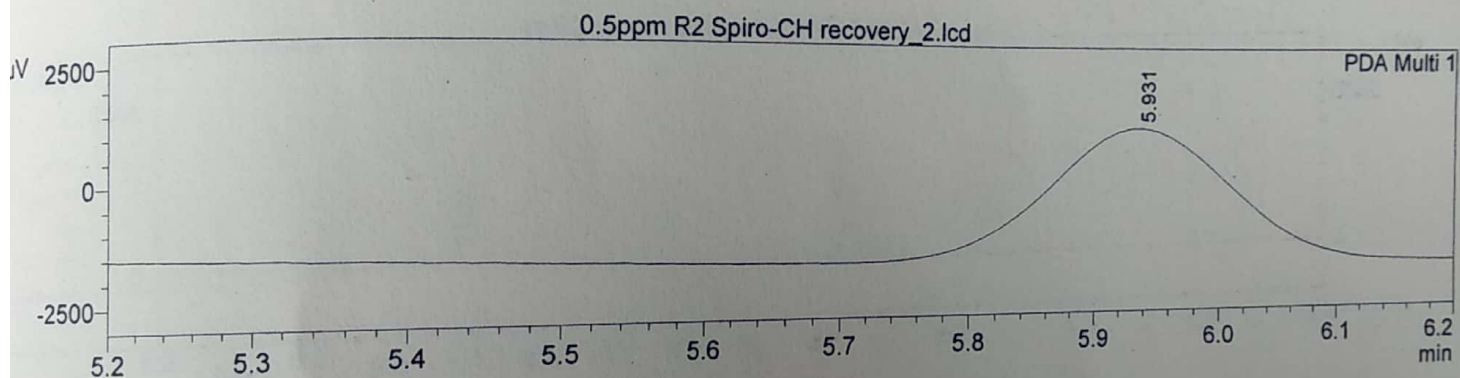
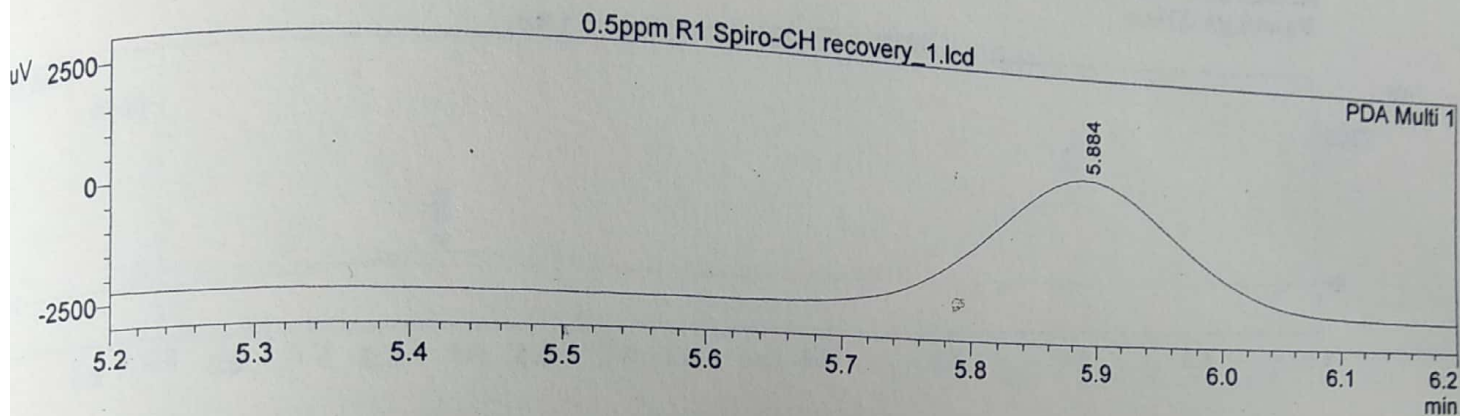
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ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
0.25ppm R1 Spiro-CH recovery_1.lcd	5.885	14562	1405
0.25ppm R2 Spiro-CH recovery_2.lcd	5.871	14951	1423
0.25ppm R3 Spiro-CH recovery_3.lcd	5.866	15250	1438

== AINP on Pestiside Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



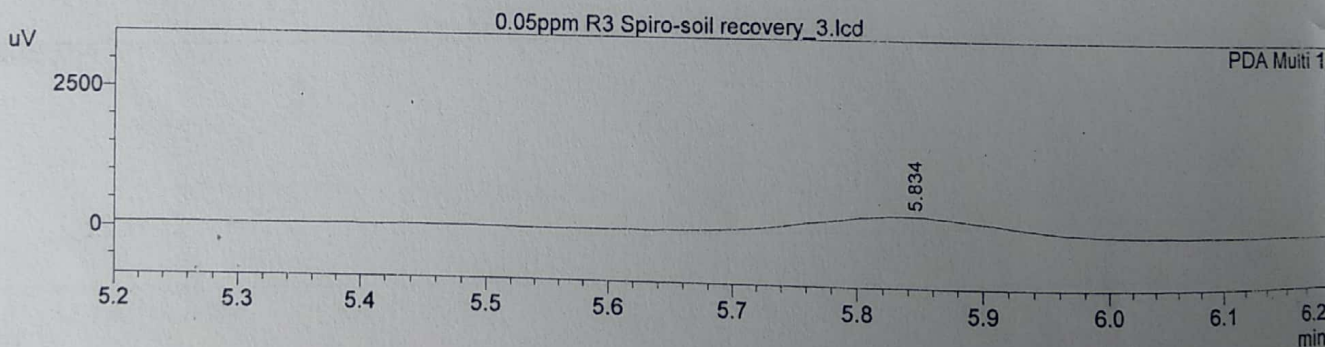
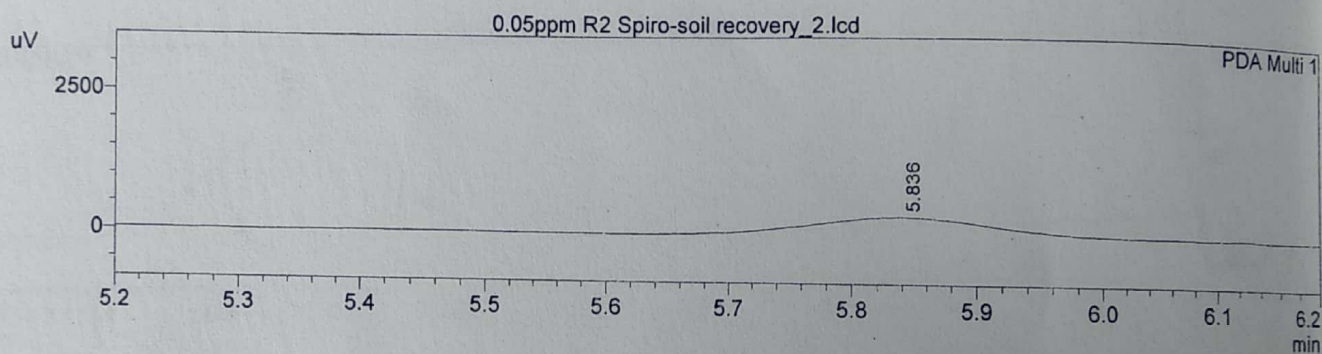
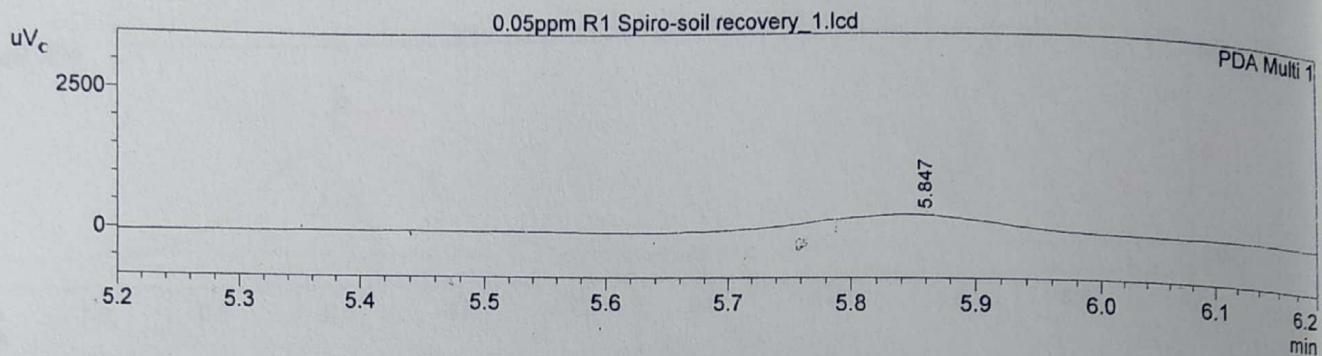
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ID#1 Compound Name: Spiromesifen	Ret. Time	Area	Height
	5.884	32464	3049
0.5ppm R1 Spiro-CH recovery 1.lcd	5.931	31189	3042
0.5ppm R2 Spiro-CH recovery 2.lcd	5.931	31238	3044
0.5ppm R3 Spiro-CH recovery 3.lcd			



== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



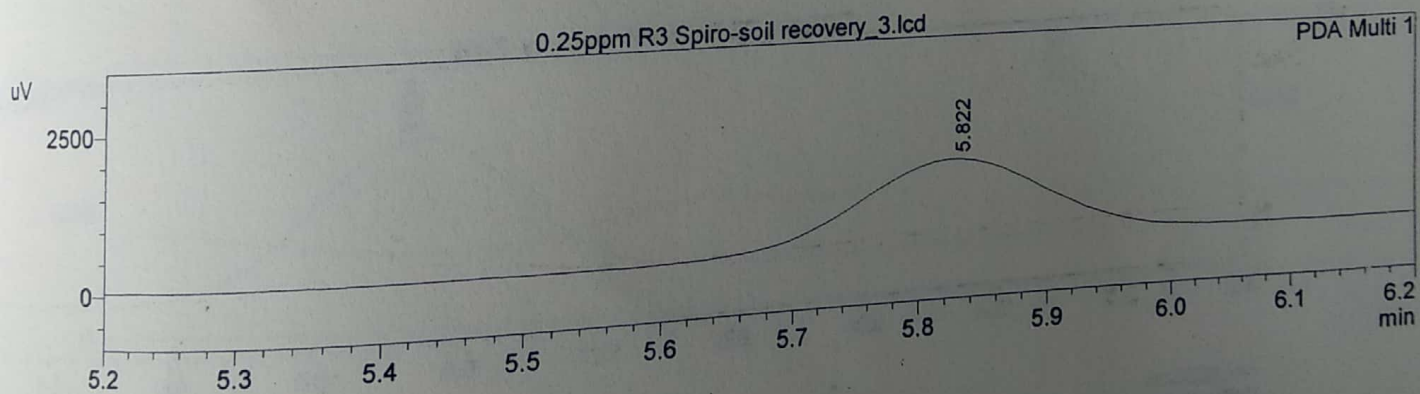
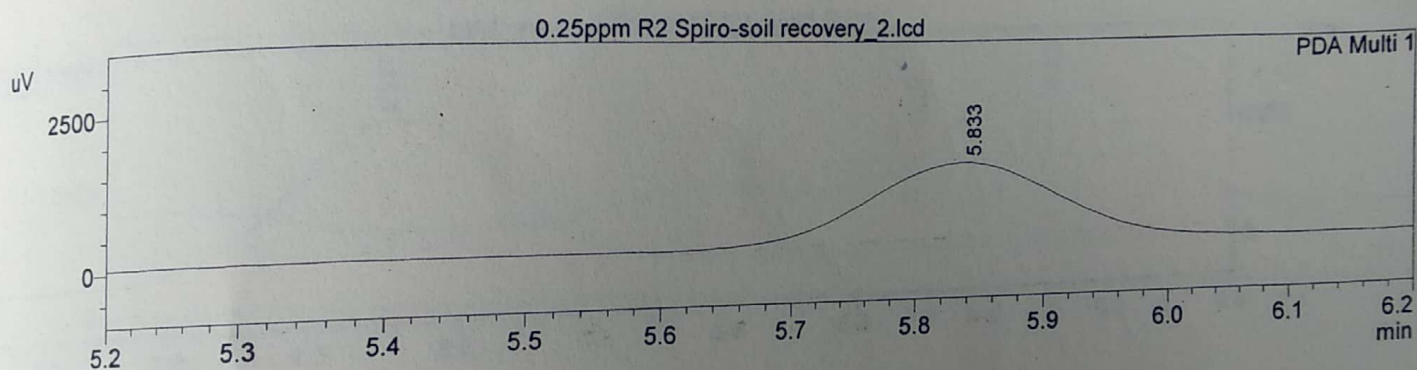
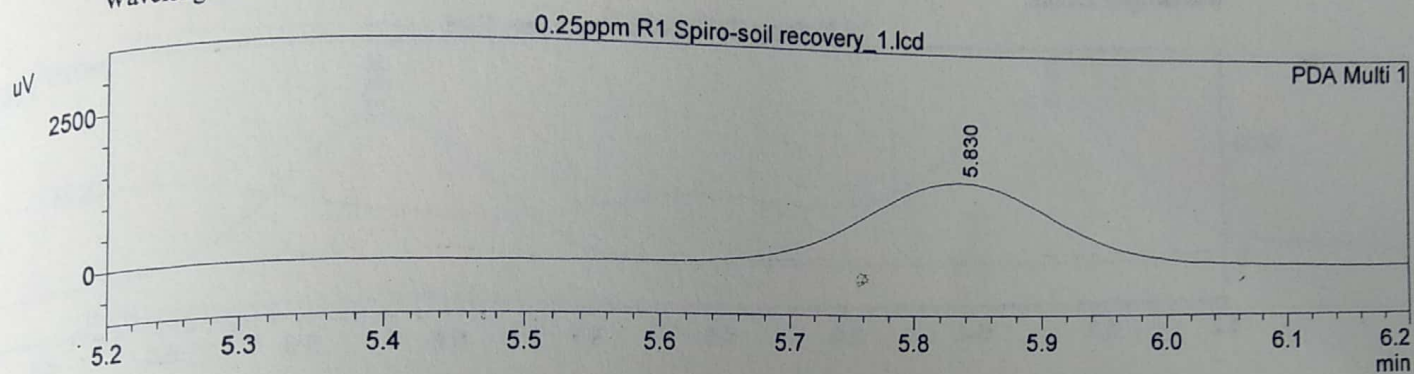
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ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
0.05ppm R1 Spiro-soil recovery_1.lcd	5.847	3513	337
0.05ppm R2 Spiro-soil recovery_2.lcd	5.836	3523	338
0.05ppm R3 Spiro-soil recovery_3.lcd	5.834	3499	338

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



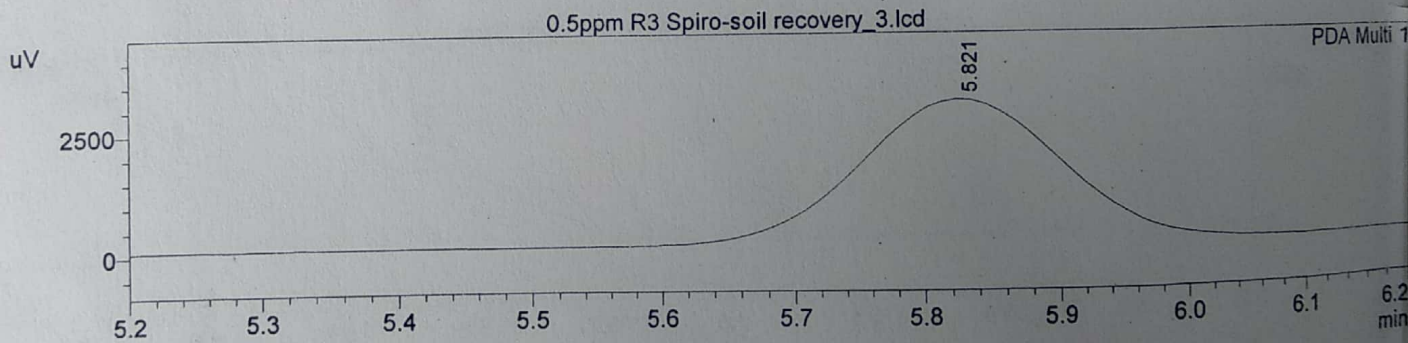
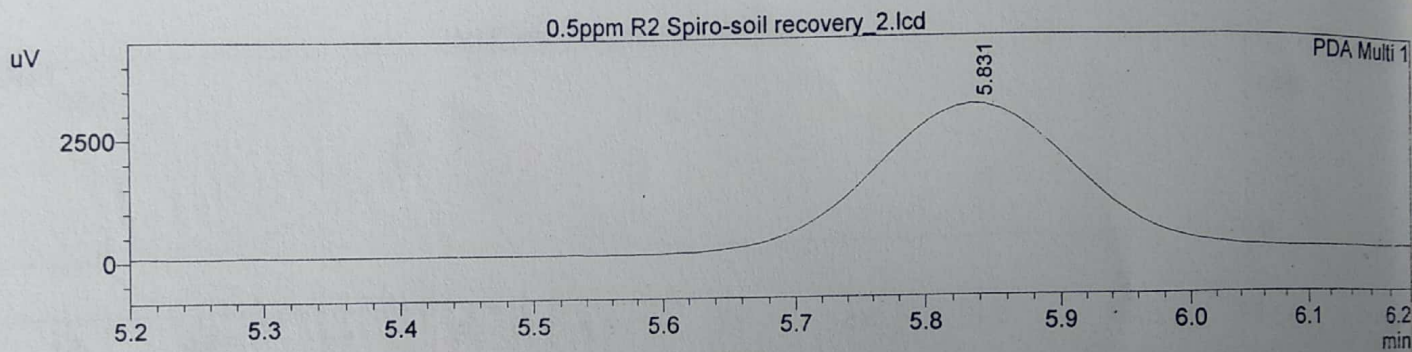
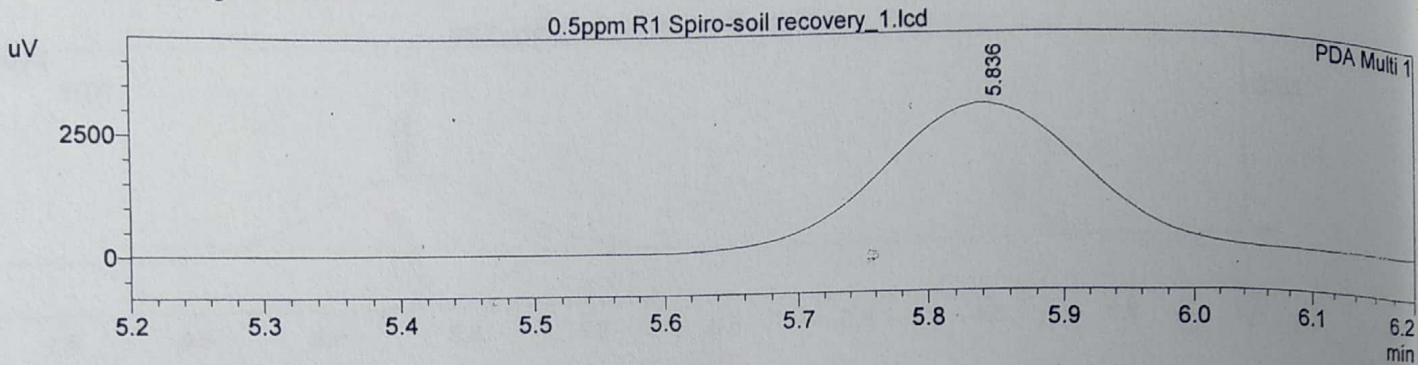
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ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
0.25ppm R1 Spiro-soil recovery_1.lcd	5.830	14429	1377
0.25ppm R2 Spiro-soil recovery_2.lcd	5.833	14457	1372
0.25ppm R3 Spiro-soil recovery_3.lcd	5.822	14330	1376

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



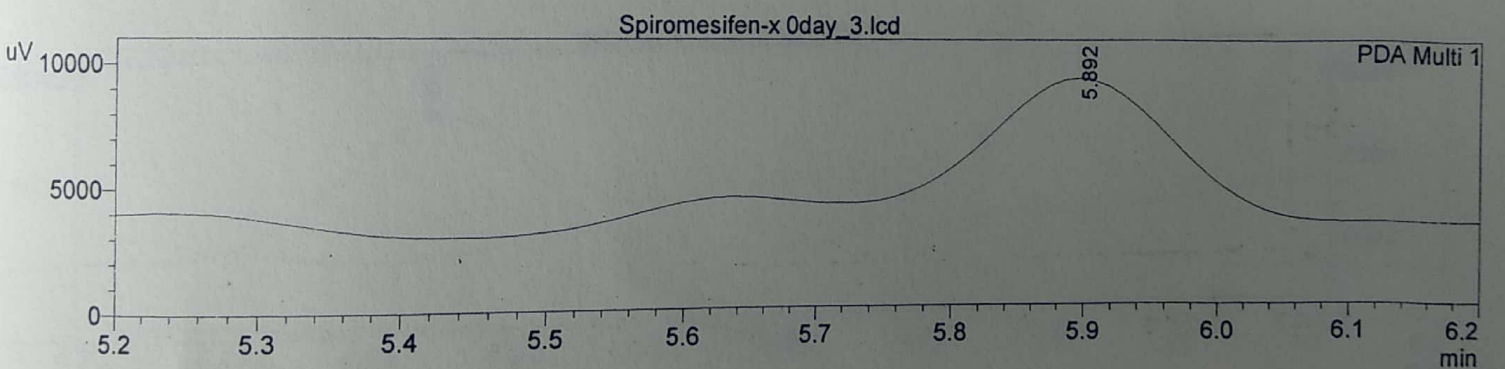
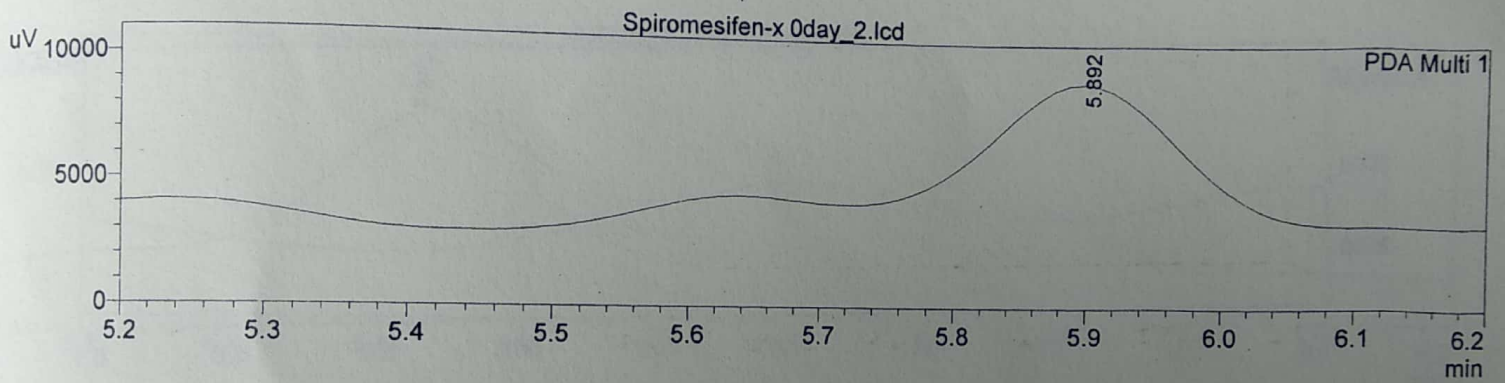
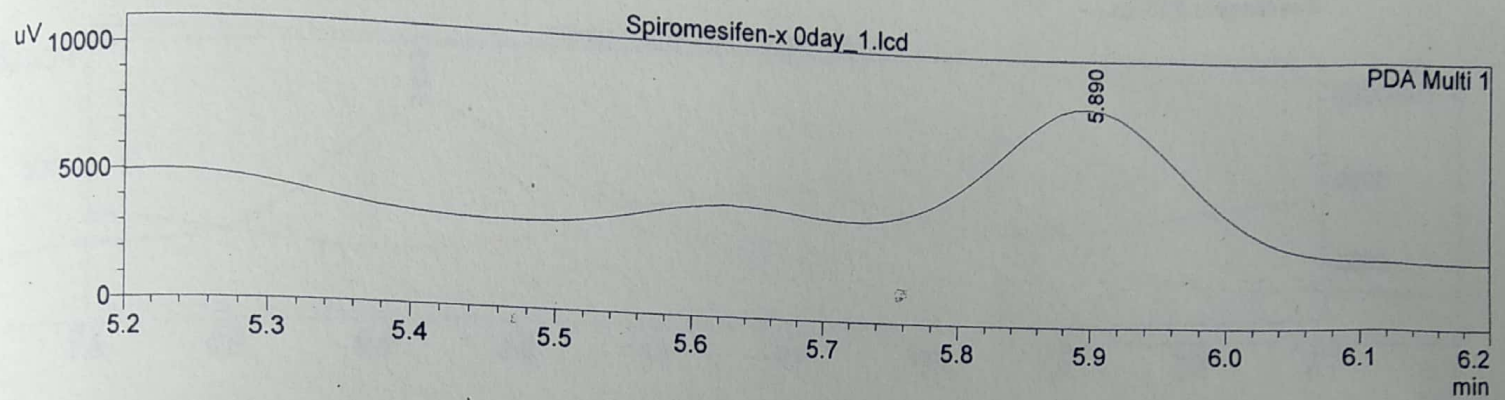
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ID#1 Compound Name: Spiromesifen

Title	Ret. Time	Area	Height
0.5ppm R1 Spiro-soil recovery_1.lcd	5.836	31797	3006
0.5ppm R2 Spiro-soil recovery_2.lcd	5.831	31615	3002
0.5ppm R3 Spiro-soil recovery_3.lcd	5.821	31678	3007

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



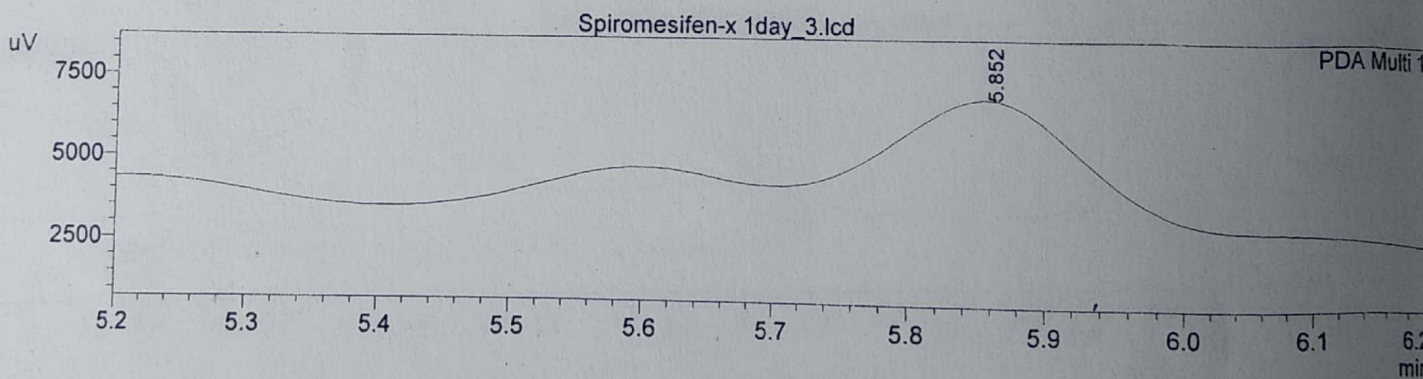
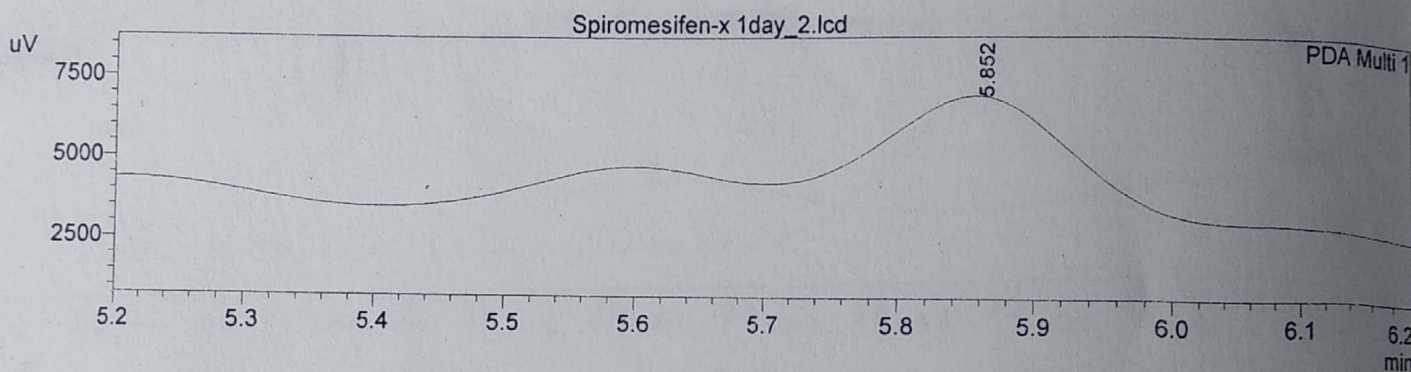
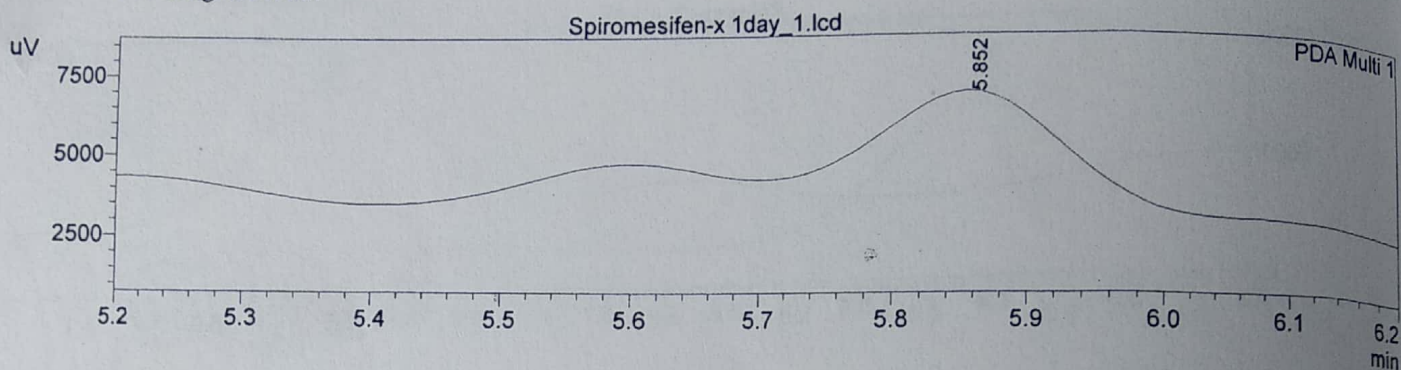
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ID#1 Compound Name: RT5.890

Title	Ret. Time	Area	Height
Spiromesifen-x Oday_1.lcd	5.890	48467	5380
Spiromesifen-x Oday_2.lcd	5.892	41415	4974
Spiromesifen-x Oday_3.lcd	5.892	48099	5437

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
Flow Rate: 0.8ml/min
Mobile Phase: ACN:Water(90:10)
Wavelength: 225nm



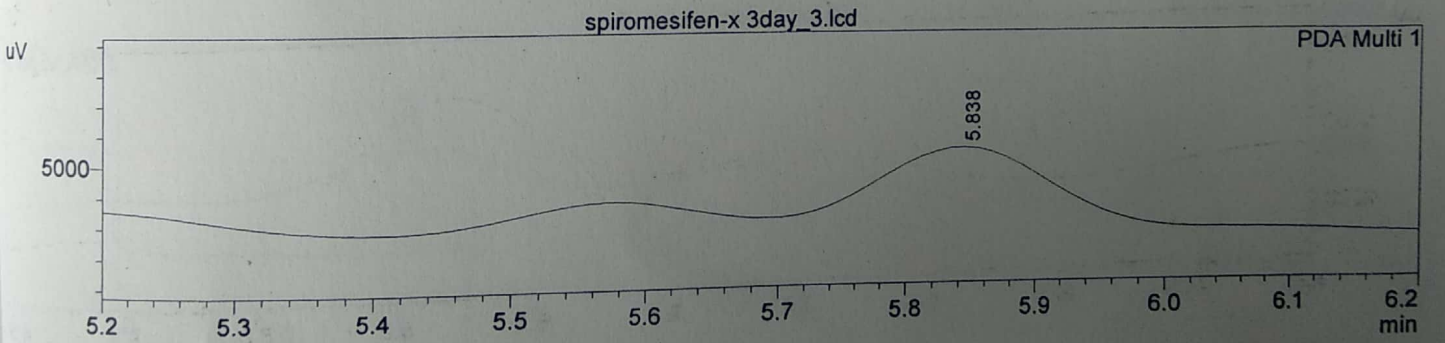
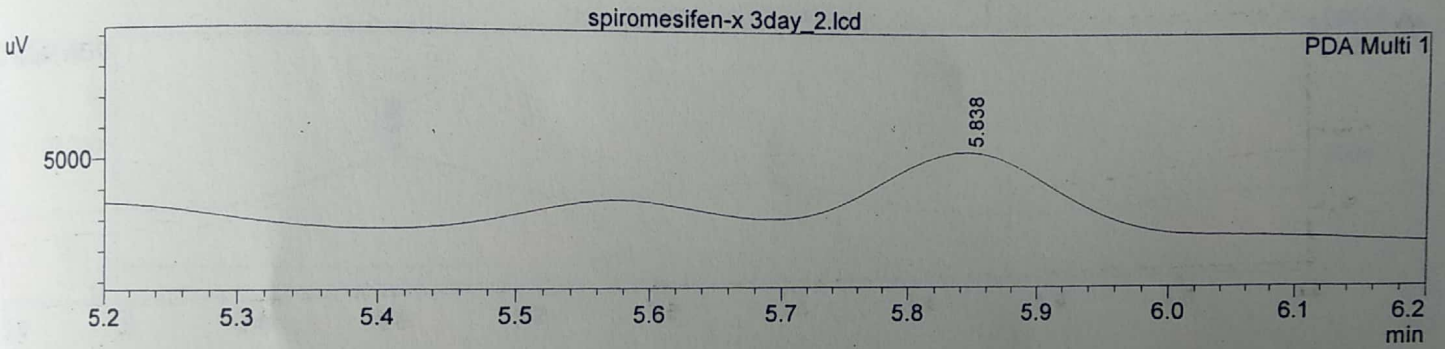
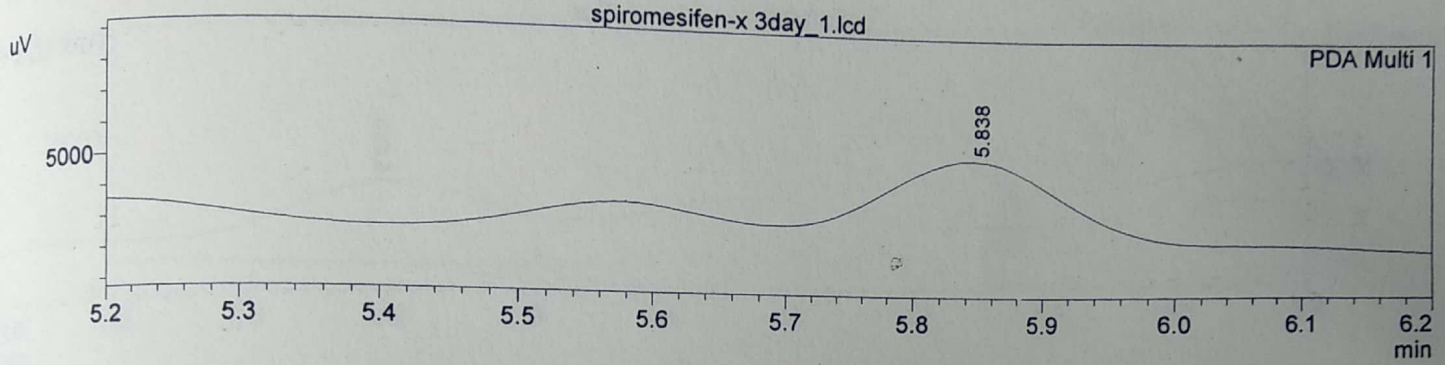
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ID#1 Compound Name: RT5.852

Title	Ret. Time	Area	Height
Spiromesifen-x 1day_1.lcd	5.852	22668	2888
Spiromesifen-x 1day_2.lcd	5.852	27230	3201
Spiromesifen-x 1day_3.lcd	5.852	26848	3188

== AINP on Pestiside Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



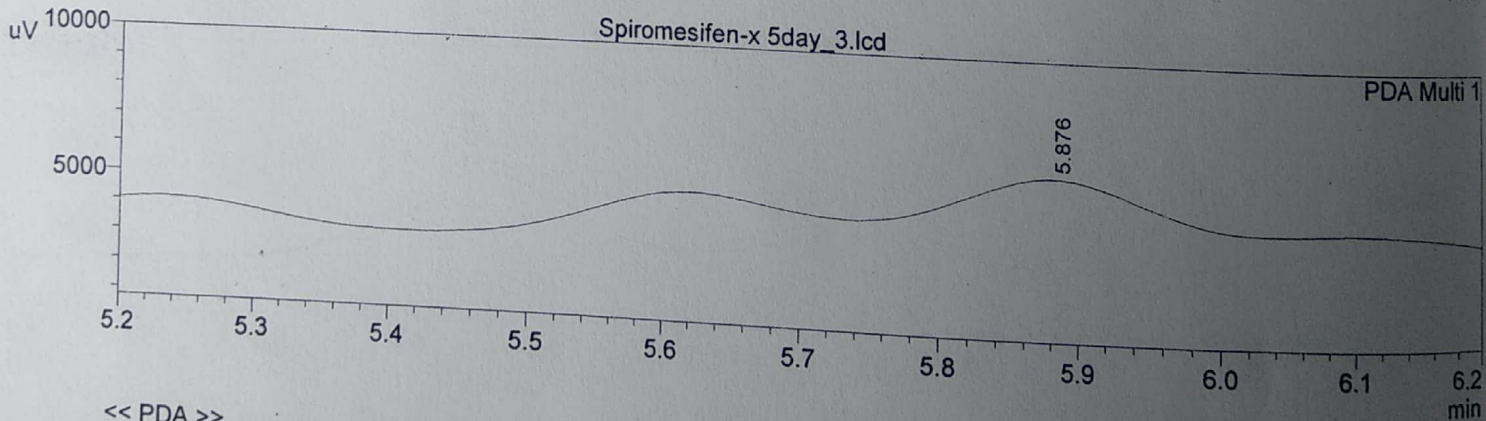
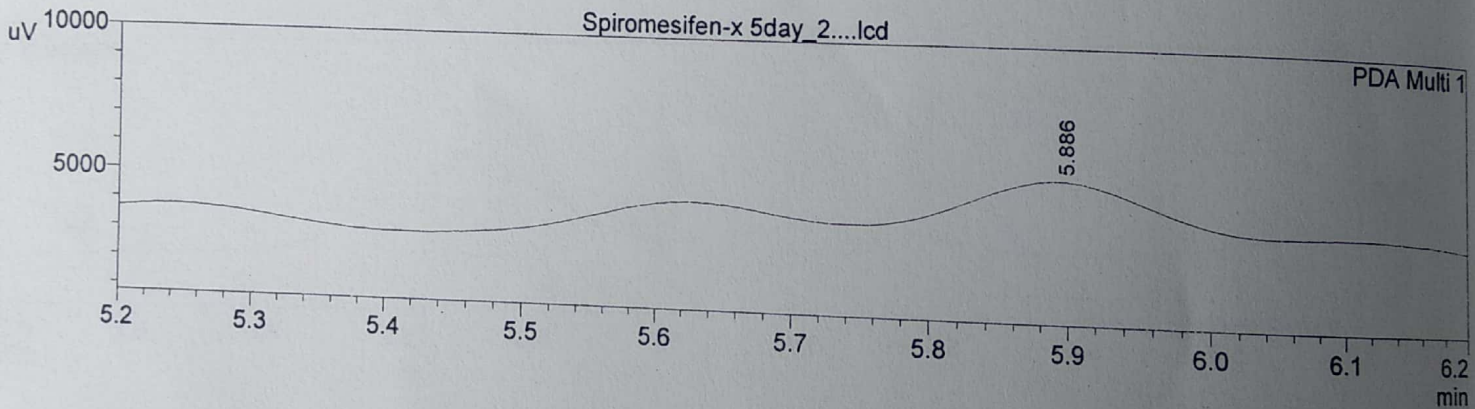
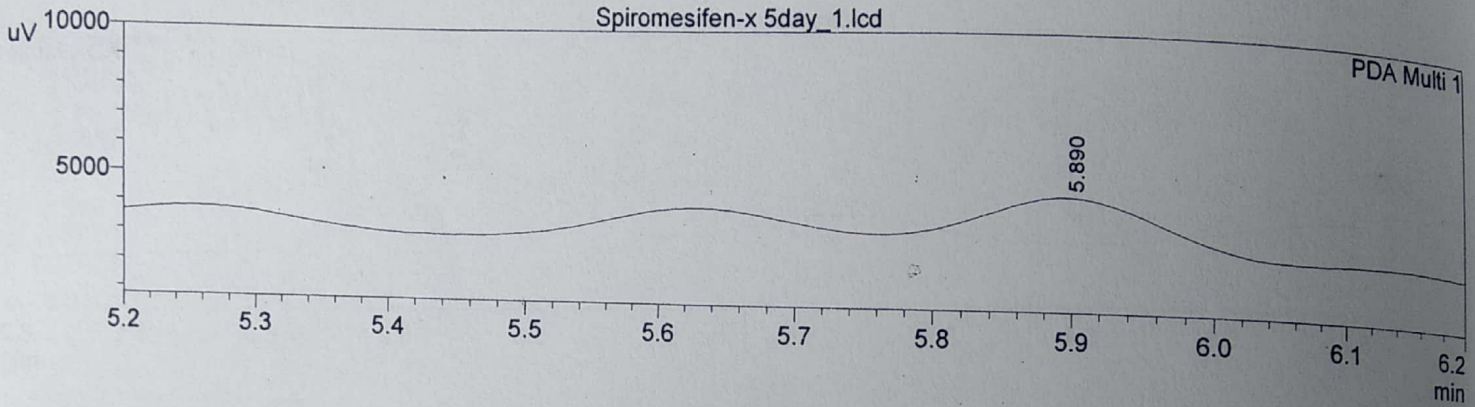
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ID#1 Compound Name: RT5.838

Title	Ret. Time	Area	Height
spiromesifen-x 3day_1.lcd	5.838	15686	2075
spiromesifen-x 3day_2.lcd	5.838	14425	1990
spiromesifen-x 3day_3.lcd	5.838	15833	2079

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



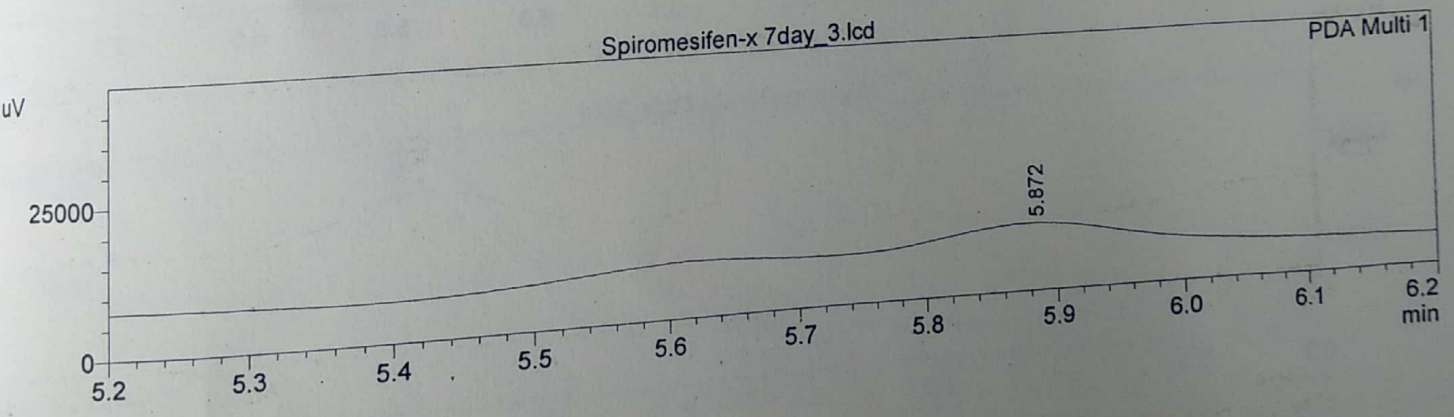
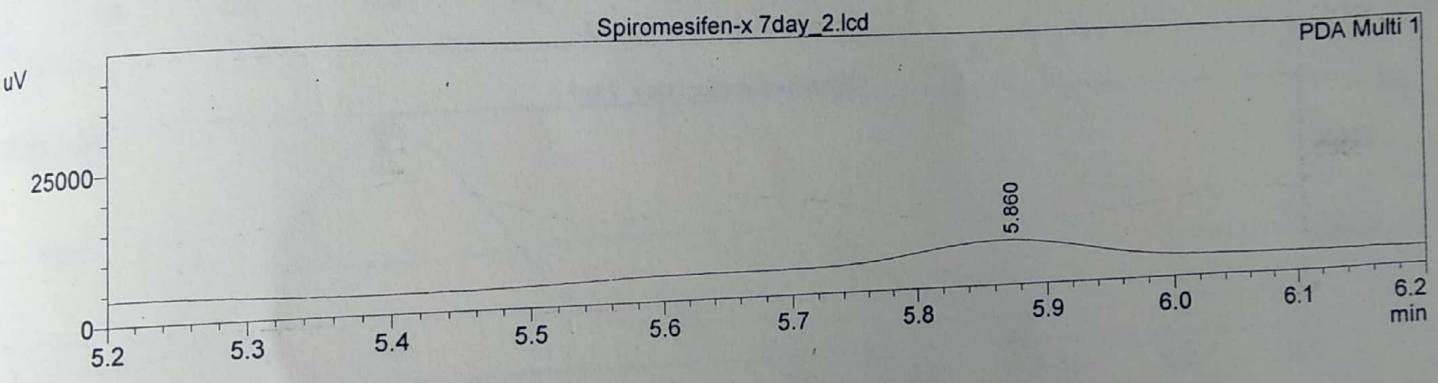
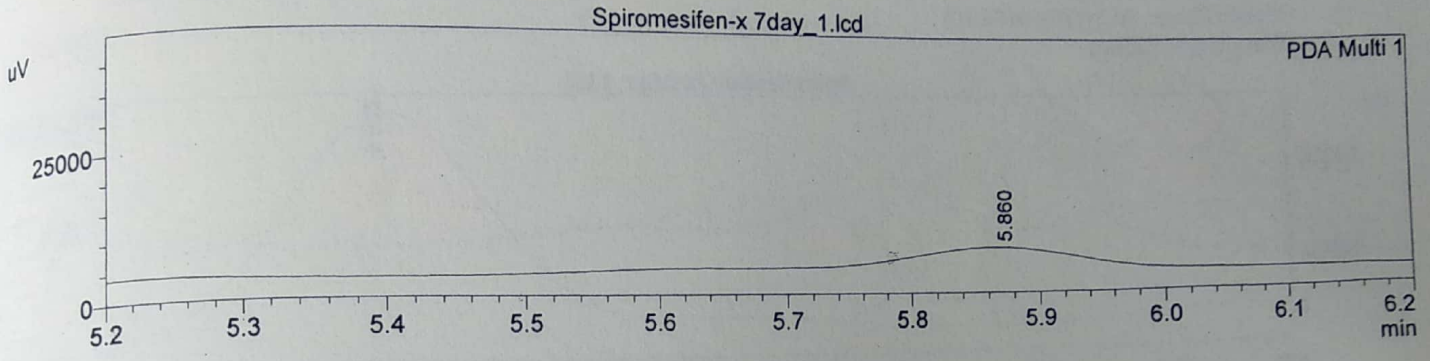
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ID#1 Compound Name: RT5.890

Title	Ret. Time	Area	Height
Spiromesifen-x 5day 1.lcd	5.890	6259	978
Spiromesifen-x 5day 2....lcd	5.886	5175	900
Spiromesifen-x 5day 3.lcd	5.876	6798	1089

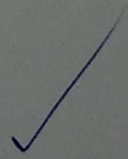
== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



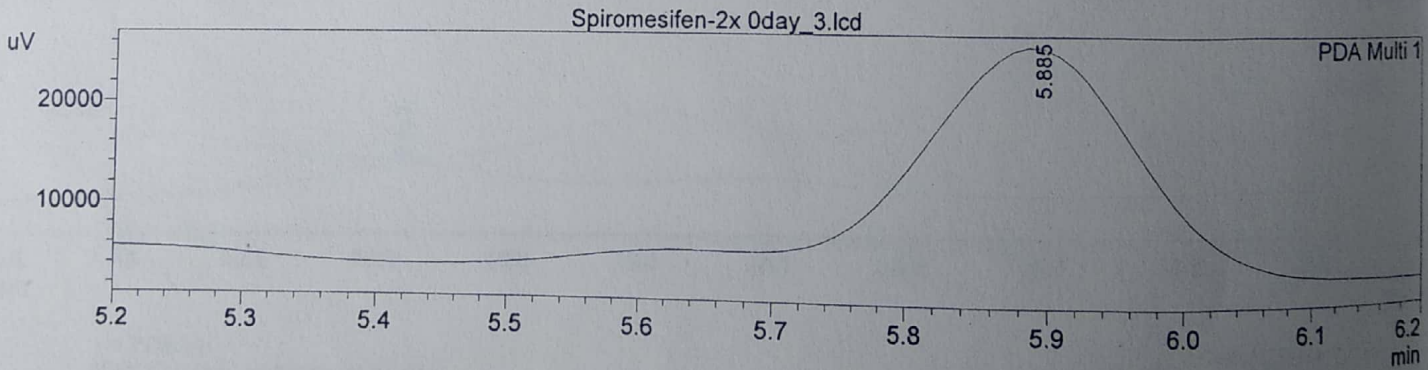
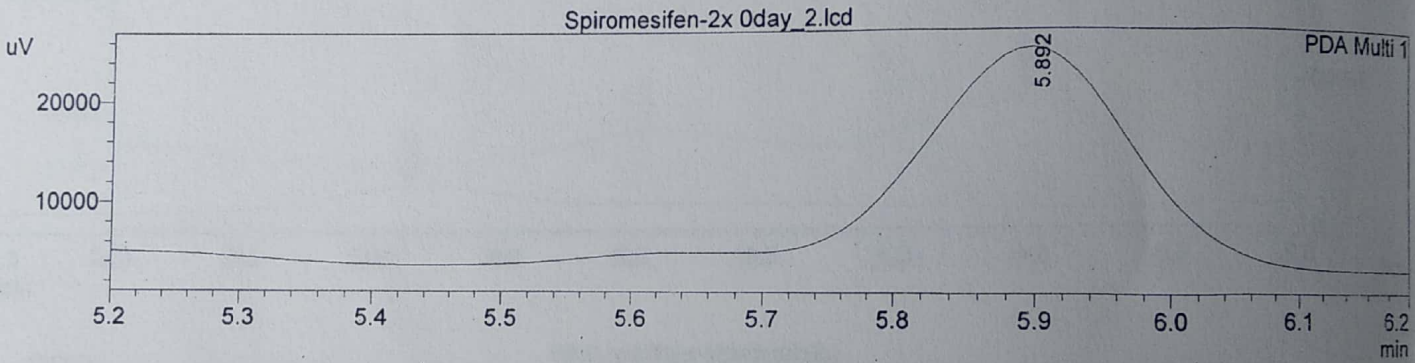
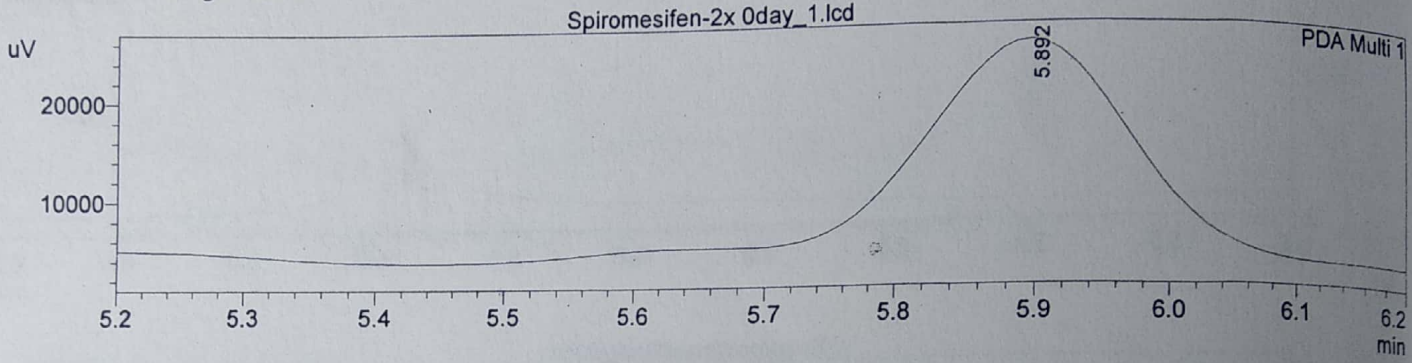
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 ID#1 Compound Name: RT5.860

Title	Ret. Time	Area	Height
Spiromesifen-x 7day_1.lcd	5.860	4923	939
Spiromesifen-x 7day_2.lcd	5.860	5473	1111
Spiromesifen-x 7day_3.lcd	5.872	3681	1002



== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



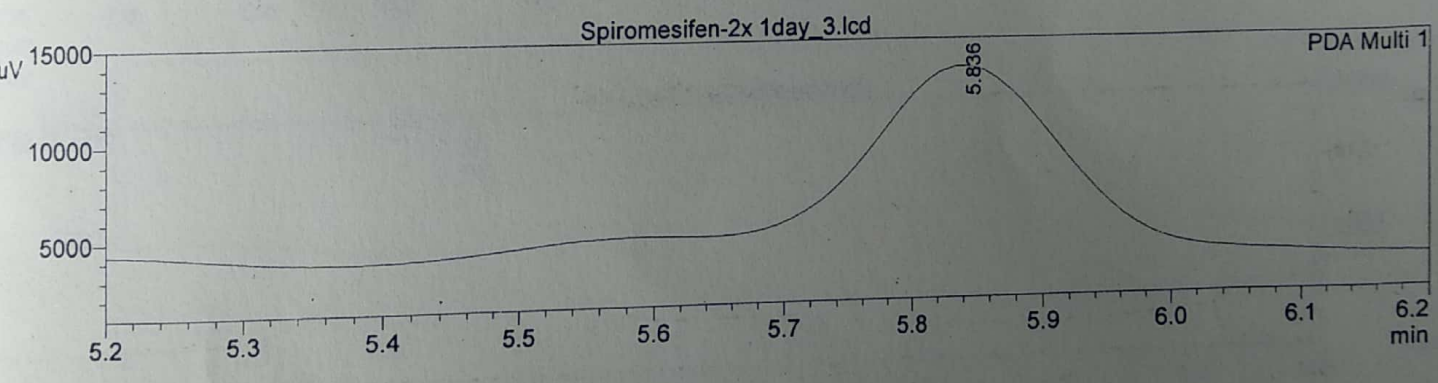
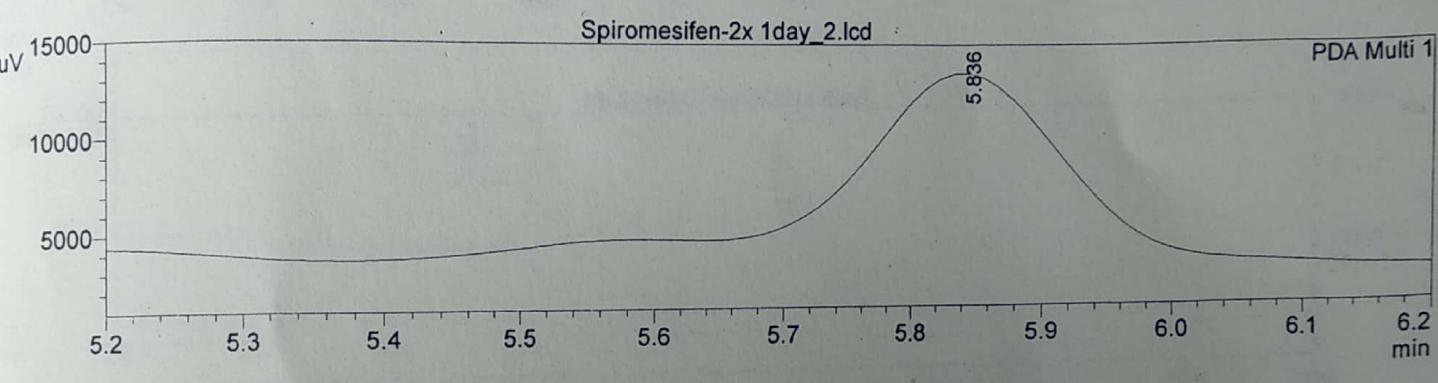
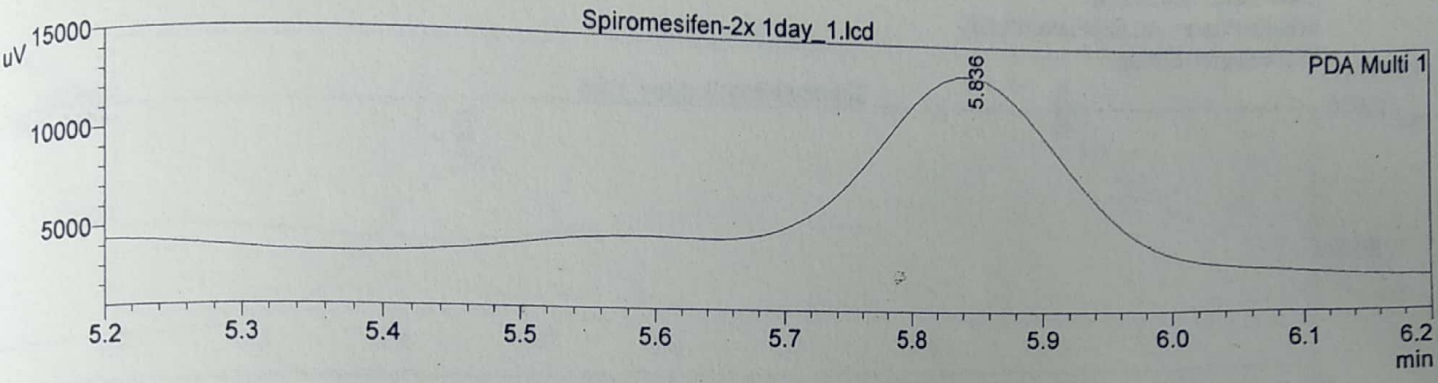
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ID#1 Compound Name: RT5.892

Title	Ret. Time	Area	Height
Spiromesifen-2x Oday 1.lcd	5.892	100708	13860
Spiromesifen-2x Oday 2.lcd	5.892	100708	13860
Spiromesifen-2x Oday 3.lcd	5.885	113661	15277

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



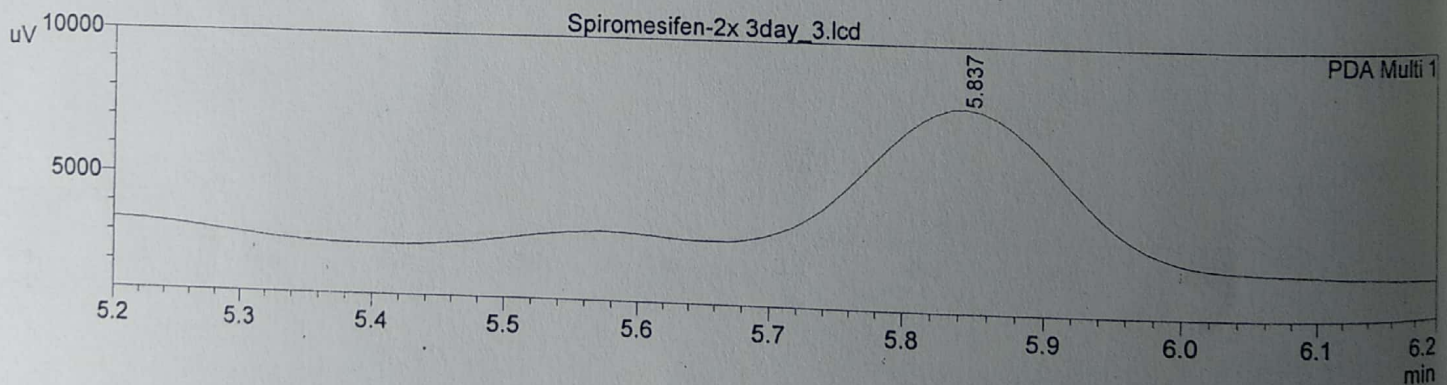
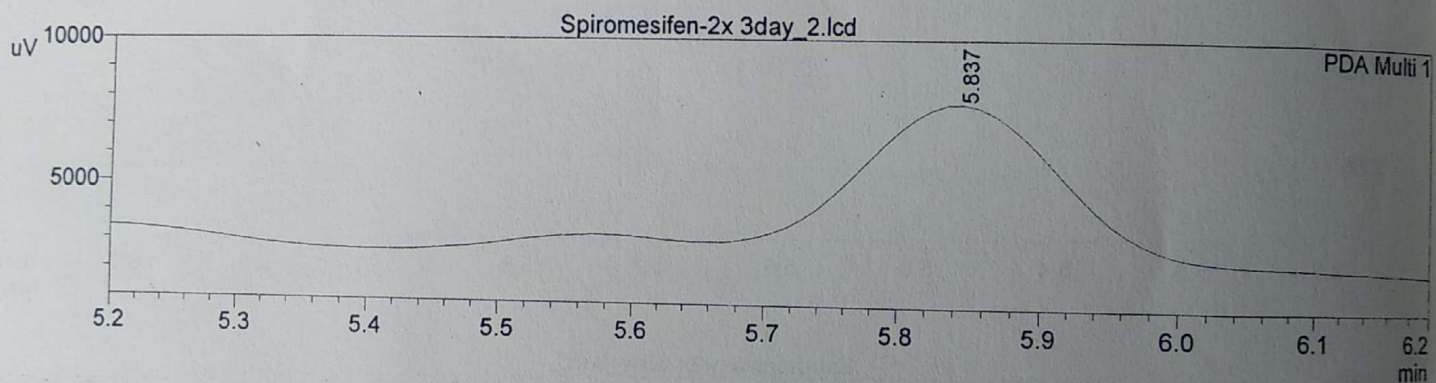
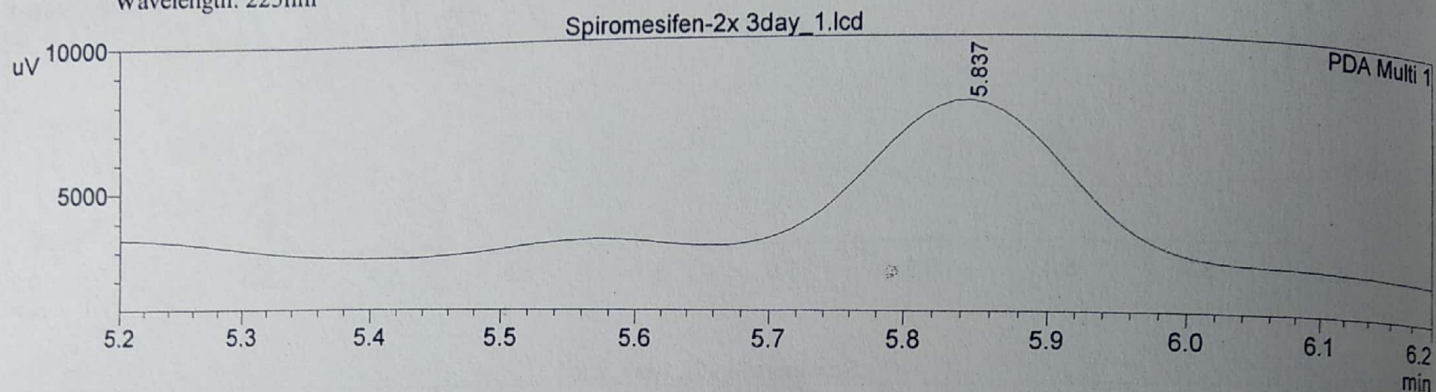
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ID#1 Compound Name: RT5.836

Title	Ret. Time	Area	Height
Spiromesifen-2x 1day 1.lcd	5.836	71937	8352
Spiromesifen-2x 1day 2.lcd	5.836	63823	7850
Spiromesifen-2x 1day 3.lcd	5.836	71356	8306

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



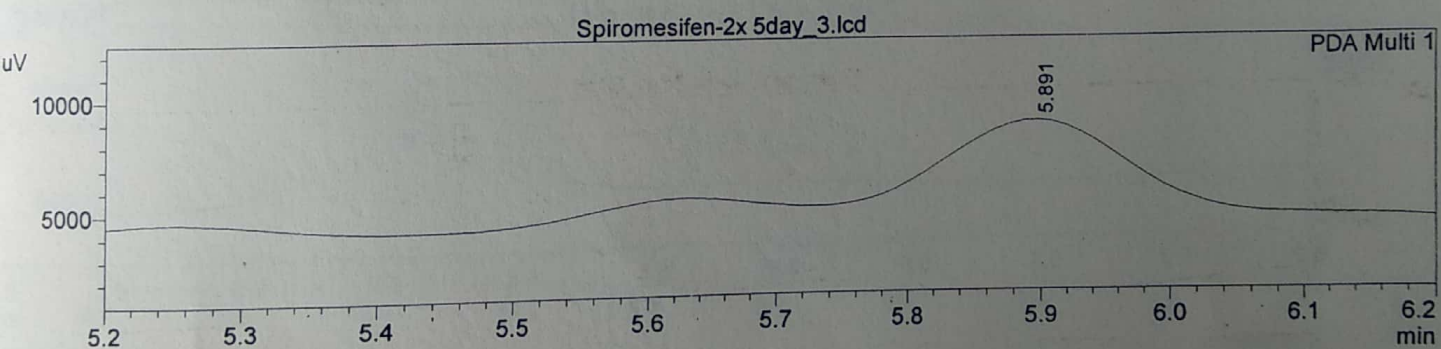
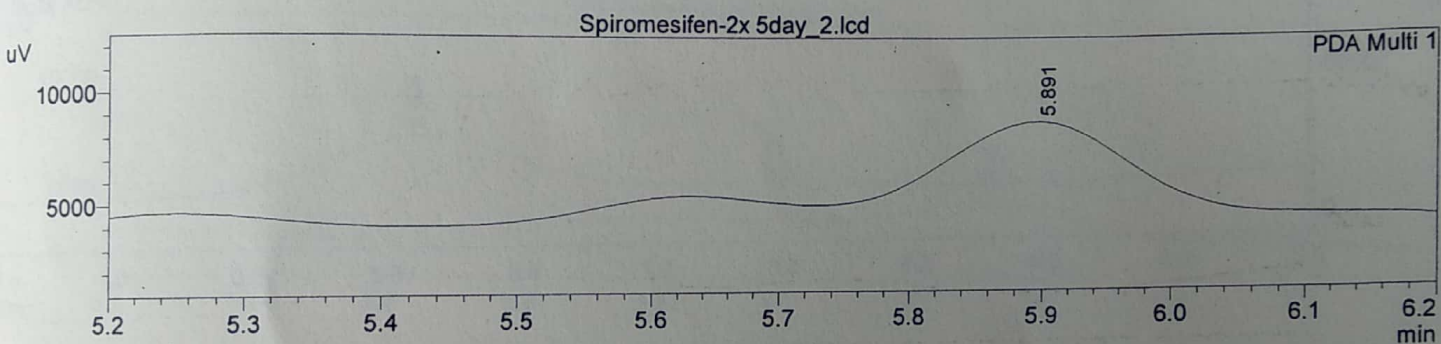
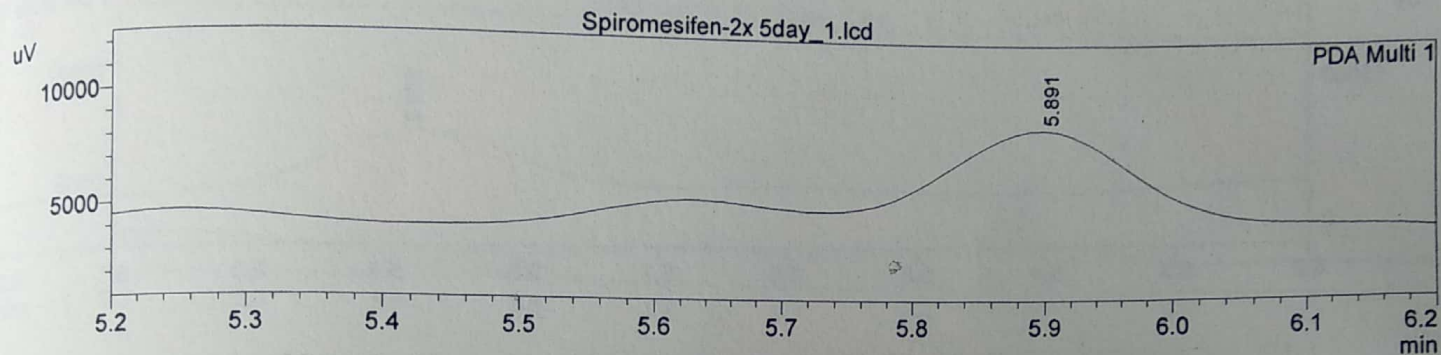
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ID#1 Compound Name: RT5.837

Title	Ret. Time	Area	Height
Spiromesifen-2x 3day 1.lcd	5.837	38908	4542
Spiromesifen-2x 3day 2.lcd	5.837	39910	4597
Spiromesifen-2x 3day 3.lcd	5.837	40069	4602

== AINP on Pestiside Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



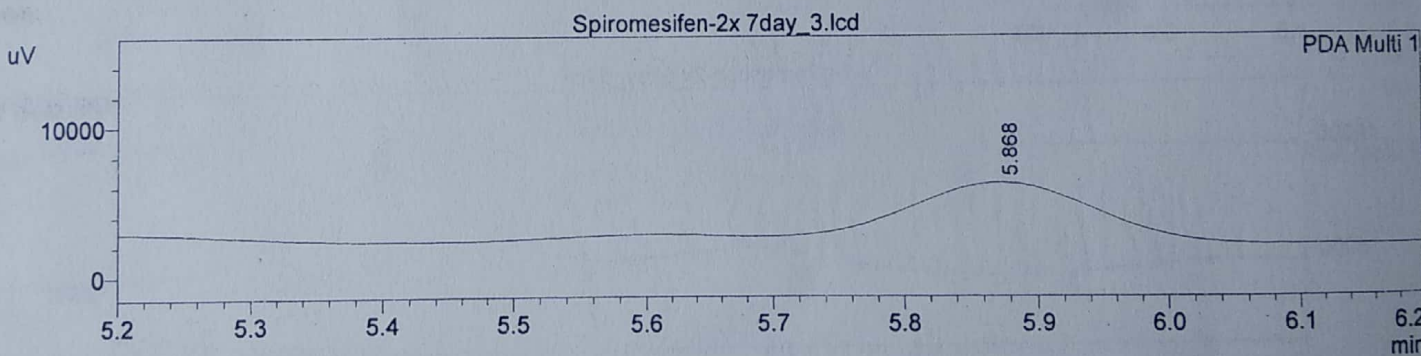
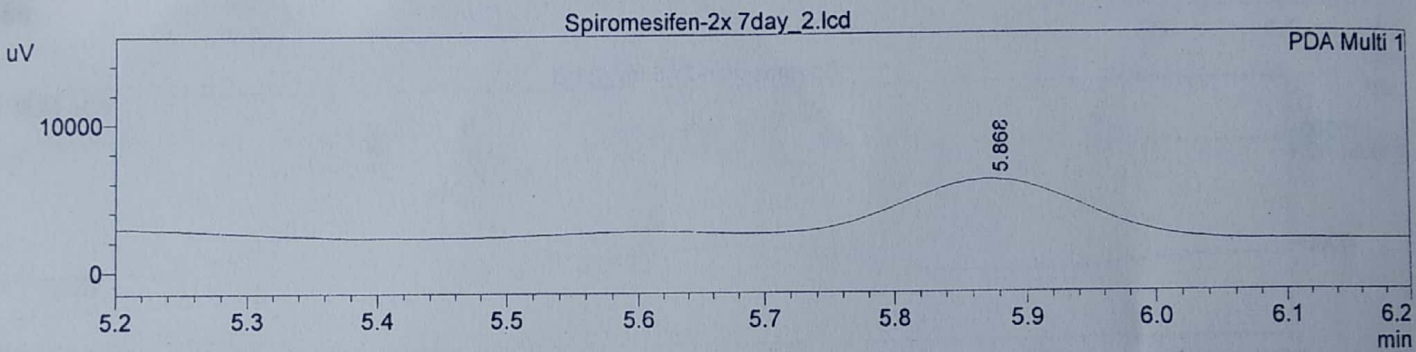
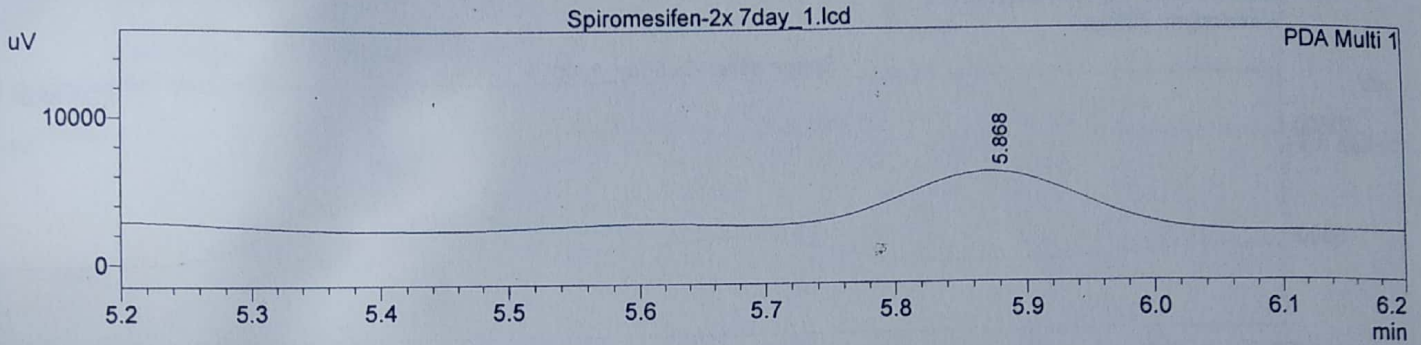
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ID#1 Compound Name: RT5.891

Title	Ret. Time	Area	Height
Spiromesifen-2x 5day_1.lcd	5.891	14209	2193
Spiromesifen-2x 5day_2.lcd	5.891	16828	2591
Spiromesifen-2x 5day_3.lcd	5.891	14001	2178

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



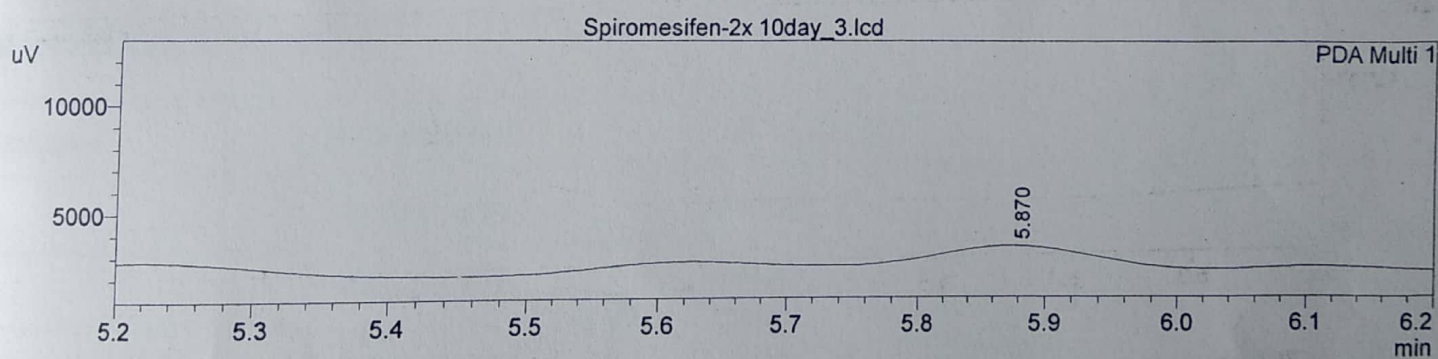
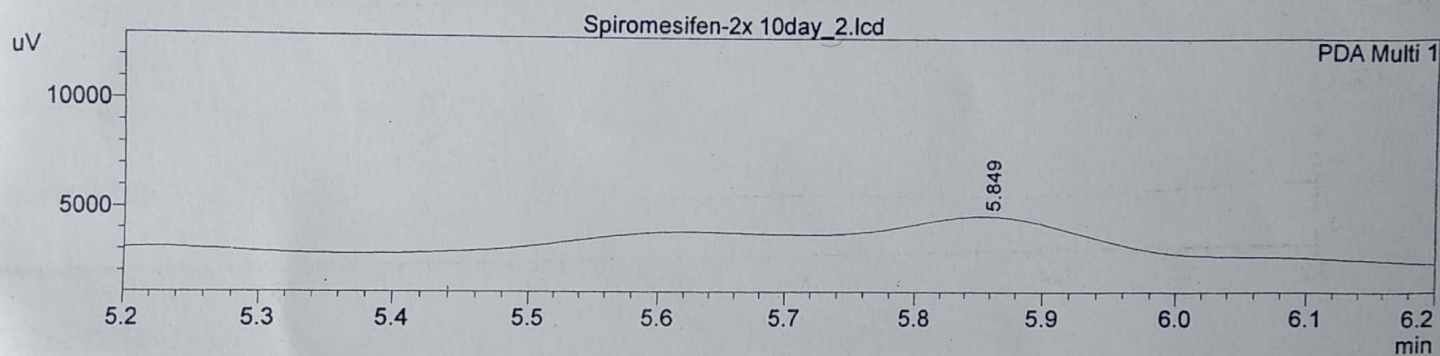
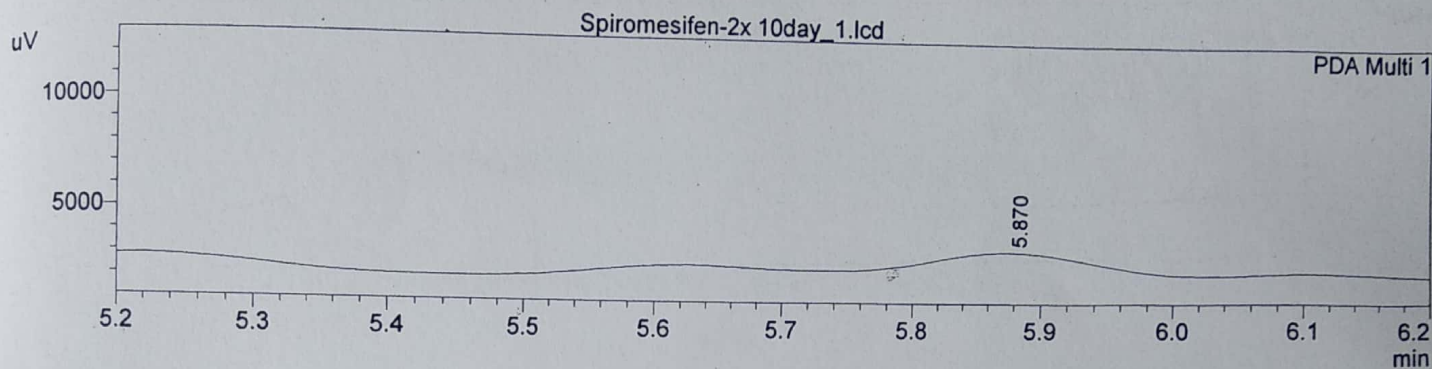
<< PDA >>

ID#1 Compound Name: RT5.868

Title	Ret. Time	Area	Height
Spiromesifen-2x 7day 1.lcd	5.868	9616	1731
Spiromesifen-2x 7day 2.lcd	5.868	9881	1746
Spiromesifen-2x 7day 3.lcd	5.868	9616	1731

== AINP on Pesticide Residue, MPKV, Rahuri ==

Sample Name: Spiromesifen
 Flow Rate: 0.8ml/min
 Mobile Phase: ACN:Water(90:10)
 Wavelength: 225nm



<< PDA >>

ID#1 Compound Name: RT5.870

Title	Ret. Time	Area	Height
Spiromesifen-2x 10day 1.lcd	5.870	4793	756
Spiromesifen-2x 10day 2.lcd	5.849	4086	748
Spiromesifen-2x 10day 3.lcd	5.870	3793	629

8. VITAE

Mr. SIDDESHA M

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

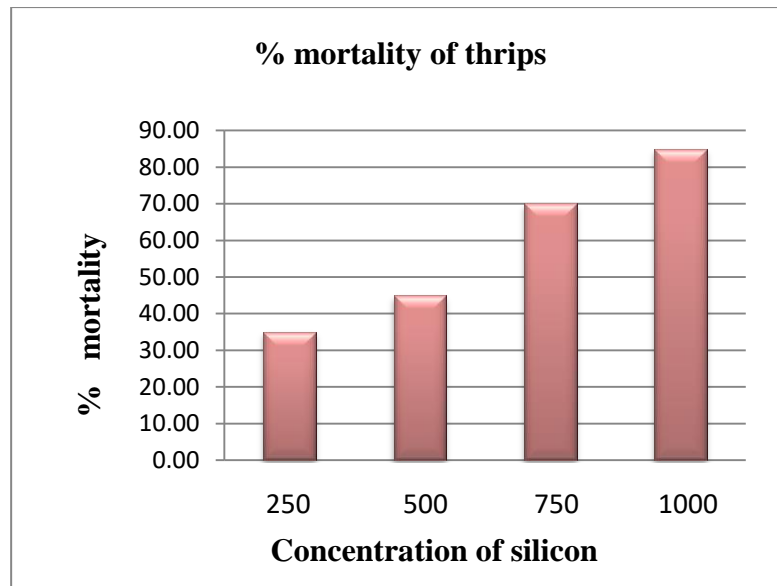
in

AGRICULTURAL ENTOMOLOGY

2019

Thesis Title		:	“ Efficacy of insecticides and some biorationals against thrips and mites in/on chilli”
Major field		:	Agricultural Entomology
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a) Thrips.



b) Mites.

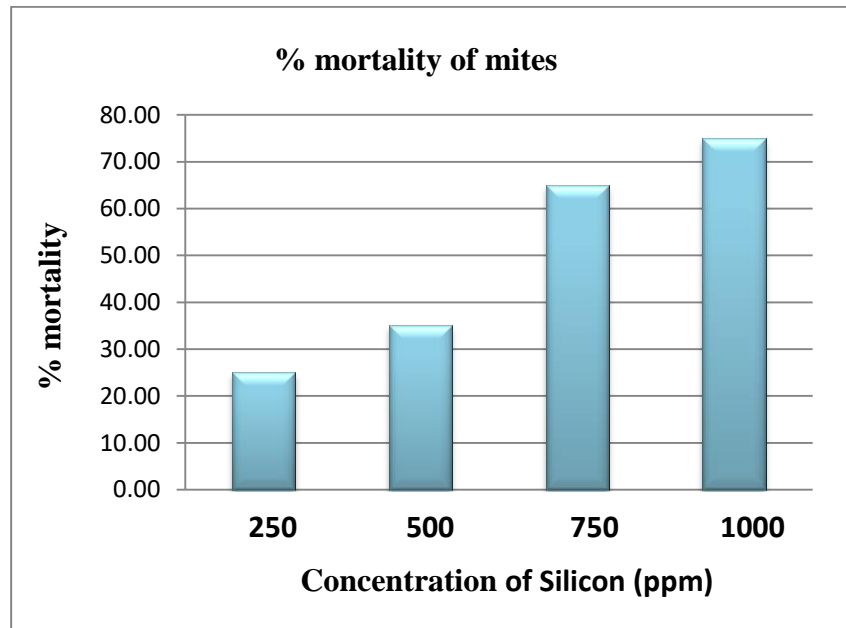


Fig. 1. Lab experiment to fix the silicon dose for field spraying.

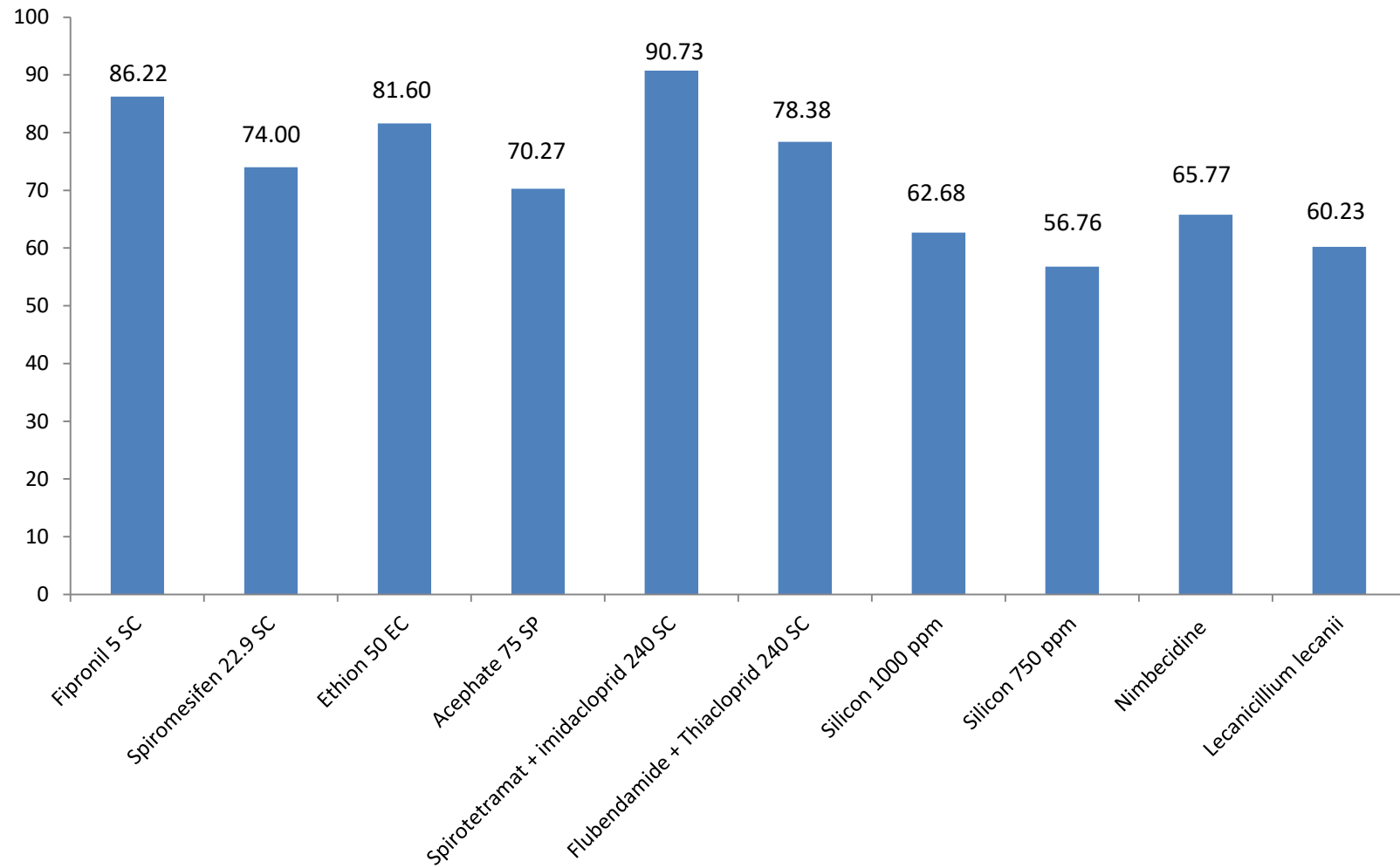


Fig. 2: Reduction of thrips population over control on chilli treated with insecticides and some bio-rationals.

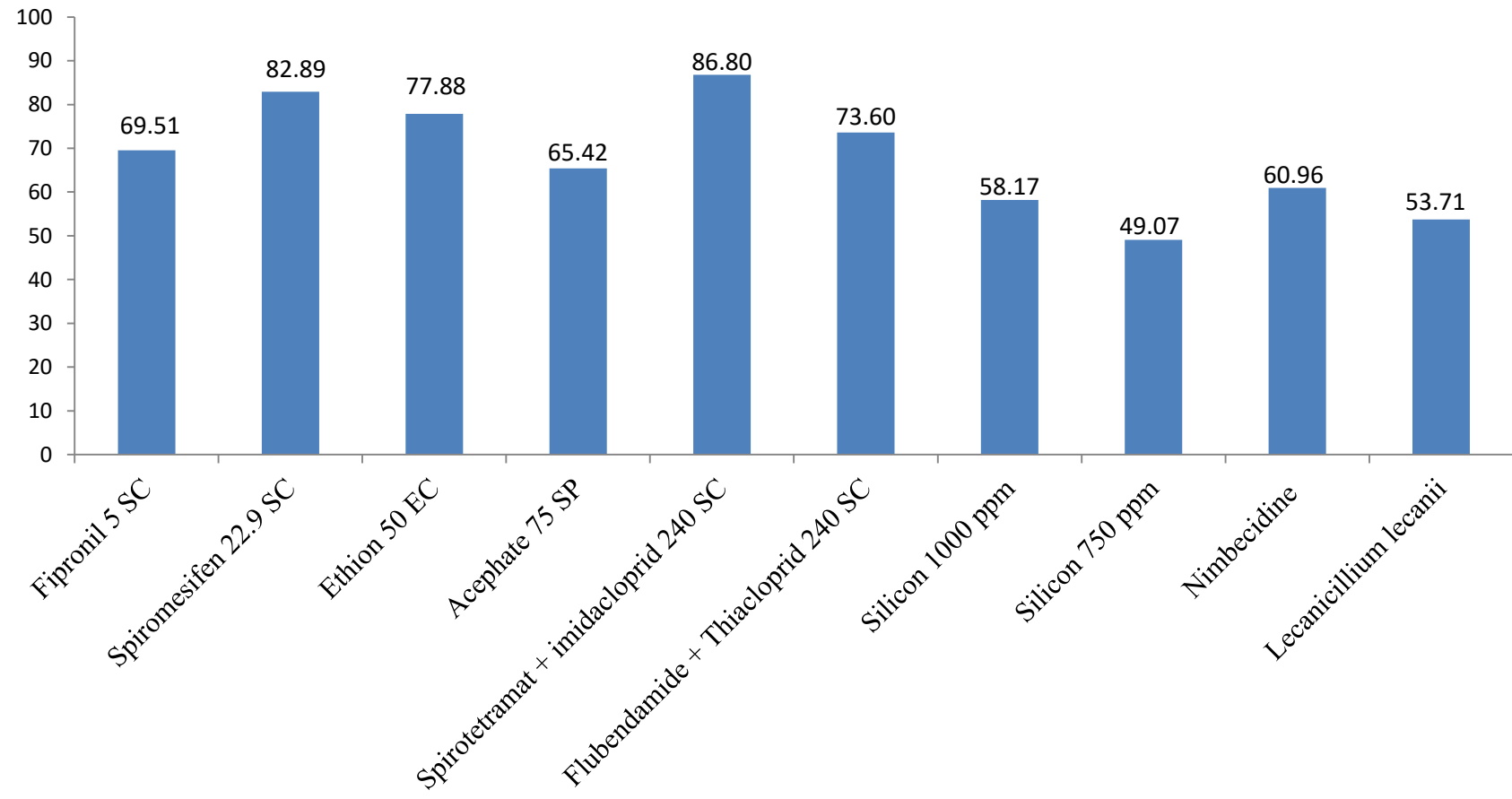


Fig. 3: Reduction of mites population over control on mites treated with insecticides and some bio-rationals.

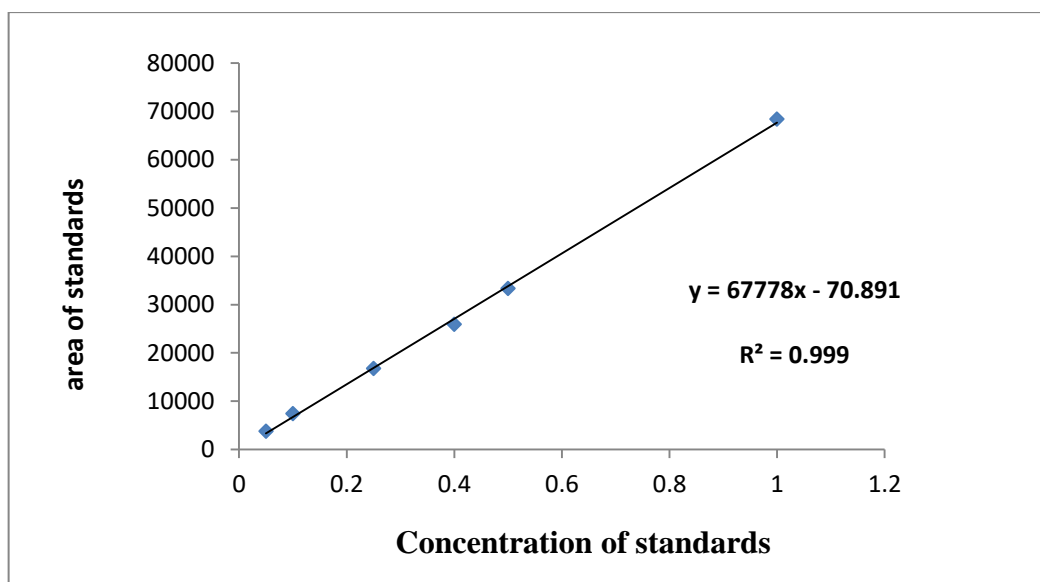


Fig. 4: Linearity curve of spiromesifen 22.9 SC

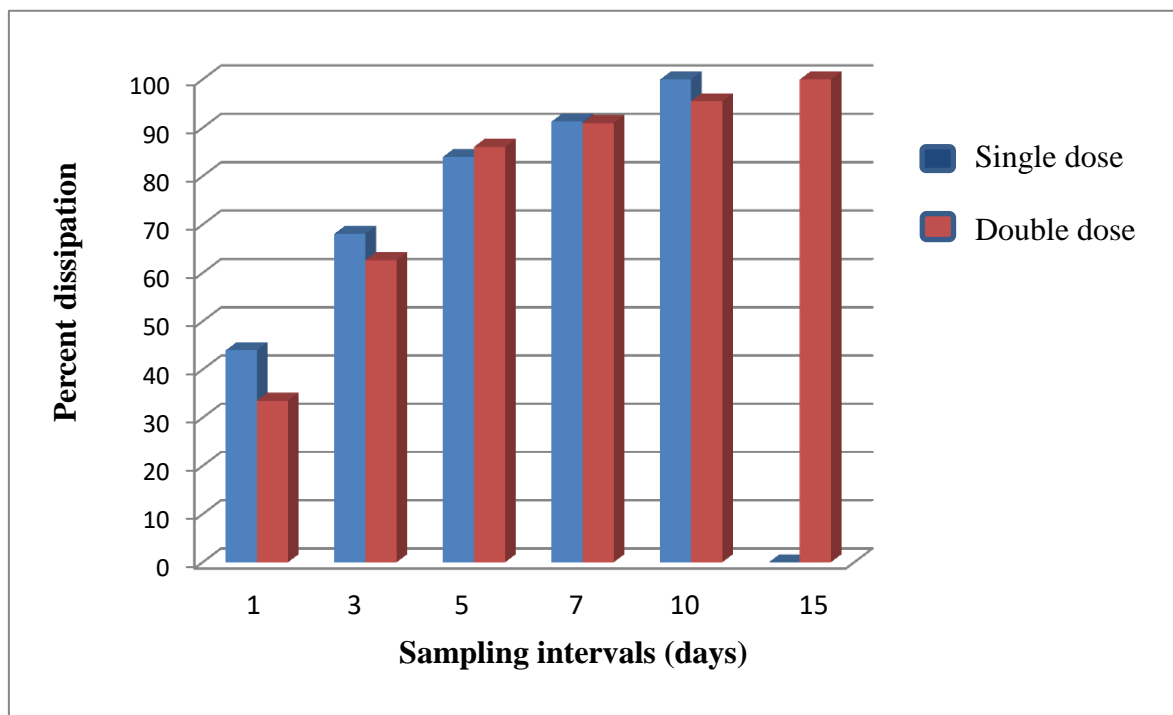


Fig. 5. Dissipation of spiromesifen in chilli fruit.



a) Preparation of rearing chamber



b) Release of thrips and mites in rearing chamber and final experimental setup

Plate 1. Preliminary lab experiment to fix the silicon dose



a) Experimental field (Summer, 2018)



b) Experimental field (Rabi, 2018)

Plate 2. Experimental fields used for bio-efficacy and dissipation study.



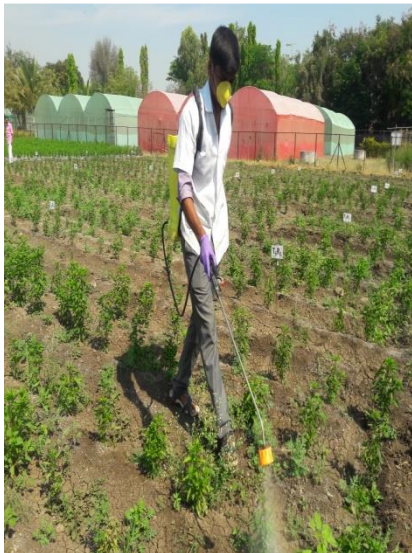
a) Land preparation



b) Tagging of plants



c) Taking appropriate quantity of insecticide



d) Imposition of treatments



e) Plant infested with thrips and mites



f) Recording of observations



g) Harvesting of chilli



f) Recording of yield

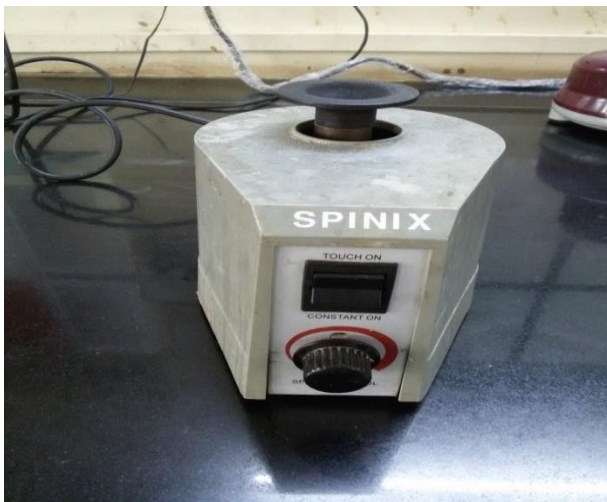
Plate 3. Study of bio-efficacy of insecticides and Biorationals.



Grinder



Digital balance



Vertex



Centrifuge



Low volume evaporator



Deep freezer

Plate 4. Apparatus used during residue analysis.



a) View of different equipments used for extraction and cleanup.



b) Grinding of chilli to get homogenous sample.



c) Extraction and cleanup

d) High Performance Liquid Chromatography (HPLC)

Plate 5. Overview of dissipation study.