“SEASONAL INCIDENCE, MANAGEMENT OF THRIPS AND RESIDUE STUDIES IN CHILLI (*Capsicum annuum* L)”

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M.Sc. (Ag.)

DOCTOR OF PHILOSOPHY IN AGRICULTURE
(ENTOMOLOGY)

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BY
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M.Sc. (Ag.)

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PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY
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(ENTOMOLOGY)

CHAIRPERSON: Dr. C. NARENDRA REDDY

DEPARTMENT OF ENTOMOLOGY

COLLEGE OF AGRICULTURE
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PROFESSOR JAYASHANKAR TELANGANA STATE
AGRICULTURAL UNIVERSITY
2017

CERTIFICATE

Mr. ANUGU ANIL REDDY has satisfactorily prosecuted the course of research and that thesis entitled "SEASONAL INCIDENCE, MANAGEMENT OF THRIPS AND RESIDUE STUDIES IN CHILLI (*Capsicum annuum* L)" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any university.

(Dr. C. NARENDRA REDDY)

Date: **Chairperson**

CERTIFICATE

This is to certify that the thesis entitled "SEASONAL INCIDENCE, MANAGEMENT OF THRIPS AND RESIDUE STUDIES IN CHILLI (*Capsicum annuum* L)" submitted in partial fulfilment of the requirements for the degree of **'**Doctor of philosophy in Agriculture' of the Professor Jayashankar Telangana State Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr. ANUGU ANIL REDDY under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigation have been duly acknowledged by the author of the thesis.

(Dr. C. Narendra Reddy)
Chairperson of the Advisory Committe

Thesis approved by the Student Advisory Committee

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Date of final viva voce : 11-07-2017

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DECLARATION

I, **ANUGU ANIL REDDY,** hereby declare that the thesis entitled **"SEASONAL INCIDENCE, MANAGEMENT OF THRIPS AND RESIDUE STUDIES IN CHILLI (*Capsicum annuum* L)"** submitted to the **Professor Jayashankar Telangana State Agricultural University** for the degree of **Doctor of Philosophy in Agriculture** is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier in any manner.

Place: Hyderabad **(ANUGU ANIL REDDY)**

Date: **I. D. No. RAD/2014-16**

LIST OF ABBREVIATIONS

%	:	Per cent
±	:	Plus or minus
µg g^{-1}	:	Microgram per gram
µl	:	Microlitre
a.i.	:	Active ingredient
AINP	:	All India Network Project
BDL	:	Below Determination Level
CD (P = 0.05%)	:	Critical Difference at 5 per cent level
cm	:	Centimeter
DAS	:	Days After Spraying
EC	:	Emulsifiable Concentrate
et al.	:	and others
FSSAI	:	Food Safety and Standard Authority of India
FYM	:	Farm Yard Manure
g a.i. ha^{-1}	:	Gram active ingredient per hectare
g	:	Gram
ha	:	Hectare
GC	:	Gas Chromatography
hrs	:	Hours
i.e.	:	that is
kg ha^{-1}	:	Kilogram per hectare
kg	:	Kilogram
km hr^{-1}	:	Kilometre per hour
l	:	Litre
m	:	Metre
m^2	:	Metre square
mg kg^{-1}	:	Milligram per kilogram
mg	:	Milligram
min	:	Minute
ml ha^{-1}	:	Millilitre per hactare
ml l^{-1}	:	Millilitre per litre
ml	:	Millilitre

mm	:	Millimetre
mm/day	:	Millimetre per day
MRL	:	Maximum Residue Limit
ng	:	nano gram
nm	:	nanometre
No.	:	Number
^{o}C	:	Degree Celsius
ppb	:	Parts per billion
ppm	:	Parts per million
q ha^{-1}	:	Quintals per hectare
RBD	:	Randomized Block Design
RL_{50}	:	Half life
SC	:	Soluble Concentrate
SEm	:	Standard Error of mean
t	:	Tonne
t ha^{-1}	:	Tonnes per hectare
T_{tol}	:	waiting or safe period
viz.,	:	namely
WG	:	Wettable Granules

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Date :

Place : Hyderabad ***(ANUGU ANIL REDDY)***

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ABSTRACT

The study entitled on "Seasonal incidence, management of thrips and residue studies in chilli (*Capsicum annuum* L)" was conducted during *kharif* 2015-16 and 2016-17. The field studies on seasonal incidence and bioefficacy studies against chilli thrips was conducted at Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad during *kharif* 2015-16 and 2016-17, while laboratory studies on dissipation, decontamination and processing factor were carried out at All India Network Project on Pesticide Residues, Rajendranagar, Hyderabad during *kharif* 2015-16.

During both the seasons of investigation *viz., kharif* 2015-16 and 2016-17, The *Scirtothrips dorsalis* incidence was observed from transplanting to harvesting stage and the highest thrips population were recorded during January 3rd week (3rd standard week) with 24.82 thrips per five leaves in *kharif* 2015-16. While during *kharif* 2016-17 it was December last week (52nd std. week) with 17.01 thrips per five leaves.

The relationship between the thrips population with preceding one week (one week lag) weather parameters during *kharif* 2015-16 revealed that there was a significant negative correlation was observed between weather parameters of maximum temperature (-0.51**), minimum temperature (-0.80**), mean temperature (-0.87**), rainfall (-0.55**), rainy days (-0.59**) at 1% level of significance. During *kharif* 2016-17, maximum temperature (-0.59**), minimum temperature (-0.83**), evening relative humidity (-0.66**), rainfall (-0.59**), rainy days (-0.67**) and mean temperature (-0.87**) were negatively significant with the thrips population at 1% level of significance.

The multiple regression equations developed for the thrips population with preceding one week weather parameters (one week lag) during *kharif* 2015-16 and 2016-17 revealed that all the weather parameters collectively influenced the thrips population to the extent of 93.92 and 92.65 per cent, respectively.

Efficacy of different insecticides on *Scirtothrips dorsalis* population during *kharif* 2015-16 and 2016-17 revealed that, spinosad at 125 g a.i. ha^{-1} was found to be the most effective treatment with 59.09 per cent reduction of *Scirtothrips dorsalis* followed by fipronil at 500 g a.i. ha^{-1} (52.11%), betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (49.07%), profenophos at 400 g a.i. ha^{-1} (47.86%), dimethoate at 300 g a.i. ha^{-1} (39.03%), lambda cyhalothrin15.63 g a.i. ha^{-1} (35.91%) and chlorantraniliprole at 30 g a.i. ha^{-1} (8.58%) over control. Highest chilli yield (kg ha^{-1}) during *kharif* 2015-16 and 2016-17 was also followed in the same trend.

The initial deposits of fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} were 1.47, 0.78, 0.56, 2.60, 1.20, 1.10, 0.28 and 3.86 mg kg^{-1}, respectively after third spray in chilli which dissipated to below detectable level at 15, 7, 7, 10, 7, 7, 5 and 15 days, respectively and the waiting periods for safe harvest were determined 36.34, 28.81, 21.98, 5.60, 11.16, 11.05, 0.59 and 6.64 days, respectively.

Among various decontamination methods tested, Formula 1 was found to be most effective in removing pesticide residues to an extent of 62.72-75.71 per cent varying with type of pesticides, followed by 2% salt solution in chlorantraniliprole, profenophos, lambda cyhalothrin and dimethoate, while 0.1% baking soda solution was found more effective than 2% salt solution in fipronil, spinosad, imidacloprid and beta cyfluthrin and least removal of all insecticides from green chillies was recorded from tap water wash which ranged from 10.57 to 30.19 per cent.

The processing factors for test insecticides *viz.*, fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} were 2.77, 1.50, 2.36, 3.01, 2.44, 2.39, 2.83 and 3.20, respectively.

Chapter I

INTRODUCTION

Chilli (*Capsicum annuum* L.), is an important vegetable and condiment crop grown throughout the world and it has immense commercial, dietary and therapeutiuc values. It is a rich source of A, C, E and P and an alkaloid capsacin, which has high medicinal value and is used in many pharmaceutical preparations. India is the world leader in chilli production followed by China and Pakistan. The major chilli exporting countries with their percentage share in world exports are India (25%), China (24%), Spain (17%), Mexico (8%), Pakistan (7.2%), Morocco (7%) and Turkey (4.5%). The bulk share of chilli production in the world is held by Asian countries. In India chilli is cultivated in an area of 774.9 lakh ha with an annual production of 1492.1 lakh tones (Horticultural Statistics, India 2015). Important chilli growing states in India are Andhra Pradesh, Telangana, Karnataka, Maharashtra and Tamilnadu which constitute nearly 75 per cent of the total area under chilli. Area under chilli crop in Andhra Pradesh and Telangana is around 1.72 lakh ha which is about 25.12 per cent of the total area in India (VenkataRamesh *et al*., 2015) In Telangana State it is grown in 73,000 hectares with 2,53,000 tonnes production from major chilli growing areas such as Khammam, Warangal, Mahabubnagar and Ranga Reddy districts (*WWW. Indiastat.com*).

Although the crop has great export potential besides huge domestic requirement, a number of limiting factors contribute for its low productivity. Among these various biotic stresses, ravages caused by insect pests are significant. The pest spectrum in chilli is complex with more than 293 insects and mites species debilitating the crop in field as well as in storage (Butani, 1976). Among these, chilli thrips, *Scirtothrips dorsalis* Hood has become the most notorious and pernicious pest on chilli. The overall reduction in fruit yield of chilli due to thrips and mites damage was up to 34 per cent (Thania *et al.*, 2011). These pests not only cause reduction in yield, but also act as vectors for several viral diseases and cause complete failure of crop and various biotic (pest and diseases), abiotic (rainfall, temperature, relative humidity and light intensity) and phonological factors (flower and fruit drop) limits the yield and quality of the chilli.

Due to variation in the agro climatic conditions of different regions, the nature and extent of damage caused by thrips varies. Environmental factors play an important role in determining the seasonal abundance and damage caused by the insect pest.

Hence it is necessary to study the influence of various abiotic factors effecting the population fluctuation of thrips in chilli crop. These studies would give an idea about the peak period of their activity which in turn may be helpful in developing better pest management strategies. Inspite of several insecticidal recommendations against this pest, desirable control has been far away, needing a constant search for effective chemicals is a regular feature of entomological research to offer timely suggestions to the growers.

A number of pesticides are being frequently used, to combat these pests. However, some of these insecticides leave residues on pods and these residues may persist up to harvest. Presence of pesticide residues in the harvested chillies was posing problem at the time of export and in recent times importing countries have rejected few consignments. Pesticide use has increased rapidly over the last two decades at the rate of 12 per cent per year (Thacker *et al*., 2005).

As per insecticides Act of 1968 (www.cibrc.nic.in), 37 insecticide formulations are registered and recommended for use on chilli targeting various pests. Indiscriminate use of synthetic pesticides causes severe ecological consequences like destruction of natural enemy fauna, effect on non-target organisms, secondary pest outbreaks. In addition it leads to pesticide residues in food and contaminates the environment which may lead to deleterious impacts not only on human health, but also on other biota (Sreelatha and Diwakar, 1997). The cultivators impressed by the apparent advantages of these insecticides are using such chemicals indiscriminately without caring for ill effects.

The crop production strategies, now-a-days has however experienced a paradigm shift from pest “control” to pest “management”. As exclusion of chemical insecticides is impracticable, the use of most selective and effective insecticide is essential. Vegetables retain residues of a varietal cocktail of chemicals since these are applied at different stages of crop growth and even just prior to frequent harvests resulting in health hazards to the consumers.

The extensive and irrational use of pesticides resulted in the presence of residues of insecticides on chilli is likely to be associated with severe effects on human health. Hence, great significance has to be given to estimate pesticide residues in chilli and to standardize simple cost effective methods which can be practiced by home makers to eliminate pesticide residues. In the light of the above facts a study was carried out to measure the residues in chilli and to assess the effect of different decontamination techniques on the removal of pesticide residues.

Sometimes, processing of chilli leads to increase in the concentration of the pesticides in final product. Hence, in view of the possible residue problems posed by these chemicals to the consumers, this study was taken up to find out the magnitude of increase in concentration of these insecticides (processing factor) in processed chilli so as to prescribe the suitable processing factor for chilli.

In this context, certain new insecticides have been considered for establishing their bio-efficacy against chilli thrips, *Scirtothrips dorsalis* Hood and their toxic residues on the produce. Hence, the present investigation entitled "Seasonal incidence, management of thrips and residue studies in chilli (*Capsicum annum* L)"has been contemplated with the following objectives:

1. To study the seasonal incidence of chilli thrips, *Scirtothrips dorsalis* Hood and to correlate the incidence with various abiotic factors of environment.
2. To evaluate the bio-efficacy of selective insecticides against chilli thrips, *Scirtothrips dorsalis* Hood.
3. To establish the dissipation pattern of selective insecticides on chilli.
4. To evaluate decontamination methods for the selective insecticides in chillies.
5. To determine the processing factor of selective insecticides in chillies.

Chapter II

REVIEW OF LITERATURE

The review pertaining to the “Seasonal incidence, management of thrips and residue studies in chilli (*Capsicum annuum* L)” are presented below. The literature on other vegetable crops were reviewed, wherever the literature was inadequate in chilli.

2.1. Seasonal incidence of chilli thrips and correlation of the incidence with various abiotic factors of environment.

Ayyar *et al*. (1935) has described the crop season and rainfall in Guntur (Andhra Pradesh) and Periyakulam (Tamil Nadu) area. In both areas, the rainfall was more during North-East monsoon. However, it was early in Guntur and late in Periyakulam. In both the places, the population of thrips was low during rainy season. Vevai (1969) reported that the incidence of *S. dorsalis* on chilli was throughout the year in Tamil Nadu and Maharashtra. Rangarajan *et al*. (1974) observed that the thrips appeared both in summer and winter in Tamil Nadu.

Amin (1980) found that the rate of reproduction was higher when *S.dorsalis* was reared at 26^{0}C. The studies on spatial and seasonal distribution pattern of *Frankliniella schultzei* infesting *Ricinus communis* and *Achyanthes aspera*, by Anantha Krishnan *et al*. (1982), revealed that the population reached its peak during warmer months.

Thrips were normally found on the adaxial surface of leaves and hence heavy rains washed off 70 per cent of *Thrips tabaci*. Irrespective of the monsoon season heavy rainfall (above 600mm) influenced the population of thrips species (Daniel, 1983). Heavy rainfall can wash thrips off the plants and down to the soil surface, causing sudden and sharp decline in population density (Bonnemaison and Bournier, 1964; North and Shelton, 1986).

Velayudhan *et al*. (1985) observed that rainfall and temperature had a significant negative impact not only in their numerical strength of thrips, but also on their reproductive ability and soil population. Rainfall and higher temperature caused dramatic decline in population during May-June and November-December.

According to Patnaik *et al*. (1986), the incidence of chilli thrips was low from August to December and from May a steady rise in the pest population was noticed. The peak incidence coincided with January, after which the population declined. They also reported that, temperature, rainfall and relative humidity were negatively correlated with thrips population but diurnal temperature variation was positively correlated. The damage was very severe during cool and dry months.

Borah (1987) observed that the activity of *S. dorsalis* was found throughout the year. However, incidence was more during September to March while it was moderate in rest of the year. The incidence of *S. dorsalis* on chillies was severe from September to January. Further, the author reported that, the population increased during dry periods with minimum temperature and less intensity of rainfall.

Varadharajan and Veeraval (1995) noticed the activity of *S. dorsalis* throughout the year. The incidence of *S. dorsalis* as indicated by yellow sticky trap catches during 1994 was minimum (9.40/ trap) during the last week of July and maximum (55.25/ trap) during the first week of September. The correlation between thrips population and maximum temperature was statistically significant and the regression equation fitted with maximum temperature showed that with a increase of 1^0C of maximum temperature would result in an increase of 3.77 thrips per leaf.

Chandrasekar (2003) studied the population dynamics of chilli thrips, *S. dorsalis* and reported a negative relationship between the population of thrips and maximum temperature which was highly significant, whereas the minimum temperature had highly significant positive relationship resulted in increase in the population of thrips. The relative humidity and sunshine hours also were significant positively correlated where as wind velocity and rainfall had no significant relationship with the population of thrips during November 2002 to July 2003 at Madurai district, Tamil Nadu.

The incidence of *S. dorsalis* on chilli was highest during 40^{th} meteorological week and the population exhibited significant negative correlation with evening relative humidity and rainfall and positive correlation with bright sunshine hours (Bhede *et al*., 2008).

Patel *et al*. (2009) reported that the incidence of *S. dorsalis* on chilli commenced from first week of September and continued up to harvest of the crops with peak activity in November (4.99 to 5.54 thrips/leaf) and February – March (5.29 to 7.39 thrips/ leaf). Correlation coefficient values worked out for thrips incidence and weather parameters revealed a significant positive correlation with bright sun shine hours and maximum temperature whereas significant negative correlation was found with morning afternoon and mean relative humidity, morning, afternoon and mean vapour pressure as well as rainfall. Among the different abiotic factors studied, decrease in afternoon relative humidity (between the range of 20 to 40 per cent) helped in buildup of the pest population, whereas thrips population decreased with increasing rainfall.

Meena *et al.* (2013) reported that the peak population of thrips (14.5 and 14.7 per 3 leaves per plant) during first week of October and the population exhibited a positive correlation with maximum temperature while the correlation was negative with minimum and mean temperature, maximum, minimum and mean relative humidity and average rainfall.

In another study, the incidence of thrips, *S. dorsalis* was observed throughout the cropping season with varying intensity ranging from 0.07 to 5.88 with a mean of 3.53 thrips per top 3 leaves per plant. The infestation of thrips was noticed in the third week of September and continued up to fourth week of December. The data on correlation between incidence of thrips and weather parameters showed significant relationship. A negative relationship was observed with maximum and minimum temperature, morning RH and sunshine hours; while, positive correlation was observed with the rainfall and evening RH (Roopa and Ashok Kumar, 2014).

Yadav *et al.* (2014) stated that the occurrence of higher temperature showed significant positive correlation with thrips while relative humidity and rainfall showed negative correlation in chilli.

Bokan *et al*. (2015) reported that incidence of thrips in chilli crop started from 35th standard week and maximum population were recorded during 42nd standard week. The population was significant and positively correlated with bright sunshine hours, while the significant and negative correlation with minimum temperature, morning and evening relative humidity.

Zainab *et al*. (2016) studied that population dynamics of chilli thrips, *Scirtothrips dorsalis* Hood, on chilli and highest incidence of thrips was observed during first week of October. The population of thrips showed significant positive correlation with maximum temperature and negatively correlated with rainfall and relative humidity.

Arti Saini *et al*. (2017) noticed that incidence of thrips commenced in second week of August and thrips touched the peak during the third week of September (10.2/3 leaves). Thrips exhibited a negative correlation with temperature and rainfall, whereas positive correlation with relative humidity.

Sahu *et al.* (2017) stated that the occurrence of chilli thrips, *Scirtothrips dorsalis* in *kharif* 2015 was commenced from 35th standard week (August third week) with an average 0.2 per cent infestation and population increased gradually reached peak level of 5.6 per cent infestation at 42nd standard week (October second week). Thereafter, declined trend were observed due to fall of maximum and minimum temperatures as optimum weather condition were decreasing.

2.2. Bio-efficacy of selective insecticides against thrips on chilli.

The bio-efficacy of insecticide *viz.,* fipronil 5% SC, spinosad 45% SC, chlorantraniliprole 20% SC, profenophos 50% EC, λ-cyhalothrin 5% SC, imidacloprid + beta cyfluthrin 300% OD and dimethoate 30 % EC along with untreated control were evaluated during *kharif* 2015 - 16 and 2016-17.

Literature pertaining to above insecticides on chilli were scanty. Hence, the information on other vegetable crops were reviewed, wherever the literature was inadequate on chilli.

2.2.1 Fipronil

Two fipronil formulations were evaluated by Kadam and Dethe (2002) against chilli thrips (*S. dorsalis*) at Rahuri (MS), India. Fipronil (0.3 G) granules incorporated in seedbed at the rate of 40 to 60 g per m^2 suppressed the incidence of thrips on seedlings considerably and four foliar sprays of fipronil 5 SC at fortnightly interval lowered the level of infestation in transplanted crop. Increase in plant height, chlorophyll content and green chilli yield was also reported.

Jadhav (2003) evaluated the efficacy of fipronil 5 SC at different concentrations against sucking pests of chilli in comparison with imidacloprid 17.8 SL @ 20 g a.i. ha^{-1}, phosalone 35 EC @ 500 g a.i. ha^{-1} and fipronil 5 SC @ 100 g a.i. ha^{-1} recorded lowest population of sucking pests and highest yield. Fipronil was found effective at 50 g a.i. ha^{-1} against chilli thrips as reported by Jadhav *et al*. (2004).

Rajkumar *et al.* (2005) studied the relative efficacy of six selected insecticides against rose thrips (*Rhipiphorothrips cruentatus* H.). The results revealed that fipronil (0.01%) was the most effective chemical and protected the crop against thrips up to 15 days after treatment. Acephate (0.075%) and imidacloprid (0.1%) were least effective against the thrips.

Reddy *et al.* (2005) studied the bioefficacy of certain new insecticides along with traditional insecticides as foliar spray against chilli thrips (*S. dorsalis*) and mites (*P. latus*). 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, while carbaryl 50 WDP (0.15%), followed by phosalone 50 EC (0.07%) and chlorpyriphos 20 EC (0.05%), were the least effective. Reddy *et al.* (2007) found fipronil 5% SC at 2 ml l^{-1} was effective in controlling thrips, mites and fruit borers in chilli.

Prasad and Ahmed (2009b) reported that fipronil 5 SC 50 g a.i. ha^{-1} was the most effective insecticide for chilli thrips followed by lufenuron 5 EC @ 30 g a.i. ha^{-1} and 25 g a.i. ha^{-1}.

Venkat Reddy and Sreehari (2009) reported that the fipronil 80 WG @ 50 g a.i. ha^{-1} recorded lowest number of thrips and was on par with fipronil 80 WG @ 40 g a.i. ha^{-1}, regent 5% SC @ 40 g a.i. ha^{-1} and acephate 75% SP @ 468.75 g a.i. ha^{-1}, whereas confidor 200 SL and fipronil 80 WG @ 30 g a.i. ha^{-1} were found least effective against thrips.

Fipronil 80 WG @ 60 g a.i. ha^{-1} was effective in reducing the thrips populations with increased yield of onion (Hosamani *et al.*, 2012).

Jacob *et al*. (2015) evaluated efficacy of eleven insecticides and natural products against cardamom thrips (*Sciothrips cardamomi*). Among that fipronil 0.005% treated plots recorded the lowest percentage of damage (6.5%) that was on par with imidacloprid 0.0089%, thiamethoxam 0.0075% and spinosad 0.0135%.

Jadhao *et al*. (2016) found that fipronil 5 SC @ 0.005% was found most effective to reduce the thrips population (57.3%) and it gave highest marketable green chilli yield (9.98 t ha^{-1}) followed by spinosad 45 SC @ 0.018%, lambda cyhalothrin 5 EC @ 0.005% and clothianidin 50 WDG @ 0.006% in reducing thrips population by 55.6, 53.7 and 51.8 per cent, respectively.

2.2.2 Spinosad

Spinosad has broad spectrum of activity against a range of agricultural insect pests, pod borer, *H. armigera* (Hines and Hutchison, 2001), cabbage butter fly, *Pieris rapae* (Linnaeus), diamond back moth (DBM), *Plutella xylostella* (Linnaeus) (Shivalingaswamy *et al*., 2006) and cabbage looper, *Trichoplusia ni* (Hubner) (Satpathy *et al*., 2007). It is the most potential and powerful insecticide for controlling the selective insects in vegetables cultivated in greenhouses (Schoonejans and Staaij, 2001). Spinosad may also be used on row crops, vegetables and ornamentals (Copping and Duke, 2007). Spinosad was rapidly degraded on soil surfaces by photolysis and below the soil surface, by soil microorganisms (Saunders and Bret, 1997). It is available in market with the trade name of Tracer 45 % SC, used @ 75-100 g a.i. ha^{-1} against bollworm complex and as Success 2.5 % SC @ 15-17.5 g a.i. ha^{-1} on vegetables (cabbage, cauliflower).

Srinivas *et al.* (2002) studied the efficacy of spinosad (Tracer 45SC) chilli thrips, *Scirtothrips dorsalis* Hood and fruit borer, *Helicoverpa armigera* (Hubner). Spinosad at all the four doses tested, *viz.*, 45, 56, 73 and 90 g a.i. ha^{-1} was highly effective in controlling the thrips and fruit borer infestation for a period of 10 days after the spray. Also, a significant increase in fruit yield in comparison to the standard recommended checks; chlorpyriphos (500 g a.i. ha^{-1}), endosulfan (525 g a.i. ha^{-1}) and fipronil (40 g a.i. ha^{-1}).

Reddy *et al*. (2007) evaluated the certain new insecticides against pest complex of chilli at Malyal, Andhra Pradesh. Spinosad 45 % SC @ 0.3 and 0.2 ml l^{-1} was found to be the best treatment against fruit borer, *S. litura* followed by indoxacarb 14.5 % SC @ 1 and 0.5 ml l^{-1}.

Prasad and Ahmed (2009a) conducted field studies to evaluate the efficacy of spinosad 45 SC @ 100, 125, 162.5 and 200 ml ha^{-1} along with standard checks viz., endosulfan and chlorpyriphos on chilli during 2002-03 and 2003-04 at Guntur. Spinosad

45 SC @ 125 ml ha^{-1} exhibited highest efficacy for control of *S. dorsalis* and fruit borer, *S.litura* on chilli.

Kumar *et al*. (2013) reported the effectiveness of spinosad 45 SC @ 0.3 ml l^{-1} on *S. dorsalis* causing adult mortality within ten days and nymph in 15 days of foliar spray on chilli. Vanisree *et al*., (2011) reported that spinosad 0.015 was most effective in reducing the population of chilli thrips as well as increasing the yield

Hossaini *et al*. (2014) found that spraying of spinosad (Tracer 45 SC) @ 0.4 ml l^{-1} + White sticky trap @ 40 traps ha^{-1} resulted the lowest thrips **(***Thrips tabaci* Lindeman) population (3.20, 3.11, 3.74 thrips per plant after first, second and third treatment application, respectively) with highest marginal benefit cost ratio (19.94) in garlic insect pest management. The highest percentage of thrips population (82.60) reduction over control and the highest garlic bulb yield (8.77 t ha^{-1}) was also obtained from spinosad @ 125 ml ha^{-1} (Tracer 45 SC) + White sticky trap treated plot.

Bokan *et al.* (2016) found that acetamiprid 20 SP @ 10 g ha^{-1} and spinosad 45 SC @ 135 g ha^{-1} were effective in controlling thrips and whiteflies in chilli. Acetamipride 20 SP @ 10 g ha^{-1} gave the highest yield (51.30 q ha^{-1}) followed by spinosad 45 SC @ 135 g ha^{-1} (48.40 q ha^{-1}).

Ravi kumar *et al*. (2016) tested the efficacy of biorationals against thrips, *Scirtothrips dorsalis* Hood on chilli. Among the biorationals, spinosad 45 SC @ 0.4 ml l^{-1} and emamectin benzoate 5 SG @ 0.4 g l^{-1} was found to be superior over standard check dimethoate 30 EC @ 2 ml l^{-1} registering the least population of 0.55 and 0.59/leaf.

2.2.3 Chlorantraniliprole

Chlorantraniliprole is a anthranilic diamide insecticides having excellent activity on lepidopteran insects with field application rate of 25 – 75 g a.i.ha^{-1} (Lahm *et al*., 2007) and can be as low as 15-20 g a.i.ha^{-1} against *Earias vitella* (Fab) and *L. orbonalis* (Kodandaram *et al*., 2010a and Kodandaram *et al*., 2010b). It provides rapid plant protection through the cessation of larval feeding soon after consumption. It also has ovicidal and ovo-larvicidal action. It was also effective against leaf miners, beetles, weevils and white grubs. Because of its translaminar and systemic action, chlorantraniliprole can be applied as foliar spray and as soil application. It is found to be safe to parasitoids, predators and pollinators. It is available as trade name as Coragen 20 SC and used at 10 g a.i.ha^{-1} against *P. xylostella* in cabbage and cauliflower.

2.2.4 Profenophos

Raghvani *et al*. (2000) reported that application of polytrin – c, a mixture of the synthetic pyrethroid, cypermethrin and an organoposphate, profenophos resulted in the lowest population of *Caliothrips indicus* and the greatest yield of bulbs in garlic.

Dey *et al.* (2001) evaluated the efficacy of profenophos 50 EC (Curacron) and profenophos 40% + cypermethrin 4% (Polytrin C) against yellow mite (*Polyphagotersonemus latus* Banks), thrips (*Scriptothrips dorsalis* Hood) and aphid (*Aphis gossypi*) infesting chilli in comparison with conventional pesticides in two different seasons. Profenophos alone at 1000 g a.i.ha^{-1} and profenophos in combination at 440 g a.i.ha^{-1} were highly effective against the three important pests of chilli and were proved to be better than monocrotophos 36 SL and diazinon 20 EC.

Sallam and Hosseny (2003) reported that profenophos 75 EC 2 ml l^{-1} was moderately effective against *T. tabaci* on onion. Chakraorthi (2004) declared that profenophos at 2 ml litre^{-1}, 6 sprays at 15 day interval, effectively controlled the thrips, *S. dorsalis* in chilli.

Singh *et al*. (2012) stated that four days after each spray, significantly lowest thrips population of 1.48, 1.27, 2.87, 1.77 and 2.0 nymphs/plant. respectively was recorded with profenophos @1 ml l^{-1} followed by spinosad @ 56 g a.i.ha^{-1} with 5.02, 8.15, 17.82, 11.82 and 9.35 nymph/plant after first, second ,third, fourth and fifth spray respectively on onion.

Tatagar *et al*. (2014) conducted field experiments to find out the bio-efficacy of Flubendiamide 24% +Thiacloprid 24% -48% SC against chilli thrips. Different dosages of Flubendiamide 24% + Thiacloprid 24% -48% SC viz., @ 36 + 36, 48 + 48 and 60 + 60 g a.i.ha^{-1}, were evaluated along with comparative checks. Among different dosages, Flubendiamide 24% + Thiacloprid 24% -48% SC @ 48 + 48 g a.i.ha^{-1} recorded least number of thrips and least leaf curl damage of 0.46 LCI plant^{-1} which was significantly superior to comparative checks and recommended insecticide, profenophos 50 EC @ 500 g a.i.ha^{-1} and equally good as that of its higher dosage.

Dwivedi *et al*. (2017) evaluated efficacy of botanicals like neem crude oil @ 4%, pongamia crude oil @ 4%, dasparni @ 50 ml l^{-1}, *Beauveria bassiana* (1013 spores ha^{-1}), spinosad @ 56 g a.i.ha^{-1} along with a chemical insecticide like profenophos @ 1 ml l^{-1} against onion thrips. The results revealed that profenophos @ 1 ml l^{-1} and Neem crude oil @ 4% significantly reduced the thrips population (3.35 and 10.45 thrips/plant) but also increased total marketable yield (30.45 and 26.50 t ha^{-1}), respectively.

2.2.5 Lamda-cyhalothrin

Ashokan *et al.* (1992) evaluated lambda-cyhalothrin (Karate), a new synthetic pyrethroid in laboratory for its efficacy against *Scirtothrips dorsalis* H. along with cypermethrin 75 µg g^{-1} , deltamethrin 15 µg g^{-1} and methyl demeton 250 µg g^{-1} etc. Lambda-cyhalothrin 62.5 and 50 µg g^{-1} and cypermethrin 75 µg g^{-1} registered cent per cent mortality.

Bocak (1995) tested eleven insecticides against *T. tabaci* in onion, of which alpha-cypermethrin (25 g a.i. ha^{-1}) and lambda-cyhalothrin (12.5 g a.i. ha^{-1}) reduced the pest population significantly. Further, he stated that pyrethroids had very good and relatively long lasting efficacy against thrips.

A field experiment on onion was conducted by Khan *et al.* (1995), they found that monocrotophos 36 WSC (60 ml per 100 lit. of water) and cypermethrin 5 EC (50 ml per 100 lit. of water) were the most effective insecticides for controlling the infestation of *T. tabaci*, followed by lambda-cyhalothrin 2.5 EC (25 ml), triazophos 40 EC (80 ml) and fenvalerate 20 EC (30 ml) per 100 liter of water.

Goncalves (1996) tested different dosages of insecticides *viz*., deltamethrin + triazophos (EC) at 3.0 + 105.0, 4.5 + 157.5 and 6.0 + 210.0 g a.i. ha^{-1}, cypermethrin (EC) at 50, 120 and 150 g a.i. ha^{-1} and lambda-cyhalothrin (WP) at 15 g a.i. ha^{-1} against *T. tabaci*. The treatments with lambda-cyhalothrin and cypermethrin were effective, but only cypermethrin at 150.0 g a.i. ha^{-1} increased the yield of onion bulbs.

Mathirajan (1998) found that thrips population on chillis were greatly reduced by lamda-cyhalothrin @ 15 g a.i. ha^{-1} with 73 per cent reduction.

An experiment was conducted to evaluate the efficacy of four newer insecticides viz., difenthiuron (Pegasus 50 WP), thiamethoxam (Actara 25 WG), acetamiprid (Pride 20 SP) and lambda-cyhalothrin (Karate 5 EC) against onion thrips during Rabi 2003 at

Pune. The results showed that lambda-cyhalothrin @ 80 g a.i. ha^{-1} was very effective, followed by lambda-cyhalothrin @ 40 g a.i. ha^{-1} and monocrotophos 0.05 per cent against onion thrips (Anonymous, 2003).

In another field experiment, four new insecticides were tested during Rabi season each at two doses against *T. tabaci* on onion. It was observed that lambda-cyhalothrin (Karate @ 50 g a.i. ha^{-1}) was significantly effective in reducing the thrips population in all the four sprays, followed by its lower dose 25 g a.i. ha^{-1} (Anonymous, 2005).

Sule *et al*. (2008) evaluated the efficacy of fipronil 5 SC (0.01%), acetamiprid 20 SP (0.004%), difenthiuron 50 WP (0.05%), lambda-cyhalothrin 5 EC (0.005%), bifenthrin 10 EC (0.016%) and endosulfan 35 EC (0.035%) against *T. tabaci* on onion (cv. N 2-4-1) in Pune, (MS), India, during the winter season of 2005. The results revealed that all the insecticides were effective against the pest. In E1 and E2, lambda-cyhalothrin was the most effective, as it recorded the lowest cumulative thrips count (2.63 and 3.62, respectively) and highest yields (23.99 and 22.55 t ha^{-1}). E1 was more effective than E2.

Patra *et al.* (2015) reported that application of lambda-cyhalothrin 4.9 CS at four dose levels (12.5, 15, 20 and 25 g a.i.ha^{-1}) against the chilli thrips. Lowest average score of thrips (0.75 and 1.19 in two years) were recorded in lambda-cyhalothrin 4.9 CS @ 25 g a.i.ha^{-1} treated plots and highest yield was recorded from lambda-cyhalothrin 4.9 CS @ 25 g a.i.ha^{-1} treated plots (62.33 and 61.06 q ha^{-1}).

Zote *et al.* (2016) conducted experiment at Regional Fruit Research Station, Vengurle, for the management of cashew thrips during 2012-13 to 2014-15. Among the different insecticides tested against cashew thrips, 0.003 per cent lmbda-cyhalothrin (three sprays) was observed to be the most effective with the least per cent incidence (2.15%) followed by a treatment comprising three sprays of different insecticides (monocrotophos 0.05 per cent at flushing, profenophos 0.05 per cent at flowering and lambda-cyhalothrin 0.003 per cent at fruit and nut development stage).

2.2.6 Imidacloprid + beta cyfluthrin

Sunanda and Dethe (1998) reported that, nursery treatment of chilli seeds with imidacloprid 70 WS at the rate of 15 g kg^{-1} of seeds was effective in keeping the chilli seedlings free from sucking pests *viz.* aphids, thrips and mites.

In another study by the same authors, the treatment with imidacloprid @ 150 ml ha^{-1} recorded significantly highest yield followed by imidacloprid @ 125 and 100 ml ha^{-1}. Lowest leaf curl index in chilli due to thrips was recorded in the sequential treatment which included seed dress and seedling dip with imidacloprid 75 SP 0.5 g l^{-1} (Manjunatha *et al*., 2001).

Patil *et al.*, (2002) reported that imidacloprid 17.8 SL @ 125 ml and 150 ml ha^{-1} was highly effective against the important sucking pest complex of chilli and proved to be better than monocrotophos and dimethoate. The treatment with imidacloprid @ 150 ml ha^{-1} recorded significantly highest yield followed by imidacloprid @ 125 and 100 ml ha^{-1} monocrotophos 36 WSC @ 650 ml ha^{-1} and dimethoate 30 EC @ 750ml ha^{-1}.

Imidacloprid 17.8 SL (0.022 kg a.i. ha^{-1}) was the most effective in suppressing the thrips population (average of 1.46 thrips per 10 apical leaves) and increasing the pod yield of chilli (27.63 q ha^{-1}), followed by monocrotophos and acetamiprid (Mishra *et al.*, 2005). Field experiment conducted by Singh *et al.*, (2005) at Chattisgarh, India, showed that imidacloprid 17.8 SL at 200 ml ha^{-1} was the most effective against *S.dorsalis* and *A. gossypii* in chilli *cv.* Pusa Sadabahar. The green chilli yield was also the highest from the plots applied with imidacloprid.

Bhede *et al*., (2008) reported that application of phosphamidon 40% + imidacloprid 2% SP was more effective for suppression of thrips population and also increased the yield of green chilli. Hosamani *et al.* (2016) tested the different insecticides against major sucking pests like thrips and aphids in chilli. The results revealed that the imidacloprid 17.8% SL @ 75 g a.i. ha^{-1} recorded highest per cent reduction of thrips (73.02) and aphids (79.69) over untreated control.

Sathua *et al*. (2017) studied the efficacy of four different insecticides (namely acephate, imidacloprid, cypermethrin, dimethoate) and three botanicals [namely *Allium sativum* extract, *Allium cepa* extract and NSKE] were against chilli thrips. Among these imidacloprid 17.8 SL reduced maximum thrips population (82.46%) followed by acephate 75 SP (80.86%).

2.2.7 Dimethoate

Bagle *et al.* (1997) reported the efficacy of dimethoate 0.03 per cent and 0.05 per cent when compared to neem product and other insecticides against thrips in chilli variety Pusa Jwala and G4 and found that dimethoate 0.05 per cent was found superior over dimethoate 0.03 per cent.

The superiority of dimethoate 0.03 per cent when compared to neem products in controlling chilli thrips and aphids was reported by Mallikarjuna Rao *et al*. (1999), where a single round of dimethoate 0.03 per cent spray and four sprays of phosalone 0.05 per cent gave good control of the sucking pest.

Bindu *et al.* (2000) studied the effect of application of recommended synthetic insecticides on leaf curl incidence in chilli S-49 due to effective control of thrips *S.dorsalis* showed higher effectiveness of triazophos 0.04% the leaf curl incidence in chlli was found comparivitively lower in a crop protected with triazophos and acephate 0.075% where as methyl -o- dimethon 0.025% was found least effective. Dimethoate 0.03% treated chilli crop had almost equal effect as acephate.

Bhudev *et al.* (2005) reported dimethoate 0.03 per cent was highly effective against jassids and thrips in moth bean, *Vigna aconitifolia* J. followed by monocrotophos (0.036%).

Suresh *et al* .(2006) conducted in vivo experiment to evaluate efficacy of some insecticides on onion in which the most effective treatment as dimethoate 30EC at 1 ml lt^{-1} (73.25) followed by neem oil 3% (64.14) neem gold at 2ml lt^{-1} (57.17) and NSKE 5% (56.06) in control of thrips.

Sakthivel and Qadri (2010) showed synergitic effect of Dimethoate (0.05) along with neem oil (3%) was found effective in reduction of thrips population.

Naik *et al*. (2015) stated that Abamectin 0.002 per cent, malathion 0.04 per cent and dimethoate 0.05 were equally effective in controlling the thrips on green chilli. However, there was variation in the incremental cost benefit ratio among them.

2.3 Establishment of dissipation pattern for selective insecticides on chilli.

The review pertaining to dissipation pattern of selective insecticides viz., fipronil, spinosad, chlorantraniliprole, profenophos, lambda-cyhalothrin, imidacloprid + beta cyfluthrin and dimethoate on chilli were scanty, hence the information on other crops were also reviewed in the foregoing text.

2.3.1 Dissipation pattern of fipronil

Dissipation of fipronil @ 0.01% and profenophos @ 0.1% on chillies were studied by spraying four times at 15 days interval starting from 45 days after transplanting. The initial deposits of fipronil and profenphos after last spray were 0.20 and 0.36 mg kg $^{-1}$ which dissipated to 0.01 and 0.02 mg kg $^{-1}$ by 30 days amounting to the loss of 94.0 and 92.4 per cent, respectively. Half life values for fipronil and profenophos were 16.8 and 41.0 days respectively. Waiting periods of 5 and 19 days have been suggested (Reddy *et al*., 2007).

Gupta *et al*. (2009) conducted the experiment on persistence of bifenthrin (25 and 50 g ai ha^{-1}), fipronil (50 and 100 g ai ha^{-1}) and indoxacarb (70 and 140 g ai ha^{-1}) on okra fruits. The initial deposits varied from 0.259–0.382 μg g^{-1} at low and 0.461–0.688 μg g^{-1} at high rate of application. The residues persisted upto 10 days with half-life of 1.32–1.58 days for bifenthrin, 0.65–1.12 days for fipronil and 0.58–1.02 days for indoxacarb.

Urvashi Bhardwaj *et al*. (2012) estimated that average initial deposits of fipronil were 1.226 and 2.704 mg kg^{-1} on the cabbage heads following 3rd application of fipronil at single and double the dosages, respectively. Half-life periods for fipronil were found to be 3.43 and 3.21 day at single and double the application rates, respectively.

Reddy and Reddy (2013) reported that when fipronil @ 75 g a.i ha^{-1} was sprayed on chilli, recorded initial deposit of 2.01 mg kg^{-1} and half- life value of 3.26 days with safe waiting period of 7.26 days.

Sunayana Saini *et al.* (2014) applied fipronil (Regent) 5% SC @ 50 and 100 g a.i.ha^{-1} at fruiting stage on chilli and recorded average initial deposits of fipronil were 0.409 and 0.808 mg kg^{-1} and half-life values were found to be 3.50 and 3.53 days at single and double doses, respectively.

Duhan *et al.* (2015) found that residues of fipronil and its metabolites dissipated to below detectable level after 30 days of application whereas in soil about 95 per cent of total fipronil residues got degraded within same time period.

Yap Chin Ann and Zehnder Jarropp (2016) reported that Regent 80WG applied at 45.0 g a.i ha^{-1} to 90.0 g a.i ha^{-1} on black pepper, recorded initial deposits below determination limit (0.01 mg kg^{-1}) and pre-harvest interval value 12 days.

2.3.2 Dissipation pattern of spinosad

Dissipation of spinosad in soil, cabbage and cauliflower under subtropical conditions was reported by Anjali *et al.* (2007) and reported that spinosad when applied at 17.5 g a.i.ha^{-1}, the chemical persisted up to 7 days in soil, cabbage and cauliflower and at 35 g a.i.ha^{-1} persisted up to 7 days in soil, 10 days in cabbage and cauliflower. The half life of spinosad residues were 1.5, 2.8 and 2.8 days for 17.5 g a.i.ha^{-1} and 2.6, 2 and 2 days for 30 g a.i.ha^{-1}, respectively.

Zhao *et al*. (2007) studied the dissipation and residues of spinosad in egg plant and soil. The residues of spinosyn A and D in egg plant were below 0.2 μg kg^{-1} at zero days after treatment with a half - life of 1.87 and 0.95 days, respectively.

Anjali *et al.* (2008) found the dissipation behaviour of spinosad on chilli at two application rates (73.0 g a.i.ha^{-1} and 146 g a.i.ha^{-1}). The half-life and safe waiting periods which were found to be 1.48 days and 0.70 days, respectively for 73.0 g a.i.ha^{-1}, 6.72 days and 5.55 days, respectively for 146 g a.i.ha^{-1} application rate. No detectable residues (< 0.05 μg g^{-1}) were found in red chilli sampled on 15th day of application.

Dissipation kinetics of spinosad on cauliflower under subtropical conditions was worked out by Mandal *et al*. (2009) and found that after three applications of spinosad (Success 2.5 SC) at 15 and 30 g a.i. ha^{-1}, the initial deposits of spinosad were observed as 0.57 and 1.34 μg kg^{-1}, respectively and were found to dissipate below the limit of quantification (LOQ) of 0.02 μg kg^{-1} after 10 days at both the doses, respectively, Thus, a waiting period of six days was suggested for the safe consumption of spinosad treated cauliflower.

Cavanna *et al*. (2012) studied the residue levels of spinosad @ 216 g ha^{-1} applied on apples and estimated the residues at 20 days before harvest of fruits and the residues were below 0.01 μg kg^{-1}.

Vijayasree *et al.* (2014) reported the spinosad dissipation kinetics in cowpea pods. The initial deposits of 0.94 and 1.9 μg kg^{-1} reached below detectable level on the seventh day and fifteenth day at single and double doses, respectively. The half-life of spinosad was 1.05-1.39 days with the calculated safe waiting period of 1.09 – 3.25 days.

Totan Adak and Irani Mukherjee (2016) reported that spinosad residues were below the determination limit on tomato fruits after 15 days of application for recommended dose (51 g a.i. ha^{-1}).

2.3.3. Dissipation pattern of chlorantraniliprole

Malhat (2012) studied the residue and persistence behaviour of chlorantraniliprole in tomato fruit samples. Residues in tomato fruit dissipated following first order kinetics. The results showed half life ($t_{1/2}$) value of 3.30 days for chlorantraniliprole in tomato fruit. According to maximum residue limit (MRL) the pre-harvest interval (PHI) of chlorantraniliprole on tomato was 8days after the treatment.

Kar *et al*. (2013) studied the dissipation pattern of chlorantraniliprole on cauliflower and to suggest suitable waiting period for the safety of consumers and found that three applications of chlorantraniliprole (coragen 18.5 SC) at recommended dose (9.25 g a.i. ha^{-1}) and double the recommended dose (18.50 g a.i. ha^{-1}), the average initial deposits of chlorantraniliprole were observed to be 0.18 and 0.29 mg kg^{-1} and decipated to BDL 3 and 5 days at recommended and double the recommended dosages, respectively.

2.3.4 Dissipation pattern of profenophos

Shah *et al*. (1999) reported deposits of 0.762 ppm of profenophos and 0.186 ppm of cypermethrin on okra fruits when sprayed with 0.444 % Polytrin-C (Profenophos 40 % + Cypermethrin 4%) and the half life values of profenophos and Cypermethrin were 1.35 and 3.95 days, respectively. Appa Rao (2003) studied dissipation of profenophos applied @ 0.05% in chilli fruits and observed that the initial deposit of 0.413 ppm reached below detectable level in 5-8 days.

Nasr and Hegazy (2003) determined the residual behaviour of profenophos on tomato and cucumber fruits under field conditions and reported the initial residue as 2.45 ppm on tomato fruits and 2.40 ppm on cucumber fruits. The data showed a gradual decrease of pesticide residues with time and the half-life in tomato fruits was 23 hrs.

Radwan *et al.* (2004) reported a waiting period of 10 and 14 days after application on green pepper and egg plant was enough to reduce the profenophos residues below the maximum residue limits (MRL). However profenophos appeared to have relatively longer persistence with half life of 1.74 and 1.96 days on pepper and egg plant fruits, respectively. Nath *et al.* (2005) studied the dissipation behaviour of Polytrin - C 44 EC (profenophos 40% + cypermethrin 4%) applied at 1 lha^{-1} on okra crop at 0, 1, 3, 5 and 7 days after treatment and found maximum dissipation of 98.4 per cent on 7th day for profenophos followed by cypermethrin (73.5 per cent).

Field trials conducted to study the persistence of profenophos 50 EC in green and cured cardamom showed the mean initial deposit as 2.76 and 2.00 ppm, with a waiting period of 11.1 and 7.8 days in green and cured cardamom capsules, respectively. The residues in all concentrations were dissipated to below detectable limit (0.0625 ppm) by 30 days after application (Renuka *et al*., 2006).

Ahmed *et al.* (2009) evaluated the residue levels of profenophos 72 % EC @ 540 g a.i ha^{-1} in tomato fruits and data showed that, tomato fruits can be safely harvested for human consumption or for processing purposes at 7 days after the spray of profenophos.

Sarangdev *et al.* (2010) studied the spray application of ready mix insecticide Rocket, a mixture of profenophos 40%+cypermethrin 4% @ 440 and 660 g a.i ha^{-1} which resulted in the deposits of 2.14, 2.24 and 2.69, 2.83 ppm on tomato fruits, respectively. The residues reached below detectable limit in 11 and 13 days after spraying in the respective doses.

Profenophos sprayed @1000 and 2000 g a.i.ha^{-1}on soybean, recorded initial deposits of 3.14 and 4.92 ppm on soybean pods, respectively and dissipated to non detectable levels by 11th and 13th days, respectively at low and high concentrations. (Jain *et al.* 2012b).

Profenophos 50 EC when sprayed at 1000 and 2000 g a.i. ha^{-1}on pigeonpea, recorded initial deposits of 3.28 and 5.01 ppm respectively on pigeonpea pods, and dissipated to non detectable levels by 11th and 13th days, respectively at low and high concentrations. (Jain *et al.* 2012a).

Kavitha *et al.* (2016) applied profenophos at 2 ml l^{-1} on capsicum and reported that initial deposits of 2.24 mg kg^{-1} and 3.71 mg kg^{-1} were recorded in open field and poly house, respectively.

Priyadarshini *et al*. (2017) studied the persistence of profenophos 50 EC at 500 g a.i. ha^{-1} on curry leaf. The initial deposits of profenophos (19.83 mg kg^{-1}) dissipated to below detectable level by 25^{th} day after application.

2.3.5 Dissipation pattern of Lambda-Cyhalothrin

Natekar *et al.* (1988) estimated that initial deposit of lambda cyhalothrin 0.005% in brinjal fruit as 0.13 ppm which dissipated to non detectable level at 8 days after application with a waiting period of one day.

Pawar and Jadhav (1993) applied lambda cyhalothrin at 20, 30, 50 and 60 ppm concentrations on okra and recorded initial deposits of 2.03, 2.62, 3.56, 4.73, 5.12 and 2.57 ppm, respectively and the residues in all concentrations became non-detectable by 7^{th} day with half-life values of 3.10, 3.04, 3.20, 3.40 and 3.30 days, respectively.

Sharma and Awasthi (2002) studied the persistence of lambda cyhalothrin (2.5 EC and 5.0 EC) on cauliflower @ 15 and 30 g a.i. ha^{-1}. The initial deposits of lambda cyhalothrin (0.81 to 1.59 mg kg^{-1}) dissipated to below detectable level by 10 days from the single dose and 15 days from the double dose. The waiting periods were between 4.2 to 5.2 days from different treatments.

Singh and Singh (2003) studied the residues of lambda cyhalothrin in chickpea @ 25 and 50 g a.i. ha^{-1} which resulted initial deposits 0.33 and 0.46 ppm and they suggested half-life values of 4.9 and 5.0 days, respectively.

Jayakrishnan *et al.* (2005) studied the dissipation of lambda cyhalothrin applied at 15 and 30 g a.i. ha^{-1} on tomato and observed the initial deposits of 0.38 and 0.52 ppm dissipated to non detectable level by 8 days.

Ahuja *et al.* (2006) studied the residue persistence of lambda cyhalothrin 2.5 EC in brinjal and lambda cyhalothrin @15 and 30 g a.i. ha^{-1} resulted in initial deposit of 0.75 and 1.27 ppm, respectively and dissipated to non detectable levels in 10 days. Reddy *et al.* (2007) studied that residues of lambda cyhalothrin in chilli and recorded an initial deposit of 0.62 ppm when applied at 50 g a.i. ha^{-1} which dissipated to below determination level by 15 days after application with safe waiting period of 4.2 days.

Mahmoud and Soliman (2011) evaluated the lambda cyhalothrin residues in chickpea and found initial deposit of 8.76 ppm which reached below determination level by 15th day. Elbashir *et al.* (2013) found the initial residues of 3.04 ppm lambda cyhalothrin applied at 30 g a.i. ha^{-1} in tomato and suggested safe waiting period of 18 days.

Gupta *et al*. (2015) reported that lambda cyhalothrin applied at 15 g a.i. ha^{-1} with initial deposits of 0.138 mg kg^{-1}, dissipated to 92.75 per cent on 10th day after application with half - life value of 2.65 days on brinjal.

Raghu *et al*. (2017) applied lambda cyhalothrin twice @15 g a.i. ha^{-1} on chilli in open and poly house conditions. The initial deposits of 0.37 mg kg^{-1} detected in chilli samples collected from poly house, dissipated to BDL by 10th day with half-life of 19.8 days. In open fields, deposits of 0.16 mg kg^{-1} dissipated to BDL by 7th day with half-life of 34.65 days, indicated that dissipation was slow in poly house compared to open field.

2.3.6 Dissipation pattern of imidacloprid + beta cyfluthrin

Dikshit and Pachauri (2000) evaluated the persistence of beta-cyfluthrin in tomato after two sprays at 18.75 and 37.50 g a.i. ha^{-1} at 15 days interval and no residues were detectable on 10th day and 15th day from recommended and double dose, respectively. Dikshit and Singh (2000) studied persistence of beta-cyfluthrin at 18.75 and 37.50 g a.i. ha^{-1} in chickpea. Beta-cyfluthrin at 18.75 g a.i. ha^{-1} recorded the initial deposits of 1.20 mg kg^{-1} which decreased by 0.08 mg kg^{-1} at 10th day whereas, beta-cyfluthrin at 37.50 g a.i. ha^{-1} recorded initial deposits by 2.00 mg kg^{-1} and decreased to 0.28 at 7th day. Residues were non-detectable from either application rate treatment by day 20.

Sharma *et al*. (2003) evaluated the persistence of beta-cyfluthrin in tomato fruits after three applications at 12.50, 18.75 or 25.00 g a.i. ha^{-1}. The initial deposits of 0.068-0.124 mg kg^{-1} dissipated by 69-76 per cent and 92-94 per cent at 3rd and 7th day after application, respectively with half life value of 1.56 -1.86 days and the waiting period of 5- 7 days.

Beta-cyfluthrin 25 SC persisted up to 15 days in brinjal fruits with half life of 2.2- 3.1 days and a waiting period of 6- 10 days at the dosages of 12.5, 18.75 and 25 g a.i. ha^{-1} (Sharma *et al*., 2004). Daraghmeh *et al*. (2007) found the highest and lowest imidacloprid residues in eggplant (0.46 mg kg^{-1}) and green beans (0.08 mg kg^{-1}), respectively. The imidacloprid residue level in several crops were found to exceed the maximum residue limit (MRL).

Karabhantanal and Awaknavar (2007) observed that beta-cyfluthrin sprayed at 7.81 g a.i ha^{-1} on tomato recorded an initial deposit of 0.925 mg kg^{-1} which dissipated to non-detectable level after 7-10 days with a waiting period of 6.75 days.

Singh and Singh (2007) studied the dissipation of beta-cyfluthrin on chickpea following foliar applications at 12.5 and 25 g a.i. ha^{-1}, recording initial deposit of 0.109 and 0.135 mg kg^{-1} in green pods which dissipated by 7^{th} day, respectively.

Dharumarajan *et al*. (2009) evaluated the persistence of combination mix (betacyfluthrin + imidacloprid) on tomato, recording initial deposit of 0.99-2.13 mg kg^{-1} for beta-cyfluthrin with persistence up to 10 days in tomato fruit, when applied in combination.

Dissipation behaviour of imidacloprid was studied by Anjumoni and Baruah (2010) on *Brassica campestris*, rapeseed. The initial deposits of imidacloprid at 20, 40 and 60 g a.i. ha^{-1} were 0.830, 1.126 and 1.280. Imidacloprid residues reached below its detectable level after 5^{th} and 10^{th} day of its application at lower and higher rates. The half life values were 1.44, 1.96 and 1.67 days for imidacloprid at 20, 40, 60 g a.i. ha^{-1}. Based on the observations, a waiting period of at least 4 days at recommended dose (20 g a.i. ha^{-1}) was suggested and considered safe.

Kousik *et al*. (2010) tried combination formulation, Solomon 300 OD (beta - cyfluthrin 9% + imidacloprid 21 %) at 60 and 120 g a.i. ha^{-1} in three sprays on brinjal which dissipated below the level of quantification (LOQ) of 0.01 mg kg^{-1} after 5 and 7 days with half-life period of 1.74 and 1.39 days for single and double doses, respectively.

Diwan *et al*. (2012) studied the dissipation of beta cyfluthrin and imidacloprid in/on mango revealed that initial deposits of 0.10 and 0.11 µg g^{-1} for beta-cyfluthrin and imidacloprid, respectively, at standard dose of application. The corresponding levels at higher dose were 0.17 and 0.23 μg g^{-1}. The residues of beta-cyfluthrin dissipated at relatively faster rate and reached below determination limit on 3rd day whereas imidacloprid residues though short lived attained the below determination limit on 7th day at standard dose of application.

Sahoo *et al*. (2012) evaluated the dissipation of (beta-cyfluthrin 9 % + imidacloprid 21 %) in okra when applied at 60 and 120 g a.i. ha^{-1} , recording half-life of 0.91 and 0.68 days for beta-cyfluthrin and dissipated below its limits of quantification (LOQ) of 0.01 mg kg^{-1} after 3 and 5 days, respectively whereas, imidacloprid took 5 and 7 days to reach LOQ of 0.01 mg kg^{-1} at single and double dosages, respectively.

Goutam *et al*. (2016) studied the dissipation of imidacloprid on okra leaf, fruit and in field soil after application of imidacloprid at 24.5 g a.i. ha^{-1} and 49.0 g a.i. ha^{-1} doses along with control showed that only 1 day after application (DAA) the residue in okra leaf dissipated to 38-48 per cent and in fruit to 31-44 per cent in 24.5 g a.i. ha^{-1} and 49.0 g a.i. ha^{-1} doses, respectively. The residues declined to below detection level (BDL) within 15-20 days after application in leaves and 7 days after application in fruits.

2.3.7 Dissipation pattern of dimethoate

Mishra and Saxena (1985) observed the dissipation pattern of dimethoate in pigeon pea and reported that dimethoate at 0.03% resulted in an initial deposit of 4.00 ppm, dissipated to non detectable level on 12th day. Dibyantoro (1987) reported that dimethoate 0.3, 0.15 and 0.075% when applied to chillies recorded residues at harvest in fruits of 0.20, 0.02 and 0.15, respectively.

Pareek and Kavadia (1990) studied residues of dimethoate on round gourd and recorded initial deposit of 9.05 ppm at 0.03% concentration which dissipated to non detectable level at 10 days after application with waiting period of 5 days, respectively.

Gajbhiye *et al.* (1994) estimated the initial deposit of dimethoate at 360 g a.i. ha^{-1} on bottle gourd (1.20 ppm), ridge gourd (2.15 ppm), bitter gourd (1.15 ppm), muskmelon (1.10 ppm) and on watermelon fruits (0.80). The residues in all the fruits became non detectable on 7th day.

Khan (1997) reported that dimethoate applied @ 0.06 g a.i. ha^{-1} on okra, recorded initial deposit of 2.93 ppm with safe waiting period of 3.17 days. Mukherjee and Gopal (1998) studied the initial deposits of dimethoate on mustard crop as 6.66 and 17.06 ppm when applied at 105 and 210 g a.i. ha^{-1} doses, respectively. Soudamini *et al.* (2004) reported that dimethoate 0.05% and 0.10% with initial deposit of 2.10 and 3.50 mg kg^{-1}, dissipated to below detectable level on 60^{th} day after application with half-life of 5.5 days on acid lime.

Pandey *et al.* (2004) studied residues of dimethoate on cabbage and recorded initial deposits of 2.46 and 4.89 ppm when sprayed at 1.5 ml l^{-1} and 2.5 ml l^{-1} which dissipated to non detectable levels by 45 days after application, respectively.

Reddy *et al.* (2007) found initial deposit of dimethoate in chilli as 0.33 ppm when applied at 300 g a.i. ha^{-1}, dissipated to non detectable level at 15 days after application and they suggested safe waiting period of one day. Khan *et al.* (2009) studied the residues of dimethoate on guava fruits after application at 120 g a.i. ha^{-1} and observed initial deposit of 2.70 ppm and safe waiting period of 3.2 days.

Waghulde *et al.* (2011) studied the residues of dimethoate on chilli and okra crop by applying at 6 g a.i. ha^{-1} and recorded initial deposits of 8.01 ppm in chilli and 22.90 ppm in okra with safe waiting period of 9.38 in chilli and 18.35 days in okra. Varghese *et al. (*2012) studied residues of dimethoate on chilli after application at 300 g a.i.ha^{-1} with an initial deposit of 7.36 ppm. The residues dissipated to non detectable level by 20 days with a safe waiting period 13.63 days.

Sharma and Parihar (2013) applied dimethoate 30 EC @ 300 and 600 g a.i.ha^{-1} on chilli. The initial deposit of dimethoate 3.12 and 5.16 mg kg^{-1}, respectively as recorded at 300 and 600 g a.i.ha^{-1} and the respective waiting periods were 3.29 and 4.50 days. Annamalai Sathesh kumar *et al*. (2014) studied the residues of dimethoate on tea after application at recommended dosage (120 g a.i. ha^{-1}) and observed that the residue of dimethoate reached below the European Union Maximum Residue Level (EU-MRL) of 0.05μg g^{-1} on the 15^{th} day after spraying.

Bhattacherjee and Abhay Dikshit (2016) applied dimethoate (0.06 and 0.12 %) on dashehari mango trees during the pre-mature stage of fruit. Dimethoate dissipated in fruit from 2.81 and 5.34 mg kg^{-1} after 2 hrs of application to 0.12 and 19 mg kg^{-1} after 10 days of application at single and double doses, respectively. No residue was detected in fruit beyond 10 days after its application.

2.4 Evaluation of decontamination methods for removal of pesticide residues on chilli.

Chilli is an important export commodity from India, It is a rich source of A, C, E and P and an alkaloid capsacin, which has high medicinal value and is used in many pharmaceutical preparations. However, along with life-saving components, they have turned into a major source of life-taking poisonous substances called pesticides and their residues into the human body. Indiscriminate use of pesticides particularly at vegetative stage and non-adoption of safe waiting period leads to accumulation of pesticide residues in consumable parts.

Scientists and food processors have long been interested in the effect of processing on pesticide residues in food commodities. The extent to which pesticide residues are removed by processing depends on a variety of factors, such as chemical properties of the pesticides, the nature of food commodity, the processing step and the length of time the compound has been in contact with the food (Farris *et al.*, 1992., Holland *et al.*, 1994 and Kumar *et al.*, 2010).

In a developing country like India, dissipation techniques at the household level can serve as an effective tool in reducing risk related to dietary exposure to residues and henceforth controlling pesticide related adversities. Washing is the most common form of processing which is a preliminary step in both household and commercial preparation. Loosely held residues of several pesticides are removed with reasonable efficiency by varied types of washing processes (Street, 1969). Several studies have examined the effects of washing solutions on removing pesticide residues from various food commodities as follows.

2.4.1 Tap water wash

Awasthi (1993) found that washing of mango fruits by dipping in water for 10 min reduced the residues up to 66–68 per cent for dimethoate and fenthion as againt 21–27 per cent for fenvalerate and cypermethrin, simply by washing treatment.

Miyahara and Saito (1994) found that Washing of soybeans twice with water reduced the pesticides by 80–90 per cent of the initial levels of 5.01 ppm dichlorvos, 7.9 ppm malathion, 11.2 ppm chlorpyriphos and 2.87 ppm captan. These results suggest that sprayed pesticides remain as micro particles on the surface of the soybeans and are easily removed by mechanical stirring in water.

Lentza-Rizos (1995) recorded 1.23 ppm of iprodione in peaches which reduced to 0.61 ppm on washing. Mergnat *et al.* (1995) found that washing of golden delicious apples brought about a reduction of 30–50 per cent in phosalone residues. The reduction was probably on account of dissolution of phosalone in water.

Ong *et al.* (1996) observed that total amount of azinphos-methyl residue on the unwashed apple fruit was 0.67 ppm. Almost 53 per cent of residues were removed from the fruit with the water wash.

Krol *et al*. (2000) observed the reduction of 12 pesticides residues on produce by rinsing. The pesticides included captan, chlorothalonil, iprodione, vinclozolin, endosulfan, permethrin, methoxychlor, malathion, diazinon, chlorpyriphos, bifenthrin and DDE. It was observed that rinsing removed residues of nine of the 12 pesticides studied whereas, residues of vinclozolin, bifenthrin and chlorpyriphos were not reduced.

Lal and Dikshit (2001) observed washing of chickpea grains reduced the deltamethrin residues by 15.69 per cent from an initial level of 0.051 ppm. Lentza-Rizos and Balokas (2001) observed that washing of potatoes reduced chlorpropham residues by 33–47 per cent from an initial concentration of 3.8 ppm in individual tubers at10 days after application.

Pugliese *et al.* (2004) reported that methidathion, parathion methyl, chlorpyriphos, and pirimicarb residues in/on nectarine samples were decreased by 7, 15, 26, and 34 per cent, respectively, by dipping them into water for 3 min.

Chavarri *et al.* (2005) reported that washing of vegetables with tap water resulted in reduction of pesticide residues. Results indicated that there was a reduction of 38 and 43 per cent residues of chlorpyriphos and Ethylene bis dithiocarbamates in tomato fruits after tap water wash. Similarly in tap water washed asparagus, chlorpyriphos, cypermethrin and Ethylene bis dithiocarbamate residues reduced by 24, 35 and 53 per cent, respectively. In case of spinach, washing completely removed Ethylene bis dithiocarbamate residues. Tap water wash of peaches reduced the residues of acephate and thiram by 18 and 41 per cent, respectively.

Cengiz *et al.* (2006) observed that the initial diazinon residue level (0.822 ppm) on cucumbers was decreased by 22.3 per cent by washing for 15 seconds by rubbing under running water. Lentza-Rizos *et al.* (2006) observed the residues of azoxystrobin on grapes were 0.49–1.84 ppm and washing removed 75 per cent of these residues. Zhang *et al.* (2006) observed that washing of cabbage with tap water for 20 min reduced residues of chlorpyriphos, *p,p*-DDT, cypermethrin and chlorothalonil by 17.6, 17.1, 19.1 and 15.2 per cent, respectively.

Klinhom *et al.* (2008) reported that washing of leafy Chinese-Kale with tap water reduced methomyl and carbaryl residues by 37 and 88 per cent, respectively.

Kumari (2008) observed that washing of brinjal, cauliflower and okra with tap water for one minute reduced the organochlorine pesticide residues by 22-44 per cent in brinjal, 34-36 per cent in cauliflower and 20-38 per cent in okra whereas, the residues of synthetic pyrethroids in brinjal, cauliflower and okra were reduced 26, 29 and 31 per cent respectively. Maximum reduction of residues was observed in case of organo phosphorus where the residues decreased to the extent of 77, 74 and 50 per cent in brinjal, cauliflower and okra, respectively.

Randhawa *et al.* (2008) observed that tap water washing reduced cypermethrin residues by 33.42-35.00 per cent and decamethrin by 25.00 - 27.90 per cent in brinjal. Chlorpyriphos residues were reduced by 33 per cent in spinach, 30 per cent in potato, 25 per cent in cauliflower and 10 per cent in tomato.

Ling *et al.* (2011) observed that washing of vegetables with tap water reduced the residues of chlorpyriphos by 0.23, 3.65, 46.60, 10.60 and 36.30 per cent in cabbage, garlic sprouts, tomato, cucumber and eggplant, respectively. Satpathy *et al*. (2012) reported that formathion, methyl parathion, fenitrothion, parathion, chlorpyriphos and malathion residues in tomato samples were reduced by 27, 32, 34, 37, 39 and 41 per cent, respectively by allowing them to be submerged in water for 15 min.

Chauhan *et al.* (2012) observed that lambda-cyhalothrin residues in tomato were reduced in the range of 37-40 per cent by tap water washing. Liang *et al.* (2012) evaluated the effect of tap water washing and time period of treatment in removal of pesticide residues of trichlorfon, dimethoate, dichlorvos, fenitrothion and chlorpyriphos in raw cucumber and results indicated washing with tap water for 20 min proved the least effective showing 53.7, 32.6, 52.4, 26.7 and 62.9 per cent reduction in the above pesticides, respectively.

Thanki *et al.* (2012) observed that in cauliflower tap water washing was found to reduce the residues of monocrotophos and parathion to the extent of 48.60 – 70.00 per cent. However it was found less effective in reducing phorate (16.27%), permethrin (6.80%) and dichlorvos (3.32%). Cengiz and Certel (2013) found that the percentage reduction of mancozeb residues was 29 per cent by dipping greenhouse tomatoes in tap water for 5 min.

Elbashir *et al.* (2013) observed the effect of washing in the removal of fenpropathrin, λ-cyhalothrin, and deltamethrin residues in tomatoes. The samples of tomato fruits were washed once to reduce the residues of fenpropathrin, λ-cyhalothrin, and deltamethrin by 37.363±0.44, 16.744±0.25, 26.881±0.31 per cent, respectively and washing three times reduced three pyrethroid residues by 58.260±0.34, 39.659±0.41, 56.202±0.3 per cent, respectively.

Panhwar and Sheikh (2013) reported that plain water washing reduced fat soluble residues of bifenthrin, endosulphan and profenophos in cauliflower by 25, 28.1 and 14.32 per cent, respectively. Degree of reduction in plain water washing on water soluble pesticides namely diafenthiuron, imidacloprid in cauliflower were 40.69, 39.07 and 21.17 per cent, respectively.

Cherukuri *et al.* (2014) observed loss of 30.7, 35.3, 45.6, 42.0, 44.1, 40.9 and 70.3 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda-cyhalothrin and malathion residues in brinjal by tap water wash.

Pallavi *et al.* (2014) detected residue loss of malathion, chlorpyriphos, quinalphos, profenophos and cypermethrin in curry leaf to an extent of 32.5, 17.8, 32.4, 27.7 and 15.5 per cent by treating with luke warm water for 15 min and loss of 25.9, 10.8, 18.6, 21.7 and 8.2 per cent by washing with tap water for 15 min.

Geetha (2015) noticed loss of 15.37, 13.30, 19.21 and 19.88 per cent of chlorpyriphos, profenophos, cypermethrin and triazophos residues in spinach by tap water wash for 10 min. Sompon *et al.* (2015) reported the reduction of 55 per cent of profenophos residues in Chinese Kale by washing under running tap water.

2.4.2 Salt solution:

Abou-Arab (1999) recorded that soaking of tomato fruits in different concentrations of NaCl solutions (2%, 4%, 6%, 8%, 10%) followed by tap water wash, helped to reduce residue content of HCB, lindane, p,p-DDT, dimethoate, profenophos and pirimiphos methyl. Results indicated that 10% solution of NaCl was found effective with 42.9, 46.1, 27.2, 90.8, 82.4 and 91.4 per cent reduction in above mentioned pesticides, respectively.

Soliman *et al.* (2001) observed that NaCl with 2, 4, 6, 8 and 10 per cent solution caused 20 to 90 per cent reduction in pesticide residues. Zohair (2001) found that soaking of potatoes in NaCl solution of 5% and 10% resulted in the reduction of 28.3 and 42 per cent of lindane, 68 and 76 per cent of aldrin, 73.3 and 85.6 per cent of heptachlor epoxide, respectively and complete removal of pirimphos methyl .

Wheeler *et al.* (2002) found that by dipping fruits and vegetables in 5 and 10 per cent NaCl solution for 15 minutes, 28 to 93 per cent reduction in residues of organochlorines and 100 per cent reduction in case of organo phoshates was noticed.

Zhang *et al.* (2006) noticed that washing of cabbage with 10% NaCl solution for 20 min reduced residues of chlorpyriphos, *p,p*-DDT, cypermethrin, chlorothalonil by 67.2, 65.0, 73.3, and 74.1 per cent, respectively. Klinhom *et al.* (2008) reported that washing of leafy Chinese-Kale with 0.9% NaCl solution reduced residues of methomyl and carbaryl by 39.33 and 91.98 per cent.

Liang *et al.* (2012) evaluated the effect of NaCl at different concentrations (2% and 5%) and different time period of treatment in the removal of pesticide residues of trichlorfon, dimethoate, dichlorvos, fenitrothion and chlorpyriphos in raw cucumber and results indicated that washing of cucumber with NaCl solution of 5% for 20 min proved least effective, showing 65.80, 65.20, 77.40, 51.10 and 69.00 per cent reduction in the above pesticides, respectively.

Cherukuri *et al.* (2014) observed loss of 45.3, 43, 52.1, 49.8, 54, 47.9 and 76.5 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda-cyhalothrin and malathion residues in brinjal by treating with 2 per cent salt solution.

Pallavi *et al.* (2014) observed loss of 62.4, 54.4, 56.2, 68.2 and 45.6 per cent of malathion, chlorpyriphos, quinalphos, profenophos and cypermethrin residues in curry leaf by treating with 2 per cent common salt for 15 min.

Geetha (2015) observed loss of 31.47, 32.13, 46.87 and 43.78 per cent of chlorpyriphos, profenophos, cypermethrin and triazophos residues in spinach by salt water treatment for 10 min.

2.4.3 Cooking

Washing and cooking were effective in lowering the alphamethrin (0.005%) residues in brinjal. However, reduction of residues was more due to cooking than simple washing (25 to 33 per cent). In tomato, both the processes reduced the residues almost to the same extent (11 to 33 per cent) (Kanta *et al*., 2001).

Cypermethrin residues in brinjal were effectively removed by grilling (50.12%) followed by cooking in oil (45.2%), cooking in water (41.4%), microwave cooking (40.89%) and washing with tap water (25.47%) (Walia *et al.*, 2010). Neha *et al.* (2012) evaluated the effect of cooking of brinjal in the removal of pesticide residues of monocrotophos, quinalphos, permethrin and cypermethrin and reported the reduction of 29.68, 22.84, 25.00 and 40.00 per cent, respectively.

Chauhan *et al.* (2012) evaluated the effect of cooking of food products in the removal of pesticide residues of pyrethroids and reported the reduction of 75-98 per cent.

Cherukuri *et al.* (2014) observed loss of 64.0, 45.9, 39.4, 52.9, 42.0, 48.7 and 81.4 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda-cyhalothrin and malathion residues in brinjal by cooking.

2.4.4 NAHCO$_3$

Klinhom *et al.* (2008) reported that washing of leafy Chinese-Kale with 0.1% $NaHCO_3$ solution resulted in 43.19 per cent of methomyl and 91.24 per cent of carbaryl residue reduction**.**

Liang *et al.* (2012) evaluated the effect of $NaHCO_3$ solution at different concentrations (2% and 5%) and different time period of treatment in removal of pesticide residues of trichlorfon, dimethoate, dichlorvos, fenitrothion and chlorpyriphos in raw cucumber and results indicated that washing of cucumber with $NaHCO_3$ solution at 5% for 20 min proved least effective. showing 85.4, 76.1, 98.8, 66.7, and 85.2 per cent reduction in the above pesticides, respectively.

Tomer and Sangha (2013) observed loss of 77.98 per cent of malathion residues in cucumber by washing with 5 per cent $NaHCO_3$ solution. Zhang *et al*. (2013) reported that dipping chinese cabbage in 5% soda salt solution for 10 min followed by tap water wash for 1 min reduced the residues of dimethoate and dicofol to an extent of 32.20 and 26.90 per cent respectively.

Cherukuri *et al.* (2014) observed loss of 25.4, 21.5, 34, 29.8, 33.6, 30.4 and 61.3 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda-cyhalothrin and malathion residues in brinjal by treating with 0.1 per cent sodium bicarbonate solution.

2.4.5 Formula 1

Cherukuri *et al.* (2014) observed loss of 24.1, 25.9, 35.7, 31.3, 31.8, 27.1 and 59.1 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda-cyhalothrin and malathion residues in brinjal by treating with formula 1.

Other methods:

Zohair (2001) evaluated the efficacy of different washing solutions in removing some organophosphorus and organochlorine pesticides residues from potatoes. Soaking of potatoes for 10 min in 5 and 10% radish solution resulted in complete removal of lindane, aldrin, heptachlore epoxide, *o,p'*-DDD and *p,p'*-DDE except *o,p'*-DDE with reduction of 73.1 per cent. Dipping of potatoes in 5% and 10% Na_2CO_3 solution for 10 min resulted in reduction of residues by 89.1 and 92 per cent of lindane, 84 and 88 per cent of Aldrin, 93.2 and 95.2 per cent of heptachlor epoxide and 98.5 and 98.8 per cent of pirimphos-methyl, respectively.

Zhang *et al.* (2006) observed the reduction in residue content of chlorpyriphos, *p,p*-DDT, cypermethrin, chlorothalonil in cabbage by 3.4, 2.6, 3.1 and 3.6 per cent, respectively due to the refrigeration for 48 hours. The stir-frying for 5 min reduced the residues by 86.6, 67.5, 84.7 and 84.8 per cent, respectively

Chen *et al.* (2013) observed the reduction in the residue content of two pesticides chlorfluazuron and chlorothalonil by 75 and 77 per cent, respectively by ozonation in chinese white cabbage and green stem bok choy.

Iizuka *et al.* (2013) revealed that hydrostatic pressure with 10% ethanol solution removed hydrophobic pesticides like chlorpyriphos from cherry tomatoes without bringing about break down into more toxic materials.

Pallavi *et al.* (2014) observed loss of 63.89, 8.9, 36.4, 41.7 and 19.6 per cent of malathion, chlorpyriphos, quinalphos, profenophos and cypermethrin residues in curry leaf by treating with 1 per cent turmeric for 15 min.

Geetha (2015) observed loss of 54.43, 45.79, 75.92 and 54.52 per cent of chlorpyriphos, profenophos, cypermethrin and triazophos residues in spinach by hot water boiling for 10 min.

2.6. Determination of the processing factor for selective insecticides in chillies.

Cabras *et al*. (1998a) noticed during prune processing that iprodione residue at harvest time was 0.68 ppm and became approximately half after the drying process, while phosalone residue level was 3 times higher after drying. This could be attributed to the concentration factor of the fruit. In the drying process, the residue decrease due to washing was compensated by the residue increase due to drying; therefore, the residue level did not change. They further investigated that some of the residues were not reduced during the fruit washing stage, but the drying stage led to complete elimination of remaining residues. Drying process caused a decrease in iprodione and bitertanol, while it did not affect phosalone. The sunlight and oven drying processes caused the fruit to concentrate by a factor of approximately six times. Nevertheless, the pesticide residues present in the dried fruit were lower than in the fresh fruit. The residue decreases were higher in the sunlight process than in the oven process. In the former, on average, the residues on the dried fruits were about half those on the fresh fruits, whereas in the latter they were about equal (Cabras *et al*. 1998b, c).

Cabras and Angioni (2000) investigated the pesticide residues in grapes and their processing products. The residue levels of benalaxyl, phosalone, metalaxyl, and procymidone on sun-dried grapes equaled those on the fresh grapes whereas they were 1.6 times higher for iprodione and one-third and one-fifth lower for vinclozolin and dimethoate, respectively. In the oven-drying process, benalaxyl, metalaxyl and vinclozolin showed the same residue value in the fresh and dried fruit, whereas iprodione and procymidone residues were lower in raisins than in the fresh fruit.

Pathan *et al*. (2009) find out the processing factor for dicofol (18.5 EC), ethion (50 EC) and cypermethrin (25 EC) in chilli and the results revealed that respective initial deposits of dicofol, ethion and cypermethrin in fresh chilli were 0.72, 0.40 and 0.02 mg kg $^{-1}$, whereas in sundried chilli powder they were 4.03, 1.41 and 0.15 mg kg^{-1}. The processing factors computed for dicofol, ethion and cypermethrin were 5.59, 3.52 and 7.5, respectively. It was revealed that by reducing the weight by 10.48 times after dehydration of the fresh chilli, the concentration of the pesticides increased by 5.59, 3.52 and 7.50 times, respectively.

Shah *et al.* (2009) find out processing factor for the chlorthalonil, chlorpyriphos and endosulfan in turmeric. The soil was drenched with pesticide solution at thrice the recommended dose near root zone seven days prior to harvest. At harvest, the fresh turmeric rhizomes revealed presence of traces of chlorthalonil, 0.047 μg g^{-1} of chlorpyriphos and 0.006 μg g^{-1} of endosulfan. The corresponding levels of in processed turmeric powder were 0.007, 0.030 and 0.028 μg g^{-1}, respectively. Based on the residues levels obtained in the present study, processing factor of 2.3, 0.6 and 4.7 was worked out for chlorthalonil, chlorpyriphos and endosulfan, respectively.

George and kumar (2013) estimated processing factor for chlorpyriphos and lambda-cyhalothrin in cardamom. The mean initial residues of chlorpyriphos applied at a concentration of 0.05 % in cardamom was 2.5 μg g$^{–1}$ and the residue was 8.1 μg g$^{–1}$ after processing, with a processing factor of 3.24, while lambda-cyhalothrin when applied at 0.0025 % resulted in initial residues of 1.63 μg g$^{–1}$ that magnified to 4.86 μg g$^{–1}$ on curing, with a processing factor of 2.98.

Pan *et al.* (2015) estimated the residue levels of dimethoate and its oxon metabolite (omethoate) during tea planting, manufacturing, and brewing and results of processing factors of dimethoate were in the range of 2.11–2.41 and 1.41–1.70 during green tea and black tea manufacturing, respectively.

Dissipation behaviour of the imidacloprid (Tatamida 17.8 % SL), in fresh and cured cardamom capsules was studied following application at doses 20 and 40 g a.i. ha^{-1} in a cardamom. At the lower dose, the initial deposits of total imidacloprid residues were 1.91 and 7.23 μg g$^{–1}$, respectively, in fresh and cured cardamom. At the higher dose, the initial residues were 3.94 and 14.72 μg g$^{–1}$, respectively, in fresh and cured capsules. The mean processing factor of imidacloprid was 3.96 at 20 g a.i. ha^{-1} (Pratheesh kumar *et al*., 2016).

Chapter III

MATERIAL AND METHODS

The present study on the "Seasonal incidence, management of thrips and residue studies in chilli (*Capsicum annuum* L)" was conducted during *kharif* 2015-16 and 2016-17. The field study was conducted at Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad and laboratory studies (Dissipation, Decontamination and Processing factor) were carried out at All India Network Project on Pesticide Residues, Rajendranagar, Hyderabad.

Different materials and various methods employed during the course of investigation are given in detail here under.

3.1 Cultivation Aspects

3.1.1 Preparatory Cultivation

The soil of the experimental block was red soil. The field was thoroughly ploughed thrice with the help of a tractor drawn cultivator, then it was evenly levelled after removal of stubbles, trash and weeds. At the last ploughing, FYM was applied @ 5 tonnes ha^{-1}. Furrows were formed at a spacing 45 cm across the furrows and irrigation water drains were formed. After this, the furrows were irrigated, so as to make the field ready for transplanting.

3.1.2 Design and Layout

The experiment was laid out in Randomized Block Design (RBD) with eight treatments including untreated control and replicated thrice as shown in figure 3.1, Plate 1 (a,b). The sub-plot size was 20 m^2.

3.1.3 Variety and nursery raising

A popular chilli variety LCA 334 was choosen for the study. Chilli seed was sown on 5th August 2015 and 10th August 2016 in the well prepared raised nursey bed. The nursery bed was regularly irrigated till the time of transplanting .

3.1.4 Transplanting

The seedlings at the age of 35 days were transplanted in the main field after providing good irrigation. An inter row spacing of 45 cm and intra row spacing of 30 cm was adopted, so as to maintain optimum plant population in the field.

3.1.5 Fertilizer application

Recommended fertilizer doses of Nitrogen @ 200 kg ha^{-1}, Phosphorous @ 60 kg ha^{-1} and Potassium @ 60 kg ha^{-1} were applied in the form of Urea, Di Ammonium Phosphate (DAP) and Muriate of Potash (MOP), respectively. Nitrogen was given in the form of urea as basal and pocket application in three equal splits at different growth stages of crop, while phosphorous and potash were applied at the time of transplanting as per the Good Agricultural Practices of PJTSAU.

3.1.6 Irrigation

The experimental plots were adequately irrigated at the time of transplanting followed by irrigation whenever required throughout the crop growth period.

3.1.7 Intercultivation

The crop was kept free from weeds by hand weeding whenever needed and was kept well managed throughout the period of experiment by adopting the recommended package of practices of PJTSAU.

3.2 Study on the seasonal incidence of chilli thrips and to correlate the incidence with various abiotic factors of environment

3.2.1 Seasonal incidence of chilli thrips

To study the seasonal incidence of chilli thrips, in 100 m^2 plot the chilli crop was grown in the field with a spacing of 45×30 cm. The study was carried out during *kharif* 2015-16 and 2016-17 at Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad. The seed of LCA 334 was raised in the nursery and six weeks old seedlings were transplanted in the main field. All the recommended agronomic practices except plant protection measures were followed for raising the crop.

3.2.1.1 Counting of insects

Observations were recorded in five plants of each treatment. Data was recorded starting from transplanting to harvest at weekly intervals as per the standard weeks. The thrips population was counted on five randomly selected plants, from five terminal leaves of each plant.

3.2.2 Effect of abiotic factors on the population bulid up of thrips in chilli

The data obtained on the seasonal incidence studies of chilli thrips were subjected to correlation and multiple regression with various weather parameters *viz*., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall, sunshine hours, evaporation etc by following the technique suggested by Panse and Sukhatme (1988).

3.3 Evaluation of the efficacy of selective insecticides against thrips on chilli

The study has been designed to evaluate a suitable insecticide to suppress the chilli thrips with eight treatments in *kharif* 2015-16 and 2016-17seasons.

3.3.1 Test insecticides

Different groups of chemicals were selected and the treatments were imposed as foliar sprays against the chilli thrips. The details of the test insecticides are presented in table 3.1.

3.3.2 Preparation of spray fluid

The measured quantities of test insecticides were mixed with small quantity of water and remaining quantity of water was added to it subsequently to make up the spray volume required for the plot. The spray fluid was evenly mixed with a stick before spraying.

3.3.3 Application of insecticidal treatments

Test insecticides were applied using a high volume knapsack compression sprayer. Sprayings were undertaken during morning hours and necessary care was taken to prevent the drift of spray fluid reaching the adjacent plots. The sprayer and the container used for preparing spray fluid were thoroughly cleaned with water before changing the insecticide and rinsed with the fluid to be applied next. The first spray was given after 50% flower initiation and treatments were imposed thrice at 10 days intervals as foliar sprays against the thrips. A total of three sprays were given during the experimental period.

3.3.4 Field observations and recording of data

Observations on insect populations of thrips, *S.dorsalis*,were recorded in five randomly tagged plants, from five terminal leaves per plant. Data on thrips population was recorded at 1,3,5,7 and 10 days after spray by using destructive sampling procedure. The collected leaf samples were brought to laboratory in separate zip-locked poly-bags. Before observation each leaf sample was tapped over a white plain paper and the thrips which fell on the paper and on the leaves were critically recorded with 10x magnifying glass. Per cent reduction over control was calculated by using the following formula (Flemming and Retnakaran, 1985).

$$\text{Per cent Population reduction} = 1 - \frac{\text{Post treatment population in treatment}}{\text{Pre treatment population in treatment}} \times \frac{\text{Pre treatment population in untreated control}}{\text{Post treatment population in untreated control}} \times 100$$

Data on mean population at 1,3,5,7 and 10 days after spraying and per cent reduction over control were calculated after each spray. Cumulative mean of three sprays during *kharif* in 2015-16 and 2016-17 was worked out.

3.3.5 Statistical Analysis

The observations recorded from the field experiment were subjected to statistical analysis (RBD) to know the significance of difference among different treatments. The values in percentages were transformed to angular values and values in number were transformed into square root values before analysis (Gomez and Gomez, 1984). The yield per plot was converted to yield per hectare by using the following formula.

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

Table 3.1. Details of insecticidal treatments

Treatment	Common Name of Insecticide	Dosage (g a.i ha^{-1})	Trade Name and Formulation
1	Fipronil 5 % SC	500	Regent 5% SC
2	Spinosad 45% SC	125	Tracer 45%SC
3	Chlorantraniliprole 20 % SC	30	Coragen 20%SC
4	Profenophos 50 % EC	400	Curacron 50% EC
5	Lambda - cyhalothrin 5% SC	15.63	Karate 5 % SC
6	Betacyfluthrin + imidacloprid 300 % OD	30	Solomon 300%OD
7	Dimethoate 30% EC	300	Rogor 30% EC
8	Control (water spray)	-	-

3.4 To establish the dissipation pattern of selective insecticides on chilli.

3.4.1 Preparation of working standards

Certified Reference Materials (CRMs) of fipronil, spinosad, chlorantraniliprole, profenophos, lambda-cyhalothrin , imidacloprid, beta cyfluthrin and dimethoate were obtained from the source of Dr. Erhenstorfer, Germany. Primary standards, intermediary and working standards were prepared from these CRMs using acetone and *n* - hexane as solvents.

Working standards of all the pesticides were prepared in the range of 0.01 ppm to 0.5 ppm in 10 ml calibrated graduated volumetric flask using distilled *n*-hexane as solvent. All the standards were stored in deep freezer and maintained at -20^{0}C.

3.4.2 Limit of Detection and Linearity of fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin , beta cyfluthrin and dimethoate

The working standards of fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin, beta cyfluthrin and dimethoate were injected in Gas Chromatograph with Electron Capture Detector (ECD) for estimating the lowest quantity of these pesticides which can be detected with injector split ratio of 1:2 under standard operating parameters as shown in table 3.2.

For confirmatory analysis fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin , beta cyfluthrin and dimethoate were analysed on both ECD and TSD as these pesticides can be detected on both detectors simultaneously using "Universal Y split" at the detector end. One micro litre of each working standard was injected for the study. The GC operating parameters for the above mentioned pesticides detection and estimation are presented in table 3.2. and the GC used for the study was shown in plate 2.

The retention time of fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin , beta cyfluthrin and dimethoate were 8.96, 4.18, 11.87, 9.11, 19.74 and 6.12 min, respectively, (Table 3.2). Each working standards of above mentioned pesticides (0.01 ppm, 0.025 ppm, 0.05 ppm, 0.075 ppm, 0.10 ppm, 0.25 ppm and 0.50 ppm) were injected 6 times and the linearity lines were drawn.

Table 3.2. Details of GC parameters

Gas Chromatograph	Gas Chromatography- AGILENT- 7890B
Column	VF -5ms Capillary Column 30 m length, 0.25 mm Internal Diameter, 0.25 μm film thickness; 1% methyl siloxane
Column Oven (^{0}C)	Fipronil- Initial 180^{0}C - 2 min hold - increase @ 10^{0}C/min upto 260^{0}C - hold time 5 mins – increase @2^{0}C/min upto 280^{0}C – hold for 10 mins. Chlorantraniliprole - Initial 180^{0}C for 2 min - increase @ 10^{0}C/min upto 260^{0}C – hold for 15 mins. Profenophos - Initial 150^{0}C for 1 min - increase @ 20^{0}C/min upto 250^{0}C – hold for 9 mins. Lambda-cyhalothrin - Initial 200^{0}C for 6 min - increase @ 20^{0}C/min upto 280^{0}C – hold for 10 mins. Beta cyfluthrin - Initial 180^{0}C - 2 min hold - increase @ 10^{0}C/min upto 260^{0}C - hold time 5 mins – increase @2^{0}C/min upto 280^{0}C – hold for 10 mins. Dimethoate - Initial 150^{0}C for 1 min - increase @ 20^{0}C/min upto 250^{0}C – hold for 14 mins.
Detectors	Electron Capture Detector (ECD)
Detector Temperature (^{0}C)	300
Injector Temperature (^{0}C)	280
Injector Status	Split Ratio: 1:2
Carrier Gas	Nitrogen, Iolar II, Purity 99.999%
Carrier Gas Flow (ml min^{-1})	2
Make-up Flow (ml min^{-1})	25
Retention time (min)	Fipronil 8.96 Chlorantraniliprole 4.18 Profenophos 11.87 lambda-cyhalothrin 9.11 Beta cyfluthrin 19.74 Dimethoate 6.12
Total run time (min)	Fipronil 35 Chlorantraniliprole 24 Profenophos 15 lambda-cyhalothrin 20 Beta cyfluthrin 35 Dimethoate 20

3.4.2.1 Fipronil

Based on the response of the detector (ECD) to different quantities (ng) of CRM standards injected, it was found that the LOD (limit of detection) for fipronil was 0.01 ng, and the linearity was in the range of 0.01 ng to 0.10 ng as given in fig 3.2.

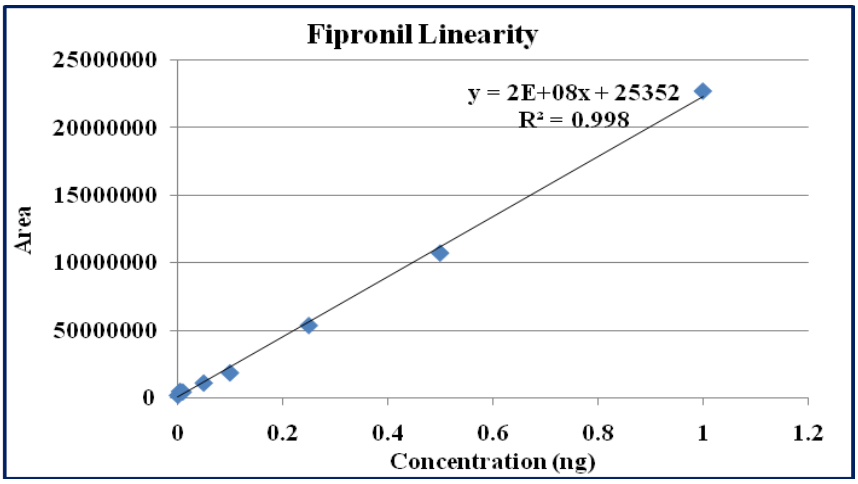

Fig. 3.2. Calibration curve for fipronil

3.4.2.2 Chlorantraniliprole

Based on the response of the detector (ECD) to different quantities (ng) of CRM standards injected, it was found that the LOD (limit of detection) for fipronil was 0.01 ng, and the linearity was in the range of 0.01 ng to 0.10 ng as given in fig 3.3.

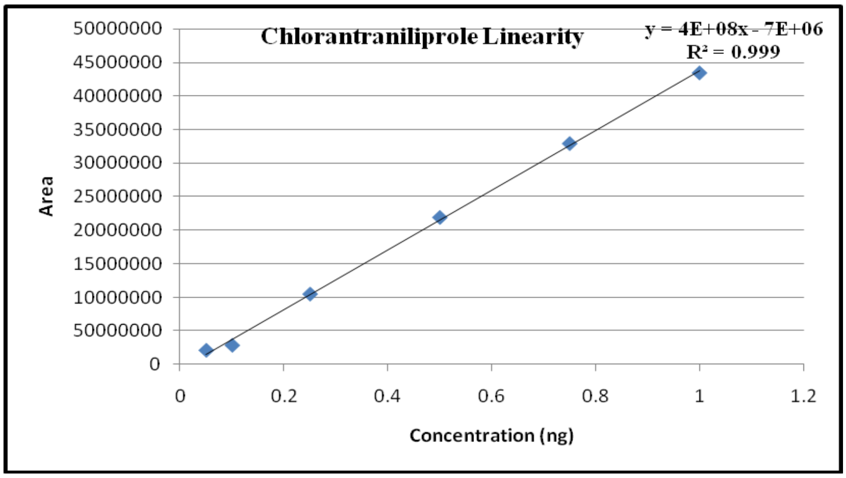

Fig. 3.3. Calibration curve for chlorantraniliprole

3.4.2.3 Profenophos

Based on the response of the detector (ECD) to different quantities (ng) of CRM standards injected, it was found that the LOD (limit of detection) for profenophos was 0.01 ng and the linearity was in the range of 0.01 ng to 0.10 ng , as given in fig 3.4.

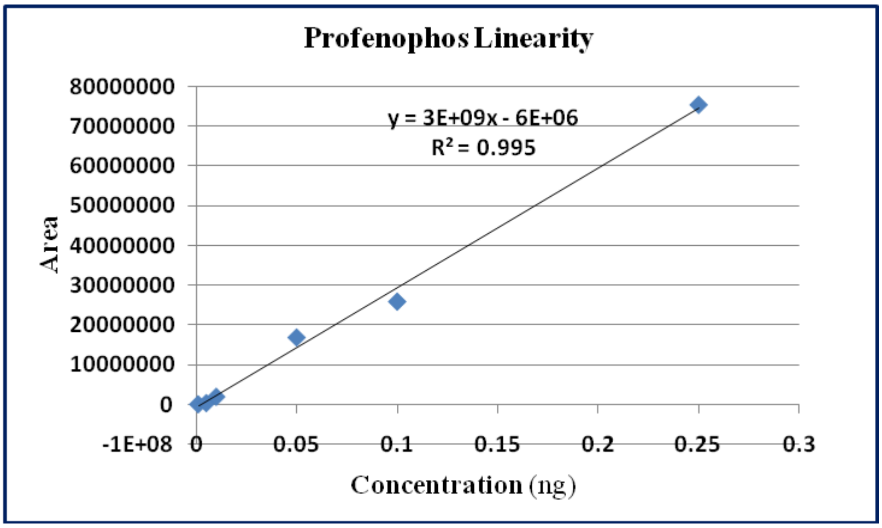

Fig. 3.4. Calibration curve for profenophos

3.4.2.4 Lambda-cyhalothrin

Based on the response of the detector (ECD) to different quantities (ng) of CRM standards injected, it was found that the LOD (limit of detection) for lamda-cyhalothrin was 0.01 ng, and the linearity was in the range of 0.01 ng to 0.10 ng , as given in fig 3.5.

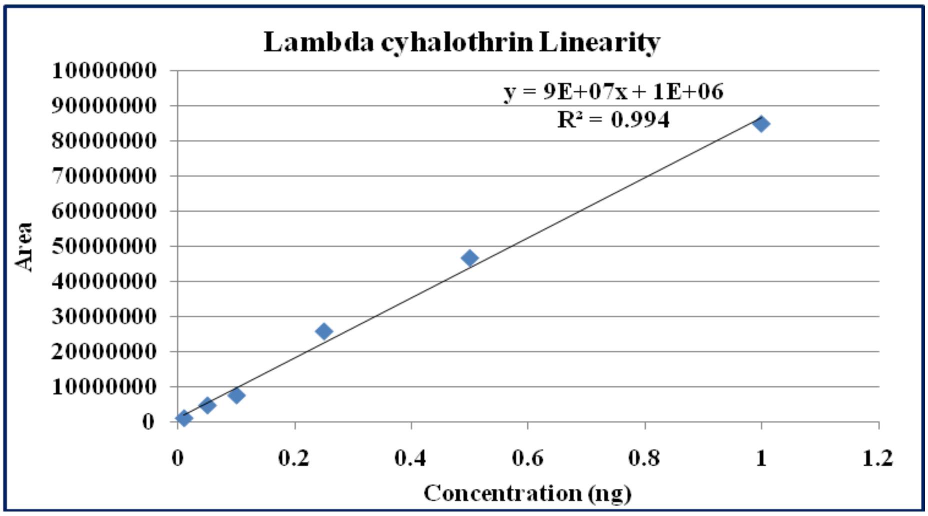

Fig. 3.5. Calibration curve for lambda-cyhalothrin

3.4.2.5 Beta cyfluthrin

Based on the response of the detector (ECD) to different quantities (ng) of CRM standards injected, it was found that the LOD (limit of detection) for beta cyfluthrin was 0.01 ng, and the linearity was in the range of 0.01 ng to 0.10 ng as given in fig 3.6.

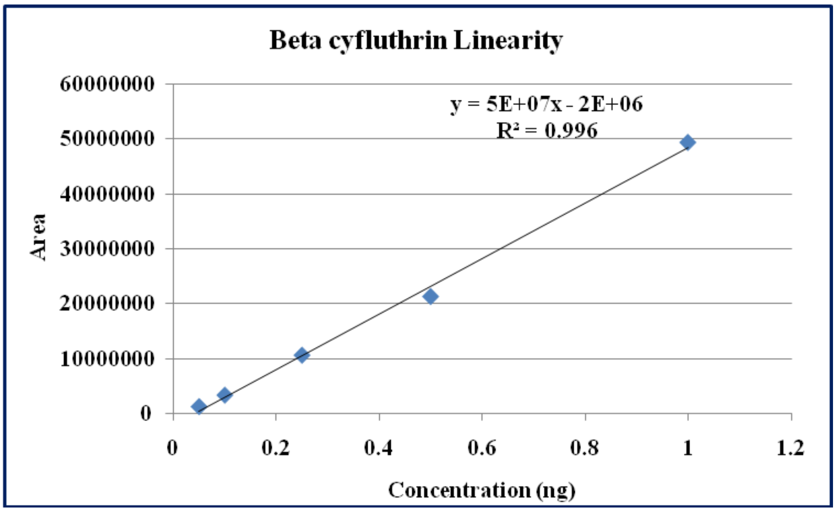

Fig. 3.6. Calibration curve for beta cyfluthrin

3.4.2.6 Dimethoate

Based on the response of the detector (ECD) to different quantities (ng) of CRM standards injected, it was found that the LOD (limit of detection) for dimethoate was 0.01 ng, and the linearity was in the range of 0.01 ng to 0.10 ng as given in fig 3.7.

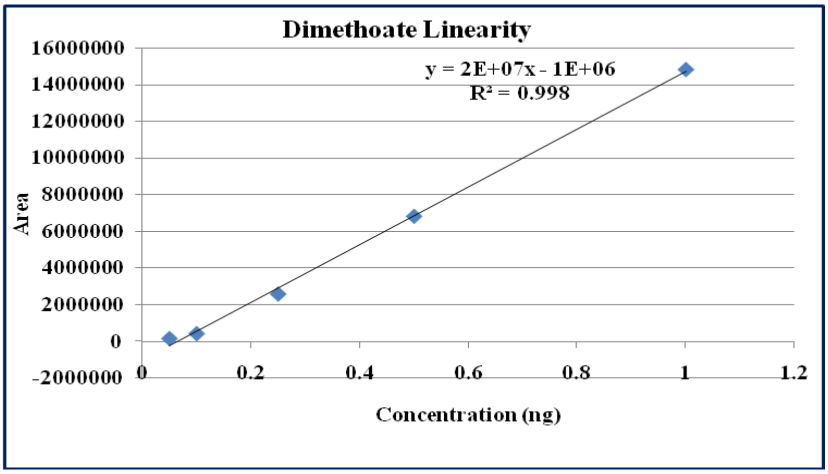

Fig. 3.7. Calibration curve for dimethoate

3.4.3 Limit of detection and linearity of spinosad and imidacloprid

The working standards of spinosad and imidacloprid were injected in Liquid Chromatograph with Mass Spectrometer Detector for estimating the lowest quantity of spinosad and imidacloprid which can be detected under standard operating parameters as shown in table 3.3.

For confirmatory analysis samples were also injected in LC-MS/MS. The LC operating parameters for spinosad and imidacloprid detection and estimation were presented in table 3.3. and the HPLC used for the study was shown in plate 3.The retention time of spinosad and imidacloprid were 2.70 and 2.29 min (Table 3.3).

Table 3.3. Details of HPLC operating parameters

HPLC	SHIMADZU LC-20		
Detector	Mass Spectrometer (MS)		
Column	HPLC Column Kinetex C18 column, 2.6 micron particle size 100 length, 3 mm ID		
Solvents in Pump A Solvents in Pump B	Water Metanol		
Solvents Gradient Program	Water: Methanol (5:95) mixture run for 2 min		
Solvents Gradient rate	0.4 ml min^{-1}		
Quantity of sample injected	1 μl		
Run time	10 min		
Retention time	Spinosad – 2.70 min imidacloprid – 2.29 min		
LC Program For spinosad	Time	Methanol	Water
	0.01 3.00 5.00 5.01	95 85 95 Stop	5 15 5
	Time	Methanol	Water
For imidacloprid	0.01 4.00	35 Stop	65

3.4.3.1 Spinosad

Based on the response of the Mass Spectrometer to different quantities (ng) of CRM standards injected under the HPLC operational parameters given in table 3.3, it was found that the LOD (limit of detection) for spinosad was 0.05 ng, and the linearity was in the range of 0.01 ng to 0.10 ng , as given in fig 3.8.

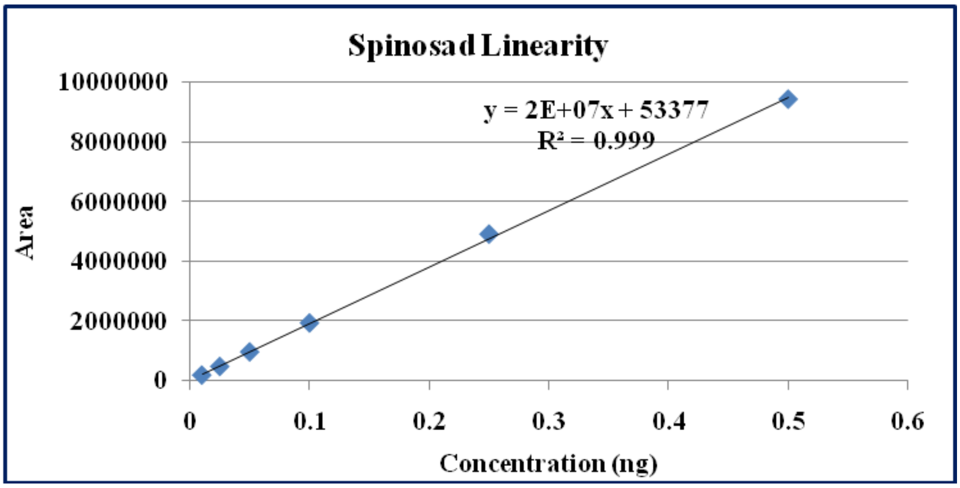

Fig. 3.8. Calibration curve for spinosad

3.4.3.2 Imidacloprid

Based on the response of the Mass Spectrometer to different quantities (ng) of CRM standards injected under the HPLC operational parameters given in table 3.3, it was found that the LOD (limit of detection) for imidacloprid was 0.05 ng and the linearity was in the range of 0.01 ng to 0.10 ng , as given in fig 3.9.

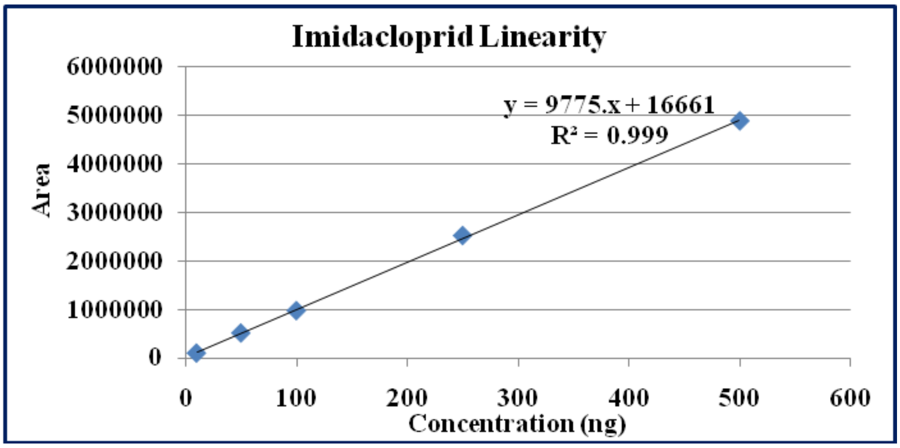

Fig. 3.9. Calibration curve for imidacloprid

3.4.4 Method validation

Prior to pesticide application and field sample analysis, the residue analysis method was validated following the SANCO document (12495/2011). The chilli fruits (5 kg) collected from untreated control plots were brought to the laboratory and the stalks were removed prior to sample preparation. The sample was homogenized using Robot Coupe Blixer (High volume homogenizer) and homogenized sample of each 15 g was taken in to 50 ml centrifuge tubes. The required quantity of fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin, beta cyfluthrin, dimethoate, spinosad and imidacloprid intermediary standard prepared from CRMs were added to each 15 g sample to get fortification levels of 0.05 ppm, 0.25 ppm and 0.5 ppm, in three replications each. These foritifcation levels were selected to know the suitability of the method to detect and quantify pesticides in green chilli. Similarly, the fortification process was repeated for red chilli powder to validate the method for chilli powder.

The AOAC official method 2007.01 (Pesticide Residues of Foods by Acetonitrile Extraction and Partitioning with Magnesium Sulfate) was slightly modified to suit to the facilties available at the laboratory and the same was validated for estimation of Limit of Quantification of above mentioned pesticides in Chilli matrix. The method followed was presented in the flow chart given at fig 3.10 and plate 4.

The final extract of the sample *i.e*. 2 ml equal to 1 g of the sample was shown in fig 3.9, was evaporated using turbovap and made up to 1 ml (equal to 1 g sample) using suitable solvent for analysis on GC, while for LC analysis, filtered 1 ml final extract (equal to 0.5 g sample) was directly injected in LC and the residues of pesticides recovered from fortified samples were calculated using the following formula.

$$\text{Residues (mg kg}^{-1}\text{)} = \frac{\text{Sample peak area X Conc of std (ppm) X µl std. X Final volume of the sample injected}}{\text{Standard Peak area X Weight of sample analysed X µl of sample injected}}$$

$$\text{Wt of the Sample analysed} = \frac{\text{Sample weight (15 g) X Aliquot taken}}{\text{Volume of acetonitrile (30 ml)}}$$

The recovery percentage and recovery factors were calculated using the following formula.

$$\text{Per cent Recovery} = \frac{\text{Residue quantified in fortified sample}}{\text{Fortified level}} \times 100$$

$$\text{Recovery factor} = \frac{100}{\text{Per cent recovery}}$$

Chilli fruits (5kg) were homogenized with robot coupe blixer

↓

Homogenised 15±0.1g sample was taken in 50 ml centrifuge tube

↓

Required quantity of standard (CRM) added to get desired fortification level

↓

30±0.1 ml acetonitrile was added to the tube

↓

The sample was homogenized at 14000-15000 rpm for 2-3 min using Heidolph silent crusher (low volume homogeniser)

↓

3±0.1g sodium chloride was added to tube and mixed by shaking gently

↓

Centrifuged for 3 min at 2500-3000 rpm to separate the organic layer

↓

The top organic layer of about 16 ml was taken into the 50 ml centrifuge tube

↓

9±0.1 g anhydrous sodium sulphate was added to remove the moisture content

↓

8 ml of extract was taken in to 15 ml tube containing 0.4±0.01g PSA sorbent (for dispersive solid phase d-SPE cleanup) and 1.2±0.01 g anhydrous magnesium sulphate

↓

The sample tube was vortexed for 30 sec followed by centrifugation for 5 min at 2500-3000 rpm

↓

The extract of about 2ml was transferred into test tubes and evaporated to dryness using turbovap with nitrogen gas and reconstituted with 1ml *n*-Hexane: Acetone (9:1) for GC analysis with ECD for fipronil, chlorantraniliprole profenophos, lambda-cyhalothrin , beta cyfluthrin and dimethoate analysis.

For analysis of spinosad and imidacloprid, 2 ml extract was filtered by using PTFE filter and finally 1 ml filtered extract is taken for injection in to the HPLC.

Fig. 3.10. Flow chart of QuEChERS method

3.4.5 Limit of quantification (LOQ) / Limit of determination

Fortified samples of fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin, beta cyfluthrin and dimethoate were analysed as part the method given in 3.4.2 while the samples of spinosad and imidacloprid were analysed by using the method given in 3.4.3.

3.4.5.1 Fipronil

The fortified samples were analysed as per the method shown in 3.4.2, 3.4.3 and the recovery factors were calculated. Chilli samples fortified with fipronil at 0.01 mg kg^{-1}, 0.05 mg kg^{-1} and 0.1 mg kg^{-1} were analysed and the mean recovery of the residues using the method was 99.18, 92.04 and 91.52 per cent, respectively in green chilli (Table 3.4) and 90.69, 99.18 and 103.53 per cent, respectively in chilli powder (Table 3.5). The results shown that the method was suitable for the analysis of fipronil residues up to 0.01 mg kg^{-1}, and the limit of quantification (LOQ) was 0.01 mg kg^{-1}.

Table 3.4. Recovery of fipronil from fortified green chilli samples

Details	**Recoveries of fipronil from fortified chilli samples**					
	Fortified level (mg kg^{-1})					
	0.01 mg kg^{-1}		**0.05** mg kg^{-1}		**0.1** mg kg^{-1}	
	Residues recovered (mg kg^{-1})	**Recovery %**	**Residues recovered (mg kg^{-1})**	**Recovery %**	**Residues recovered (mg kg^{-1})**	**Recovery %**
R1	0.0098	98.11	0.0457	91.42	0.0904	90.45
R2	0.0096	96.62	0.0462	92.58	0.0914	91.49
R3	0.0102	102.80	0.0460	92.11	0.0926	92.61
Mean		99.18		92.04		91.52
SD		3.22		0.59		1.08
RSD		3.25		0.64		1.18

Table 3.5. Recovery of fipronil from fortified chilli powder samples

Details	**Recoveries of fipronil from fortified chilli powder samples**					
	Fortified level (mg kg^{-1})					
	0.01 mg kg^{-1}		0.05 mg kg^{-1}		0.1 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.0089	89.78	0.490	98.11	0.100	100.28
R2	0.0090	90.73	0.483	96.62	0.103	103.16
R3	0.0091	91.56	0.514	102.80	0.107	107.16
Mean		90.69		99.18		103.53
SD		0.89		3.22		3.45
RSD		0.98		3.25		3.33

3.4.5.2 Chlorantraniliprole

Chilli samples fortified with chlorantraniliprole at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1}, respectively were analysed and the mean recovery of the residues using the method was 99.23, 94.68 and 88.27 per cent, respectively in green chilli (Table 3.6) and 87.03, 94.64 and 92.13 per cent, respectively in chilli powder (Table 3.7). The results shown that the method was suitable for the analysis of chlorantraniliprole residues up to 0.05 mg kg^{-1} and the limit of quantification (LOQ) was 0.05 mg kg^{-1}.

Table 3.6. Recovery of chlorantraniliprole from fortified green chilli samples

Details	**Recovery of chlorantraniliprole from fortified chilli samples**					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.050	100.80	0.244	97.71	0.446	89.15
R2	0.053	105.20	0.232	92.78	0.433	86.68
R3	0.046	91.70	0.234	93.55	0.445	89.00
Mean		99.23		94.68		88.27
SD		6.907		2.652		1.379
RSD		6.961		2.801		1.563

Table 3.7. Recovery of chlorantraniliprole from fortified chilli powder samples

Details	**Recovery of chlorantraniliprole from fortified chilli powder samples**					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.042	85.54	0.235	94.18	0.448	89.74
R2	0.044	88.96	0.247	98.88	0.470	94.01
R3	0.043	86.60	0.227	90.85	0.463	92.65
Mean		87.03		94.64		92.13
SD		1.75		4.03		2.18
RSD		6.961		2.801		1.563

3.4.5.3 Profenophos

Chilli samples fortified with profenophos at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1} were analysed and the mean recovery of the residues using the method was 98.25, 103.08 and 107.69 per cent, respectively in green chilli (Table 3.8) and 99.17, 95.70 and 103.66 per cent, respectively in chilli powder. (Table 3.9). The results shown that the method was suitable for the analysis of profenophos residues up to 0.05 mg kg^{-1}, and the limit of quantification (LOQ) was 0.05 mg kg^{-1}.

Table 3.8. Recovery of profenophos from fortified green chilli samples

Details	**Recoveries of profenophos from fortified chilli samples**					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.5 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.051	101.31	0.259	103.65	0.539	107.86
R2	0.049	97.59	0.267	106.91	0.535	107.00
R3	0.048	95.86	0.247	98.70	0.541	108.21
Mean		98.25		103.08		107.69
SD		2.783		4.137		0.62
RSD		2.832		4.01		0.57

Table 3.9. Recovery of profenophos from fortified chilli powder samples

Details	**Recoveries of profenophos from fortified chilli powder samples**					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.5 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.049	98.08	0.232	92.92	0.522	104.41
R2	0.049	98.72	0.242	96.87	0.509	101.83
R3	0.050	100.72	0.243	97.31	0.524	104.76
Mean		99.171		95.702		103.664
SD		1.376		2.418		1.602
RSD		1.387		2.527		1.545

3.4.5.4 lamda-cyhalothrin

Lamda-cyhalothrin at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1} were analysed and the mean recovery of the residues using the method was 88.10, 86.67 and 84.56 per cent, respectively in green chilli (Table 3.10) and 93.91, 87.46 and 83.77 per cent, respectively in chilli powder. (Table 3.11). The results shown that the method was suitable for the analysis of lamda cyhalothrin residues up to 0.05 mg kg^{-1}, and the limit of quantification (LOQ) was 0.05 mg kg^{-1}.

Table 3.10. Recovery of lambda-cyhalothrin from fortified green chilli samples

Details	**Recoveries of lambda-cyhalothrin from fortified chilli samples**					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.5 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.046	91.74	0.217	86.86	0.412	82.50
R2	0.044	84.46	0.216	86.55	0.433	86.61
R3	0.042	84.78	0.216	86.60	0.422	84.15
Mean		88.10		86.67		84.56
SD		5.14		0.16		2.91
RSD		5.84		0.19		3.44

Table 3.11. Recovery of lambda-cyhalothrin from fortified chilli powder samples

Details	Recoveries of lambda-cyhalothrin from fortified chilli powder samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.5 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.049	97.55	0.213	85.40	0.419	83.95
R2	0.045	90.27	0.223	89.52	0.418	83.65
R3	0.045	90.59	0.217	87.06	0.418	83.70
Mean		93.91		87.46		83.77
SD		5.14		2.91		0.16
RSD		5.48		3.33		0.20

3.4.5.5 Beta cyfluthrin

Chilli samples fortified with beta cyfluthrin at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1} were analysed and the mean recovery of the residues using the method was 92.41, 94.76 and 98.61 per cent, respectively in green chilli (Table 3.12) and 100.40, 98.45 and 88.70 per cent, respectively in chilli powder. (Table 3.13). The results revealed that the method was suitable for the analysis of beta cyfluthrin residues up to 0.05 mg kg^{-1}, and the limit of quantification (LOQ) was 0.05 mg kg^{-1}.

Table 3.12. Recovery of beta cyfluthrin from fortified green chilli samples

Details	Recoveries of beta cyfluthrin from fortified chilli samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.047	94.08	0.242	96.76	0.526	105.16
R2	0.045	89.83	0.222	88.72	0.481	96.17
R3	0.047	93.32	0.247	98.79	0.473	94.51
Mean		92.41		94.76		98.61
SD		2.263		5.33		5.733
RSD		2.449		5.62		5.814

Table 3.13. Recovery of beta cyfluthrin from fortified chilli powder samples

Details	Recoveries of beta cyfluthrin from fortified chilli powder samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.049	97.30	0.245	97.90	0.450	90.04
R2	0.052	103.40	0.247	98.94	0.432	86.33
R3	0.050	100.50	0.246	98.52	0.449	89.74
Mean		100.40		98.45		88.70
SD		3.060		0.523		2.060
RSD		3.040		0.531		2.323

3.4.5.6 Dimethoate

Chilli samples fortified with dimethoate at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1} were analysed and the mean recovery of the residues using the method was 88.45, 106.57 and 103.96 per cent, respectively in green chilli (Table 3.14) and 102.42, 94.63 and 97.78, respectively in chilli powder. (Table 3.15). The results shown that the method was suitable for the analysis of dimethoate residues up to 0.05 mg kg^{-1}, and the limit of quantification (LOQ) was 0.05 mg kg.

Table 3.14. Recovery of dimethoate from fortified green chilli samples

Details	Recoveries of dimethoate from fortified chilli samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.5 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.042	85.70	0.265	106.18	0.519	103.89
R2	0.045	90.21	0.268	107.43	0.512	102.58
R3	0.047	89.45	0.265	106.09	0.527	105.41
Mean		88.45		106.57		103.96
SD		2.41		0.75		1.42
RSD		2.73		0.70		1.36

Table 3.15. Recovery of dimethoate from fortified chilli powder samples

Details	**Recoveries of dimethoate from fortified chilli powder samples**					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.5 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.050	101.83	0.236	94.56	0.490	98.14
R2	0.051	103.07	0.240	96.36	0.497	99.54
R3	0.051	102.36	0.232	92.98	0.48	95.67
Mean		102.42		94.63		97.78
SD		0.62		1.69		1.96
RSD		0.61		1.79		2.00

3.4.5.7 Spinosad

Chilli samples fortified with spinosad at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1}, respectively were analysed and the mean recovery of the residues using the method was 93.48, 96.88 and 102.32 per cent, respectively in green chilli (Table 3.16) and 101.33, 96.20 and 102.67 per cent, respectively in chilli powder. (Table 3.17). The results shown that the method was suitable for the analysis of spinosad residues up to 0.05 mg kg^{-1} and the limit of quantification (LOQ) was 0.05 mg kg^{-1}**.**

Table 3.16. Recovery of spinosad from fortified green chilli samples

Details	**Recoveries of spinosad from fortified chilli samples**					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.046	91.63	0.248	99.01	0.504	100.84
R2	0.047	94.91	0.237	94.66	0.509	101.83
R3	0.047	93.89	0.242	96.96	0.512	104.30
Mean		93.48		96.88		102.32
SD		1.67		2.174		1.780
RSD		1.78		2.24		1.74

Table 3.17. Recovery of spinosad from fortified chilli powder samples

Details	Recoveries of spinosad from fortified chilli powder samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.051	101.88	0.242	96.98	0.520	104.01
R2	0.050	100.03	0.232	92.63	0.504	100.77
R3	0.051	102.08	0.247	99.00	0.516	103.24
Mean		101.33		96.20		102.67
SD		1.129		3.253		1.692
RSD		1.78		2.24		1.74

3.4.5.8 Imidacloprid

Chilli samples fortified with imidacloprid at 0.05 mg kg^{-1}, 0.25 mg kg^{-1} and 0.5 mg kg^{-1} were analysed and the mean recovery of the residues using the method was 95.42, 99.53 and 95.67 per cent, respectively in green chilli (Table 3.18) and 99.58, 95.57 and 99.75 per cent, respectively in chilli powder. (Table 3.19). The results revealed that the method was suitable for the analysis of flubendiamide residues up to 0.05 mg kg^{-1}, and the limit of quantification (LOQ) was 0.05 mg kg^{-1}.

Table 3.18. Recovery of imidacloprid from fortified green chilli samples

Details	Recoveries of imidacloprid from fortified chilli samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.048	95.77	0.247	98.79	0.478	95.67
R2	0.048	96.13	0.255	101.97	0.489	97.71
R3	0.047	93.34	0.245	97.85	0.468	93.63
Mean		95.42		99.53		95.67
SD		0.95		2.160		2.04
RSD		0.99		2.17		2.13

Table 3.19. Recovery of imidacloprid from fortified chilli powder samples

Details	Recoveries of imidacloprid from fortified chilli powder samples					
	Fortified level (mg kg^{-1})					
	0.05 mg kg^{-1}		0.25 mg kg^{-1}		0.50 mg kg^{-1}	
	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %	Residues recovered (mg kg^{-1})	Recovery %
R1	0.049	97.56	0.237	94.82	0.499	99.75
R2	0.050	99.70	0.225	90.06	0.509	101.79
R3	0.051	101.48	0.255	101.81	0.489	97.71
Mean		99.58		95.57		99.75
SD		1.962		5.910		2.040
RSD						

Hence, the method described and followed in 3.4.2 and 3.4.3 was suitable for the analysis of samples collected from the field amples sprayed with fipronil, chlorantraniliprole, profenophos, lambda-cyhalothrin, beta cyfluthrin, dimethoate spinosad and imidacloprid to study the dissipation pattern in green chilli and for the determination of processing factor in chilli powder.

3.4.6 Dissipation pattern of insecticides in chilli

Dissipation pattern of most commonly used insecticides *viz.*, fipronil 5% SC, spinosad 45% SC, chlorantraniliprole 20% SC, profenophos 50% EC, lambda cyhalothrin 5% SC, imidacloprid + beta cyfluthrin 300% OD and dimethoate 30 % EC were studied by spraying thrice at 10 days interval starting from 50% flowering @ 500 g a.i. ha^{-1}, 125 g a.i. ha^{-1}, 30 g a.i. ha^{-1}, 400 g a.i. ha^{-1}, 15.63 g a.i. ha^{-1} , 30 g a.i. ha^{-1} and 300 g a.i. ha^{-1}, respectively in three replications. The samples of green chilli were collected from these treated plots and residues were estimated at AINP on pesticide residue laboratory, Rajendranagar, Hyderabad.

3.4.6.1 Sample collection

Samples of green chilli were collected from individual treatments in all replications after three sprays, in labeled polybags. Care was taken to wear hand gloves to avoid contamination. Pest damage free and crack free chilli fruits were collected in saperate polythene bags and brought to the labarotary. Samples were collected at regular intervals *i.e*. 0, 1, 3, 5, 7, 10 and 15 days after last spray.

3.4.6.2 Sample analysis

Collected samples were analysed for residues following the validated method (Fig 3.9). Residues (mg kg^{-1}) were calculated using the formula given below.

$$\text{Residues (mg kg}^{-1}\text{)} = \frac{\text{Sample peak area X Conc of std (ppm) X } \mu\text{l std. injected X Final volume of the sample}}{\text{Standard Peak area X Weight of sample analysed X } \mu\text{l of sample injected}} \text{ X Recovery factor}$$

The following parameters were calculated to know the dissipation pattern of the insecticides on chilli.

Dissipation percentage:

$$\text{Per cent dissipation} = \frac{\text{Initial deposit - Residues at given time}}{\text{Initial deposit}} \text{ X 100}$$

Waiting period: Waiting period (T_{tol}) is defined as the minimum number of days to lapse before the insecticide reaches the tolerance limit.

The waiting periods were calculated wherever MRLs are available as per CAC/FSSAI, by the following formula.

$$Ttol = \frac{[a - \text{Log tol}]}{b}$$

Where

T_{tol} = Minimum time (in days) required for the pesticide residue to reach below the tolerance limit.

a = Log of apparent initial deposits obtained in the regression equation (Y = a + b X)

tol = Tolerance limit of the insecticide (MRL)

b = Slope of the regression line

3.5 Evaluation of decontamination methods for the removal of pesticide residues.

The zero day samples after third spray from the bioefficacy trail from different treatments in large quantities and made into six sets, each with four replications. One set of sample from each treatment (in 4 replications) was analyzed for deposits of the pesticide. The remaining sets of samples of zero day from each treatment samples were subjected to various decontamination methods separately and these samples were analysed for residues through validated method (Fig 3.9) Finally the residues were calculated for each treatment to know the efficiency of the various decontamination methods for the removal of pesticide residues from the chilli samples.The following decontamination / risk mitigation methods were selected for evaluation of efficiency in removal of pesticide residues from chilli.

3.5.1 T_1 (Tap water wash):

Four litres of tap water was taken into the plastic tub of 7 litres capacity and 2 kg of chilli fruits were dipped in the tub for 10 min, followed by the tap water wash for 30 sec, further the fruits were kept for air drying on tissue paper for 5 min.

3.5.2 T_2 (Soaking in 2% salt solution for 10 min followed by tap water wash):

Four litres of 2 % salt solution was prepared by mixing 80 g of table salt in 4 litres of water in plastic tub of 7 litres capacity and 2 kg chilli fruits were dipped in the tub for 10 min, followed by the tap water wash for 30 sec, further the fruits were kept for air drying on tissue paper for 5 min, followed by analysis.

3.5.3 T_3 (Cooking in pressure cooker for 10 min) :

Cooking of the 2 kg chilli fruits in pressure cooker for 10 min, followed by the tap water wash for 30 sec, further the fruits were kept for air drying on tissue paper for 5 min, followed by analysis.

3.5.4 T_4 (Dipping in 0.1% Sodium Bicarbonate solution keep it for 10 min followed by tap water wash):

Four litres of 0.1 % of $NaHCO_3$ solution was prepared by mixing of 4 g of $NaHCO_3$ in 4 litres of water in plastic tub of 7 litres capacity, mixture was kept for 1 min and 2 kg of chilli fruits were dipped in the tub for 10 min, followed by the tap water wash for 30 sec, further the fruits were kept for air drying on tissue paper for 5 min, followed by analysis.

3.5.5 T_5 (Dipping in Formula 1 (4 % Acetic Acid + 0.1% $NAHCO_3$ + 1 Lemon):

Four litres of formula 1 was prepared by mixing 160 ml of acetic acid, 4 g of sodium bicarbonate and lemon juice of 4 lemons added to 4 litres of water in plastic tub of 7 litres capacity, mixture was kept for 1 min and 2 kg chilli fruits were dipped in the tub for 10 min, followed by the tap water wash for 30 sec, further the fruits were kept for air drying on tissue paper for 5 min, followed by analysis.

Per cent removal of pesticide:

$$\text{Per cent removal} = \frac{\text{Initial deposit - Residues after treatment}}{\text{Initial deposit}} \times 100$$

3.6 Determination of the processing factor for selective insecticides in chillies.

The seven insecticides viz., Fipronil, Spinosad, Chlorantraniliprole, Profenophos, Lambdacyhalothrin, Betacyfluthrin + imidacloprid (soloman), Dimethoate and control (water spray) were sprayed as per the dosages given in table 3.1 at red chilli stage of the crop and samples were collected immediately after spray. Insecticide residues were estimated from the fresh samples from each replicated treatment. Then the left over sample was shade dried and powdered. Then the insecticide residues of all the treatments were estimated from the red chilli powder. The processing factor was worked out by using the formula.

Processing factor = residues in chilli powder / residues in fresh sample

3.7 Meteorological data

Data on maximum and minimum temperature, relative humidity, rainfall and sunshine hours recorded at meteorological Centre of Agricultural Research Institute, Professor Jayashankar Telangana State Agricultural University, Rajendranagar.

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation on seasonal incidence, population dynamics of chilli thrips in relation to abiotic factors and evaluation of efficacy of selective insecticides against chilli thrips were carried out during *kharif* 2015-16 and 2016-17 while dissipation studies of selective insecticides, decontamination of insecticides and processing factor experiments were conducted during *kharif* 2015-16.

4.1 Seasonal incidence of chilli thrips, *Scirtothrips dorsalis* Hood

Seasonal abundance of chilli thrips were recorded from unprotected chilli crop at weekly intervals during *kharif* 2015-16 and 2016-17 and the results were presented in tables 4.1 and 4.2 and fig 4.1. The observations were recorded starting from transplanting to harvest at weekly intervals as per the standard weeks.Thrips population was counted on five randomly tagged plants, from five terminal leaves of each plant from each replication.

4.1.1. Seasonal incidence of *S. dorsalis* on chilli in *kharif* 2015-16

Observations on the incidence of thrips on chilli during *kharif* 2015-16 revealed that the activity of *S. dorsalis* on chilli started from fourth week of September during 39th standard week (Table 4.1) and it continued throughout the crop growth period. Population of *S. dorsalis* recorded on chilli leaves ranged from 2.94 to 24.82 thrips (per five leaves). The population of thrips increased gradually from fourth week of September (39th standard week) and attained a first peak during second week of December (50th standard week) with 20.54 thrips per five leaves, while second peak was noticed during January 3rd week (3rd standard week) with 24.82 thrips per five leaves. There after the population showed decreasing trend and the population count reduced to 2.10 thrips per five leaves by the end of crop growth period *i.e.* during 9th standard week.

4.1.2 Seasonal incidence of *S. dorsalis* on chilli in *kharif* 2016-17

During *kharif* 2016-17 incidence of thrips population started from first week of October (during 40th standard week) and it continued throughout the crop growth period. Population of *S. dorsalis* recorded on chilli ranged from 0.10 to 17.01 thrips per five leaves. The population of thrips increased gradually from first week of October (40^{th} standard week) and attained a peak during December last week (52^{nd} standard week) with 17.01 thrips per five leaves. There after the population showed decreasing trend and the population counts reduced to 1.89 per five leaves by the end of crop growth period *i.e.* during 8^{th} standard week (Table 4.2).

The results of both *kharif* 2015-16 and 2016-17 derived support from the findings of Lingeri *et al*.,(1998) who observed that the peak population of chilli thrips during December and January months. Bindu and Patel (2001) observed the activity of chilli thrips *S. dorsalis* from 1^{st} week of September to 2^{nd} week of January. Patel *et al*., (2009) reported that the incidence of *S. dorsalis* in chillies started from 1^{st} week of September and it continued up to the harvest of the crop with a peak activity during November and February to March. Vanisree *et al*., (2011) observed the peak activity of chilli thrips observed during 1^{st} standard week in Andhra Pradesh, Bapatla. Roopa and Ashok Kumar (2014) who reported the maximum population of chilli thrips ranging from 0.07 to 5.88 with a mean of 3.53 thrips per top 3 leaves per plant and the incidence of thrips, *S. dorsalis* was observed throughout the cropping season with varying intensity ranging from 0.07 to 5.88 per top 3 leaves per plant. Arti Saini *et al*. (2017) noticed that the incidence of thrips commenced in second week of August and peak incidence was observed during the third week of September (10.2/3 leaves). Several authors have reported the peak activity of chilli thrips in August to September (Patel, 1992; Bindu, 2000; Hosamani,2007 and Arti Saini *et al*., 2017) and October and November months (Rai *et al*., 2009; Patil and Nandihalli 2009; Barot *et al*., 2012; Nandini *et al*., 2012; Bokan *et al*., 2015; Zainab *et al*., 2016 and Sahu *et al*., 2017). The variation in the peak activity of thrips observed in different regions could be attributed to the variation in ecological conditions, dates of transplantation and the chilli varieties used in the study.

4.2 Effect of abiotic factors on the incidence of chilli thrips *S. dorsalis* in chilli

The seasonal incidence data of chilli thrips collected at weekly intervals were subjected to correlation with weather parameters of one week lag during *kharif* 2015-16 and 2016-17 and the results obtained were presented in tables 4.3 and 4.4.

4.2.1 *Kharif* 2015-16

Correlation coefficients between *S. dorsalis* population and weather parameters of one week lag (Table 4.3) indicated that among the various weather parameters, significant negative correlation was observed between weather parameters of maximum temperature (-0.51^{**}), minimum temperature (-0.80^{**}), mean temperature (-0.87^{**}), rainfall (-0.55^{**}), rainy days (-0.59^{**}) at 1% level of significance while evening relative humidity was found negatively significant (-0.50^{*}) at 5% level of significance with *S. dorsalis* population. The other parameters of morning relative humiditiy (-0.39) and evaporation (-0.33) showed negatively non significant while sunshine hours (0.39) and wind speed (0.04) showed positively significant effect on *S. dorsalis* population.

4.2.2 *Kharif* 2016-17

Correlation studies during *kharif* 2016-17 revealed that maximum temperature (-0.59^{**}), minimum temperature (-0.83^{**}), evening relative humidity (-0.66^{**}), rainfall (-0.59^{**}), rainy days (-0.67^{**}) and mean temperature (-0.87^{**}) were significant and negatively correlated with the thrips population at 1% level of significance while sunshine hours (0.53^{**}) was significant and positively correlated with thrips population at 1% level of significance. The morning relative humidity (-0.27), wind speed (-0.11) and evaporation (-0.07) were non significant with the *S. dorsalis* population in chilli during *kharif* 2016-17 (Table 4.4).

These results strongly support the findings of Varadharajan and Veeraval (1995); Hosamani (2007); Bhede *et al*., (2008); Pathipati *et al*., (2014) who reported a significant negative correlation of rainfall with *S. dorsalis* population. Hosamani (2007);Pathipati *et al*., (2014) and Bokan *et al*., (2015) observed negative correlation between *S. dorsalis* population and minimum temperature. Roopa and Ashok kumar (2014) observed the thrips population buildup a significant negative relationship of weather parameters with maximum and minimum temperatures. Arti saini *et al.,* (2017) observed that negative relationship with temperature and rainfall. These findings indicated that population build-up of *S. dorsalis* population on leaves was mainly influenced by temperature and rainfall and other parameters like morning relative humidity, evaporation and sunshine hours did not show any significant effect on the population buildup of thrips population in chilli.

4.2.3 Development of multiple regression equation for *S. dorsalis*

Multiple regression equation developed for the thrips population with preceding one week weather parameters (one week lag) data during *kharif* 2015-16 and 2016-17 was presented in table 4.5

The multiple regression equation for *S. dorsalis* during *kharif* 2015-16 (Table 4.5) indicated that, increase in one unit of maximum temperature, minimum temperature, morning relative humidity, rainy days, mean sunshine hours and wind speed resulted in increase of population of thrips by 2.05, 4.11, 0.05, 0.65, 0.15 and 0.22 units, respectively and with one unit of increase in the evening relative humidity, rainfall, mean evaporation and mean temperature the thrips was decreased by 0.31, 1.05, 0.70 and 5.36 units, respectively in *kharif* 2015-16. The weather parameters collectively influenced the population of thrips to the extent of 93.92 per cent (R^2 = 0.94%).

During *kharif* 2016-17, preceding one week weather parameters (one week lag) indicated that, increase in one unit of evening relative humidity, rainy days, mean sunshine hours, wind speed and mean temperature resulted in the increase of thrips population by 0.05, 0.19, 0.14, 0.25 and 9.31units, respectively. Further, with the increase in one unit of maximum temperature, minimum temperature, morning relative humidity, rainfall and mean evaporation, the thrips population was decreased by 2.45, 9.99, 0.14, 0.79 and 0.82 units respectively. However, in the study, entire weather parameters collectively influenced the thrips population to an extent of 92.65 per cent (R^2 =0.93%). The present results corroborate with the findings of Pathipati *et al*., (2014) who revealed that 81 per cent of the variation in the *S. dorsalis* population was contributed by the weather parameters. Similar findings were reported by Bindu and Patel (2001).According to them the weather parameters could explain the variation in *S. dorsais* population in chilli to an extent of 55 per cent.

4.3 Efficacy of Selective insecticides against chilli thrips *Scirtothrips dorsalis* Hood

The insecticides *viz.*,fipronil 5% SC @ 500g a.i ha^{-1}, spinosad 45% SC @ 125 g a.i ha^{-1}, chlorantraniliprole 20% SC @ 30g a.i ha^{-1}, profenophos 50% EC @ 400g a.i ha^{-1}**,** lambda cyhalothrin 5% SC @ 15.63g a.i ha^{-1}, imidacloprid + beta cyfluthrin 300% OD @ 30g a.i ha^{-1} and dimethoate 30 % EC @ 300g a.i ha^{-1} along with untreated control (water spray) were sprayed thrice starting the first spray at 50% flowering while second and third spray at 10 days interval to determine their efficacy against chilli thrips *Scirtothrips dorsalis* Hood during *kharif* 2015-16 and 2016-17. Efficacy of insecticidal treatments were determined in terms of mean per cent reduction of the insect population in the treatment over untreated control (water spray).

4.3.1 Efficacy of Insecticides against chilli thrips *S. dorsalis* Hood in *kharif*2015-16

The efficacy of different selective insecticidal treatments during *kharif*, 2015-16 against chilli thrips were presented in tables 4.6 to 4.8.

4.3.1.1 Reduction of *S. dorsalis* population after first Spray during *kharif* 2015-16

The results on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after first spray during *kharif* 2015-16 was presented in table 4.6.

4.3.1.1.1 Reduction of *S. dorsalis* population at one day after first spray

The mean per cent reduction of *S. dorsalis* population at one day after first spray indicated that all the insecticidal treatments were superior over control. Data revealed that spinosad at 125 g a.i. ha^{-1} exhibited supremacy by recording 72.33 per cent reduction of *S. dorsalis* population over untreated control and significantly different from other treatments (Table 4.6).

The next effective treatments were fipronil at 500 g a.i. ha^{-1} (67.26%), betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (65.10%), profenophos at 400 g a.i. ha^{-1} (62.84%), dimethoate at 300 g a.i. ha^{-1} (48.13%) and lambda cyhalothrin at 15.63 g a.i. ha^{-1} (48.05%). The treatment with fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other. The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 11.74 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at one day after first spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.1.2 Reduction of *S. dorsalis* population at three days after first spray

The observations on mean percent reduction of thrips population at three days after first spray revealed that Spinosad at 125 g a.i. ha^{-1} was found to be superior over all other treatments by recording 78.43 per cent reduction of *S. dorsalis* population over untreated control (Table 4.6) and was on par with fipronil at 500 g a.i. ha^{-1} (77.24%) and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (74.24%). The next effective treatment was profenophos at 400 g a.i. ha^{-1} with 63.35 per cent reduction of *S. dorsalis* population over control. The treatments dimethoate at 300 g a.i. ha^{-1} (54.27%) and lambda cyhalothrin at 15.63 g a.i. ha^{-1} (49.72%) were significantly on par with each other.

Among all the insecticides evaluated, chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 13.88 per cent reduction of *S. dorsalis* population over untreated control even at three days after spray. The efficacy of different insecticidal treatments against *S. dorsalis* at three days after first spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.1.3 Reduction of *S. dorsalis* population at five days after first spray

The results of mean per cent reduction of chilli thrips at five days after first spray showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 86.15 per cent population reduction of *S. dorsalis* over control and was on par with fipronil at 500 g a.i. $ha^{-1}$with 85.15 per cent (Table 4.6).

The next effective treatment was betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} with 82.04 per cent and this treatment was on par with fipronil at 500 g a.i. ha^{-1}. The treatments with profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} has recorded 72.87, 55.63 and 48.63 per cent reduction in *S. dorsalis* population over control and these treatments were significantly different from each other. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (16.15%). The efficacy of different insecticidal treatments against *S. dorsalis* at five days after first spray was found to be in the following order.

T2 > T1 > T6> T4 > T7 > T5 > T3

4.3.1.1.4 Reduction of *S. dorsalis* population at seven days after first spray

The observations made on the reduction of *S. dorsalis* population at seven days after first spray indicated that all the treatments were superior over control. Spinosad at

125 g a.i. ha^{-1} recorded the highest population reduction of 76.92 per cent and found significantly superior over all other treatments (Table 4.6).

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate and lambda cyhalothrin 15.63 g a.i. ha^{-1} at 300 g a.i. ha^{-1} at with 70.12, 68.84, 64.04, 46.93 and 46.39 per cent reduction in *S. dorsalis* population over control. The respecting treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 12.67 per cent population reduction of *S. dorsalis* over control even at seven days after spray.The efficacy of different insecticidal treatments against *S. dorsalis* at seven days after first spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.1.5 Reduction of *S. dorsalis* population at ten days after first spray

Spinosad at 125 g a.i. ha^{-1} were found to be most effective treatments with 54.89 per cent reduction of *S. dorsalis* population over control and significantly different from other treatments, at ten days after first spray (Table 4.6)

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} reduced the population of *S. dorsalis* to an extent of 50.12, 48.87 and 45.18 per cent, respectively. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other in terms of mean per cent reduction of chilli thrips over untreated control.

The treatments that were followed in descending order of efficacy were dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 38.21 and 34.82 per cent reduction in *S. dorsalis* population over control and were on par each other. The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with population reduction of 8.15 per cent over untreated control. The efficacy of different insecticidal treatments against *S. dorsalis* at ten days after first spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.2 Reduction of *S. dorsalis* population after second spray during *kharif* 2015-16

The results on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after second spray during *kharif* 2015-16 was presented in table 4.7.

4.3.1.2.1 Reduction of *S. dorsalis* population at one day after second spray

The data collected at one day after second spray showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 73.98 per cent population reduction of *S. dorsalis* over control and was significantly different from other treatments (Table 4.7).

The next effective treatments that were followed in the descending order of efficacy were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 68.44, 67.21, 63.18, 51.50 and 49.26 per cent reduction in *S. dorsalis* population over control.The treatments fipronil at 500 g a.i. ha^{-1} and responding betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other in reduction of chilli thrips. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other at one day after second spray.

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (12.63%). The efficacy of different insecticidal treatments against *S. dorsalis* at one day after second spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.2.2 Reduction of *S. dorsalis* population at three days after secondspray

The observations recorded at third day after second spraying showed that the treatment spinosad at 125 g a.i. ha^{-1} was most effective and was found significantly superior over all other treatments in reducing the *S. dorsalis* population (78.20%). The other promising treatments were fipronil at 500 g a.i. ha^{-1} (74.02%) and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (73.12%) were significantly on par each other (Table 4.7).

The next effective treatment was profenophos at 400 g a.i. ha^{-1} with 68.18 per cent reduction of *S. dorsalis* population over control. Lambda cyhalothrin 15.63 g a.i. ha^{-1} and dimethoate at 300 g a.i. ha^{-1} were on par in thrips population reduction with 52.81 and 52.55 per cent, respectively. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (14.74%). The efficacy of different insecticidal treatments against *S. dorsalis* at three days after second spray was found to be in the following order.

T2 > T1 > T6 > T4 > T5 > T7 > T3

4.3.1.2.3 Reduction of *S. dorsalis* population at five days after secondspray

The observations on mean percent reduction of thrips population at five days after second spray revealed that spinosad at 125 g a.i. ha^{-1} was found to be superior over all other treatments by recording 82.18 per cent reduction of *S. dorsalis* population over untreated control and was on par with fipronil at 500 g a.i. ha^{-1} (81.60%) and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (78.24%). The treatment profenophos at 400 g a.i. ha^{-1} recorded 71.12 per cent reduction of *S. dorsalis* population over control (Table 4.7).

The treatment dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. $ha^{-1}$with 55.57 and 54.31 per cent reduction, respectively and were on par with each other. Among all the insecticides tested, chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 17.19 per cent reduction of *S. dorsalis* population over untreated control even at five days after second spray. The efficacy of different insecticidal treatments against *S. dorsalis* at five days after second spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.2.4 Reduction of *S. dorsalis* Population at seven days after secondspray

The results indicated that spinosad at 125 g a.i. ha^{-1} exhibited supremacy by recording 73.18 per cent reduction of *S. dorsalis* population over untreated control and was on par with fipronil at 500 g a.i. ha^{-1} (71.14%) and betacyfluthrin + imidacloprid at

30 g a.i. ha^{-1} (70.18%) in reducing the *S. dorsalis* population over control. Profenophos at 400 g a.i. ha^{-1} recorded 66.12 per cent reduction of thrips population over control and significantly different from the other treatments (Table 4.7).

The next effective treatments were dimethoate at 300 g a.i. ha^{-1} (52.32%) and lambda cyhalothrin 15.63 g a.i. ha^{-1} (48.92%) and were on par each other. Among the treatments, chlorantraniliprole at 30 g a.i. ha^{-1} recorded 14.49 per cent reduction of thrips over control. The efficacy of different insecticidal treatments against *S. dorsalis* at seven days after second spray were found to be in the following order.

T2 > T1 > T6> T4 > T7 > T5 > T3

4.3.1.2.5 Reduction of *S. dorsalis* population at ten days after second spray

The observations made with regard to the reduction of *S. dorsalis* population at ten days after spraying indicated that all the treatments were superior over control (Table 4.7). Spinosad at 125 g a.i. ha^{-1} recorded the highest population reduction of 50.12 per cent and was on par with fipronil at 500 g a.i. ha^{-1} (46.96%).

The treatments that were followed in descending order of efficacy were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, Profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 43.27, 40.86, 38.97 and 36.97 per cent reduction in *S. dorsalis* population over control respectively The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatment profenophos at 400 g a.i. ha^{-1} was on par with dimethoate at 300 g a.i. ha^{-1}and lambda cyhalothrin at 15.63 g a.i. ha^{-1} in terms of per cent reduction of chilli thrips over control.

The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 11.73 per cent population reduction of *S. dorsalis* responding over control even at ten days after spray. The efficacy of different insecticidal treatments against *S. dorsalis* at ten days after spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.3 Reduction of *S. dorsalis* population after third spray during *kharif* 2015-16

The results on the mean per cent reduction of *Scirtothrips dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after third spray during *kharif* 2015-16 was presented in table 4.8.

4.3.1.3.1 Reduction of *S. dorsalis* Population at one day after third spray

The observations recorded at one day after third spray showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 70.10 per cent population reduction of *S. dorsalis* over control (Table 4.8) and was on par with fipronil at 500 g a.i. ha^{-1} (66%).

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (60%) and profenophos at 400 g a.i. ha^{-1} (58%) were on par with each other in reduction of *S. dorsalis* over control. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} were on par with 45.39 and 42.78 per cent reduction of thrips population over control, respectively. Among all the insecticides tested, chlorantraniliprole at 30 g a.i. ha^{-1} was found to be the least effective treatment with 9.63 per cent reduction of *S. dorsalis* population over untreated control at one day after third spray. The efficacy of different insecticidal treatments against *S. dorsalis* at one day after third spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.3.2 Reduction of *S. dorsalis* population at three days after third spray during *kharif* 2015-16.

The data collected at three days after third spray showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 76.24 per cent population reduction of *S. dorsalis* over control (Table 4.8). The next effective treatments were fipronil at 500 g a.i. ha^{-1} (68.74%), betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (68.12%) and profenophos at 400 g a.i. ha^{-1} (66.94%) were on par with each other in the reduction of thrips population over control.

The treatments that were followed in the descending order of efficacy were dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 47.84 and 44.19 per cent reduction in *S. dorsalis* population over control and were on par each other. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 11.19 per cent population reduction of *S. dorsalis* over control even at three days after third spray. The efficacy of different insecticidal treatments against *S. dorsalis* at three days after third spray was found to be in the following order.

T2 > T1 > T6 > T4> T7 > T5 > T3

4.3.1.3.3 Reduction of *S. dorsalis* Population at five days after third spray

Spinosad at 125 g a.i. ha^{-1} was found to be most effective treatment with 82.14 per cent reduction of *S. dorsalis* population over control and significantly different from other treatments (Table 4.8).

The next effective treatments that were followed in descending order of efficacy were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 76.24, 72.12, 70.18, 50.67 and 45.98 per cent reduction in *S. dorsalis* population over control. Betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with population reduction of 12.98 per cent over untreated control. The efficacy of different insecticidal treatments against *S. dorsalis* at five days after third spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.1.3.4 Reduction of *S. dorsalis* population at seven days after third spray

The mean per cent reduction of *S. dorsalis* population at seven days after third spraying indicated that all the insecticidal treatments were superior over control (Table 4.8). The data revealed that spinosad spraying at of 125 g a.i. ha^{-1} exhibited supremacy by recording 72.24 per cent reduction of *S. dorsalis* population over untreated control and was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (70.12%) and fipronil at 500 g a.i. ha^{-1} (70.09%).

The next effective treatments were profenophos at 400 g a.i. ha^{-1} (65.29%), dimethoate at 300 g a.i. ha^{-1} (55.23%) and lambda cyhalothrin 15.63 g a.i. ha^{-1} (41.89%) were significantly different from each other. The least effective treatment chlorantraniliprole at 30 g a.i. ha^{-1} recorded 11.16 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at seven days after third spray was found to be in the following order.

T2 > T6 > T1 > T4 > T7 > T5 > T3

4.3.1.3.5 Reduction of *S. dorsalis* population at ten days after third spray

The observations made with regard to the reduction of *S. dorsalis* population at ten days after spraying indicated that all the treatments were superior over control (Table 4.8). Spinosad at 125 g a.i. ha^{-1} has recorded the highest population reduction of 62.19 per cent and found significantly superior over other treatments. The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} recorded 52.94, 50.89, 48.74, 39.34 and 34.96 per cent reduction of *S. dorsalis* population over control.

The treatments fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other, while dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other in reducing of thrips population over cntrol

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be the least effective treatment with 7.26 per cent population reduction of *S. dorsalis* over control even at ten days after third spray. The efficacy of different insecticidal treatments against *S. dorsalis* at ten days after third spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.2 Efficacy of Insecticides against *S. dorsalis* during *kharif*, 2016-17

The efficacy of different selective insecticidal treatments during *kharif*, 2016-17 against chilli thrips was presented in tables 4.9 to 4.11.

4.3.2.1 Reduction of *S. dorsalis* population after first Spray

The results on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after first spray during *kharif* 2016-17 was presented in table 4.9.

4.3.2.1.1 Reduction of *Scirtothrips dorsalis* population at one day after first spray

The mean per cent reduction of *S. dorsalis* population at one day after first spray indicated that all the insecticidal treatments were superior over control. The data revealed that spinosad at 125 g a.i. ha^{-1} exhibited supremacy by recording 70.18 per cent reduction of *S. dorsalis* population over untreated control (Table 4.9) and was on par with fipronil at 500 g a.i. ha^{-1} (65.91%) and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (65.86%). Similarly fipronil at 500 g a.i. ha^{-1} (65.91%) was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (65.86) and profenophos at 400 g a.i. ha^{-1} (61.45%) in reduction of thrips population over control.

The next effective treatments were dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 48.67 and 41.93 per cent reduction of thrips population respectively over control. The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 11.49 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at one day after first spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.1.2 Reduction of *S. dorsalis* population at three days after first spray

Observations recorded at three days after first spray showed that spinosad at 125 g a.i. ha^{-1} was found to be superior over all other treatments by reducing 86.12 per cent reduction of *S. dorsalis* population over untreated control. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}recorded 79.16 and 76.91 per cent reduction of thrips population over control and were on par each other, while fipronil at 500 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were also on par each other with per cent reduction of thrips population in profenophos at 400 g a.i. ha^{-1} was 72.42 (Table 4.9).

The other treatments followed in descending order of efficacy were dimethoate at 300 g a.i. ha^{-1} (54.37%) and lambda cyhalothrin 15.63 g a.i. ha^{-1} (47.91%) were statistically different from each other. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 12.68 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at three days after first spray was found to be in the following order.

T2 >T1 > T6 > T4 >T7 > T5 > T3

4.3.2.1.3 Reduction of *S. dorsalis* population at five day after first spray

Spinosad at 125 g a.i. ha^{-1} (89.42%) was superior over remaining treatments in per cent reduction of thrips population over control and was on par with fipronil at 500 g a.i. ha^{-1} (86.12%). The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} with 86.12 and 85.23 per cent reduction of thrips population over control and were on par each other. The treatment with profenophos at 400 g a.i. ha^{-1} reduced the *S. dorsalis* population to an extent of 78.42 per cent over control (Table 4.9).

The treatments with lambda cyhalothrin reducing thrips population 15.63 g a.i. ha^{-1} and dimethoate at 300 g a.i. ha^{-1} were found to be 49.84 and 49.58 per cent of thrips over control and were on par each other. The least efficacy was observed with chlorantraniliprole at 30 g a.i. ha^{-1} concentration (14.43%). The efficacy of different insecticidal treatments against *S. dorsalis* at five days after first spray was found to be in the following order.

T2 >T1 > T6 > T4 > T5 > T7 > T3

4.3.2.1.4 Reduction of *S. dorsalis* population at seven days after first spray

The observations made with regard to the reduction of *S. dorsalis* population at seven days after first spray indicated that all the treatments were superior over control (Table 4.9). Spinosad at 125 g a.i. ha^{-1} recorded the highest population reduction of 78.12 per cent and were on par with fipronil at 500 g a.i. ha^{-1} (74.16%).

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate and lambda cyhalothrin 15.63 g a.i. ha^{-1} at 300 g a.i. ha^{-1} with 74.16, 70.36, 68.18, 42.68 and 42.62

per cent reduction of *S. dorsalis* population respectively over control. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other in thrips reducing population over control. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 11.50 per cent population reduction of *S. dorsalis* over control even at seven days after first spray.The efficacy of different insecticidal treatments against *S. dorsalis* at seven days after first spray were found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.2.1.5 Reduction of *S. dorsalis* population at ten days after first spray

Spinosad at 125 g a.i. ha^{-1} was found to be most effective treatment with 52.93 per cent reduction of *S. dorsalis* population over control and were on par with fipronil at 500 g a.i. ha^{-1} (48.92%) at ten days after first spray (Table 4.9).

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1},dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with reduced the population of *S. dorsalis* to an extent of 45.82, 43.14, 38.90 and 34.78 per cent, respectively. The treatments fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1}were on par with each other in reduction of thrips population over control.

The least effective treatment was chlorantraniliprole (30 g a.i. ha^{-1}) with population reduction of 9.27 per cent over untreated control. The efficacy of different insecticidal treatments against *S. dorsalis* at ten days after first spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.2.2 Reduction of *S. dorsalis* population after second spray during *kharif* 2016-17

The results on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after second spray during *kharif* 2016-17 was presented in table 4.10.

4.3.2.2.1 Reduction of *S. dorsalis* population at one day after second spray

All the insecticidal treatments were superior over control at one day after second spray. Observations recorded at one day after second spray showed that spinosad at 125 g a.i. ha^{-1} was found to be superior over all treatments by reducing 72.14 per cent reduction of *S. dorsalis* population over untreated control and was on par with fipronil at 500 g a.i. ha^{-1} (68.92%). Betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} recorded 63.18 and 61.92 per cent reduction of thrips population over control and these two treatments were on par with each other in reduction of thrips population over control (Table 4.10).

The other treatments followed in descending order of efficacy were dimethoate at 300 g a.i. ha^{-1} (52.84%) and lambda cyhalothrin 15.63 g a.i. ha^{-1} (47.55%) and were statistically different with each other. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 11.30 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at one day after second spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.2.2 Reduction of *S. dorsalis* population at three day after secondspray

Observations recorded at three days after second spray showed that spinosad at 125 g a.i. ha^{-1} was found to be significantly superior over all treatments by reducing 79.18 per cent reduction of *S. dorsalis* population over untreated control (Table 4.10). Fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} recorded 74.97 and 72.12 per cent reduction of thrips population respectively over control and were on par each other. Similarly betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} was on par with profenophos at 400 g a.i. ha^{-1} (68.18%).

The other treatments followed in descending order of efficacy were dimethoate at 300 g a.i. ha^{-1} (56.50%) and lambda cyhalothrin 15.63 g a.i. ha^{-1} (49.95%). Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 14.49 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at three days after second spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.2.3 Reduction of *S. dorsalis* population at five days after second spray

The mean per cent reduction of *S. dorsalis* population at five days after second spray indicated that all the insecticides were superior over control. The data revealed that spinosad at 125 g a.i. ha^{-1} exhibited supremacy by recording 82.14 per cent reduction of *S. dorsalis* population over untreated control (Table 4.10).

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} with 78.14, 76.18 and 74.96 per cent reduction of thrips population respectively and three treatments were on par each other in reduction of thrips population over control.Dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} recorded 54.47 and 52.06 per cent reduction of *S. dorsalis* population over control and were on par with each other. The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 12.01 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at five days after second spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.2.4 Reduction of *S. dorsalis* population at seven days after second spray

Spinosad at 125 g a.i. ha^{-1} (80.46%) was significantly superior over remaining treatments in per cent reduction of thrips population over control, followed by fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}and profenophos at 400 g a.i. ha^{-1}with 70.19, 66.14 and 64.18 per cent reduction of thrips population over control (Table 4.10).

The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} reduced the thrips population to an extent of 45.54 and 42.91 per cent over control and were on par with each other. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 10.06 per cent reduction of thrips over control. The efficacy of different insecticidal treatments against *S. dorsalis* at seven days after spray were found to be in the following order.

T2 >T1 > T6 > T4> T7 > T5 > T3

4.3.2.2.5 Reduction of *S. dorsalis* population at ten days after second spray

Data generated at ten days after treatment revealed that all insecticidal treatments were superior over control. The treatment with spinosad at 125g a.i. ha^{-1} concentration was adjudged as the best treatment (56.55%) and was found to be significantly superior over all the treatments (Table 4.10).

The next effective treatments were fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} with 51.46 and 48.32 per cent reduction of thrips population and were statistically on par with each other. The treatments with profenophos at 400 g a.i. ha^{-1} and dimethoate at 300 g a.i. ha^{-1} which recorded 42.80 and 39.10 per cent reduction of *S. dorsalis* population over control and were on par with each other. The treatments with dimethoate at 300 g a.i. ha^{-1} (39.10%) and lambda cyhalothrin 15.63 g a.i. ha^{-1} (35.97%) were also on par each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1}with 7.82 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at ten days after second spray was found to be in the following order.

T2 >T1> T6 > T4 > T5 > T7 > T3

4.3.2.3 Reduction of *Scirtothrips dorsalis* population after third spray during *kharif* 2016-17

The results on the mean per cent reduction of *Scirtothrips dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after second spray during *kharif* 2016-17 was presented in table 4.11.

4.3.2.3.1 Reduction of *S. dorsalis* population at one day after third spray

The mean per cent reduction of *S. dorsalis* population at one day after third spraying indicated that all the insecticidal treatments were superior over control. The data revealed that spinosad at 125 g a.i. ha^{-1} has exhibited supremacy by recording 71.81 per cent reduction of *S. dorsalis* population over untreated control (Table 4.11) and was significantly differ from other treatments. The treatment fipronil at 500 g a.i. ha^{-1} (67.19%) was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (64.68%) and profenophos at 400 g a.i. ha^{-1} (64.54%).

The next effective treatments were dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 47.76 and 45.39 per cent reduction of thrips population over control and these two treatments were significantly on par with each other. The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 12.01 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at one day after third spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.3.2 Reduction of *S. dorsalis* population at three days after third spray

Spinosad at 125 g a.i. ha^{-1} (76.98%) and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (72.90%) were on par with each other and superior over other treatments in per cent reduction of thrips population over control (Table 4.11). Similarly fipronil at 500 g a.i. ha^{-1} (71.24%) was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (72.90%), while fipronil at 500 g a.i. ha^{-1} (71.24%) and profenophos at 400 g a.i. ha^{-1} (67.92%) were on par with each other.

The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 50.28 and 43.18 per cent reduction of thrips population over control were significantly different from each other. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 12.71 per cent reduction of thrips over control. The efficacy of different insecticidal treatments against *S. dorsalis* at three days after third spray was found to be in the following order.

T2 >T6 > T1 > T4 > T7 > T5 > T3

4.3.2.3.3 Reduction of *S. dorsalis* population at five days after third spray

The mean per cent reduction of *S. dorsalis* population at five days after third spray indicated that all the insecticides were superior over control. The data revealed that spinosad at 125 g a.i. ha^{-1} exhibited supremacy by recording 80.46 per cent reduction of *S. dorsalis* population over untreated control (Table 4.11) and was on par with fipronil at 500 g a.i. ha^{-1} (78.12%).

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1},dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 75.86, 72.86, 47.85 and 44.89 per cent reduction of thrips population respectively The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other in reduction of thrips population over control.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 15.06 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at fivedays after third spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.3.4 Reduction of *S. dorsalis* population at seven days after third spray

Data generated at seven days after third spray revealed that all insecticidal treatments were superior over control. The treatment spinosad at 125 g a.i. ha^{-1} concentration was adjudged as the best treatment (78.10%) and was found to be significantly superior to all the treatments (Table 4.11).

The next effective treatments were fipronol at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} with 73.24, 68.96 and 67.14 per cent reduction of thrips population respectively. The treatments betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1}were statistically on par with each other.

The treatment with dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} recorded 45.47 and 42.25 per cent reduction of *S. dorsalis* population over control and were on par with each other. The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 13.70 per cent reduction of *S. dorsalis* over control. The efficacy of different insecticidal treatments against *S. dorsalis* at seven days after third spray was found to be in the following order.

T2 >T1 > T6 > T4 > T7 > T5 > T3

4.3.2.3.5 Reduction of *S. dorsalis* population at ten days after third spray

All the insecticidal treatments were significantly superior over control. Spinosad at 125 g a.i. ha^{-1} recorded the highest population reduction of 55.92 per cent (Table 4.11) and found superior to all other treatments and were on par with fipronil at 500 g a.i. ha^{-1} (51.27).

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} with 47.84 and 46.98 per cent reduction of thrips population were statistically on par with fipronil at 500 g a.i. ha^{-1}. The treatment with dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} reduced the population of *S. dorsalis* to an extent of 38.71 and 36.86 per cent, respectively and were on par with each other in reduction of thrips population over control. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment with 9.89 per cent population reduction of *S. dorsalis* over control even at ten days after third spray. The efficacy of different insecticidal treatments against *S. dorsalis* at ten days after third spray was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3 Pooled efficacy of Insecticides against chilli thrips *S. dorsalis* during *kharif* 2015-16 and 2016-17

The pooled efficacy of different selective insecticidal treatments during *kharif*, 2015-16 and 2016-17 against chilli thripswas presented in tables 4.12 to 4.14.

4.3.3.1 Reduction of *S. dorsalis* population after first spray (Pooled)

The pooled data on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after first spray during *kharif* 2015-16 and 2016-17 was presented in table 4.12.

4.3.3.1.1 Reduction of *S. dorsalis* population at one day after first spray

The pooled mean per cent reduction of *Scirtothrips dorsalis* population at one day after first spray during *kharif* 2015-16 and 2016-17 indicated that all the insecticidal treatments were superior over control (Table 4.12). The data revealed that spinosad at 125 g a.i. ha^{-1} exhibited supremacy by recording 71.26 per cent reduction of *S. dorsalis* population over untreated control and significantly different from other treatments.

The next effective treatments were fipronil at 500 g a.i. ha^{-1} (66.59%), betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (65.48%), profenophos at 400 g a.i. ha^{-1} (62.15%), dimethoate at 300 g a.i. ha^{-1} (48.40%) and lambda cyhalothrin at 15.63 g a.i. ha^{-1} (44.99%). The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} were on par with each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with 11.62 per cent reduction of *S. dorsalis* over control. The pooled efficacy of different insecticidal treatments against *S. dorsalis* at one day after first spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.1.2 Reduction of *S. dorsalis* population at three days after first spray

The observations on mean percent reduction of thrips population at three days after first spray revealed that spinosad at 125 g a.i. ha^{-1} was found to be superior over all other treatments by recording 82.28 per cent reduction of *S. dorsalis* population over untreated control and significantly different from other treatments. The next effective treatments were fipronil at 500 g a.i. ha^{-1} (78.20%) and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (75.58%) were on par with each other, followed by profenophos at 400 g a.i. ha^{-1} (68.89%), dimethoate at 300 g a.i. ha^{-1} (54.32%) and lambda cyhalothrinat 15.63 g a.i. ha^{-1} (48.82%) and these treatments were significantly different from each other (Table 4.12).

Among all the insecticides tested, chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatments with 13.28 per cent reduction of *S. dorsalis* population over untreated control even at three days after spray. The pooled efficacy of different insecticidal treatments against *S. dorsalis* at three days after first spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.1.3 Reduction of *S. dorsalis* population at five days after first spray

The pooled data of mean per cent reduction of chilli thrips at five days after first spray during *kharif* 2015-16 and 2016-17 showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 87.80 per cent population reduction of *S. dorsalis* over control and was on par with fipronil at 500 g a.i. ha^{-1} with 85.65 per cent.

The next effective treatment was betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} with 83.65 per cent and this treatment was on par with fipronil at 500 g a.i. ha^{-1} (Table 4.12). The treatment with profenophos at 400 g a.i. ha^{-1} recorded with 75.66 per cent reduction in *S. dorsalis* population over control and significantly different from other treatments, followed by dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} recorded with 52.62 and 49.24 per cent reduction in *S. dorsalis* population over control and these treatments were significantly on par with each other. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (15.31%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at five days after first spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.1.4 Reduction of *S. dorsalis* population at seven days after first spray

The observations made on the reduction of *S. dorsalis* population at seven days after first spray during *kharif* 2015-16 and 2016-17 indicated that all the treatments were significantly superior over control (Table 4.12). Spinosad at 125 g a.i. ha^{-1} recorded the highest population reduction of 77.52 per cent and found significantly superior over all other treatments.

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate and lambda cyhalothrin 15.63 g a.i. ha^{-1} at 300 g a.i. ha^{-1} at with 72.14, 69.60, 66.16, 44.81 and 44.51 per cent reduction in *S. dorsalis* population over contro respectively. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} were on par with each other. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 12.09 per cent population reduction of *S. dorsalis* over control even at seven days after first spray.

The pooled efficacy of different insecticidal treatments against *S. dorsalis* at seven days after first spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.1.5 Reduction of *S. dorsalis* population at ten days after first spray

Spinosad at 125 g a.i. ha^{-1} was found to be most effective treatment with 53.91 per cent reduction of *S. dorsalis* population over control (Table 4.12) and was on par with fipronil at 500 g a.i. ha^{-1} (49.52%).

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin15.63 g a.i. ha^{-1} reduced the population of *S. dorsalis* to an extent of 47.35, 44.16, 38.56 and 34.80 per cent, respectively. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other in terms of mean per cent reduction of chilli thrips over untreated control. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} were on par with each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with population reduction of 8.71 per cent over untreated control. The pooled efficacy of different insecticidal treatments against *S. dorsalis* at ten days after first spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.2 Reduction of *S. dorsalis* population after second spray (Pooled)

The pooled data on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after second spray during *kharif* 2015-16 and 2016-17 was presented in table 4.13.

4.3.3.2.1 Reduction of *S. dorsalis* population at one day after second spray

The pooled data at one day after second spray during kharif 2015-16 and 2016-17 showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 73.06 per cent population reduction of *S. dorsalis* over control and was significantly different from other treatments (Table 4.13).

The next effective treatments that were followed in the descending order of efficacy were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 68.68, 65.19, 62.55, 52.17 and 48.40 per cent reduction in thrips population over control. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other in reduction of chilli thrips over control. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1}were on par with each other at one day after second spray.

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (11.97%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at one day after second spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.2.2 Reduction of *S. dorsalis* population at three days after second spray

The observations recorded at third day after second spray during kharif 2015-16 and 2016-17 showed that the treatment spinosad at 125 g a.i. ha^{-1} was most effective (Table 4.13) and was found superior over all other treatments in reducing the

Scirtothrips dorsalis population (78.69%) was on par with fipronil at 500 g a.i. ha^{-1} (74.50%).

The other promising treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (72.62%), profenophos at 400 g a.i. ha^{-1}(68.18%).The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other in reduction of chilli thrips.

The next effective treatment was dimethoate at 300 g a.i. ha^{-1}, and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 54.53 and 51.38 per cent reduction of *S. dorsalis* population over control and was significantly on par with each other.

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (14.02%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at three days after second spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.2.3 Reduction of *S. dorsalis* population at five days after second spray

The pooled data of mean per cent reduction of chilli thrips at five days after second spray during *kharif* 2015-16 and 2016-17 showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 82.16 per cent population reduction of *S. dorsalis* over control and was on par with fipronil at 500 g a.i. ha^{-1} with 79.87 per cent (Table 4.13).

The next effective treatment was betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} with 77.21 per cent and this treatment was on par with fipronil at 500 g a.i. ha^{-1}. The treatment with profenophos at 400 g a.i. ha^{-1} recorded with 72.60 per cent reduction in *S. dorsalis* population over control and significantly different from other treatments, followed by dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} recorded with 55.02 and 53.19 per cent reduction in *S. dorsalis* population over control and these treatments were significantly on par with each other.

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (14.60%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at five days after spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1> T6> T4 > T7 > T5 > T3

4.3.3.2.4 Reduction of *S. dorsalis* population at seven days after second spray

The observations made on the reduction of *S. dorsalis* population at seven days after second spray indicated that all the treatments were significantly superior over control (Table 4.13). Spinosad at 125 g a.i. ha^{-1} recorded the highest population reduction of 76.82 per cent and found significantly superior over all other treatments.

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate and lambda cyhalothrin 15.63 g a.i. ha^{-1} at 300 g a.i. ha^{-1} at with 70.67, 68.16, 65.15, 48.93 and 45.92 per cent reduction in *S. dorsalis* population over control. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 12.28 per cent population reduction of *S. dorsalis* over control even at seven days after second spray.

The pooled efficacy of different insecticidal treatments against *S. dorsalis* at seven days after second spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.2.5 Reduction of *S. dorsalis* population at ten days after second spray

Spinosad at 125 g a.i. ha^{-1} was found to be most effective treatments with 53.34 per cent reduction of *S. dorsalis* population over control (Table 4.13) and were on with fipronil at 500 g a.i. ha^{-1} (49.21%) at ten days of second spray during *kharif* 2015-16 and 2016-17.

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin15.63 g a.i. ha^{-1} reduced the population of *S. dorsalis* to an extent of 45.80, 41.83, 39.04 and 36.47 per cent, respectively. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin

+ imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other in terms of mean per cent reduction of chilli thrips over untreated control. Profenophos at 400 g a.i. ha^{-1} and dimethoate at 300 g a.i. ha^{-1} were on par with each other in terms of mean per cent reduction of chilli thrips over untreated control.The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} were on par with each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with population reduction of 9.78 per cent over untreated control. The pooled efficacy of different insecticidal treatments against *S. dorsalis* at ten days after second spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.3 Reduction of *S. dorsalis* population after third spray (Pooled)

The pooled data on the mean per cent reduction of *S. dorsalis* population over untreated control in different treatments at 1, 3, 5, 7 and 10 days after third spray during *kharif* 2015-16 and 2016-17 was presented in table 4.14.

4.3.3.3.1 Reduction of *S. dorsalis* population at one day after third spray

The pooled data at one day after third spray during *kharif* 2015-16 and 2016-17 showed that spinosad at 125 g a.i. ha^{-1} and fipronil at 500 g a.i. ha^{-1} were the most effective treatments with 70.96 and 66.81 per cent population reduction of *S. dorsalis* over control and were significantly different from other treatments (Table 4.14).

The next effective treatments that were followed in the descending order of efficacy were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 62.40, 61.33, 46.58 and 44.09 per cent reduction in thrips population over control. The treatments betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other while, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other at one day after third spray.

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (10.82%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at one day after third spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.3.2 Reduction of *S. dorsalis* population at three days after third spray

The observations recorded at third day of third spray during *kharif* 2015-16 and 2016-17 showed that the treatment spinosad at 125 g a.i. ha^{-1} was most effective and was found superior over all other treatments in reducing the *S. dorsalis* population (76.61%) and was significantly different from other treatments (Table 4.14).

The other promising treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (70.51%), fipronil at 500 g a.i. ha^{-1} (69.99%) and profenophos at 400 g a.i. ha^{-1} (67.02%) were significantly on par with each other.

The next effective treatments were dimethoate at 300 g a.i. ha^{-1}, and lambda cyhalothrin 15.63 g a.i. ha^{-1} with 49.06 and 43.69 per cent reduction of *S.dorsalis* population over control and were significantly different from each other. Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (11.95%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at three days after third spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T6 > T1> T4 > T7 > T5 > T3

4.3.3.3.3 Reduction of *S. dorsalis* population at five days after third spray

The pooled data of mean per cent reduction of chilli thrips at five days after third spray during *kharif* 2015-16 and 2016-17 showed that spinosad at 125 g a.i. ha^{-1} was the most effective treatment with 81.30 per cent population reduction of *Scirtothrips dorsalis* over control and was significantly different from other treatments (Table 4.14).

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} recorded with 77.18, 73.99, 71.52, 49.26 and 45.44 per cent reduction in *S. dorsalis* population over control. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i.

ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} were on par with each other.

Chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective treatment in reducing the *S. dorsalis* population (14.02%). The pooled efficacy of different insecticidal treatments against *S. dorsalis* at five days after spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.3.4 Reduction of *S. dorsalis* population at seven days after third spray

The pooled data on the reduction of *Scirtothrips dorsalis* population at seven days after third spray during *kharif* 2015-16 and 2016-17 indicated that all the treatments were significantly superior over control (Table 4.14). Spinosad at 125 g a.i. ha^{-1} recorded the highest population reduction of 75.17 per cent and were on par with fipronil at 500 g a.i. ha^{-1} (71.67%)

The next effective treatments were betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} with 69.54 and 66.22 per cent reduction in *S. dorsalis* population over control. The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other.

Dimethoate at 300 g a.i. ha^{-1} (50.35%) and lambda cyhalothrinat 15.63 g a.i. ha^{-1} (42.07%) were significantly different in reducing the *S. dorsalis* population over control. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1} was found to be least effective with 12.43 per cent population reduction of *S. dorsalis* over control even at seven days after spray.

The pooled efficacy of different insecticidal treatments against *S. dorsalis* at seven days after third spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

4.3.3.3.5 Reduction of *Scirtothrips dorsalis* population at ten days after third spray

The pooled data recorded at ten days after final spray *i.e.*, third spray during *kharif* 2015-16 and 2016-17 which was considered as cumulative effect of all the sprays (fig 4.2.). All the insecticidal treatments were significantly superior over control.

Spinosad at 125 g a.i. ha^{-1} was found to be most effective treatments with 59.09 per cent reduction of *S. dorsalis* population over control and was significantly different from other treatments (Table 4.14).

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin15.63 g a.i. ha^{-1} reduced the population of *S. dorsalis* to an extent of 52.11, 49.07, 47.86, 39.03 and 35.91 per cent, respectively. The treatments fipronil at 500 g a.i. ha^{-1} was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} while, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} were on par with each other in reduction of the chilli thrips population over control.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} with population reduction of 8.58 per cent over untreated control. The cumulative efficacy of different insecticidal treatments against *S. dorsalis* at ten days after third spray during *kharif* 2015-16 and 2016-17 was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3

The findings of present investigation proved that all the insecticidal treatments were superior over control. The cumulative efficacy of all insecticidal treatments during *kharif* 2015-16 and 2016-17 revealed that spinosad at 125 g a.i. ha^{-1} was found to be most effective treatments with 59.09 per cent reduction of *S. dorsalis* population over control, which was in conformity with the findings of Prasad and Ahmed (2009) who reported that spinosad was superior in reducing thrips, *S. dorsalis* population, while, Hossaini *et al.* (2014) and Srinivas *et al*. (2002) were also observed similar observations.

The present findings on efficacy of spinosad was in conformity with the findings of Vanisree *et al.* (2011), who also reported that spinosad 0.015 % was most effective in reduction of thrips, *S. dorsalis* population in chilli in Andhra Pradesh. Kumar *et al*. (2013) reported the effectiveness of spinosad 45 SC @ 0.3 ml l^{-1} on *S. dorsalis* causing adult mortality within ten days and nymph in 15 days of foliar spray on chilli. The superior efficacy of spinosad may be due to the excitation of insect nervous system leading to involuntary muscle contraction, prostration with tremors and paralysis. These effects are consistent with the activation of nicotinic acetylcholine receptors by a mechanism that was clearly novel and unique. Spinosad also effects GABA receptor function that may contribute further to its insect activity (Sparks *et al*. 2001).

The present results differed from Jacob *et al*. (2015) who reported against cardamom thrips that fipronil 0.005% treated plots recorded the lowest percentage of damage (6.5%) that was on par with imidacloprid 0.0089%, thiamethoxam0.0075% and spinosad 0.0135%. Jadhao *et al*. (2016) found that fipronil 5 SC @ 0.005% was found most effective to reduce the thrips population (57.3%) and it gave highest marketable green chilli yield (9.98 t ha^{-1}) followed by spinosad 45 SC @ 0.018%, lambda cyhalothrin 5 EC @ 0.005% and clothianidin 50 WDG @ 0.006% by reducing 55.6, 53.7 and 51.8 per cent, respectively.This variation may be attributed to change in crop eco system, crop variety, seasonal change, geographical area, type of formulation and dosage.

The next effective treatment was fipronil at 500 g a.i. $ha^{-1}$with cumulative reduction of the *S.dorsalis* population over control by 52.11 per cent was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1}. Fipronil was the second best compound found during the present studies against thrips. It has unique mode of action of interference with GABA regulated chloride channel in target pest and is systemic nature.The findings of present investigation with respect to fipronil at 500 g a.i. ha^{-1} were comparable with Reddy *et al.* (2005) revealed that fipronil 5 SC (0.01%) was the most effective treatments against thrips, followed by thiamethoxam 25 WG (0.005%), acetamiprid 20 SP (0.002%) and dimethoate 30 EC (0.06%). Jadhav (2003) reported that fipronil 5 SC at different concentrations against sucking pests of chilli in comparison with imidacloprid 17.8 SL @ 20 g a.i. ha^{-1} ; phosalone 35 EC @ 500 g a.i. ha^{-1} and fipronil 5 SC @ 100 g a.i. ha^{-1} recorded the lowest population of sucking pests and highest yield. Fipronil was found effective at 50 g a.i. ha^{-1} against chilli thrips as reported by Jadhav *et al*. (2004).

Cumulative efficacy of all insecticidal treatments during *kharif* 2015-16 and 2016-17 of present investigation revealed that betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} was found to be next effective treatment with 49.07 per cent reduction of *S. dorsalis* population. The performance of betacyfluthrin + imidacloprid corroborate with the reports of Patil *et al.,* (2002) who reported that imidacloprid 17.8 SL @ 125 ml and 150 ml ha^{-1} were highly effective against the important sucking pest complex of chilli and proved to be better than monocrotophos and dimethoate. The treatment with imidacloprid @ 150 ml ha^{-1} recorded significantly highest yield followed by imidacloprid @ 125 and 100 ml ha^{-1} monocrotophos 36 WSC @ 650 ml $ha^{-1}$and dimethoate 30 EC @ 750ml ha^{-1}. Sathua *et al*. (2017) studied the efficacy of four different insecticides (acephate, imidacloprid, cypermethrin and dimethoate) and three botanicals [namely *Allium sativum* extract, *Allium cepa* extract and NSKE] gainst chilli thrips. Among these imidacloprid 17.8 SL reduced maximum thrips population (82.46%) followed by acephate 75 SP (80.86%).

The present investigations on cumulative efficacy of all insecticidal treatments during *kharif* 2015-16 and 2016-17 revealed that next effective treatment followed was profenophos at 400 g a.i. ha^{-1} against chilli thrips. The performance of profenophos corroborate with the reports of Sallam and Hosseny (2003) who reported that profenophos 75 EC 2 ml $l^{-1}$was moderately effective against *T. tabaci* on onion.Similarly, Chakrabarthi (2004) declared that profenophos at 2 ml $litre^{-1}$, 6 sprays at 15 day interval, effectively controlled the thrips *S. dorsalis* in chilli.

The cumulative efficacy of all insecticidal treatments during *kharif* 2015-16 and 2016-17 revealed that next effective treatment followed was dimethoate at 300 g a.i. ha^{-1}. Dimethoate at 300 g a.i. $ha^{-1}$was less effective than spinosad at 125 g a.i. ha^{-1}, fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}. These results were in conformity with Sathua *et al*. (2017); Patil *et al.*, (2002) and Reddy *et al.* (2005).

The present investigations on cumulative efficacy of all insecticidal treatments during *kharif* 2015-16 and 2016-17 revealed that next effective treatment was lambda cyhalothrin at 15.63 g a.i. ha^{-1} with 35.91 per cent reduction of *S. dorsalis* population. The present results were in concurrence with the results of Khan *et al*. (1995), they found that monocrotophos 36 WSC (60 ml per 100 lit. of water) and cypermethrin 5 EC (50 ml per 100 lit. of water) were the most effective insecticides for controlling the infestation of *T. tabaci*, followed by lambda-cyhalothrin 2.5 EC (25 ml), triazophos 40 EC (80 ml) and fenvalerate 20 EC (30 ml) per 100 liter of water. These results were in agreement with Mathirajan (1998) and Sule *et al.*, (2008).

Chlorantraniliprole at 30 g a.i. ha^{-1} was recorded as the least effective treatment during *kharif* 2015-16 and 2016-17 because it didnot show any effect on sucking pests.

Chlorantraniliprole is a anthranilic diamide insecticides having excellent activity on lepidopteran insects with field application rate of 25 – 75 g a.i.ha^{-1} (Lahm *et al*., 2007).

4.3.4 Effectiveness of different insecticides on chilli yield

The efficitiveness of different selective insecticidal treatments during *kharif*, 2015-16 and 2016-17 on chilli yieldwas presented in table 4.15.

4.3.4.1 Effectiveness of different insecticides on chilli yield during *kharif*2015-16

The data (Table 4.15) on chilli yield during *kharif* 2015-16 revealed that, all the insecticidal treatments registered higher yields over untreated control. Among the treatments, Spinosad at 125 g a.i. ha^{-1} recorded the highest yield (2136.19 kg ha^{-1}) and found significantly superior to all other treatments.

The next effective treatment was fipronil at 500 g a.i. ha^{-1} with 2019.47 kg ha^{-1}and this treatment was on par with betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} with 1923.23 kg ha^{-1}. The treatment with profenophos at 400 g a.i. ha^{-1} recorded an yield of 1816.05 kg ha^{-1}and significantly different from other treatments, followed by dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrinat 15.63 g a.i. ha^{-1} recorded an yield of 1671.94 and 1623.58 kg ha^{-1}and these treatments were significantly on par with each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} recorded an yield of 1396.27 kg ha^{-1} and was on par with untreated control (1295.37 kg ha^{-1}). The effectiveness of different insecticidal treatments on chilli yield found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3> T8

4.3.4.2 Effectiveness of different insecticides on chilli yield during *kharif* 2016-17

The observations made with regard to the yield during *kharif* 2016-17 indicated that all the treatments were superior over control. Spinosad at 125 g a.i. ha^{-1} has recorded the highest yield of 2288.04 kg ha^{-1}(Table 4.15) and were on par with fipronil at 500 g a.i. ha^{-1} (2156.10 kg ha^{-1}).

The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate and lambda cyhalothrin 15.63 g a.i. ha^{-1} at 300 g a.i. ha^{-1} with 2156.10, 2048.24, 1985.73, 1752.00 and 1698.09 kg ha^{-1} yield over control. The yield recorded in treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other in terms of yield. The treatment with chlorantraniliprole at 30 g a.i. ha^{-1}was found to be least effective with 1439.20 kg ha^{-1} and was on par with control (1319.21 kg ha^{-1}).

The effectiveness of different insecticidal treatments on chilli yield was found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3 > T8

4.3.4.3 Effectiveness of different insecticides on chilli yield during *kharif* 2015-16 and 2016 -17 (Pooled)

The pooled yield recorded during *kharif* 2015-16 and 2016-17 in different treatments was presented in table 4.15and fig 4.3. The results revealed that all the insecticidal treatments recorded higher yield over untreated control. The highest yield of 2212.12 kg ha^{-1} was recorded in spinosad at 125 g a.i. ha^{-1} and found significantly superior to all other treatments. The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin 15.63 g a.i. ha^{-1} recorded with 2087.79, 1985.74, 1900.89, 1711.97 and 1660.84 kg ha^{-1}, respectively in chilli.

The treatments fipronil at 500 g a.i. ha^{-1} and betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} were on par with each other while, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were on par with each other. The treatments dimethoate at 300 g a.i. ha^{-1} and lambda cyhalothrin at 15.63 g a.i. ha^{-1} were on par with each other.

The least effective treatment was chlorantraniliprole at 30 g a.i. ha^{-1} recorded yield of 1417.74 kg ha^{-1} and was on par with untreated control (1307.29 kg ha^{-1}). The effectiveness of different insecticidal treatments on chilli yield found to be in the following order.

T2 > T1 > T6 > T4 > T7 > T5 > T3 > T8

The highest per cent increase in yield over control was recorded in spinosad 45% SC @ 125 g a.i ha^{-1} (69.21), fipronil 5% SC @ 500 g a.i ha^{-1} (59.70), imidacloprid + beta cyfluthrin 300% OD@ 30 g a.i ha^{-1} (51.90), profenophos 50% EC @ 400 g a.i ha^{-1} (45.40), dimethoate 30 % EC @ 300 g a.i ha^{-1} (30.96), lambda cyhalothrin 5% SC @ 15.63 g a.i ha^{-1} (27.04) and chlorantraniliprole 20% SC @ 30 g a.i ha^{-1} (8.45) with 2212.12, 2087.79, 1985.74, 1900.89, 1711.97, 1660.84, 1417.74 kg ha^{-1}, respectively. The increased yield in spinosad 45% SC @ 125 g a.i ha^{-1} may be due to effectively control of chilli thrips in the present investigation and the results were in agreement with Kadam and Dethe (2002), Jadhav (2003), Srinivas *et al*., 2002, Bokan *et al*., 2016, Dwievdi *et al*., 2017, Patra *et al*., 2015, Bhede *et al*., 2008, Singh *et al*., 2005, Patil *et al*., 2002 were effective insecticides in increasing of the chilli yields.

4.4 Dissipation pattern of insecticides in chilli

Dissipation pattern of most commonly used insecticides *viz*., fipronil 5% SC, spinosad 45% SC, chlorantraniliprole 20% SC, profenophos 50% EC, lambda cyhalothrin 5% SC, imidacloprid + beta cyfluthrin 300% OD and dimethoate 30 % EC were studied by spraying thrice at 10 days interval starting from 50% flowering @ 500 g a.i. ha^{-1}, 125 g a.i. ha^{-1}, 30 g a.i. ha^{-1}, 400 g a.i. ha^{-1}, 15.63 g a.i. ha^{-1} , 30 g a.i. ha^{-1} and 300 g a.i. ha^{-1}, respectively in three replications. The samples of green chilli were collected from these treated plots and residues were estimated at AINP on pesticide residue laboratory, Rajendranagar, Hyderabad. The results on dissipation pattern of above mentioned pesticides in chilli fruits were presented here under.

4.4.1 Fipronil 5% SC (500 g a.i. ha^{-1})

Fipronil @ 500 g a.i. ha^{-1} was sprayed thrice *viz*., first spray was given at 50 per cent flowering while second and third spray at 10 days after each spray and chilli samples were collected at regular intervals of 0, 1, 3, 5, 7, 10, and 15 days after third spray. The samples were processed and estimated for residues of fipronil on gas chromatograph (GC - ECD). The dissipation pattern of fipronil was presented in table 4.16 and depicted in figure 4.4. The results indicated that the initial deposits of 1.47 mg kg^{-1} were dissipated to below detectable levels by 15^{th} day after third spray on chilli. The residues of 0.97, 0.52, 0.41, 0.36, and 0.16 mg kg^{-1} were recorded at 1, 3, 5, 7 and 10 days after last spray, respectively.

Based on the first order kinetics, waiting periods have been worked out using linear semi-logarithmic regression analysis (Hoskins, 1961). The dissipation pattern showed a continuous decrease of residues from 1st to 15th day. The residues dissipated to 34.01, 64.62, 72.11, 75.51, 89.11 and 100 per cent on 1, 3, 5, 7, 10, and 15 days after last spray, respectively. The time required to reach below tolerance limit (T_{tol}) of 0.001 mg kg^{-1} (as per FSSAI) was 36.34 days. The regression equation was Y= 1.143 + (-0.114) X with R^2 = 0.794.

Urvashi Bhardwaj*et al*. (2012) reported that average initial deposits of fipronil on cabbage heads were 1.226 and 2.704 mg kg^{-1}, respectively, following three sprays of fipronil at 75 g a.i.ha^{-1} and 150 g a.i.ha^{-1} dosages, while Sunayana Saini *et al.* (2014) established that the initial deposits of fipronil in chilli were 0.409 and 0.808mg kg^{-1}, respectively at 50 and 100 g a.i.ha^{-1}. The variation of initial deposits in the present investigation may be due to variation in climatic conditions, matrix and variation in the dosage of the insecticide applied, (Khay *et al*., 2008).

The present findings differ from the results of Yap Chin Ann and Zehnder Jarropp (2016) who reported the initial deposits of 0.23 mg kg^{-1} when fipronil 80WG applied at 90.0 g a.i ha^{-1} on black pepper. The pre-harvest interval value was 12 days with proposed maximum residue limit was 0.20 mg kg^{-1}. The variation may be due to change in the matrix of black pepper and chilli.

4.4.2 Spinosad 45 % SC (125 g a.i. ha^{-1})

Spinosad was sprayed thrice @ 125 g a.i. ha^{-1} with first spray at 50 per cent flowering while second and third spray at 10 days after each spray. The green chilli samples were collected at regular intervals of 0, 1, 3, 5, 7, 10, and 15 days after third spray. The samples were estimated for residues of spinosad on High Performance Liquid Chromatograph (HPLC) after processing. The initial deposits of 0.78 mg kg^{-1} were dissipated to 0.10 mg kg^{-1} by 5th day after third spray on chilli. The residues of 0.43, 0.18 and 0.10 mg kg^{-1} were recorded at 1, 3 and 5 days after last spray, respectively. However residues were below detectable level (BDL) from 7 days after third spray and showed 100.00 per cent dissipation. The dissipation pattern of spinosad was presented in table 4.17 and depicted in figure. 4.5.

Using linear semi-logarithmic regression analysis and based on the first order kinetics, waiting period was worked out (Hoskins, 1961). There was continuous decrease of residues from 1st to 7th day. The residues dissipated to 44.87, 76.92, 98.72 and 100.00 per cent on 1, 3, 5 and 7 days, respectively. The initial deposit of spinosad to reach below tolerance limit (T_{tol}) of 0.001 mg kg^{-1} (as per FSSAI) was 28.81 days. The regression equation was Y= 0.659 + (-0.127) X with R^2 = 0.856.

Mandal *et al*. (2009) found, the initial deposits of spinosad were 0.57 and 1.34 µg kg^{-1}, respectively following three sprays of spinosad 2.5 SC at 15 and 30 g a.i. ha^{-1} , respectively on cauliflower. Residues of spinosad dissipated to below the limit of quantification (LOQ) of 0.02 µg kg^{-1} after 10 days at both the doses and waiting period of six days was suggested, while Sandeep Singh and Battu (2012) reported the initial deposits as 0.33 and 0.56 µg kg^{-1} of spinosad at single and double doses, respectively *viz.*,15 and 30 g a.i. ha^{-1}.They dissipated below its limit of quantification of 0.01 µg kg^{-1} after five and seven days at single and double doses, respectively on cabbage. Vijayasree *et al.* (2014) reported the initial deposits of 0.94 and 1.9 µg kg^{-1} of spinosad reached below detectable level on the seventh day and fifteenth day at 73 and 146 g a.i. ha^{-1}, respectively and calculated safe waiting period of 1.09 – 3.25 days on cowpea. The slight variation in initial deposits from the present findings may be due to variation in matrix and dosage of the insecticide applied (Khay *et al.*, 2008).

4.4.3 Chlorantraniliprole 20 % SC (30 g a.i. ha^{-1})

Chlorantraniliprole was sprayed thrice @ 30 g a.i. ha^{-1}*viz.*, first spray was given at 50 per cent flowering while second and third spray at 10 days after each spray. The green chilli samples were collected after third spray at regular intervals of 0, 1, 3, 5, 7, 10 and 15 days. The samples were processed and estimated on gas chromatograph (GC - ECD) for chlorantraniliprole. The results were presented in table 4.18 and depicted in figure 4.6. The results showed that the initial deposits of 0.56 mg kg^{-1} were dissipated to 0.06 mg kg^{-1} by 5th day after third spray on green chilli. The residues of 0.31, 0.17 and 0.06 mg kg^{-1} were recorded at 1, 3 and 5 days after last spray, respectively. However residues were below detectable level (BDL) and showed 100.00 per cent dissipation from 7 days after third spray.

Based on the first order kinetics, waiting periods have been worked out using linear semi-logarithmic regression analysis (Hoskins, 1961). Dissipation pattern showed a continuous decrease of residues from 1st day to 7th day. The residues dissipated to 44.64, 69.64, 89.26 and 100.00 per cent on 1, 3, 5 and 7 days, respectively. The initial time required deposit of chlorantraniliprole to reach below tolerance limit (T_{tol}) of 0.03 mg kg^{-1} (As per FSSAI) was 21.98 days. The regression equation was Y= 0.481 + (-0.091) X with R^2 = 0.891.

Kar *et al*. (2013) reported that the initial deposits of chlorantraniliprole 18.5 SC on cauliflower from treatments @ 9.25 and 18.50 g a.i.ha^{-1} were 0.18 and 0.29 mg kg^{-1}, respectively and waiting period of 1 day was suggested for safe consumption of cauliflower curds. The dissipation of pesticide residues in/on crops depends on climatic conditions, type of application, plant species, dosage, interval between application and time of harvest (Khay *et al.*, 2008).

4.4.4 Profenophos 50 % EC (400 g a.i. ha^{-1})

Profenophos sprayed thrice @ 400 g a.i. ha^{-1} and green chilli samples were collected at regular intervals of 0, 1, 3, 5, 7, 10 and 15 days after last spray. The samples were processed and estimated for residues of profenophos on gas chromatograph (GC – ECD). The dissipation pattern was presented in table 4.19 and depicted in figure 4.7. Profenophos @ 400 g a.i. ha^{-1} after three sprays left the initial deposit of 2.60 mg kg^{-1}. The residues degraded to an extent of 1.07, 0.74, 0.44 and 0.13 mg kg^{-1} at 1, 3, 5 and 7 days, after last spray respectively. However residues were below detectable level from 10th day onwards.

There was a rapid decrease in residue levels from 0 to 10th day of sampling, the dissipation being 58.85, 71.54, 83.08, 95.00 and 100 per cent on 1st, 3rd, 5th, 7th and 10thday of sampling, respectively. The waiting period (Ttol) for profenophos on chilli was worked out to be 5.60 days. The regression equation was Y= 1.926 + (-0.290) X with R^2 = 0.748.

The results were in agreement with the findings of Ahmad *et al.(*2009) who reported that profenophos spray on tomato @ 500 g a.i. ha^{-1}, resulted in initial deposit of 2.58 mg kg^{-1} dissipating to BDL in 15 days, tomato fruits can be safely harvested for human consumption or for processing purposes at 7 days after the spray. However, the studies conducted by various workers (Gupta *et al* 2011., Renuka *et al* 2006., Katroju *et* *al.,* 2014) on dissipation on profenophos on different crops clearly indicated that when profenophos applied at recommended dose, the initial deposits were less than 3 mg kg^{-1} and dissipate to BDL in 7-10 days depending on the crop, except on cardamom, while Kavitha *et al.* (2016) applied profenophos at 500 g a.i. ha^{-1} on capsicum and reported initial deposits of 2.24 mg kg^{-1} and 3.71 mg kg^{-1} in open field and poly house, respectively and dissipated to below determination level (BDL) of 0.05 mg kg-1 by 10^{th} and 15^{th} day after last spraying on capsicum in open field and poly house, respectively.

Jain *et al.* (2012b) recorded initial deposits of profenophos were 3.14 and 4.92 ppm on soybean pods which dissipated to non detectable levels by 11^{th} and 13^{th} days, respectively at 1000 and 2000 g a.i. ha^{-1}. Experimental results of Radwan *et al.* (2004) indicated that at application of very high dose @ 1280 g a.i. ha^{-1} on three crops *viz.,* green pepper, hot pepper and brinjal resulted in very high initial deposit of 10-11 mg kg^{-1} on pepper and 4.50 mg kg^{-1} on brinjal, which dissipated to BDL in 2 weeks. Priyadarshini *et al*. (2017) who reported the initial deposits of profenophos (19.83 mg kg^{-1}) dissipated to below detectable level by 25^{th} day after application at 500 g a.i. ha^{-1} on curry leaf. The variation in the results from the present findings may be due to change in the matrix of crop, climatic conditions and variation in the dosages applied (Khay *et al.,* 2008).

4.4.5 Lambda cyhalothrin 5 % SC (15.63 g a.i. ha^{-1})

Lambda cyhalothrin was sprayed thrice @ 15.63 g a.i. ha^{-1} on chilli and green chilli samples were collected at regular intervals of 0, 1, 3, 5, 7, 10 and 15 days after third spray. The samples were processed and estimated for the residues of lambda cyhalothrin on Gas Chromatograph (GC - ECD). The dissipation pattern was presented in table 4.20 and depicted in figure 4.8. The results showed that the initial deposits of 1.20 mg kg^{-1} were detected in green chilli. The residues recorded at 1, 3 and 5 days after third spraying were found to be 0.78, 0.36 and 0.09 mg kg^{-1}, showing a dissipation per cent of 35.00, 70.00 and 92.50, respectively at 7 days after last spray. The residues were below detectable level (BDL) showing 100 per cent dissipation.

Based on the dissipation curve waiting periods have been worked out using linear semi-logarithmic regression analysis (Hoskins, 1961). The results showed that the residues of lambda cyhalothrin reached to below tolerance limit of 0.05 mg kg^{-1} (As per FSSAI) in 11.16 days. The regression equation was Y= 1.089 + (-0.214) X with R^2 = 0.952.

Sharma and Awasthi (2002) reported that average initial deposits of lambda cyhalothrin (2.5 EC and 5.0 EC) on cauliflower found to be 0.81 to 1.59 mg kg^{-1} following application at 15 and 30 g a.i. ha^{-1}. Residues of lambda cyhalothrin (0.81 to 1.59 mg kg^{-1}) dissipated to below detectable level by 10 days at the single dose and 15 days from the double dose.The waiting periods were between 4.2 to 5.2 days from different treatments, while Ahuja *et al.* (2006) sprayed lambda cyhalothrin on brinjal at both recommended (@ 15 g a.i. ha^{-1}) and double dosage (@ 30 g a.i. ha^{-1}) and found that the initial deposits of 0.75 mg kg^{-1}, and 1.27 mg kg^{-1} dissipated to BDL in 10 days, respectively. The variation of results from the present findings may be due to change in matrix, dosage and time of application.

The present findings differ from Reddy *et al.* (2007) using lambda cyhalothrin on chilli at 50 g a.i. ha^{-1}, recorded initial deposits of 0.62 mg kg^{-1}. Further, it was also reported that the initial deposits may vary with formulation for the same dosage. Mahmoud and Soliman (2011) who reported that an average initial deposit of 8.76 ppm of lambda cyhalothrin on chickpea, which reached below determination level by 15^{th} day. Elbashir *et al.* (2013) found the initial residues of 3.04 ppm, when lambda cyhalothrin was applied at 30 g a.i. ha^{-1} in tomato and suggested safe waiting period of 18 days. Gupta *et al*. (2015) reported that lambda cyhalothrin applied at 15 g a.i. ha^{-1} recorded initial deposits of 0.138 mg kg^{-1}, dissipated to 92.75 per cent on 10^{th} day after application on brinjal. The initial deposits and dissipation vary from crop to crop depending up on the crop canopy, season, age of the crop, sample matrix, surface area of sample etc., (Khay *et al*., 2008) and the same can be witnessed based on the test reports published by Pawar and Jadhav (1993), Singh and Singh (2003) and Ahuja *et al.* (2006) on various crops at different doses.

4.4.6 Imidacloprid + Beta cyfluthrin 300 % OD (30 g a.i. ha^{-1})

Imidacloprid + Beta cyfluthrin was sprayed thrice @ 30 g a.i. ha^{-1} *viz.*, first spray was given at 50 per cent flowering while second and third spray at 10 days after each spray. The green chilli samples were collected at regular intervals of 0, 1, 3, 5, 7, 10 and 15 days after third spray.

4.4.6.1 Imidacloprid

The samples were estimated for residues of imidacloprid on High Performance Liquid Chromatograph (HPLC) after processing. The initial deposits of 1.10 mg kg^{-1} of imidacloprid were dissipated to 0.09 mg kg^{-1} by 5th day after third spray on chilli.The residues of 0.85, 0.32 and 0.09 mg kg^{-1} were recorded after 1, 3 and 5 days after last spray, respectively. However residues were below detectable level (BDL) from 7 days after third spray and showed 100.00 per cent dissipation. The dissipation pattern of imidacloprid was presented in table 4.21 and depicted in figure. 4.9.

Using linear semi-logarithmic regression analysis and based on the first order kinetics, waiting period have been worked out (Hoskins, 1961). There was continuous decrease of residues from 1st to 7th day which was noticed from the dissipation pattern. The residues dissipated to 22.73, 70.90, 91.82 and 100.00 per cent on 1, 3, 5 and 7 days, respectively. The initial deposit of imidacloprid to reach below tolerance limit (T_{tol}) of 0.3 mg kg^{-1} was 11.05 days. The regression equation was Y= 1.045 + (-0.140) X with R^2 = 0.988.

Anjumoni and Baruah (2010) reported the dissipation pattern of imidacloprid on *Brassica campestris*, rapeseed and found the initial deposits of imidacloprid when sprayed at 20, 40 and 60 g a.i. ha^{-1} were 0.830, 1.126 and 1.280. Imidacloprid residues reached below detectable level after 5th and 10th day of its application at lower and higher rates. Based on the observations, a waiting period of at least 4 days after imidacloprid application at recommended dose (20 g a.i. ha^{-1}) was suggested. While Hassanzadeh *et al*. (2012) studied the residues of imidacloprid in greenhouse cucumbers applied @ 30.0 g a.i. ha^{-1} and its double @ 60.0 g a.i. ha^{-1}. The average initial deposits of imidacloprid on the cucumber fruits were found to be 1.93 and 3.65 mg kg^{-1} at the single and double dosages, respectively. A waiting period of 3 days was suggested for safe consumption of cucumber. The variation in the waiting period in the present finding may be due to variation in the matrix, dosages of insecticides and time of application (Khay *et al*., 2008).

4.4.6.2 Beta cyfluthrin

The samples were estimated for residues of beta cyfluthrin on Gas Chromatograph (GC - ECD) after processing. Beta cyfluthrin initial deposits of 0.28 mg kg^{-1} were dissipated to 0.06 mg kg^{-1} by 3rd day after third spray on chilli. The residues of

0.16 and 0.06 mg kg^{-1} were recorded at 1 and 3 days after last spray, respectively. However residues were below detectable level (BDL) from 5 days after third spray and showed 100.00 per cent dissipation. The dissipation pattern of beta cyfluthrin was presented in table 4.22 and depicted in figure. 4.10.

Using linear semi-logarithmic regression analysis and based on the first order kinetics, waiting period have been worked out (Hoskins, 1961). There was continuous decrease of residues from 1st to 5th day which was attributed by the dissipation pattern. The residues dissipated to 42.86, 78.57 and 100.00 per cent on 1, 3 and 5 days after last spray, respectively. The initial deposit of beta cyfluthrin to reach below tolerance limit (T_{tol}) of 2 mg kg^{-1} was 0.59 days. The regression equation was Y= 0.26 + (-0.07) X with R^2 = 0.942.

Sharma *et al*. (2003) who reported that the initial deposits of 0.068-0.124 mg kg^{-1} of beta-cyfluthrin in tomato fruits after three applications @ 12.50, 18.75 or 25.00 g a.i. ha^{-1} on tomato. The beta cyfluthrin dissipated by 69-76 per cent and 92-94 per cent at 3rd and 7th day after application, respectively with the waiting period of 5- 7 days, while Singh and Singh (2007) reported that the initial deposit of beta cyfluthrin were found to be 0.109 and 0.135 mg kg^{-1} in green pods of chickpea which dissipated by 7th day 88.1-92.6 per cent, respectively for 12.5 and 25 g a.i. ha^{-1} doses. Kousik *et al*. (2010) found that, the dissipation of combination formulation, Solomon 300 OD (beta cyfluthrin 9% + imidacloprid 21 %) at 60 and 120 g a.i. ha^{-1} in three sprays on brinjal below the level of quantification (LOQ) of 0.01 mg kg^{-1} after 5 and 7 days, respectively, while Diwan *et al*. (2012) found the initial deposits of 0.10 and 0.11 µg g^{-1} of beta-cyfluthrin and imidacloprid, respectively when spryaed at 0.025 ml l^{-1} on mango. The dissipation of pesticide residues in/on crops depends on climatic conditions, type of application, plant species, dosage, interval between application and time of harvest (Khay *et al.*, 2008).

4.4.7 Dimethoate 30 % EC (300 g a.i. ha^{-1})

Dimethoate was sprayed thrice @ 30 g a.i. ha^{-1} and green chilli samples were collected at regular intervals of 0, 1, 3, 5, 7, 10 and 15 days after last spray. The samples were processed and estimated for residues of dimethoate on Gas Chromatograph (GC - ECD). The dissipation pattern was presented in table 4.23 and depicted in figure 4.11. The results showed that the initial deposits of 3.86 mg kg^{-1} were detected in chilli. The residues recorded at 1, 3, 5, 7 and 10 daysafter third spraying were found to be 2.66, 2.28, 1.06, 0.22 and 0.08 mg kg^{-1}, showing adissipation per cent of 31.09, 40.93, 72.54, 94.30 and 97.93, respectively. After 15 days, theresidues were below detectable level (BDL) showing 100 per cent dissipation.

Based on the dissipation curve waiting periods have been worked out using linearsemi-logarithmic regression analysis (Hoskins, 1961). The results showed that the residues of dimethoate reached to below tolerance limit of 0.50 mg kg^{-1} in 6.64 days. The regression equation was Y= 3.326 + (-0.376) X with R^2 = 0.909.

The results were in agreement with the findings of Sharma and Parihar (2013) who reported that an average initial deposit of 3.12 and 5.16 mg kg^{-1}, respectively of dimethoate was observed when sprayed at 300 and 600 g a.i.ha^{-1} on chilli with waiting periods were 3.29 and 4.50 days, while Khan (1997) reported that the initial deposit of dimethoate 30 EC were found to be 2.93 ppm on okra fruits which reached to safe waiting period of 3.17 days. Soudamini *et al.* (2004) also reported that the initial deposits of dimethoate 0.05% and 0.10% were 2.10 and 3.50 mg kg^{-1}, respectively on acid lime. The variation in the waiting period in the present finding may be due to variation in the matrix.

The present findings differ from Waghulde *et al.* (2011) who reported that an initial deposit of 8.01 ppm in chilli and 22.90 ppm of dimethoate 30 EC was observed in okra when sprayed at 6 g a.i. ha^{-1} and also Varghese *et al. (*2012) observed initial deposit of 7.36 ppm on chilli after application at 300 g a.i.ha^{-1}. In another study Reddy *et al.* (2007) recorded the initial deposit of dimethoate in chilli was 0.33 ppm when applied at 300 g a.i. ha^{-1}, which dissipated to non detectable level at 15 days after application and they suggested safe waiting period of one day. This variation may be due to change in the matrix of the different crops. The dissipation of pesticide residues in/on crops depends on climatic conditions, type of application, plant species, dosage, interval between application and time of harvest (khay *et al.,* 2008).

4.5 Evaluation of decontamination methods for removal of pesticide residues from chilli

The chilli samples were collected from various plots treated with recommended doses of fipronil 5% SC @ 500 g a.i ha^{-1}, spinosad 45% SC @ 125 g a.i ha^{-1}, chlorantraniliprole 20% SC @ 30 g a.i ha^{-1}, profenophos 50% EC @ 400 g a.i ha^{-1}, lambda cyhalothrin 5% SC @ 15.63 g a.i ha^{-1}, imidacloprid + beta cyfluthrin 300%

OD@ 30 g a.i ha^{-1} anddimethoate 30 % EC @ 300 g a.i ha^{-1} were used to estimate the initial deposits and efficiency of different decontamination methods through quantification of their residues after subjecting to risk mitigation methods and the results were presented in table 4.24.

4.5.1 Fipronil 5 % SC @ 500 g a.i ha^{-1}

The treatment dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be most effective (69.27%) in removal of insecticides than other decontamination methods and further this decontamination method was significantly efficient in the removal of fipronil when compared to other methods. The per cent removal of fipronil residues due to various decontamination methods in descending order were tap water wash for 30 sec, formula 1(69.27) > dipping in 0.1% Baking soda solution (50.19) > soaking in 2% salt solution (44.84) > cooking in pressure cooker (33.04) > Tap water (14.91). Per cent removal of fipronil residues from various decontamination methods was depicted in fig. 4.12.

4.5.2 Spinosad 45 % SC @ 125 g a.i ha^{-1}

Various decontamination methods were evaluated in order to know their efficiency in removing spinosad residues from green chilli. Results revealed that all the treatment solutions significantly differed among each other in their efficiency in removing spinosad residues. Dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be most effective (66.43%) than other treatments. The next promising treatment was dipping in 0.1% baking soda solution for 10 min followed by tap water wash for 30 sec (44.29%). The next best treatment followed was soaking in 2% salt solution followed by tap water wash for 30 sec (40.39%) and cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (36.59%) while tap water wash for 10 min (16.37 %) found to be least effective in removal of spinosad residues from green chilli fruits. Per cent removal of spinosad residues due to various decontamination methods was depicted in fig. 4.13.

4.5.3 Chlorantraniliprole 20 % SC @ 30 g a.i ha^{-1}

The green chilli samples obtained from the plots sprayed with chlorantraniliprole @ 30 g a.i ha^{-1} were subjected to various decontamination methods. The results indicated that among the different treatments employed, dipping fruits in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be more effective (73.37%) than other treatments. Soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec (50.97%) was found to be next promising treatment, followed by dipping in 0.1% baking soda solution for 10 min followed by tap water wash for 30 sec (43.99%), cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (36.84%) and tap water wash for 10 min (19.33%). Per cent removal of chlorantraniliprole residues from various decontamination methods was depicted in fig. 4.14.

4.5.4 Profenophos 50 % EC @ 400 g a.i ha^{-1}

The green chilli samples were collected from the plots sprayed with profenophos @ 400 g a.i ha^{-1} were subjected to different decontamination methods at 2 hours after spraying. Results revealed that dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be most effective among all treatments. In this treatment residues were reduced up to 71.06 per cent. The next promising treatment was soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec (44.27%), followed by dipping in 0.1% baking soda solution for 10 min followed by tap water wash for 30 sec (38.47%), cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (29.93%) and tap water wash for 10 min (12.61%). Per cent removal of profenophos residues from various decontamination methods was depicted in fig. 4.15.

4.5.5 Lambda cyhalothrin 5 % SC (15.63 g a.i. ha^{-1})

Various decontamination methods were evaluated in order to know their efficiency in removing lambda cyhalothrin residues from green chilli. Results revealed that all the treatment solutions significantly differed among each other in their efficiency in removing lambda cyhalothrin residues. Dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be most effective (62.72%) than other treatments. Next promising treatment was soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec (49.32%), followed by dipping 0.1% baking soda solution for 10 min followed by tap water wash for 30 sec (42.59%), cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (38.15%) and tap water wash for 10 min (30.19%). Per cent removal of lambda cyhalothrin residues due to various decontamination methods was depicted in fig. 4.16.

4.5.6 Imidacloprid + Beta cyfluthrin 300 % OD @ 30 g a.i. ha^{-1}

To study the efficacy of various decontamination methods, the chilli samples collected from the plots treated with imidacloprid + beta cyfluthrin 300 OD @ 30 g a.i. ha^{-1} were subjected to different decontamination methods.

4.5.6.1 Imidacloprid

The collected green chilli samples were subjected to different decontamination solutions at 2 hours after spraying. The resultes depicted that dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be significantly effective in removing 64.17 per cent residues, than other treatments. The next promising treatment was dipping in 0.1% Baking soda solution for 10 min followed by tap water wash for 30 sec (56.16%), followed by soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec (50.37%), cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (43.41%) and tap water for 10 min (21.86%). Per cent removal of imidacloprid residues from various decontamination methods was depicted in fig. 4.17.

4.5.6.2 Beta cyfluthrin

The green chilli samples collected from the plots treated with imidacloprid + beta cyfluthrin @ 30 g a.i. ha^{-1} were subjected to various decontamination methods. The results revealed that all the treatments were significantly differed among each other in their efficiency in removing beta cyfluthrin residues. Dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be most effective (66.31 %) than other treatments. The next promising treatment was dipping in 0.1% baking soda for 10 min followed by tap water wash for 30 sec (48.54%) followed by soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec (42.02%), cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (36.87%) and tap water wash for 10 min (27.60%). Per cent removal of beta cyfluthrin residues due to various decontamination methods was depicted in fig. 4.18.

4.5.7 Dimethoate 30 % EC (300 g a.i. ha^{-1})

The removal of dimethoate residues from green chilli samples were significantly differed in different decontamination methods at 2 hours after spraying of dimethoate @ 300 g a.i ha^{-1}. The results revealed that dipping in formula 1 solution for 10 min followed by tap water wash for 30 sec was found to be significantly effective when compared to other treatments. In this treatment residues were reduced up to 75.71 per cent. The next promising treatment was soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec (49.55%) followed by dipping in 0.1% baking soda solution for 10 min followed by tap water wash for 30 sec (40.78%), cooking in pressure cooker for 10 min followed by tap water wash for 30 sec (31.97%) and tap water wash for 10 min (10.57%). Per cent removal of dimethoate residues from various decontamination methods was depicted in fig. 4.19.

In the present study, dipping in formula 1 (4 % Acetic Acid + 0.1% $NAHCO_3$ + 1 Lemon), a formulation prepared by AINP on Pesticide Residues proved to be the most efficient in removing various pesticides and these findings were in agreement with the results of Dikshit *et al.* (1984) who reported that washing of cowpea with 1% acetic acid solution was capable of removing 85.70 and 88.60 per cent of metasystox and carbaryl residues, respectively. Similar results were also reported by Radwan *et al.* (2004) who reported that washing of hot pepper, sweet pepper and brinjal with 2% acetic acid removed pirimophos-methyl residues by 76.61, 95.74 and 94.58 per cent, respectively.

Reddy and Rao (2004) found that dipping of grapes in 1% acetic acid solution for 10 min, followed by water wash removed 51.80, 46.60, and 70.00 per cent of chlorpyriphos, quinalphos and bifenthrin residues, respectively. Similarly, Zhang *et al.* (2006) found that 79.8, 65.8, 74.0 and 75.00 per cent residues of chlorpyrifos, *p,p*-DDT, cypermethrin and chlorothalonil were removed by washing cabbage with 10% acetic acid solution for 20 min, respectively.

The treatment with soaking in 2% salt solution for 10 min followed by tap water wash for 30 sec was found to be next best decontamination method in case of chlorantraniliprole, profenophos, lambda- cyhalothrin and dimethoate. The results were in agreement with the findings of Geetha (2015) who reported that loss of 31.47, 32.13, 46.87 and 43.78 per cent of chlorpyriphos, profenophos, cypermethrin and triazophos residues in spinach by salt water treatment for 10 min. Washing of brinjal with 2 per cent salt solution removed the 45.3, 43.0, 52.1, 49.8, 54.0, 47.9 and 76.5 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda cyhalothrin and malathion residues, respectively (Cherukuri *et al*., 2014).

Reddy and Rao (2004) who reported 72.80, 67.50, 51.80 and 58.20 per cent removal of acephate, chlorpyriphos, quinalphos and bifenthrin residues from grapes by dipping them in 2% salt solution for 10 min, followed by water wash. Zhang *et al.* (2006) noticed that washing of cabbage with 10% NaCl solution for 20 min reduced residues of chlorpyriphos, *p,p*-DDT, cypermethrin, chlorothalonil by 67.2, 65.0, 73.3, and 74.1 per cent, respectively. Klinhom *et al.* (2008) reported that washing of leafy Chinese-Kale with 0.9% NaCl solution reduced residues of methomyl and carbaryl by 39.33 and 91.98 per cent.

Washing of tomato fruits with 10% salt solution removed 90.80 and 82.40 per cent of dimethoate and profenophos residues (Abou-Arab., 1999), the residues of metasystox and carbaryl were removed up to 86.4 and 88.7 per cent from cowpea by washing with 5% salt solution respectively (Dikshit *et al*., 1984).Washing of cucumbers in 2% salt solution for 10 min removed residues of trichlorfon, dimethoate, dichlorovos, fenitrothian and chlorpyriphos residues by 46.30, 47.80, 70.20, 28.90 and 60.50 per cent, respectively (Liang *et al.,* 2012).

Dipping in 0.1% baking soda ($NaHCo_3$) solution for 10 min followed by tap water wash for 30 sec was the next best treatment in removing residues of fipronil, spinosad, imidacloprid and beta cyfluthrin from chilli. The results were in line with the findings of Cherukuri *et al.* (2014) who reported that dipping with 0.1 per cent sodium bicarbonate solution in brinjal removed the 25.4, 21.5, 34.0, 29.8, 33.6, 30.4 and 61.3 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda cyhalothrin and malathion residues, respectively.

Liang *et al.* (2012) who reported that washing of cucumber with 2% $NaHCO_3$ was efficient enough to remove the trichlorfon, dimethoate, dichlorovos, fenitrothian and chlorpyriphos residues by 73.20, 58.70, 96.40, 51.10 and 77.80 per cent, respectively while Satpathy (2012) who found that tomato fruits washed with 0.1% $NaHCO_3$ solution removed residues of parathion, methyl parathion, malathion, fenitrothion, formothion and chlorpyriphos by 73.10, 77.40, 86.80, 57.00, 86.40 and 87.20 per cent, respectively. Washing of Chinese Kale with 0.1% $NaHCO_3$ solution removed methomyl and carbaryl residues by 43.19 and 91.24 per cent, respectively (Klinhom., 2008).

The next best decontamination method was cooking in pressure cooker for 10 min followed by tap water wash for 30 sec. The reports of Neha *et al.* (2012) indicated that cooking of brinjal removed the monocrotophos, quinalphos, permethrin and cypermethrin residues by 29.68, 22.84, 25.00 and 40.00 per cent, respectively. While Walia *et al.*, 2010 found that cooking of brinjal in water removed residues of cypermethrin 41.40 per cent.

Tap water wash for 10 min was the least effective treatment and the findings of present investigations were in agreement with the findings of Abou-Arab (1999) who reported that washing of tomato fruits with water removed dimethoate and profenophos residues up to 18.80 and 22.17 per cent, respectively. Jayakrishnan *et al.* (2005) reported that washing of tomato fruits with water removed lambda cyhalothrin residues by 29-30 per cent. Similar results were obtained by Mergnat *et al*. (1995) who reported that washing of apples with water removed 30-50 per cent of phosalone residues. 13.50 per cent of profenophos residues were removed from potato tubers when washed with tap water (Zohair., 2001). The tap water wash for 10 min removed trichlorfon, dimethoate, dichlorovos, fenitrothian and chlorpyriphos residues by 36.60, 21.70, 22.60, 22.20 and 59.20 per cent in cucumber, respectively (Liang *et al.*, 2012).

Cherukuri *et al.* (2014) who reported that the loss of 30.7, 35.3, 45.6, 42, 44.1, 40.9 and 70.3 per cent of dimethoate, chlorpyriphos, quinalphos, profenophos, phosalone, lambda cyhalothrin and malathion residues in brinjal by tap water wash. While Pallavi *et al.* (2014) reported the loss of malathion, chlorpyriphos, quinalphos, profenophos and cypermethrin in curry leaf to an extent of 25.9, 10.8, 18.6, 21.7 and 8.2 per cent by washing with tap water for 15 min. Similarly tap water wash for 10 min removed chlorpyriphos, profenophos, cypermethrin and triazophos residues by 15.37, 13.30, 19.21 and 19.88 per cent, respectively in spinach (Geetha., 2015).

4.6 Determination of the processing factor for selective insecticides in chillies.

The red chilli samples were collected from various plots treated with fipronil 5% SC @ 500 g a.i ha^{-1}, spinosad 45% SC @ 125 g a.i ha^{-1}, chlorantraniliprole 20% SC@ 30 g a.i ha^{-1}, profenophos 50% EC @ 400 g a.i ha^{-1}, lambda cyhalothrin 5% SC @ 15.63 g a.i ha^{-1}, imidacloprid + beta cyfluthrin 300% OD@ 30 g a.i $ha^{-1}$and dimethoate 30 % EC@ 300 g a.i ha^{-1} at harvest to estimate initial deposits and residues in sundried red chilli powder. After estimating the residues from red chilli and powdered chilli, the processing factor was calculated.

The results of the experiment revealed that respective initial deposits of fipronil, spinosad, chlorantraniliprole, profenophos, lambdacyhalothrin, imidacloprid, betacyfluthrin and dimethoate in fresh red chilli were 1.71, 0.80, 0.96, 3.14, 1.34, 1.28, 0.36, 3.97 mg kg^{-1} , whereas in sundried red chilli powder were 4.74, 1.20, 2.27, 9.46, 3.27, 3.06, 1.02 and 12.72 mg kg^{-1} (Table 4.25 and fig 4.20). In case of control, none of these pesticide residues were detected. The processing factors computed for fipronil, spinosad, chlorantraniliprole, profenophos, lambdacyhalothrin, imidacloprid, betacyfluthrin and dimethoate were 2.77, 1.50, 2.36, 3.01, 2.44, 2.39, 2.83 and 3.20, respectively. The results revealed that by reducing the weight after dehydration of the fresh chilli, the concentration of the pesticides increased to 2.77, 1.50, 2.36, 3.01, 2.44, 2.39, 2.83 and 3.20, respectively. Similar results were also reported in a field experiment by Pathan *et al*. (2009) who reported that the processing factor for dicofol (18.5 EC), ethion (50 EC) and cypermethrin (25 EC) in chilli were 5.59, 3.52 and 7.50, respectively. Similarly Shah *et al.* (2009) find out processing factor for the chlorthalonil, chlorpyriphos and endosulfan in turmeric were 2.3, 0.6 and 4.7, respectively.

George and kumar (2013) reported the processing factor for chlorpyriphos and lambda cyhalothrin were 3.24 and 2.98, respectively in cardamom, while, Pan *et al.* (2015) reported the processing factors of dimethoate were in the range of 2.11–2.41 and 1.41–1.70 during green tea and black tea manufacturing, respectively.

Table 4.1Seasonal incidence of chilii thrips *Scirtothrips dorsalis* on chilli during *kharif* 2015-16

MSW	Date & Month	Thrips per 5 leaves	Temperature (0C)		Relative Humidity (%)		Rainfall (mm)	Rainy Days	Mean Sunshine (hrs day^{-1})	Wind Speed (km hr^{-1})	Mean Evaporation (mm day^{-1})	Mean Temp (0C)
			Maximum	Minimum	I	II						
36	03 – 09 (Sept)	0	33.4	22.9	88.4	59.1	30.8	3	7.2	1.4	5.6	28.2
37	10 – 16	0	28.4	21.9	95.9	85.7	92.0	4	1.7	0.8	2.5	25.1
38	17 – 23	0	30.4	22.2	89.6	61.0	43.4	2	4.4	1.2	3.5	26.3
39	24 – 30	2.94	31.9	22.3	89.4	57.6	2.0	0	7.2	0.2	4.3	27.1
40	01 – 07 (Oct)	2.32	31.4	21.1	96.0	55.0	34.6	2	5.8	0.2	3.4	26.3
41	08 – 14	3.50	33.4	19.6	88.4	37.4	0.0	0	7.9	0.1	4.5	26.5
42	15 – 21	5.75	32.8	19.1	91.7	42.0	0.0	0	8.4	0.6	4.5	26.0
43	22 – 28	8.82	32.4	18.1	89.3	43.6	0.0	0	8.9	1.8	4.7	25.3
44	29 - 04 (Nov)	10.49	31.3	20.7	91.7	50.9	18.3	1	7.3	1.3	3.6	26.0
45	05 – 11	12.38	31.3	17.4	90.6	73.6	0.0	0	7.3	2.3	4.4	24.3
46	12 – 18	13.24	30.0	15.8	85.1	52.9	0.0	0	6.7	2.4	4.0	22.9
47	19 – 25	14.53	29.4	19.1	83.0	53.9	0.8	0	6.6	1.4	3.9	24.2
48	26 – 02 (Dec)	15.95	30.4	17.8	87.4	47.0	0.0	0	7.7	0.6	3.8	24.1
49	03 – 09	18.06	29.4	14.4	91.7	36.7	1.4	0	7.0	0.4	3.5	21.9
50	10 – 16	20.54	32.2	17.0	90.0	37.0	0.0	0	7.6	0.7	3.9	24.6
51	17 – 23	18.27	32.4	15.7	92.9	35.3	0.0	0	8.9	0.9	4.2	24.1
52	24 – 31	18.03	30.0	11.1	73.3	24.6	0.0	0	8.8	0.8	3.9	20.6
1	01 – 07 (Jan)	20.38	30.4	11.8	84.1	26.0	0.0	0	9.6	0.9	3.9	21.1
2	08 – 14	22.57	29.2	11.0	78.4	25.6	0.0	0	9.1	1.2	3.9	20.1
3	15 – 21	24.82	29.1	16.6	76.6	36.4	0.0	0	6.8	1.6	3.7	22.9
4	22 – 28	23.65	29.1	15.6	79.4	37.3	0.0	0	7.2	1.6	3.8	22.4
5	29-04 (Feb)	20.73	32.9	13.6	70.7	25.6	0.0	0	9.7	1.2	4.6	23.3
6	05-11	14.42	32.6	16.9	81.3	32.7	0.0	0	8.7	1.2	4.8	24.8
7	12-18	10.92	32.9	17.3	80.4	29.4	0.0	0	8.6	2.3	6.0	25.1
8	19-25	4.63	35.4	17.4	78.0	25.4	0.0	0	9.5	1.9	6.5	26.4
9	26-04 MAR	2.10	33.3	21.4	80.4	37.1	0.0	0	7.1	2.9	6.2	27.3

* MSW- Metrological Standard Week

Table 4.2 Seasonal incidence of chilli thrips *Scirtothrips dorsalis*on chilli during *kharif* 2016-17

MSW	Date & Month	Thrips per 5 leaves	Temperature (0C)		Relative Humidity (%)		Rainfall (mm)	Rainy Days	Mean Sunshine (hrs day^{-1})	Wind Speed (km hr^{-1})	Mean Evaporation (mm day^{-1})	Mean Temp (0C)
			Maximum	Minimum	I	II						
36	03-09 (Sept)	0	30.1	21.6	90.1	59.1	19.2	2	7.2	0.0	4.3	25.9
37	10-16	0	27.7	22.1	93.1	81.9	128.2	6	0.9	0.0	2.6	24.9
38	17-23	0	28.6	21.9	94.1	85.1	105.4	4	2.5	0.0	2.6	25.3
39	24-30	0	27.9	22.0	97.0	78.9	70.6	3	2.1	0.0	2.5	24.9
40	01-07 (Oct)	0.10	30.1	21.9	90.3	65.9	4.4	1	5.7	0.0	3.8	26.0
41	08-14	1.53	29.9	20.8	94.4	50.9	27.8	3	5.3	0.0	3.1	25.3
42	15-21	2.98	30.6	14.6	92.7	34.1	0.0	0	9.2	0.0	4.0	22.6
43	22-28	4.75	30.2	15.1	91.9	38.3	0.0	0	8.8	0.0	4.1	22.7
44	29-04 (Nov)	5.86	30.9	19.9	84.0	47.1	0.0	0	7.0	0.0	3.6	25.4
45	05-11	7.10	30.1	12.3	88.0	28.7	0.0	0	8.5	0.0	3.8	21.2
46	12-18	9.92	29.8	15.7	88.7	44.9	0.0	0	6.5	0.0	3.3	22.8
47	19-25	12.04	29.7	9.8	89.7	28.1	0.0	0	8.7	0.0	3.6	19.8
48	26-02 (Dec)	12.41	30.8	10.0	90.9	31.4	0.0	0	8.3	0.0	3.3	20.4
49	03-09	15.06	29.1	14.0	92.6	42.3	0.0	0	7.4	0.0	3.1	21.5
50	10-16	16.01	27.9	13.1	86.3	51.3	2.0	0	6.7	0.0	3.1	20.5
51	17-23	16.48	29.4	9.5	88.3	24.0	0.0	0	9.1	0.0	3.6	19.5
52	24-31	17.01	29.4	8.9	91.4	31.0	0.0	0	9.0	0.0	3.5	19.2
1	01 – 07 (Jan)	16.82	29.1	9.7	89.6	29.7	0.0	0	8.8	0.0	3.4	19.4
2	08 – 14	15.05	29.3	13.2	84.0	38.0	0.0	0	7.6	0.8	3.4	21.25
3	15 – 21	13.83	28.2	11.4	89.1	31.7	0.0	0	7.7	1.2	3.6	19.8
4	22 – 28	13.01	29.9	14.7	85.9	38.4	0.0	0	7.6	3.0	4.3	22.3
5	29-04 (Feb)	12.51	31.3	12.7	86.3	27.7	0.0	0	9.0	3.3	4.4	22.0
6	05-11	8.90	31.9	13.6	78.0	28.4	0.0	0	9.3	3.0	4.6	22.75
7	12-18	4.69	30.8	13.8	87.4	32.7	0.0	0	9.4	4.6	5.3	22.3
8	19-25	1.89	35.4	13.8	70.7	20.4	0.0	0	10.3	3.0	5.8	24.6

* MSW- Metrological Standard Week

Table 4.3. Correlation coefficients between chilli thrips *S. dorsalis* and weather parameters (one week lag) during *Kharif*, 2015-16

Observatory weather parameters	**Correlation coefficients (r)**
Maximum temperature	-0.51**
Minimum temperature	-0.80**
Morning relative humidity (RH I %)	-0.39
Evening relative humidity (RH II %)	-0.50*
Rainfall (mm)	-0.55**
Rainy days (R.D)	-0.59**
Sunshine hours (S.S.H)	0.39
Wind speed (W.S) Km/h	0.04
Evaporation (E. pan) (mm)	-0.33
Mean temperature	-0.87**

* Significant at 5 % level

* * Significant at 1 % level

Table 4.4. Correlation coefficients between chilli thrips *S. dorsalis* and weather parameters (one week lag) during *Kharif*, 2016-17

Observatory weather parameters	Correlation coefficients (r)
Maximum temperature	-0.59**
Minimum temperature	-0.83**
Morning relative humidity (RH I %)	-0.27
Evening relative humidity (RH II %)	-0.66**
Rainfall (mm)	-0.59**
Rainy days (R.D)	-0.67**
Sunshine hours (S.S.H)	0.53**
Wind speed (W.S) Km/h	-0.11
Evaporation (E. pan) (mm)	-0.07
Mean temperature	-0.87**

* Significant at 5 % level
* * Significant at 1 % level

Table 4.5. Multiple regression equation developed for *S. dorsalis* infesting chilli based on weather parameters During *Kharif*, 2015-16 and 2016-17

Season	Step down Multiple Linear regression equation	Coefficient of determination (R^2)
***Kharif*2015-16**	Y= 73.77 + 2.05X1 + 4.11X2 + 0.05X3 - 0.31X4 - 1.05X5 + 0.65X6 + 0.15X7 + 0.22X8 - 0.70X9 - 5.36X10	0.94
***Kharif*2016-17**	Y=93.94 - 2.45X1 - 9.99X2 - 0.14X3 + 0.05X4 - 079X5 + 0.19X6 + 0.14X7 + 0.25X8 - 0.82X9 + 9.31X10	0.93

X1- Maximum temperature

X2- Minimum temperature

X3- Morning relative humidity

X4- Evening relative humidity

X5- Rainfall (mm)

X6-Rainy days

X7- Sunshine hours

X8- Wind Speed

X9-Evaporation

X10- Mean Temperature

Table 4.15. Effectiveness of different insecticides on chilli yield (kg ha^{-1}) during *kharif* 2015-16 and 2016-17

Treatment	Concentration (g a.i. ha^{-1})	Yield (kg ha^{-1}) *Kharif* 2015-16	Yield (kg ha^{-1}) *Kharif* 2016-17	Pooled yield *Kharif* 2015-16 and 2016-17	Per cent increased yield over control
T_1- Fipronil 5 % SC	500	2019.47^{b}	2156.10^{ab}	2087.79^{b}	59.70
T_2-Spinosad 45% SC	125	2136.19^{a}	2288.04^{a}	2212.12^{a}	69.21
T_3-Chlorantraniliprole 20 % SC	30	1396.27^{e}	1439.20^{e}	1417.74^{e}	8.45
T_4-Profenophos 50 % EC	400	1816.05^{c}	1985.73^{c}	1900.89^{c}	45.40
T_5-Lambda - cyhalothrin 5% SC	15.63	1623.58^{d}	1698.09^{d}	1660.84^{d}	27.04
T_6-Betacyfluthrin + imidacloprid 300 % OD	30	1923.23^{b}	2048.24^{bc}	1985.74^{bc}	51.90
T_7-Dimethoate 30% EC	300	1671.94^{d}	1752.00^{d}	1711.97^{d}	30.96
T_8-Control		1295.37^{e}	1319.21^{e}	1307.29^{e}	0.00
SEm±		34.89	54.81	40.57	
CD (P= 0.05%)		104.32	163.88	121.29	

Table 4.24. Effectiveness of various decontamination methods for the removal of insecticides in chilli

Insecticides	Initial deposits (mg kg^{-1})	Mean per cent removal of Insecticides					CD (5%)
		Tap water	2 % salt solution	cooking	0.1% $NaHCO_3$	Formula 1	
Fipronil	1.47	14.91	44.84	33.04	50.19	69.27	2.43
Spinosad	0.78	16.37	40.39	36.59	44.29	66.43	4.36
Chlorantraniliprole	0.56	19.33	50.97	36.84	43.99	73.37	3.37
Profenophos	2.60	12.61	44.27	29.93	38.47	71.06	4.20
Lambda – cyhalothrin	1.20	30.19	49.32	38.15	42.59	62.72	5.52
Imidacloprid	1.10	21.86	50.37	43.41	56.16	64.17	6.38
Betacyfluthrin	0.28	27.60	42.02	36.87	48.54	66.31	4.44
Dimethoate	3.86	10.57	49.55	31.97	40.78	75.71	3.39

Table 4.25. Processing factor for selective insecticides in chilli

Insecticides	Residues (mg kg^{-1})		Processing factor
	Red chilli	Sundried red chilli powder	
Fipronil	1.71	4.74	2.77
Spinosad	0.80	1.20	1.50
Chlorantraniliprole	0.96	2.27	2.36
Profenophos	3.14	9.46	3.01
Lambda - cyhalothrin	1.34	3.27	2.44
Imidacloprid	1.28	3.06	2.39
Betacyfluthrin	0.36	1.02	2.83
Dimethoate	3.97	12.72	3.20

Table 4.6. Efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after first spray in *kharif* 2015-16

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	67.26^{b} (55.10)	77.24^{a} (61.56)	85.15^{ab} (68.01)	70.12^{b} (56.87)	50.12^{b} (45.05)
T_2 - Spinosad 45% SC	125	72.33^{a} (58.29)	78.43^{a} (62.39)	86.15^{a} (68.22)	76.92^{a} (61.32)	54.89^{a} (47.79)
T_3 -Chlorantraniliprole 20 % SC	30	11.74^{e} (19.89)	13.88^{d} (21.73)	16.15^{f} (23.64)	12.67^{e} (20.69)	8.15^{e} (16.40)
T_4 - Profenophos 50 % EC	400	62.84^{c} (52.45)	63.35^{b} (53.96)	72.87^{c} (58.63)	64.14^{c} (53.21)	45.18^{c} (42.21)
T_4 - Profenophos 50 % EC	400	62.84^{c} (52.45)	63.35^{b} (53.96)	72.87^{c} (58.63)	64.14^{c} (53.21)	45.18^{c} (42.21)
T_5 - Lambda cyhalothrin5% SC	15.63	48.05^{d} (43.88)	49.72^{c} (44.82)	48.63^{e} (44.21)	46.39^{d} (42.91)	34.82^{d} (36.14)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	65.10^{bc} (53.81)	74.24^{a} (59.54)	82.04^{b} (64.97)	68.84^{bc} (56.07)	48.87^{bc} (44.33)
T_7 - Dimethoate 30% EC	300	48.13^{d} (43.92)	54.27^{b} (47.45)	55.63^{d} (48.23)	46.93^{d} (43.22)	38.21^{d} (38.16)
T_8 – Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.86	0.97	1.04	1.00	0.89
CD (P= 0.05%)		2.59	2.90	3.11	2.99	2.66

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.7. Efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after second spray in *kharif* 2015-16

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	68.44^{b} (55.84)	74.02^{b} (59.38)	81.60^{a} (64.77)	71.14^{a} (57.51)	46.96^{ab} (43.24)
T_2 - Spinosad 45% SC	125	73.98^{a} (59.37)	78.20^{a} (62.21)	82.18^{a} (65.07)	73.18^{a} (58.82)	50.12^{a} (45.05)
T_3 -Chlorantraniliprole 20 % SC	30	12.63^{e} (20.57)	14.74^{e} (22.50)	17.19^{d} (24.45)	14.49^{d} (22.26)	11.73^{e} (19.93)
T_4 - Profenophos 50 % EC	400	63.18^{c} (52.65)	68.18^{c} (55.67)	71.12^{b} (57.51)	66.12^{b} (54.40)	40.86^{d} (39.71)
T_5 - Lambda cyhalothrin 5% SC	15.63	49.26^{d} (44.56)	52.81^{d} (46.61)	54.31^{c} (47.47)	48.92^{c} (44.36)	36.97^{d} (37.42)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	67.21^{bc} (55.08)	73.12^{b} (58.80)	78.24^{a} (62.22)	70.18^{a} (56.91)	43.27^{bc} (41.11)
T_7 - Dimethoate 30% EC	300	51.50^{d} (45.84)	52.55^{d} (46.46)	55.57^{c} (48.20)	52.32^{c} (46.31)	38.97^{d} (38.61)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.99	0.85	0.96	0.75	0.82
CD (P= 0.05%)		2.97	2.54	2.89	2.25	2.46

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.8. Efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after third spray in *kharif* 2015-16

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	66.42^{a} (54.60)	68.74^{b} (56.04)	76.24^{b} (60.86)	70.09^{a} (56.83)	52.94^{b} (46.67)
T_2 - Spinosad 45% SC	125	70.10^{a} (56.87)	76.24^{a} (60.85)	82.14^{a} (65.05)	72.24^{a} (58.19)	62.19^{a} (52.04)
T_3 -Chlorantraniliprole 20 % SC	30	9.63^{d} (17.95)	11.19^{d} (19.44)	12.98^{f} (21.02)	11.16^{e} (19.45)	7.26^{d} (15.43)
T_4 - Profenophos 50 % EC	400	58.12^{b} (49.68)	66.94^{b} (54.92)	70.18^{c} (56.92)	65.29^{b} (53.89)	48.74^{b} (44.26)
T_5 - Lambda cyhalothrin 5% SC	15.63	42.78^{c} (40.84)	44.19^{c} (41.66)	45.98^{e} (42.69)	41.89^{d} (40.31)	34.96^{c} (36.22)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	60.12^{b} (50.85)	68.12^{b} (55.64)	72.12^{c} (58.15)	70.12^{a} (56.85)	50.89^{b} (45.49)
T_7 - Dimethoate 30% EC	300	45.39^{c} (42.35)	47.84^{c} (43.76)	50.67^{d} (45.38)	55.23^{c} (47.99)	39.34^{c} (38.82)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.97	1.00	0.89	0.78	1.08
CD (P= 0.05%)		2.90	2.99	2.66	2.33	3.23

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.9. Efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after first spray in *kharif* 2016 – 17

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	65.91[ab] (54.26)	79.16[b] (62.88)	86.12a[ab] (68.16)	74.16[ab] (59.46)	48.92[ab] (44.36)
T_2 - Spinosad 45% SC	125	70.18[a] (56.89)	86.12[a] (68.20)	89.42[a] (71.12)	78.12[a] (62.13)	52.93[a] (46.66)
T_3 -Chlorantraniliprole 20 % SC	30	11.49[e] (19.73)	12.68[f] (20.77)	14.43[e] (22.26)	11.50[e] (19.67)	9.27[e] (17.59)
T_4 - Profenophos 50 % EC	400	61.45[b] (51.6)	72.42[c] (58.34)	78.42[c] (62.35)	68.18[c] (55.66)	43.14[bc] (41.04)
T_5 - Lambda cyhalothrin 5% SC	15.63	41.93[d] (40.34)	47.91[e] (43.80)	49.84[d] (44.91)	42.62[d] (40.73)	34.78[d] (36.11)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	65.86[ab] (54.23)	76.91[bc] (61.31)	85.23[b] (67.46)	70.36[bc] (57.02)	45.82[b] (42.58)
T_7 - Dimethoate 30% EC	300	48.67[c] (44.22)	54.37[d] (47.51)	49.58[d] (44.76)	42.68[d] (40.77)	38.90[cd] (38.56)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.98	1.06	1.12	0.92	1.17
CD (P= 0.05%)		2.93	3.17	3.35	2.75	3.50

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.10. Efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after second spray in *kharif* 2016-17

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	68.92^{a} (56.14)	74.97^{b} (59.99)	78.14^{b} (62.20)	70.19^{b} (56.90)	51.46^{b} (45.82)
T_2 - Spinosad 45% SC	125	72.14^{a} (58.17)	79.18^{a} (62.87)	82.14^{a} (65.06)	80.46^{a} (63.78)	56.55^{a} (48.75)
T_3 -Chlorantraniliprole 20 % SC	30	11.30^{e} (19.47)	14.49^{f} (22.35)	12.01^{d} (20.16)	10.06e (18.38)	7.82^{e} (15.94)
T_4 - Profenophos 50 % EC	400	61.92^{b} (51.91)	68.18^{c} (55.67)	74.96^{b} (60.01)	64.18^{c} (53.23)	42.80^{c} (40.84)
T_5 - Lambda cyhalothrin 5% SC	15.63	47.55^{d} (43.59)	49.95^{e} (44.97)	52.06^{c} (46.18)	42.91^{d} (40.90)	35.97^{cd} (36.82)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	63.18^{b} (52.66)	72.12^{bc} (58.14)	76.18^{b} (62.17)	66.14^{bc} (54.41)	48.32^{b} (44.02)
T_7 - Dimethoate 30% EC	300	52.84^{c} (46.63)	56.50^{d} (48.74)	54.47^{c} (47.57)	45.54^{d} (42.42)	39.10^{d} (38.68)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.77	0.86	0.82	0.90	0.78
CD (P= 0.05%)		2.33	2.57	2.45	2.69	2.36

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.11. Efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after third spray in *kharif* 2016-17

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	67.19^{b} (55.05)	71.24^{bc} (57.58)	78.12^{ab} (62.15)	73.24^{b} (58.84)	51.27^{b} (45.71)
T_2 - Spinosad 45% SC	125	71.81^{a} (57.93)	76.98^{a} (61.34)	80.46^{a} (63.81)	78.10^{a} (62.09)	55.92^{a} (48.39)
T_3–Chlorantraniliprole 20 % SC	30	12.01^{e} (20.18)	12.71^{f} (20.85)	15.06^{e} (22.76)	13.70^{e} (21.68)	9.89^{e} (18.15)
T_4 - Profenophos 50 % EC	400	64.54^{b} (53.44)	67.92^{c} (55.51)	72.86^{c} (58.63)	67.14^{c} (55.01)	46.98^{c} (43.25)
T_5 - Lambda cyhalothrin 5% SC	15.63	45.39^{d} (42.34)	43.18^{e} (41.08)	44.89^{d} (42.06)	42.25^{d} (40.52)	36.86^{d} (37.35)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	64.68^{b} (53.53)	72.90^{ab} (58.64)	75.86^{bc} (60.60)	68.96^{b} (56.13)	47.84^{c} (43.75)
T_7 - Dimethoate 30% EC	300	47.76^{c} (43.7)	50.28^{d} (45.16)	47.85^{d} (43.77)	45.47^{c} (42.38)	38.71^{d} (38.45)
T_8–Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.90	0.96	0.98	0.87	1.02
CD (P= 0.05%)		2.69	2.87	2.93	2.60	3.05

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.12. Pooled efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after first spray in *kharif* 2015-16 and 2016-17

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	66.59^{b} (54.70)	78.20^{b} (62.22)	85.65^{ab} (68.19)	72.14^{b} (58.19)	49.52^{ab} (44.72)
T_2 - Spinosad 45% SC	125	71.26^{a} (57.60)	82.28^{a} (65.30)	87.80^{a} (71.12)	77.52^{a} (61.75)	53.91^{a} (47.25)
T_3 -Chlorantraniliprole 20 % SC	30	11.62^{e} (19.82)	13.28^{f} (21.25)	15.31^{e} (22.26)	12.09^{e} (20.19)	8.71^{e} (17.00)
T_4 - Profenophos 50 % EC	400	62.15^{c} (52.04)	68.89^{c} (56.15)	75.66^{c} (62.35)	66.16^{c} (54.46)	44.16^{c} (41.64)
T_5 - Lambda cyhalothrin 5% SC	15.63	44.99^{d} (42.12)	48.82^{e} (44.32)	49.24^{d} (44.56)	44.51^{d} (41.84)	34.80^{d} (36.14)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	65.48^{bc} (54.03)	75.58^{b} (60.73)	83.65^{b} (66.22)	69.60^{bc} (56.57)	47.35^{bc} (43.48)
T_7 - Dimethoate 30% EC	300	48.40^{d} (44.08)	54.32^{d} (47.48)	52.62^{d} (46.51)	44.81^{d} (42.01)	38.56^{d} (38.38)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.86	0.87	1.00	0.82	0.98
CD (P= 0.05%)		2.59	2.60	2.99	2.45	2.93

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.13.Pooled efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after second spray in *kharif* 2015-16 and 2016-17

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	68.68^{b} (56.00)	74.50^{ab} (59.69)	79.87^{ab} (63.40)	70.67^{b} (57.23)	49.21^{ab} (44.55)
T_2 - Spinosad 45% SC	125	73.06^{a} (58.78)	78.69^{a} (62.54)	82.16^{a} (65.07)	76.82^{a} (61.32)	53.34^{a} (46.92)
T_3 -Chlorantraniliprole 20 % SC	30	11.97^{e} (20.03)	14.02^{e} (22.42)	14.60^{e} (22.30)	12.28^{e} (20.33)	9.78^{f} (17.94)
T_4 - Profenophos 50 % EC	400	62.55^{c} (52.29)	68.18^{c} (55.67)	72.60^{c} (58.47)	65.15^{c} (53.84)	41.83^{cd} (40.29)
T_5 - Lambda cyhalothrin 5% SC	15.63	48.40^{d} (44.08)	51.38^{d} (45.79)	53.19^{d} (46.83)	45.92^{d} (42.65)	36.47^{e} (37.14)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	65.19^{bc} (53.88)	72.62^{bc} (58.47)	77.21^{b} (61.52)	68.16^{bc} (55.68)	45.80^{bc} (42.58)
T_7 - Dimethoate 30% EC	300	52.17^{d} (46.25)	54.53^{d} (47.60)	55.02^{d} (47.88)	48.93^{d} (44.39)	39.04^{de} (38.66)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.89	1.00	0.87	0.96	0.90
CD (P= 0.05%)		2.68	2.99	2.60	2.87	2.69

Days After Spraying

Figures in parentheses are angular transformed values

Table 4.14.Pooled efficacy of different insecticides against *Scirtothripsdorsalis* on chilli after third spray in *kharif* 2015-16 and 2016-17

Treatment	Concentration (g a.i. ha^{-1})	Mean % reduction over control				
		1DAS	3 DAS	5 DAS	7 DAS	10DAS
T_1 - Fipronil 5 % SC	500	66.81^{b} (54.83)	69.99^{b} (56.80)	77.18^{b} (61.50)	71.67^{ab} (57.86)	52.11^{b} (46.21)
T_2 - Spinosad 45% SC	125	70.96^{a} (57.41)	76.61^{a} (61.10)	81.30^{a} (64.43)	75.17^{a} (60.16)	59.09^{a} (50.23)
T_3 -Chlorantraniliprole 20 % SC	30	10.82^{e} (19.07)	11.95^{e} (20.15)	14.02^{e} (21.89)	12.43^{f} (20.58)	8.58^{d} (16.80)
T_4 - Profenophos 50 % EC	400	61.33^{c} (51.57)	67.02^{b} (54.96)	71.52^{c} (57.77)	66.22 (54.47)	47.86^{b} (43.77)
T_5 - Lambda cyhalothrin 5% SC	15.63	44.09^{d} (41.60)	43.69^{d} (41.37)	45.44^{d} (42.38)	42.07^{e} (40.43)	35.91^{c} (36.80)
T_6 - Betacyfluthrin + imidacloprid 300 % OD	30	62.40^{c} (52.20)	70.51^{b} (57.14)	73.99^{bc} (59.38)	69.54^{bc} (56.51)	49.07^{b} (44.47)
T_7 - Dimethoate 30% EC	300	46.58^{d} (43.03)	49.06^{e} (44.46)	49.26^{d} (44.58)	50.35^{d} (45.20)	39.03^{c} (38.65)
T_8 - Control		0.00	0.00	0.00	0.00	0.00
SEm±		0.85	0.88	0.92	1.03	0.98
CD (P= 0.05%)		2.54	2.63	2.75	3.07	2.93

DAS – Days After Spraying

Figures in parentheses are angular transformed values

Table 4.23. Dissipation pattern of dimethoate 30% EC (300 g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of dimethoate (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	3.82	3.96	3.78	3.86	--
1	2.75	2.68	2.55	2.66	31.09
3	2.24	2.28	2.31	2.28	40.93
5	1.12	1.10	0.95	1.06	72.54
7	0.22	0.22	0.23	0.22	94.30
10	0.08	0.08	0.08	0.08	97.93
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 3.326 + (-0.376) X				
R^2	0.909				
MRL (As per FSSAI) mg kg^{-1}	0.50				
Waiting period (days)	6.64				

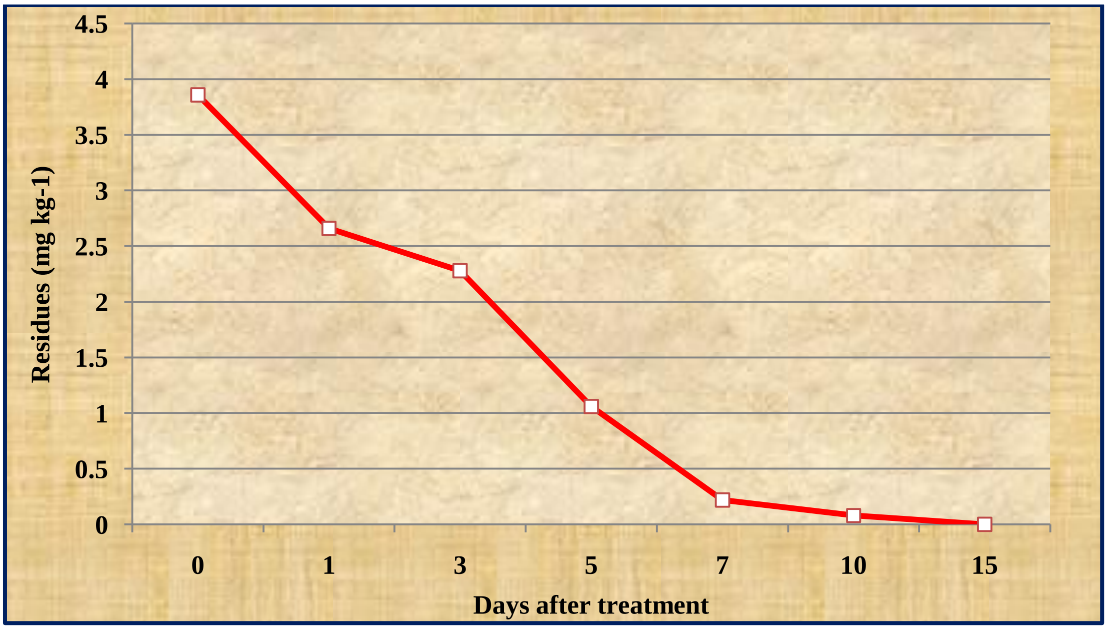

Fig. 4.11. Dissipation kinetics of dimethoate residues in chilli after three sprays

Table 4.19.Dissipation pattern of profenophos 50% EC (400 g a.i ha^{-1}) in Chilli after three sprays

Days after last spray	Residues of profenophos (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	2.53	2.61	2.67	2.60	--
1	1.07	1.06	1.07	1.07	58.85
3	0.73	0.75	0.73	0.74	71.54
5	0.43	0.45	0.44	0.44	83.08
7	0.14	0.12	0.14	0.13	95.00
10	BDL	BDL	BDL	BDL	100.00
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 1.926 + (-0.290) X				
R^2	0.748				
MRL (As per FSSAI) mg kg^{-1}	2				
Waiting period (days)	5.60				

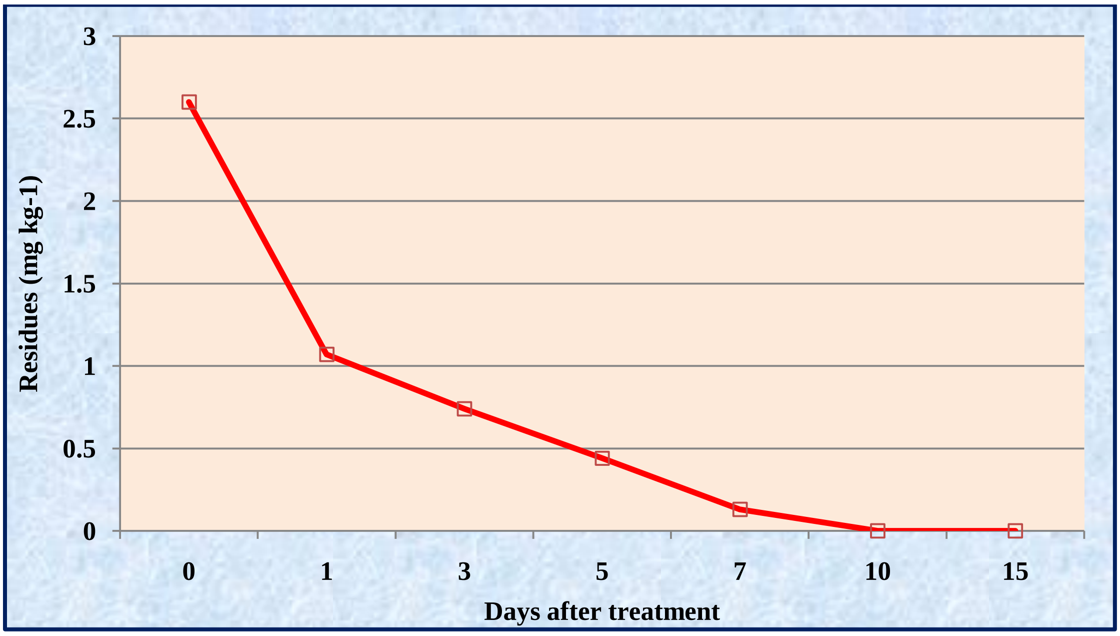

Fig. 4.7. Dissipation kinetics of profenophos residues in chilli after three sprays

Table 4.20. Dissipation pattern of lambda cyhalothrin5% SC (15.63 g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of lambda cyhalothrin (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	1.19	1.17	1.23	1.20	--
1	0.78	0.77	0.78	0.78	35.00
3	0.32	0.35	0.43	0.36	70.00
5	0.10	0.09	0.09	0.09	92.50
7	BDL	BDL	BDL	BDL	100.00
10	BDL	BDL	BDL	BDL	100.00
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 1.089 + (-0.214) X				
R^2	0.952				
MRL (As per FSSAI) mg kg^{-1}	0.05				
Waiting period (days)	11.16				

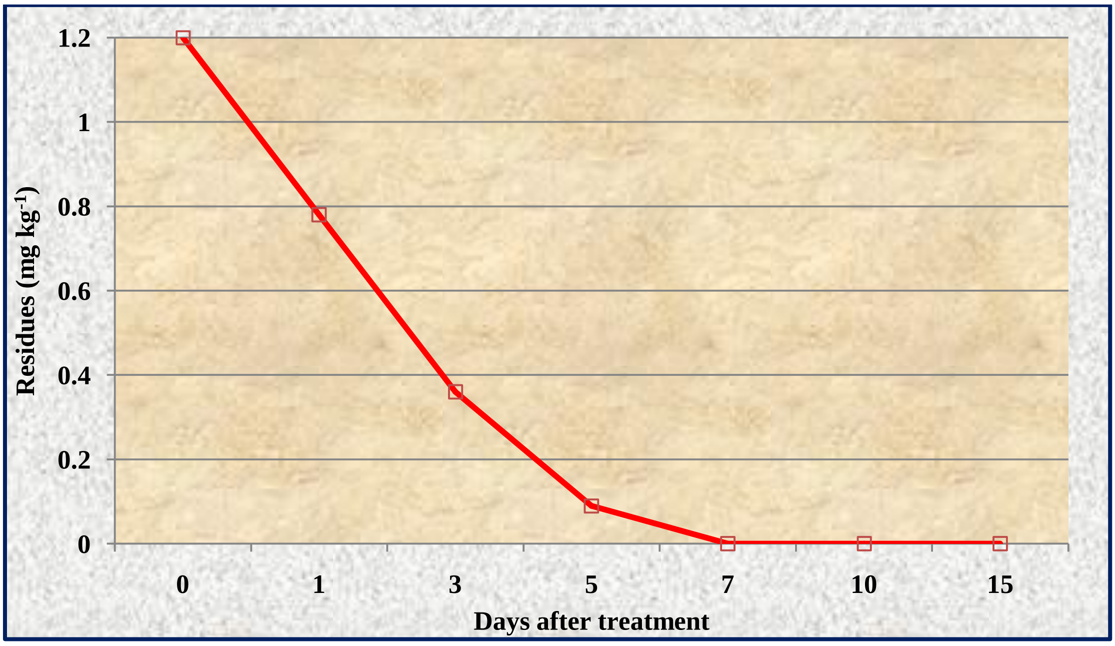

Fig. 4.8. Dissipation kinetics of lambda cyhalothrin residues in chilli after three sprays

Table 4.16.Dissipation pattern of fipronil5% SC (500 g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of fipronil (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	1.47	1.44	1.49	1.47	--
1	0.94	0.98	0.99	0.97	34.01
3	0.49	0.52	0.55	0.52	64.62
5	0.41	0.41	0.40	0.41	72.11
7	0.36	0.37	0.35	0.36	75.51
10	0.15	0.19	0.14	0.16	89.11
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 1.143 + (-0.114) X				
R^2	0.794				
MRL (As per FSSAI) mg kg^{-1}	0.001				
Waiting period (days)	36.34				

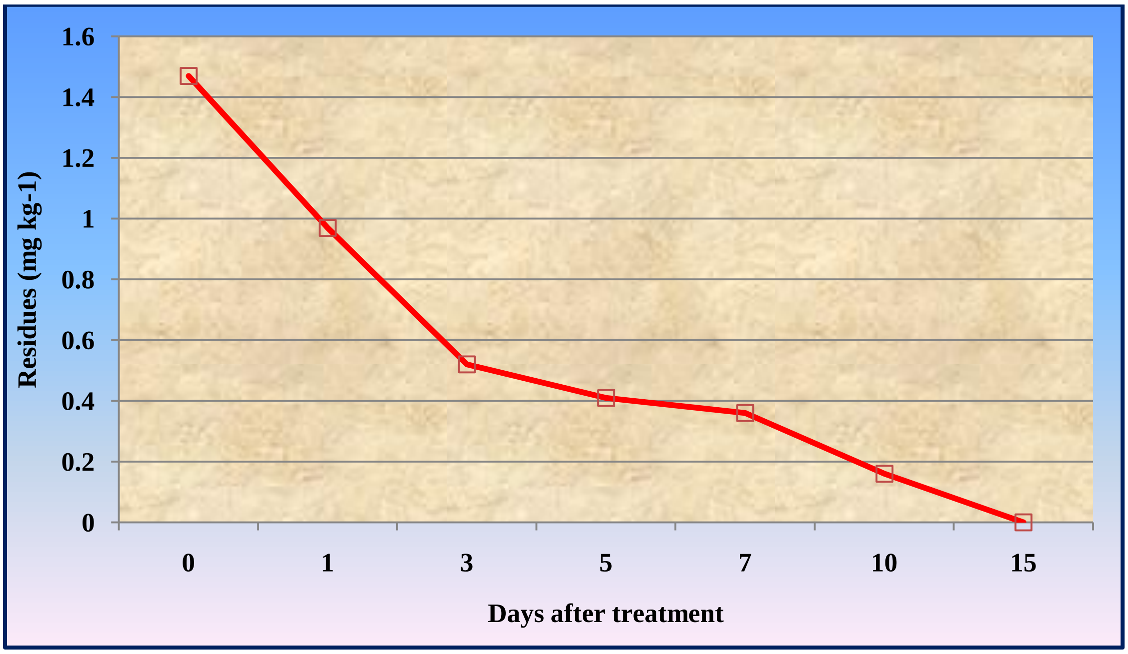

Fig.4.4. Dissipation kinetics of fipronil residues in chill after three sprays

Table 4.17. Dissipation pattern of spinosad 45% SC (125 g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of spinosad (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	0.77	0.82	0.74	0.78	--
1	0.47	0.45	0.39	0.43	44.87
3	0.16	0.19	0.19	0.18	76.92
5	0.10	0.11	0.10	0.10	98.72
7	BDL	BDL	BDL	BDL	100.00
10	BDL	BDL	BDL	BDL	100.00
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 0.659 + (-0.127) X				
R^2	0.856				
MRL (As per FSSAI) mg kg^{-1}	0.001				
Waiting period (days)	28.81				

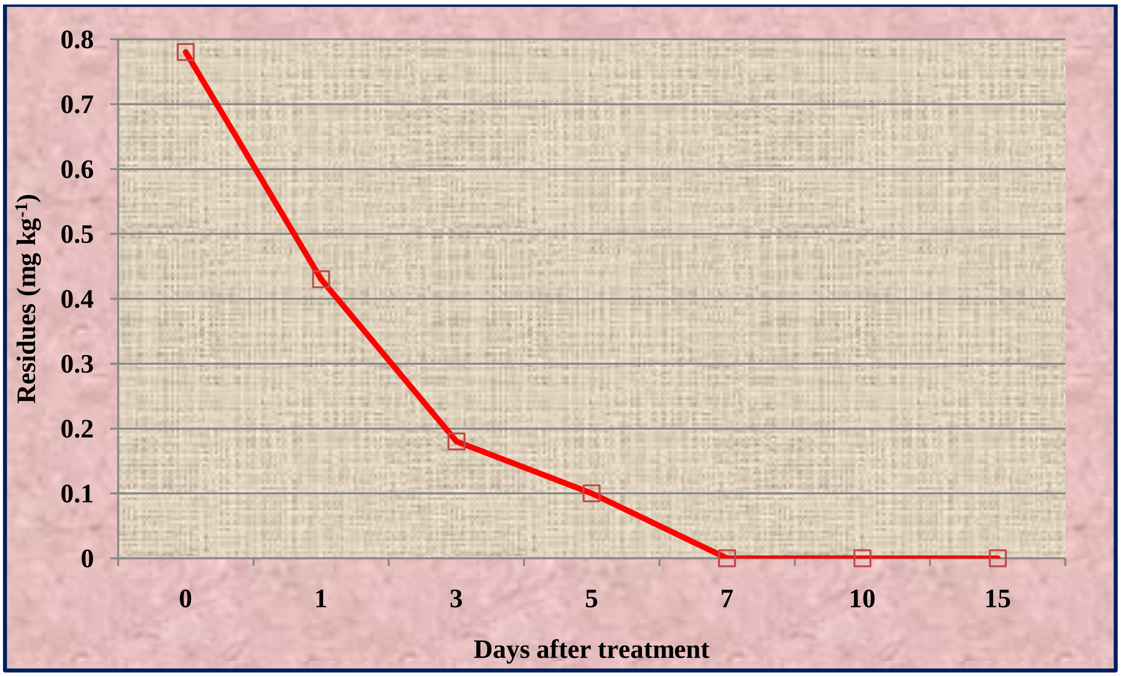

Fig. 4.5. Dissipation kinetics of spinosad residues in chill after three sprays

Table 4.21. Dissipation pattern of imidacloprid (imidacloprid + beta cyfluthrin 300% OD@ 30g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of imidacloprid (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	1.06	1.14	1.10	1.10	--
1	0.75	0.93	0.86	0.85	22.73
3	0.32	0.31	0.33	0.32	70.90
5	0.10	0.09	0.07	0.09	91.82
7	BDL	BDL	BDL	BDL	100.00
10	BDL	BDL	BDL	BDL	100.00
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 1.045 + (-0.140) X				
R^2	0.988				
MRL (As per FSSAI) mg kg^{-1}	0.3				
Waiting period (days)	11.05				

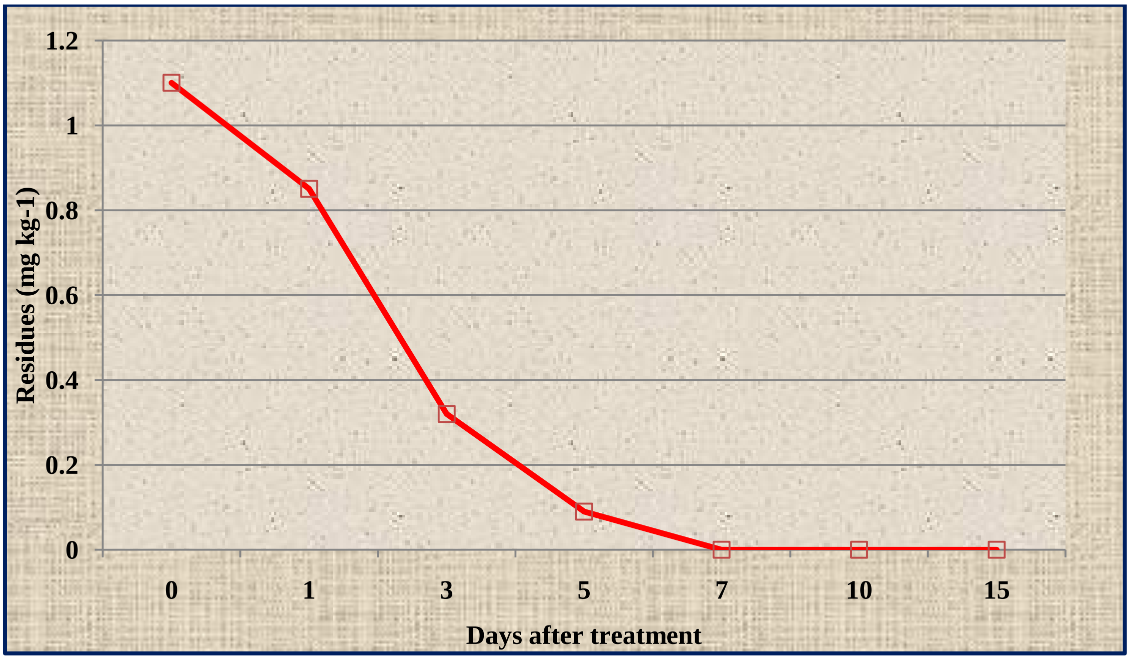

Fig. 4.9. Dissipation kinetics of imidacloprid residues in chili after three sprays

Table 4.18.Dissipation pattern of chlorantraniliprole 20% SC (30 g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of chlorantraniliprole (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	0.54	0.59	0.55	0.56	--
1	0.33	0.28	0.31	0.31	44.64
3	0.18	0.18	0.16	0.17	69.64
5	0.07	0.06	0.06	0.06	89.28
7	BDL	BDL	BDL	BDL	100.00
10	BDL	BDL	BDL	BDL	100.00
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 0.481 + (-0.091) X				
R^2	0.891				
MRL (As per FSSAI) mg kg^{-1}	0.03				
Waiting period (days)	21.98				

Fig. 4.6. Dissipation kinetics of chlorantraniliprole residues in chilli after three sprays

Table 4.22.Dissipationpattern of beta cyfluthrin (imidacloprid + beta cyfluthrin 300% OD@ 30g a.i ha^{-1}) in chilli after three sprays

Days after last spray	Residues of beta cyfluthrin (mg kg^{-1})				Dissipation %
	R1	R2	R3	Average	
0	0.27	0.30	0.28	0.28	--
1	0.18	0.16	0.15	0.16	42.86
3	0.06	0.08	0.06	0.06	78.57
5	BDL	BDL	BDL	BDL	100.00
7	BDL	BDL	BDL	BDL	100.00
10	BDL	BDL	BDL	BDL	100.00
15	BDL	BDL	BDL	BDL	100.00
Regression equation	Y = 0.26 + (-0.07) X				
R^2	0.942				
MRL (As per FSSAI) mg kg^{-1}	2.0				
Waiting period (days)	0.59				

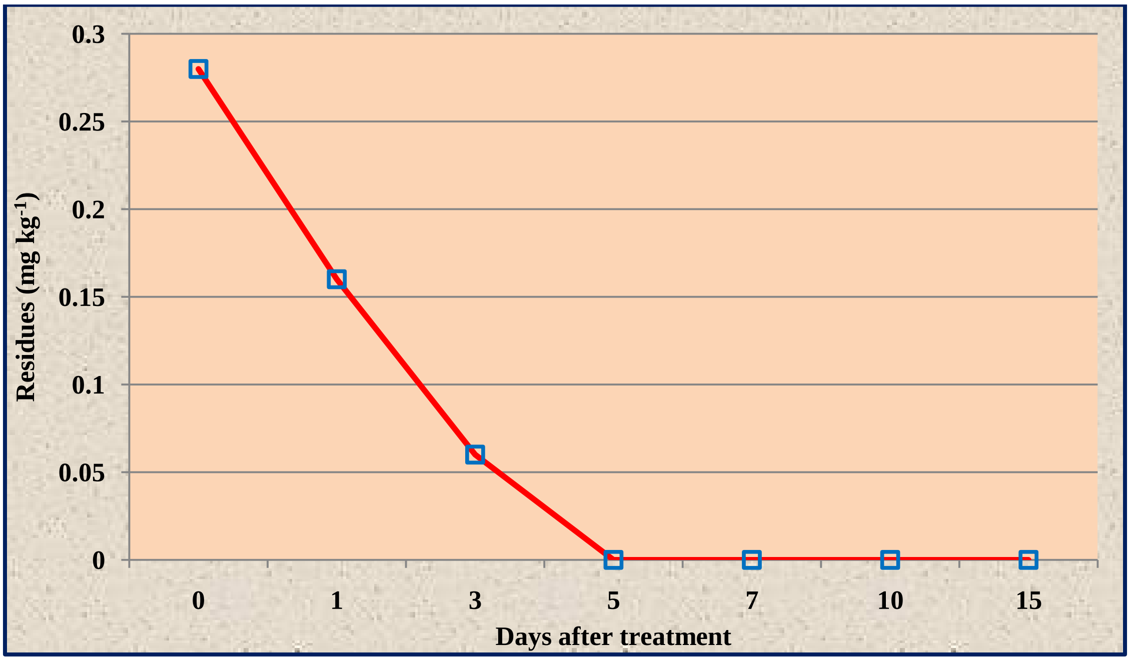

Fig. 4.10. Dissipation kinetics of beta cyfluthrin residues in chilli after three sprays

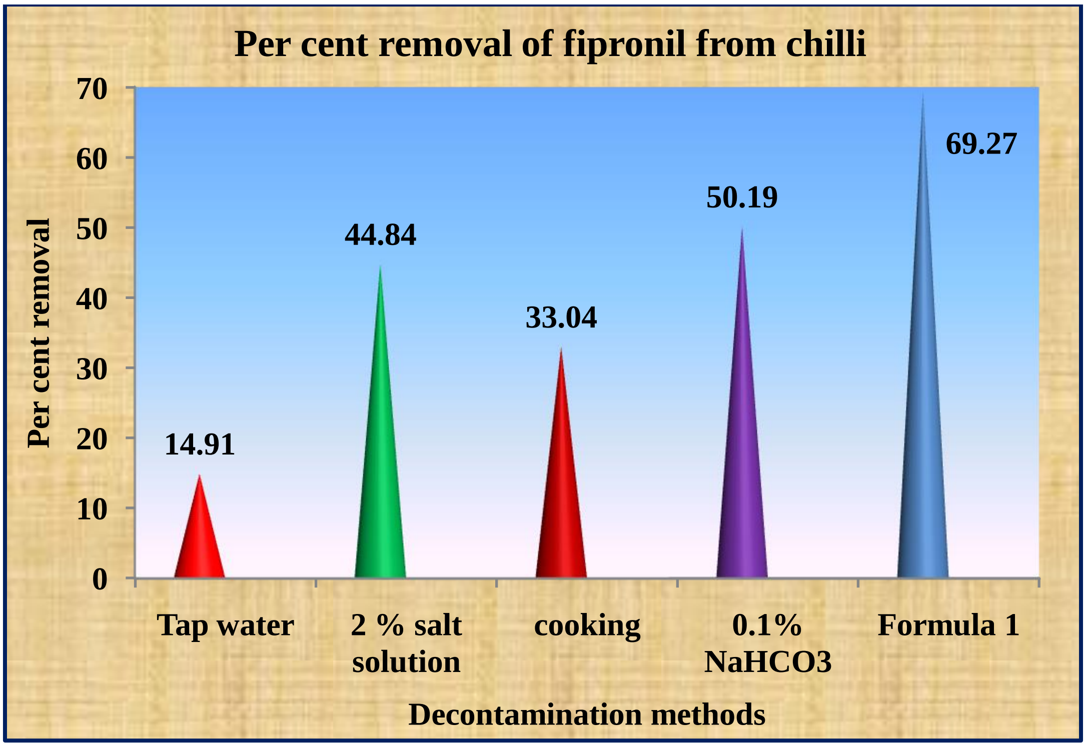

Fig. 4.12. Per cent removal of fipronil residues from chilli by various decontamination methods

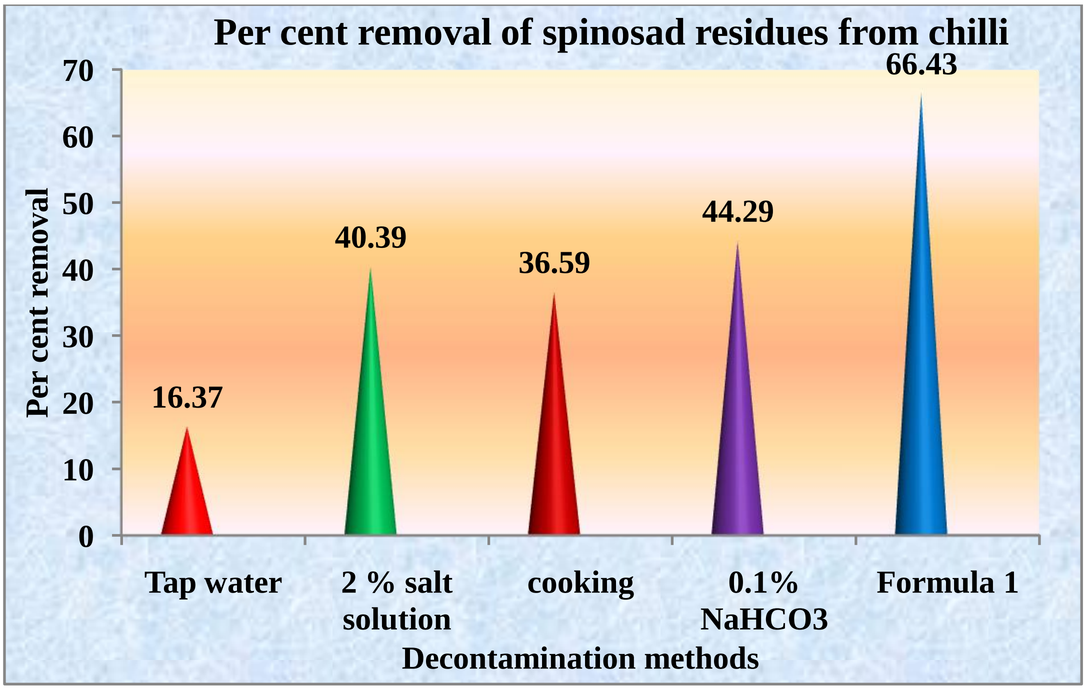

Fig.4.13. Per cent removal of spinosad residues from chilli by various decontamination methods

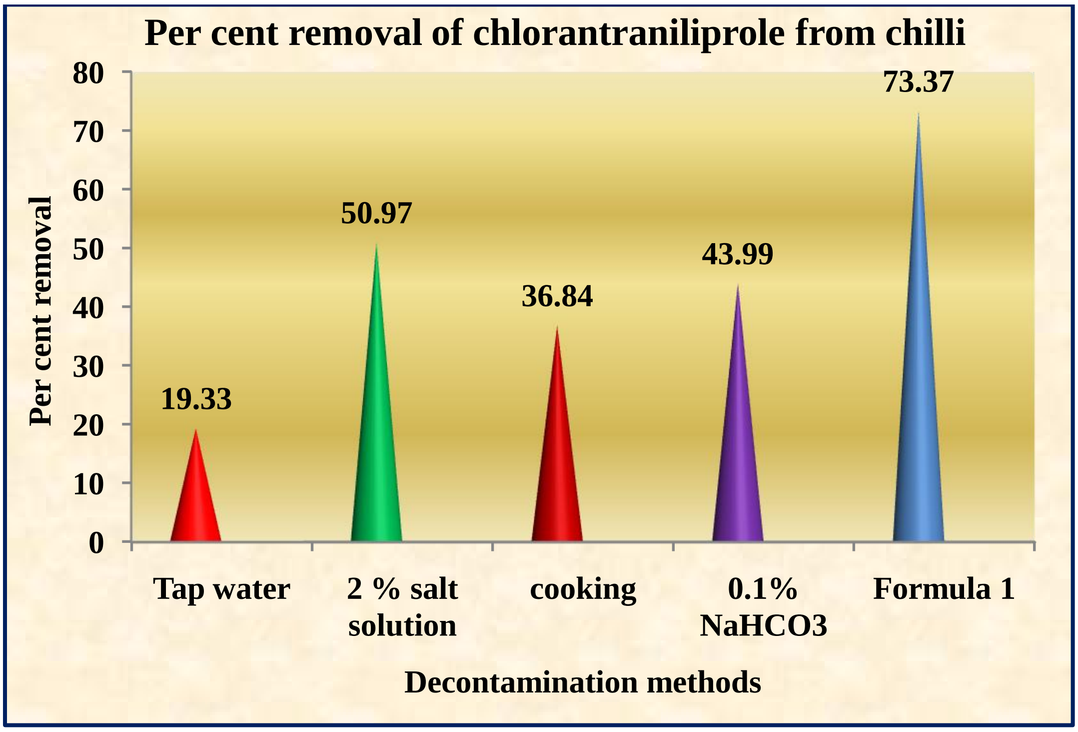

Fig. 4.14. Per cent removal of chlorantranili prole residues from chilli by various decontamination methods

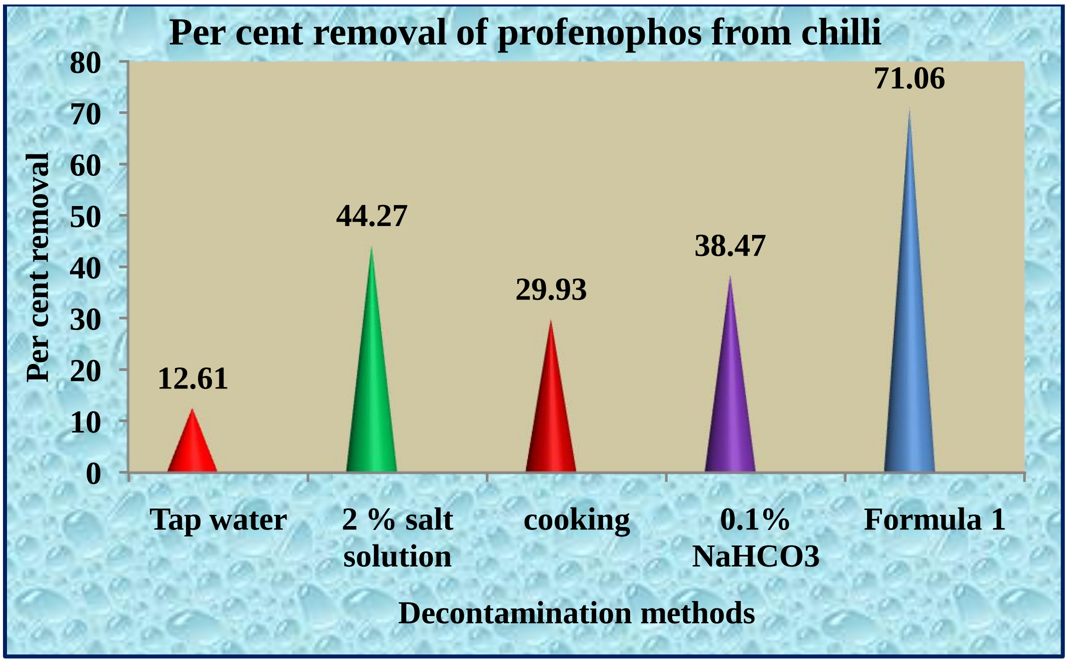

Fig. 4.15. Per cent removal of profenophos residues from chilli by various decontamination methods

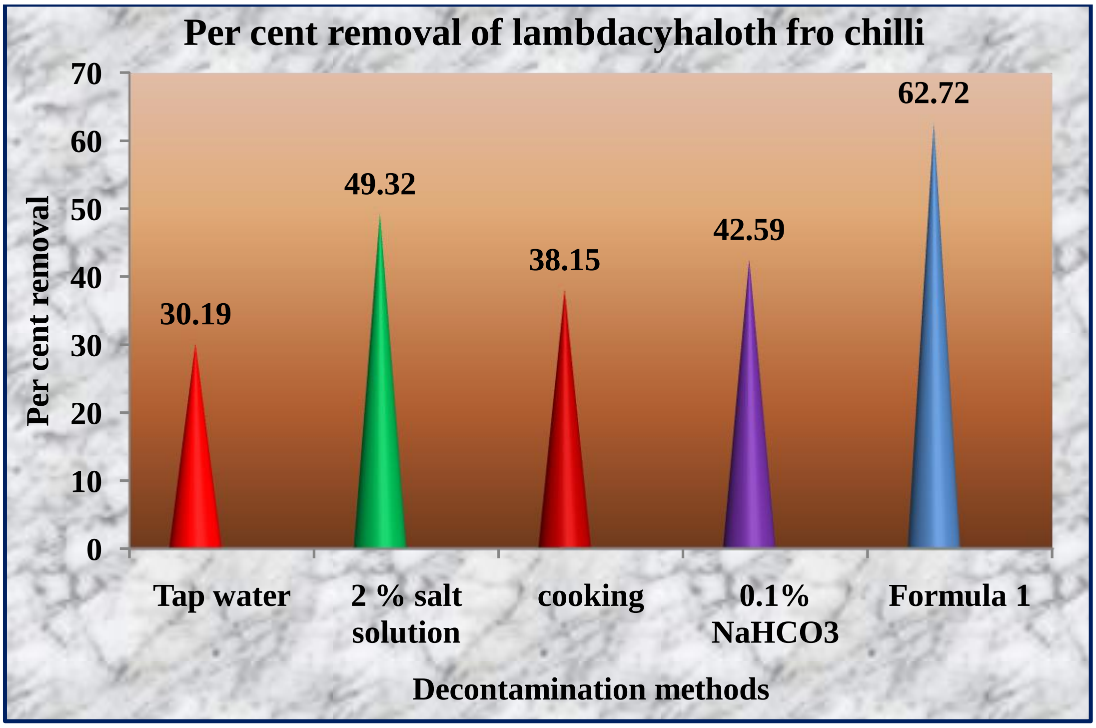

Fig. 4.16. Per cent removal of lambda cyhalothrin residues from chilli by various decontamination methods

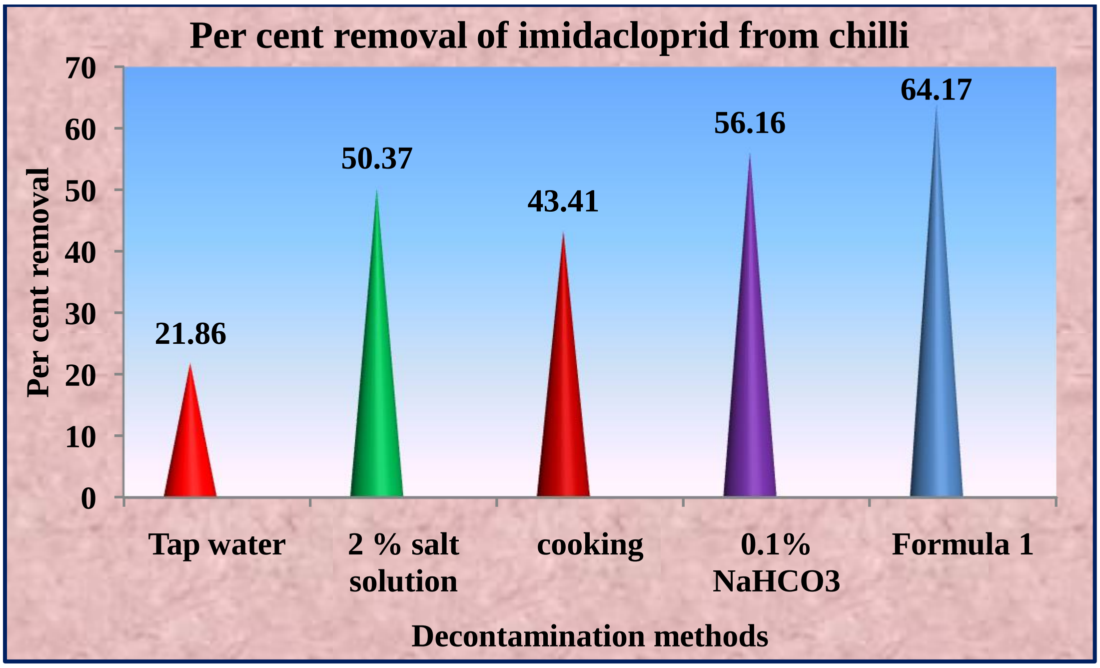

Fig. 4.17. Per cent removal of imidacloprid residues from chilli by various decontamination methods

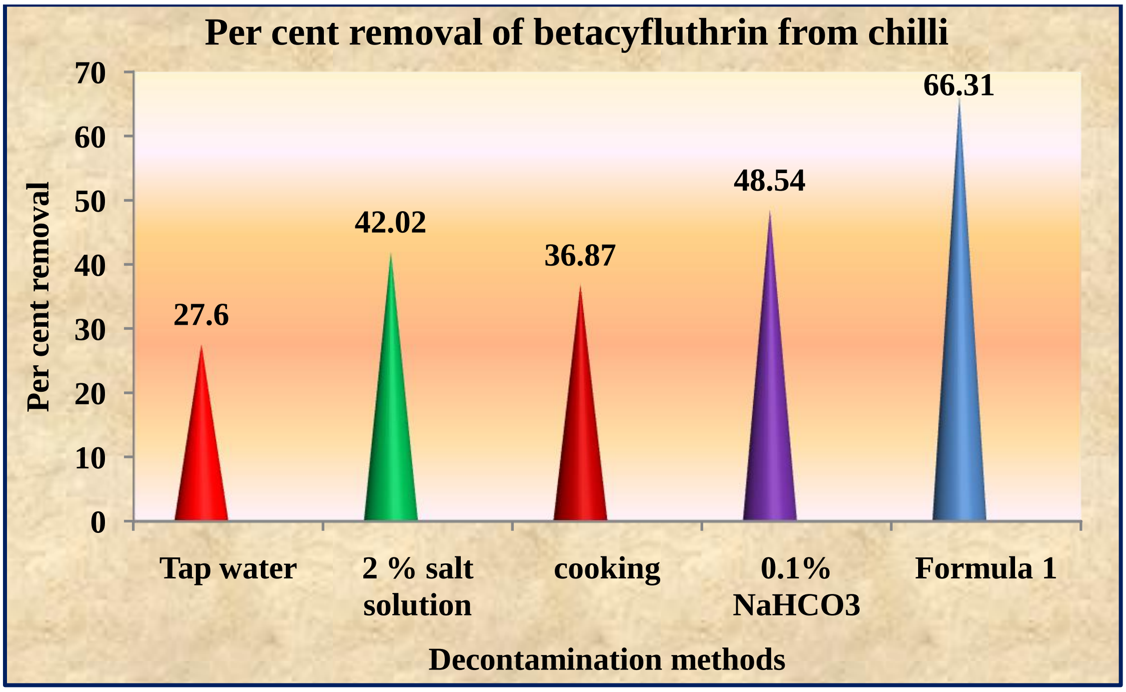

Fig. 4.18. Per cent removal of beta cyfluthrin residues from chilli by various decontamination methods

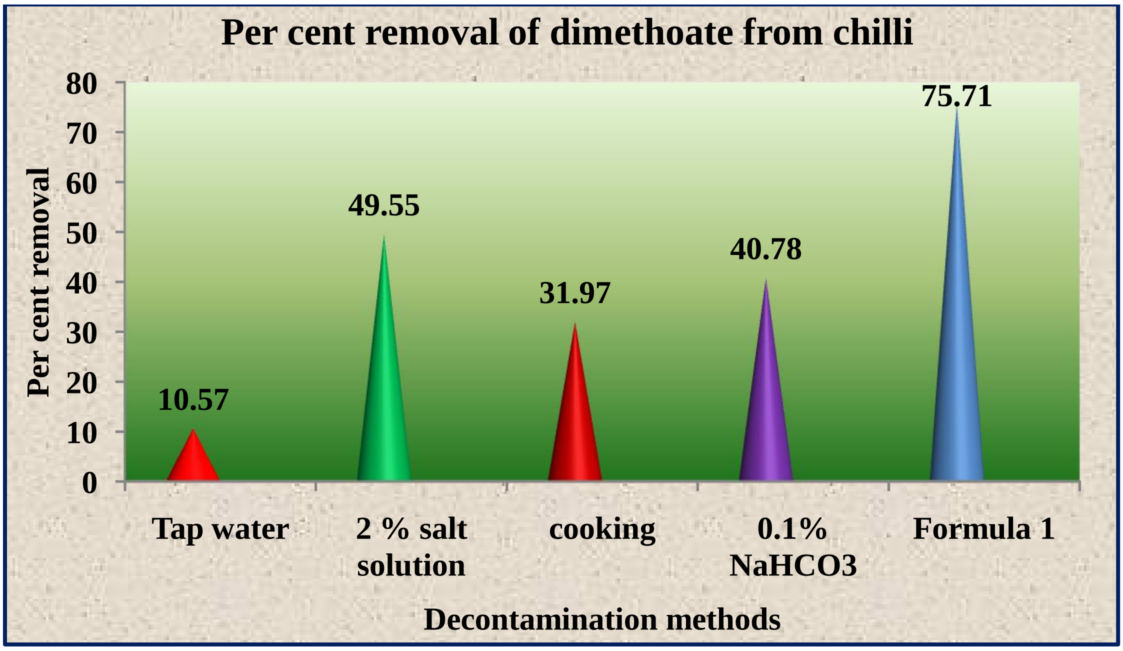

Fig. 4.19. Per cent removal of dimethoate residues from chilli by various decontamination methods

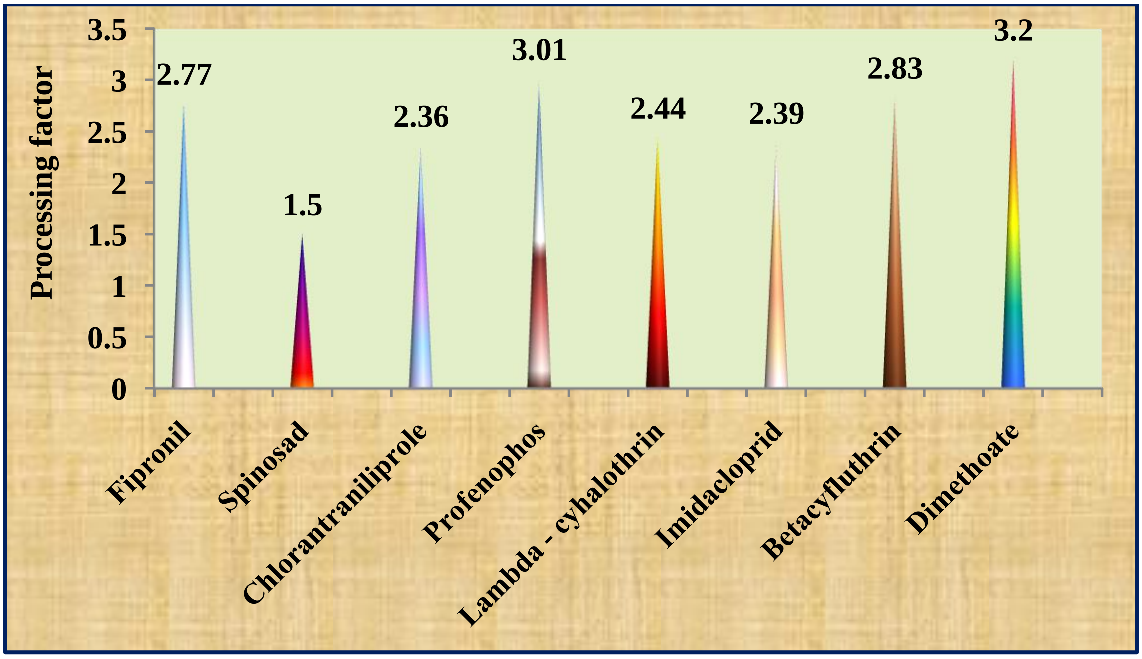

Fig. 4.20. Processing factor for selective insecticides in chilli

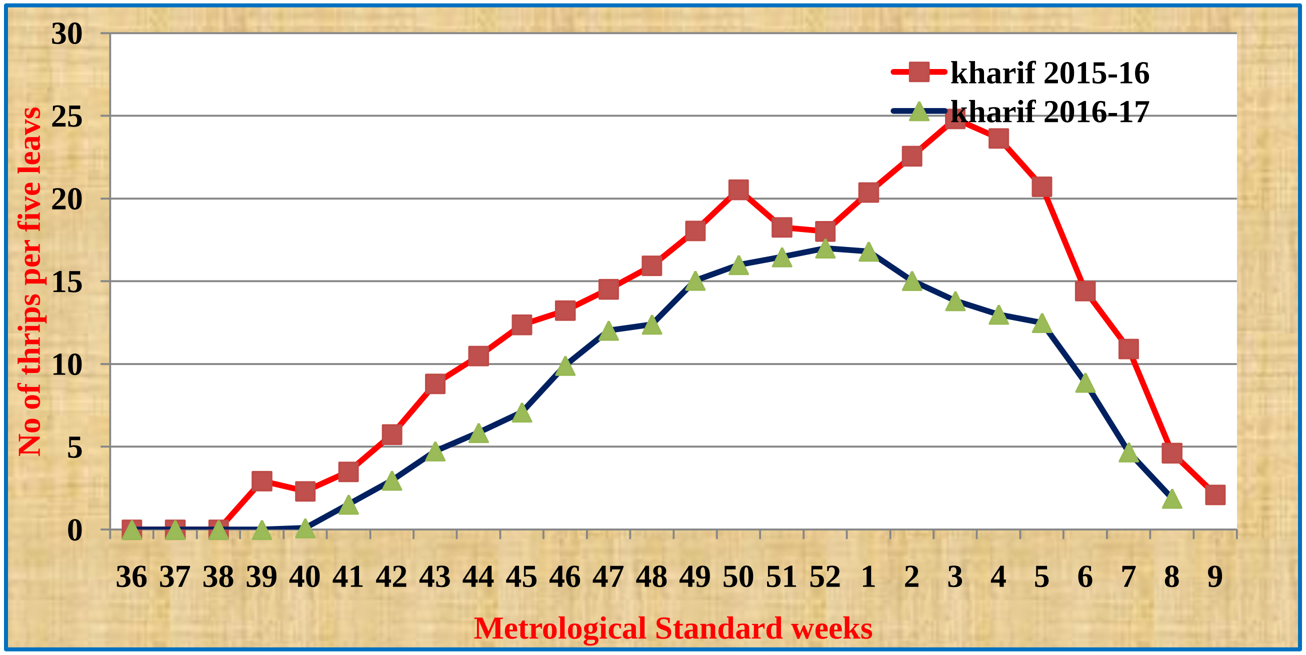

Figure 4.1.Seasonal incidence of *Scirtothrips dorsalis* on chilli during *kharif* 2015-16 and 2016-17

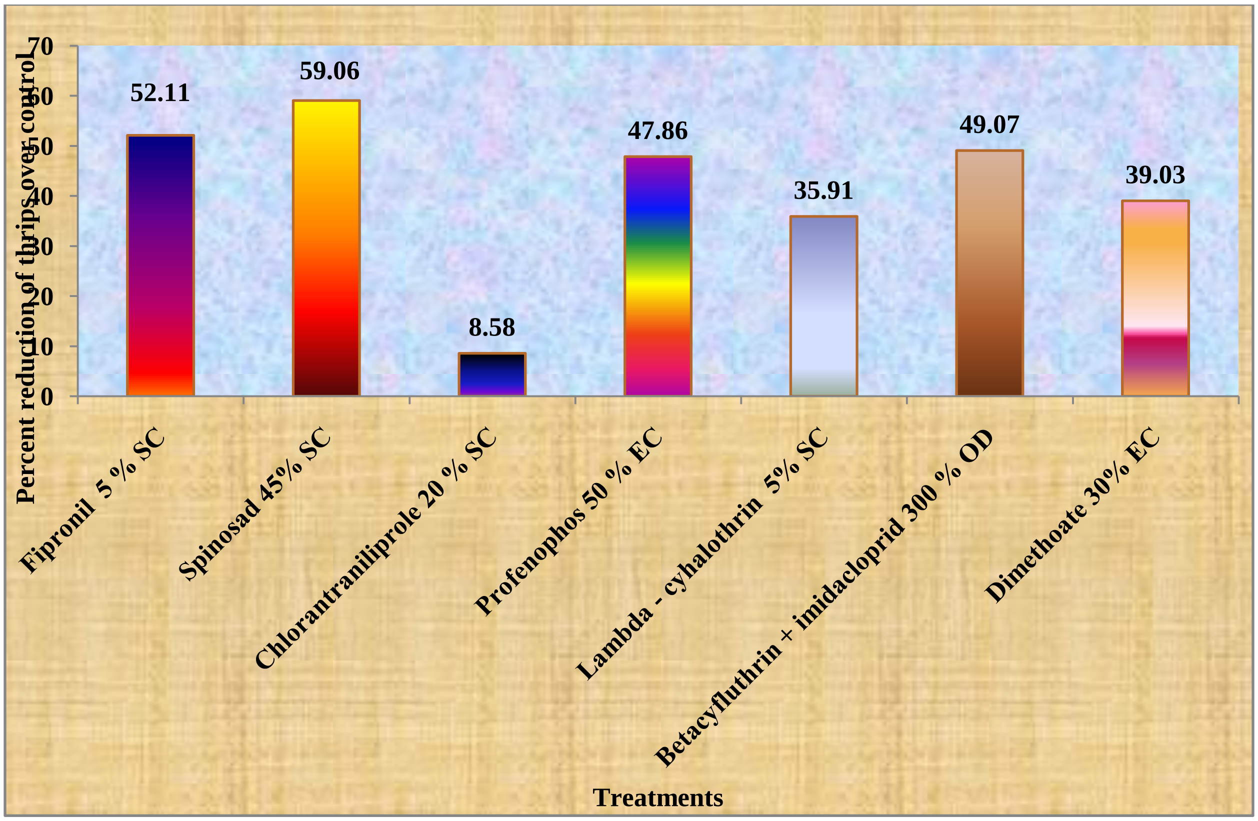

Fig. 4.2. Cumulative efficacy of different insecticides against *Scirtothrips dorsalis* on chilli during *kharif* 2015-16 and 2016-17 (Pooled data)

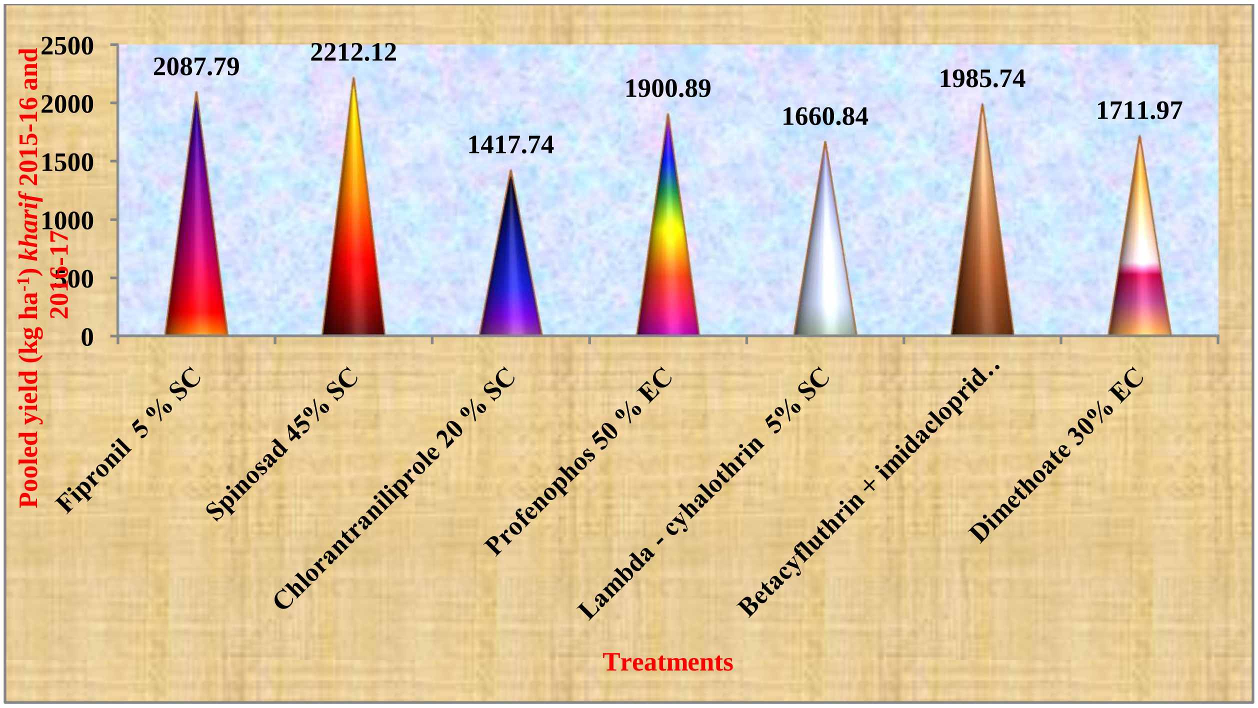

Fig. 4.3. Effectiveness of different insecticides on chilli yield (kg ha^{-1}) during *kharif* 2015-16 and 2016-17 (Pooled data)

Chapter V

SUMMARY AND CONCLUSIONS

The study entitled "Seasonal incidence, management of thrips and residue studies in chilli (*Capsicum annuum* L)" was conducted during *kharif* 2015-16 and 2016-17. The field studies on seasonal incidence and bioefficacy studies against chilli thrips was conducted at Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad during *kharif* 2015-16 and 2016-17, while laboratory studies on dissipation, decontamination and processing factor were carried out at All India Network Project on Pesticide Residues, Rajendranagar, Hyderabad during *kharif* 2015-16.

The studies on seasonal incidence of chilli thrips was carried out by raising 100 m^2 chilli crop without any plant protection measures in a non replicated trail with chilli variety LCA-334 during *kharif* 2015-16 and 2016-17. Observations were record from transplanting to harvest at weekly intervals on thrips population by recording absolute count on five randomly tagged plants with five terminal leaves of each plant. In turn this data was correlated and multiple regression equations were worked out between thrips population and weather parameters for both the years.

Similarly another field experiment was laid out in randomized block design with eight treatments including untreated control which was replicated thrice during *kharif* 2015-16 and 2016-17 at Horticulture Garden, College of Agriculture, Rajendranagar, Hyderabad.To study the efficacy of seven insecticides viz., fipronil 5% SC @ 500 g a.i ha^{-1}, spinosad 45% SC @ 125 g a.i ha^{-1}, chlorantraniliprole 20% SC @ 30 g a.i ha^{-1}, profenophos 50% EC @ 400 g a.i ha^{-1}, Lambda cyhalothrin 5% SC @ 15.63 g a.i ha^{-1}, imidacloprid + beta cyfluthrin 300% OD @ 30 g a.i ha^{-1} and dimethoate 30 % EC @ 300 g a.i ha^{-1} along with untreated control against, *S. dorsalis* on chilli.

Residue studies were conducted during *kharif* 2015-16 to establish dissipation pattern of fipronil 5% SC @ 500 g a.i ha^{-1}, spinosad 45% SC @ 125 g a.i ha^{-1}, chlorantraniliprole 20% SC @ 30 g a.i ha^{-1}, profenophos 50% EC @ 400 g a.i ha^{-1}, Lambda cyhalothrin 5% SC @ 15.63 g a.i ha^{-1}, imidacloprid + beta cyfluthrin 300% OD @ 30 g a.i ha^{-1} and dimethoate 30 % EC @ 300 g a.i ha^{-1} in green chillies. Samples were collected at 0, 1, 3, 5, 7, 10 and 15 days after third spray from the bioefficacy trail during *kharif* 2015-16. Samples were analyzed at All India Network Project on Pesticide Residues, Rajendranagar, Hyderabad.

The evaluation of decontamination methods for the removal of pesticide residues was carried out by collecting zero day samples after third spray from the bioefficacy trail during *kharif* 2015-16 from different treatments in large quantities and made into six sets and each with four replications. One set of sample from each treatment was analyzed for deposits of the pesticide and remaining sets of samples of zero day from each treatment samples were subjected to various decontamination methods.

The experiment on determination of the processing factor for selective insecticides in chillies was carried out by spraying fipronil 5% SC @ 500 g a.i ha^{-1}**,** spinosad 45% SC @ 125 g a.i ha^{-1}**,** chlorantraniliprole 20% SC @ 30 g a.i ha^{-1}**,** profenophos 50% EC @ 400 g a.i ha^{-1}**,** Lambda cyhalothrin 5% SC @ 15.63 g a.i ha^{-1}, imidacloprid + beta cyfluthrin 300% OD @ 30 g a.i ha^{-1} and dimethoate 30 % EC @ 300 g a.i ha^{-1} and control (water spray) were sprayed at red chilli stage of the crop and samples were collected immediately after spray. The insecticide residues were estimated from the fresh samples and shade dried and powdered red chilli samples from each treatment and processing factor was worked out.

The results on the seasonal incidence of chilli thrips revealed that the incidence was recorded from fourth week of September during 39th standard week to 9th standard week in *kharif* 2015 – 16. The highest thrips population were recorded during January 3rd week (3rd standard week) with 24.82 thrips per five leaves. During *kharif* 2016-17 the population of thrips increased gradually from first week of October (40th standard week) to 8th standard week and highest thrips population were recorded during December last week (52nd std. week) with 17.01 thrips per five leaves.

The relationship between the thrips population with preceding one week (one week lag) weather parameters during *kharif* 2015-16 revealed that there were a significant negative correlation was observed between weather parameters of maximum temperature (-0.51**), minimum temperature (-0.80**), mean temperature (-0.87**), rainfall (-0.55**), rainy days (-0.59**) at 1% level of significance. During *kharif* 2016-17, maximum temperature (-0.59**), minimum temperature (-0.83**), evening relative humidity (-0.66**), rainfall (-0.59**), rainy days (-0.67**) and mean temperature (-0.87**) were negatively significant with the thrips population at 1% level of significance.

Multiple regression equations developed for the thrips population with preceding one week weather parameters (one week lag) during *kharif* 2015-16 and 2016-17 revealed that all the weather parameters collectively influenced the thrips population to the extent of 93.92 and 92.65 per cent, respectively.

The cumulative efficacy of different insecticides during *kharif* 2015-16 and 2016-17 revealed that spinosad at 125 g a.i. ha^{-1} was found to be most effective treatment in reduction of *Scirtothrips dorsalis* population over control (59.09%) and was significantly different from other treatments. The next effective treatments were fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, dimethoate at 300 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1} and chlorantraniliprole at 30 g a.i. ha^{-1} with 52.11, 49.07, 47.86, 39.03, 35.91 and 8.58 per cent, respectively in reducing the population of *Scirtothrips dorsalis* over control. The cumulative yield during *kharif* 2015-16 and 2016-17 reveald highest chilli yield (kg ha^{-1}) was recorded from spinosad at 125 g a.i. ha^{-1} (2212.12) followed by fipronil at 500 g a.i. ha^{-1} (2087.79), betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} (1985.74), profenophos at 400 g a.i. ha^{-1} (1900.89), dimethoate at 300 g a.i. ha^{-1} (1711.97), lambda cyhalothrin15.63 g a.i. ha^{-1} (1600.84) and chlorantraniliprole at 30 g a.i. ha^{-1} (1417.74).

Initial deposits of fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} after three sprays were 1.47, 0.78, 0.56, 2.60, 1.20, 1.10, 0.28 and 3.86, respectively after third spray in chilli which dissipated to below detectable level at 15, 7, 7, 10, 7, 7, 5 and 15 days, respectively.

The waiting period determined for fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} after third spray in chilli were 36.34, 28.81, 21.98, 5.60, 11.16, 11.05, 0.59 and 6.64 days, respectively.

The highest removal of all insecticides from green chillies were obtained from the treatment Formula 1 (4 % Acetic Acid + 0.1% $NAHCO_3$ + 1 Lemon) ranging from

62.72 to 75.71 per cent followed by 2% salt solution in chlorantraniliprole, profenophos, lambda cyhalothrin and dimethoate, while 0.1% baking soda solution was found more effective than 2% salt solution in fipronil, spinosad, imidacloprid and beta cyfluthrin and least removal of all insecticides from green chillies was recorded from tap water wash which ranged from 10.57 to 30.19 per cent.

The processing factor determined in red chilli powder for the test insecticides *viz.,* fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} were 2.77, 1.50, 2.36, 3.01, 2.44, 2.39, 2.83 and 3.20, respectively.

Conclusions:

Based on the results obtained from the "Seasonal incidence, management of thrips and residue studies in chilli (*Capsicum annum* L)" the following conclusions were drawn.

- During both the seasons of investigation *viz., kharif* 2015-16 and 2016-17, incidence of *S. dorsalis* was observed from transplanting to harvesting stage.
- The highest thrips incidence was recorded on January 3rd week (3rd standard week) in *kharif* 2015-16 and December last week (52nd std. week) in *kharif* 2016-17.
- The relationship between thrips population were significant negative correlation with maximum temperature, minimum temperature, mean temperature, rainfall, rainy days during *kharif* 2015-16 and 2016-17.
- All the insecticidal treatments tested against chilli thrips were found to be superior over untreated control.
- Spinosad at 125 g a.i. ha^{-1} followed by fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} were found to be effective in checking population of *Scirtothrips dorsalis* in chillies.

- Highest chilli yield was obtained from spinosad at 125 g a.i. ha^{-1} followed by fipronil at 500 g a.i. ha^{-1}, betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1} and profenophos at 400 g a.i. ha^{-1} in chilli.

- The waiting period for safe harvest of chilli when sprayed thrice with fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} were 36.34, 28.81, 21.98, 5.60, 11.16, 11.05, 0.59 and 6.64 days, respectively.

- Treating chillies in Formula 1 for 10 min followed by washing under tap water gave very efficient removal compared to other methods, besides good old practice of 2% salt solution which can also removes residues to an extent of 40.39 -50.97% depending on the type of pesticide.

- The processing factor determined in red chilli powder for the test insecticides *viz.,* fipronil at 500 g a.i. ha^{-1}, spinosad at 125 g a.i. ha^{-1}, chlorantraniliprole at 30 g a.i. ha^{-1}, profenophos at 400 g a.i. ha^{-1}, lambda cyhalothrin15.63 g a.i. ha^{-1}, imidacloprid (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}), betacyfluthrin (betacyfluthrin + imidacloprid at 30 g a.i. ha^{-1}) and dimethoate at 300 g a.i. ha^{-1} were 2.77, 1.50, 2.36, 3.01, 2.44, 2.39, 2.83 and 3.20, respectively.

Future thrust:

- The continuous study on seasonal incidence of thrips is necessary due to variation in the agro climatic conditions of different regions and environmental factors play an important role in determining the seasonal abundance and damage caused by thrips. This data can be used in simulation modeling and forecasting of thrips incidence in chilli.

- In the present investigation few pesticides were tested for efficacy studies. There is a tremendous scope to test different new insecticides either alone or in combination to find out their efficacy against thrips.

- For different new test insecticides assessment of safe waiting periods necessary.

- These studies can be carried out for all the pests of chilli having local importance.

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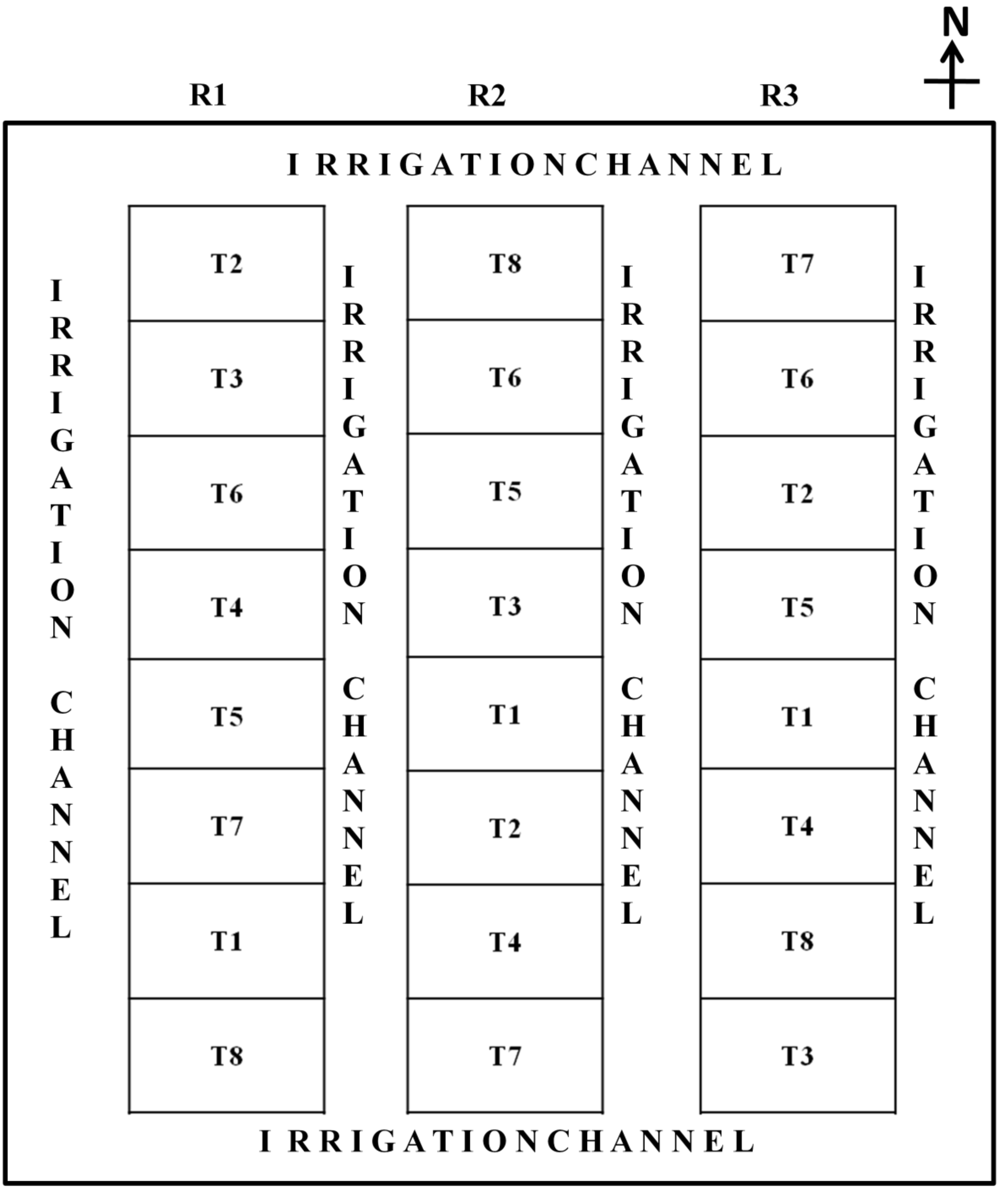

Fig. 3.1. Layout of the experimental field

T_1 - Fipronil 5% SC

T_2 - Spinosad 45% SC

T_3 - Chlorantraniliprole 20% SC

T_4 - Profenophos 50% EC

T_5 - Lambda Cyhalothrin 5% SC

T_6 - Imidacloprid + Beta Cyfluthrin 300% OD

T_7 - Dimethoate 30 % EC

T_8 – Control (Water Spray)

Plate 1.a. Open field trial view during *kharif* 2015-16

Plate 1.b. Open field trial view during *kharif* 2016-17

Plate 2. Over view of Gas Chromatograph

Plate 3. Over view of HPLC

Plate 4. Flow chart of QuEChERS method

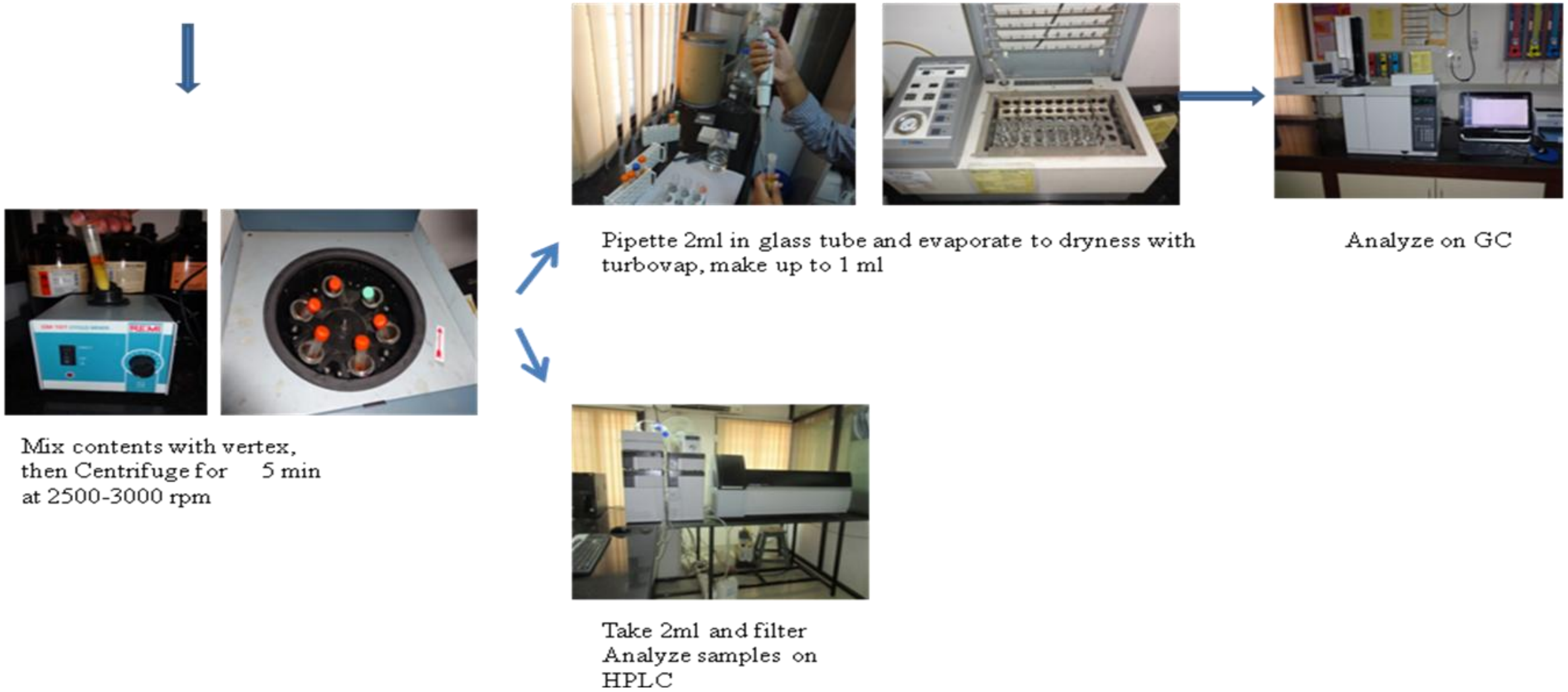

Plate 4 (cont.). Flow chart of QuEChERS method