"EVALUATION OF SOME NEWER INSECTICIDES AGAINST *Helicoverpa armigera* Hub. AND THEIR RESIDUES IN PEA (*Pisum sativum* L.)"

by

Mr. Mahesh G Koulagi
(Reg. No. 2021/160)

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

In partial fulfilment of the requirements

for the degree of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI
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CANDIDATE'S DECLARATION

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

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

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Date : / /2023

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Place : MPKV, Rahuri

Date : / /2023 **(Mahesh G Koulagi)**

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LIST OF ABBREIVATIONS AND SYMBOLS

-	: Minus
%	: Percentage
/	: Per
@	: At the Rate of
+	: Plus
<	: Less than
=	: Equal to
µl	: Microliter
^{0}C	: Degree Celsius
a.i.	: Active Ingredient
AINP	: All India Network Project on Pesticide Residues
B:C Ratio	: Benefit to Cost Ratio
BQL	: Below Quantification Limit
C.D	: Critical Difference
cm	: Centimeter (S)
DAS	: Days After Spraying
DT_{50}	: Dissipation Time/ Half Life
EC	: Emulsifiable Concentrate
et al.	: etc. all (and others)
Fig.	: Figure
FSSAI	: Food Safety and Standards Authority of India
G	: Gram (S)
G	: Granules (S)
ha	: Hectare (S)
HPLC	: High Performance Liquid Chromatography
hrs.	: Hours (S)
i.e.	: That is
ICBR	: Incremental Cost Benefit Ratio
Kg	: Kilogram (S)

LOD	: Limit of Detection
LOQ	: Limit of Quantification
m	: Meter (S)
mg	: Milligram
ml	: Milliliter
MPKV	: Mahatma Phule Krishi Vidyapeeth
MRL	: Maximum Residue Limit
N.D.	: Not Detected
N.S.	: Non Significant
No.	: Number
PHI	: Pre Harvest Interval
ppm	: Parts Per Million
PSA	: Primary Secondary Amine
q	: Quintal (S)
QuEChERS	: Quick, Easy, Cheap, Rugged and Safe
RBD	: Randomized Block Design
R_f	: Retention Factor
RH	: Relative Humidity
Rs	: Rupees (S)
RSD	: Relative Standard Deviation
S. E	: Standard Error
SC	: Suspension Concentrate
S. D	: Standard Deviation
SG	: Soluble Granule
t	: Tonnes
Via	: Through
Viz.	: *Videlicet* (Namely)
WP	: Wettable Powder
Wt.	: Weight
L	: Liter (S)

ABSTRACT

"EVALUATION OF SOME NEWER INSECTICIDES AGAINST *Helicoverpa armigera* Hub. AND THEIR RESIDUES IN PEA, (*Pisum sativum* L.)"

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2023

Research Guide	**:**	**Dr. B. V. Deore**
Department	**:**	**Agricultural Entomology**

An investigation entitled "Evaluation of some newer insecticides against *Helicoverpa armigera* Hub. and their residues in pea, (*Pisum sativum* L.)" was undertaken at Instructional Farm and AINP on Pesticide Residues, Department of Agril. Entomology, Post Graduate Institute, M.P.K.V.,Rahuri.

Samples of pea collected from local markets of Akole (Ahmednagar), Narayangoan (Pune), Phaltan (Satara) were analysed for residues following the validated QuChERS multiresidue method. Out of 75 samples, 67 samples did not record detectable residues and 08 samples were recorded with insecticide residues. None of the samples were recorded with insecticide residues above MRL values prescribed by FSSAI. Dimethoate (08 samples) was detected in all the positive samples from all three locations. The range of dimethoate residues was 0.02 mg/kg to 0.09 mg/kg.

The field experiment on evaluation of insecticides *viz.,*spinosad 45% SC @ 0.3 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, flubendiamide 39.35% SC @ 0.2ml/l, *Bacillus thuringiensis var kurstaki* @ 1.5 ml/l, azadirachtin 10000 ppm @ 1 ml/l, and chlorantraniliprole 18.5% SC @ 0.3 ml/l was conducted in Randomized Block Design with three replications during *rabi*-2022-23. Observations were recorded on five randomly selected plants in each replication. Total two sprays were given at 15 days interval starting first spray at pod initiation stage. Considering the performance of different treatments, chlorantraniliprole was proved to be highly effective by recording lowest per cent of pod damage and reduction in pod damage over control (7.62% & 70.34% on number basis and 6.36% & 76.77% on weight basis**)**, the data was at par with flubendiamide by registering 7.79% pod damage and 69.68% reduction in pod damage

Abstract contd…. **Mr. Mahesh G Koulagi**

over control (on number basis) and 6.54% pod damage & 76.11% reduction in pod damage over control (on weight basis). Spinosad (8.40% pod damage & 69.32% reduction over control), azadirachtin (12.38% pod damage & 51.81% reduction over control), *Beauveria bassiana* (12.72% pod damage & 50.48% reduction over control), *Bacillus thuringiensis var kurstaki* (13.01% pod damage & 49.36% reduction over control) were next to follow in the order of effectiveness.

The efficacy of chlorantraniliprole and flubendiamide was also reflected in the yield. Highest yield of 11.90 t/ha reported in the treatment chlorantraniliprole 18.5% SC and this was at par with flubendiamide 39.35% SC with yield of 11.46 t/ha and ICBR ratios were 1:25.68 & 1:25.51 respectively for the treatments chlorantraniliprole 18.5% SC and flubendiamide 39.35% SC. Highest incremental cost benefit ratio (ICBR) was obtained from *Beauveria bassiana* (1:41.80).

Studies on dissipation pattern of flubendiamide 39.35% SC @ 48 and 60 g a.i./ha and chlorantraniliprole 18.5% SC @ 30 and 37.5 g a.i./ha was undertaken by following two applications of each insecticide separately at both doses at an interval of fifteen days starting 1st application at pod initiation stage. The results were revealed that initial residues of flubendiamide (0.05 and 0.06 mg/kg) reached below quantification limit on 1st day. In case of chlorantraniliprole initial residues (0.08 and 0.09 mg/kg) reached below quantification limit on 3rd day at both doses. Half-life values for chlorantraniliprole were 1 47 and 1.71 days at recommended and 1.25X of recommended doses, respectively.

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1. INTRODUCTION

Vegetables are very useful for the maintenance of human health and are important part of a balanced diet providing many essential minerals and vitamins (Walia *et al*. 2010). Higher intake of vegetables is associated with healthier lives including lowering the risks of cancer, cardiovascular diseases, and obesity. Among the vegetables, pea (*Pisum sativum* L.) is important herbaceous annual crop in leguminaceae family which is majorly grown in temperate climates, and it is categorised into field pea and garden pea. Garden pea is suited for cooler seasons, typically cultivated in winter in plains and during summer in hilly areas (Mohan *et al.,* 2013).

In India, it is grown in an area of 0.64 million ha with a production of 0.88 MT and productivity is 1375 kg/ha. It is grown in all states of the country during the *rabi* season (Singh *et al.,* 2001). The major pea producing states in India are Uttar Pradesh, Madhya Pradesh, Punjab, Himachal Pradesh, Orissa, Karnataka, Maharashtra, Haryana, *etc*. Uttar Pradesh is the leading state in both area (361.00 thousand ha) and production (562.00 thousand tonnes), Madhya Pradesh is following closely with area of 86.00 thousand ha and production of 90.00 thousand tonnes, respectively. Himachal Pradesh has the highest productivity (25.72 q/ha) which trailed by Rajasthan with productivity of 24.34 q/ha (Anonymous, 2022).

Pea crop is patronised throughout the world because of its taste, nutritive value, fast growth, and high yield. It is utilized as a nutritious vegetable for the luscious green seeds, succulent green pods, and dried seeds. It can be consumed either fresh, canned, pulse, frozen, or in dehydrated forms (Ibrahim *et al.,* 2020). It is known to have essential amino acids such as tryptophan and lysine that are scarce in cereals (McPhee, 2003). It contains 35 to 50 per cent starch, 18 to 30 per cent protein, 4 to7 per cent crude fibre, 1.2 per cent fats and minerals like calcium, iron and vitamins like riboflavin, thiamine and niacin (McPhee, 2003; Abhilasha and Shekharappa, 2017). Dry peas are also suitable as fodder for meat production due to their low levels of trypsin activity, amino acid composition, and high digestibility. Cooked green peas are a rich source of proteins. Fresh green pea seeds contain 17 to 22 g carbohydrates, 20 to 50 g starch, 14 to 26 g dietary fibre, 6.2 to 6.5 g protein, 0.4 g fat, 1.0 g ash per 100 g with 9 to 10 mg calcium, 3 to 5 mg sodium, 97 to 99 mg potassium per 100 g and vitamin contents are 0.7 mg riboflavin, 5 to 6 mg thiamine and foliate 0.54 mg/kg (Kumari and Deka, 2021).

This crop is the leading remunerative off-season cash crop in high and mid hill areas of different countries. The crop is susceptible to various insect like pod borers [*Etiella zinckenella* Tr. and *Helicoverpa armigera* (Hub.)], stem fly (*Melanagromyza phaseoli* Tyron), leaf miner (*Chromatomyia horticola* Goureau), aphid (*Acyrthosiphon pisum*) and thrips (*Caliothrips indicus* Bagnall). The pod borer, *Helicoverpa armigera* (Hub.) is one of the serious insect pests affecting vegetable peas during the flowering and pod stages can inflict severe damage to the crop, making them a significant constraint in vegetable pea production (Vaibhav *et al.,* 2018). *H. armigera* completes its life cycle (from egg to adult) in 4 to 5 weeks at an average temperature of 28^0 C. A female moth can lay up to 500-600 eggs. Eggs are generally laid on leaves, pods, and flowers. First to third instar larvae generally feed on leaves, twigs, and flowers. In later stages, larger larvae shift to developing pods by making holes and consume entire developing seeds. Pod borers can cause yield losses up to 90 per cent depending upon the insect density and susceptibility of cultivars (Mahmood *et al.,* 2021).

These pests are managed by usage of pesticides, as the productivity of crops depends on the effective management strategy of these pests (Jeyanthi and Kombairaju, 2005). The national recommendation of pesticides by the Central Insecticide Board and Registration Committee (CIBRC) approved very few pesticides like monocrotophos 36% SL, malathion 50% EC and carbofuran 3% G *etc*. to manage leaf miners, pod borers, shoot flies, and aphids in pea (Anonymous, 2017). Even then, many non-approved pesticides are largely being used by the growers for enhancing the productivity and increasing the income as per the report of ICAR (Anonymous, 2015b) and it was stressed at the national level to conduct supervised field experiments of the non-approved pesticides *viz*. lambda-cyhalothrin, flubendiamide, chlorantraniliprole, imidacloprid and spiromesifen on garden pea for their recommendation by the CIBRC in order to extend their label claim by generating its persistence data for suggesting safe limits by the Food Safety and Standards Authority of India (FSSAI) (Gupta, 2018).

Though pesticides play a pivotal role in bringing about the green revolution in many countries of the world, their continuous and indiscriminate use induced health impacts besides contaminating cultivable soil. The chemicals used to kill insect pests are characterized by pronounced persistence against chemical/biological degradation, high environmental mobility, and a strong tendency for bioaccumulation in human and animal tissues. They have been linked to a broad range of human health issues, ranging from short-term effects like headaches and nausea to chronic impacts like cancer and reproductive harm. It is well recognized that the risks associated with the consumption of pesticide-treated crops lead to harmful residues in the consumer products and hence increasing the risk to consumer safety. Based on the recommendation of the Government of India funded project "Monitoring of pesticide residues at the national level", it has been decided to carry out multilocation supervised field experiments to fulfil the requirement of CIBRC from registration purpose so that MRLs of the non-approved pesticides should be fixed at the national level by the Food Safety and Standards Authority of India (FSSAI). Hence, it is necessary to generate data for fixation of its MRL in green peas to safeguard the interest of the consumer and possible health hazards (Gupta, 2018).

Many countries have established regular monitoring programs for quantitative determination of residues in food products (Reed *et al*., 1987) as pesticide residues above the maximum residue limits (MRL) at harvest time are a subject of great concern both globally and nationally. Surveys conducted by various institutions across the country have revealed that insecticide residues contaminate approximately 50 to 70% of vegetables (Karanth, 2002). The application of pesticides on any crop or product can result in the presence of residues at the time of harvest. The continuous intake of these residues, even in minimal quantities, can lead to their accumulation in the body, potentially resulting in adverse effects on human health. Therefore, understanding the nature and amount of chemicals, which persist in food commodities at the time of their consumption, is very important from public health perspective. By keeping all these points in view, the present study has been envisaged with the following objectives:

1. To monitor the insecticide residues in the market samples of pea
2. To evaluate the performance of some newer insecticides against pod borer in pea
3. To study the dissipation pattern of flubendiamide and chlorantraniliprole in pea

2. REVIEW OF LITERATURE

The literature pertaining to monitoring of insecticide residues in market samples of pea, performance of some newer insecticides against pod borer, *Helicoverpa armigera* Hub. in pea and dissipation pattern of flubendiamide and chlorantraniliprole in pea is reviewed and presented here under.

2.1 To monitor the insecticide residues in the market samples of pea

The literature pertaining to the monitoring of insecticide residues in peas is very scanty hence the results of the studies on monitoring of insecticides residues in other vegetables have been presented here.

Kumari *et al*. (2002) collected the market samples (60) of six seasonal vegetables and monitored during 1996–1997 to determine the magnitude of pesticidal contamination. The estimation of organochlorine, organophosphate, synthetic pyrethroid and carbamate group of insecticides was done by adopting a multiresidue analytical technique employing GC-ECD and GC-NPD systems with capillary columns. The result indicated that the tested samples showed 100% contamination with low but measurable amounts of residues. Among the four chemical groups, the organophosphate was dominant followed by organochlorine, synthetic pyrethroid and carbamate. About 23% of the samples showed contamination with organophosphorus compounds above their respective MRL values.

Iqbal *et al*. (2009) monitored insecticide residues in market samples of brinjal. The results indicated that imidacloprid, carbofuran and chlorpyriphos residues were in the range of 0 to 0.028 mg/kg, 0 to 0.034 mg/kg and 0 to 0.060 mg/kg, respectively. The residues of imidacloprid and carbofuran were below the maximum residue limits (MRL's) of 0.050 mg/kg for carbofuran and chlorpyriphos and 0.230 mg/kg for imidacloprid. The present research revealed that fresh brinjal samples from the studied area were contaminated and not suitable for consumption by public.

Latif *et al*. (2011) conducted a study to assess pesticide residues in vegetables in the Hyderabad region of Pakistan. The concentrations of six pesticides were determined in locally produced vegetables purchased from wholesale markets. A total of 200 samples of eight vegetables *viz*. cauliflower, green chilli, eggplant, tomato, peas, bitter gourd, spinach and apple were analysed for pesticide residues. The result showed that almost all samples were contaminated by pesticides, only 39 per cent of the contaminated samples contained pesticide residues were at or below MRLs, and 61 per cent samples contained pesticide residues above MRLs. From the six analysed pesticides, carbofuran and chlorpyrifos were found above MRLs with concentrations ranging from 0.01-0.39 and 0.05-0.96 mg/kg, respectively.

Srivastava *et al*. (2011) conducted a study on 20 vegetables *viz*, bitter gourd, jack fruit, french-bean, onion, colocasia, pointed gourd, capsicum, spinach, potato, fenugreek seeds, carrot, radish, cucumber, beetroot, brinjal, cauliflower, cabbage, tomato, okra, and bottle gourd. Forty-eight pesticides including 13 organochlorines (OCs), 17 organophosphates (OPs), 10 synthetic pyrethroids (SPs), and 8 herbicides (H) were analyzed. The result indicated that, out of 48, 23 pesticides in the range of 0.005–12.35 mg/kg were detected from the samples monitored. The detected pesticides were: HCH, Dicofol, Endosulfan, Fenpropathrin, Permethrin-II, β-cyfluthrin-II, Fenvalerate-I, Dichlorvos, Dimethoate, Diazinon, Malathion, Chlorfenvinfos, Anilophos, and Dimethachlor. In some vegetables like radish, cucumber, cauliflower, cabbage, and okra, the detected pesticides (HCH, Permethrin-II, Dichlorvos, and Chlorofenvinfos) were above maximum residues limit (MRL) (PFA 1954). However, in other vegetables the level of pesticide residues was either below detection limit or MRL.

Choudhury *et al*. (2013) analysed five market samples of each vegetable species *viz*., tomato, cabbage, cauliflower, brinjal, french bean, cow pea and okra for pesticide residues. The result indicated that contamination by OC group ranged from 0.001-0.004 mg/kg. The contamination by synthetic pyrethroid group ranged from 0.001-0.003 mg/kg. The highest contaminated sample was brinjal followed by cauliflower, cabbage and tomato. Among the organochloride compound the major contaminant was β-HCH followed by δ-HCH, α-HCH, P, P’-DDE and P, P’-DDT.

Sheikh *et al*. (2013) conducted a study to determine the pesticide residues in market samples of different vegetables. The result showed that seven vegetables namely okra, bitter gourd, brinjal, tomato, onion, cauliflower, and chilies, were heavily contaminated with chlorpyrifos, profenofos, endosulfan, imidacloprid, emamectin benzoate, lufenuron, bifenthrin, diafenthiuron, and cypermethrin. Moreover, every vegetable was contaminated with more than one pesticide and majority of samples violated the Japanese MRLs. Spinach, lettuce, bottle gourd, fenugreek, peas, and cluster bean are not sprayed with pesticides normally, but these were found contaminated with trace level residues within MRL(s).

Pujeri *et al*. (2015) conducted a study to investigate pesticide residues in vegetables collected from Vijayapur market, Karnataka. They analysed 40 residues in locally sold vegetables like cauliflower and cabbage. The result indicated that three (12%) out of 25 samples, contained residues of chlorpyrifos ethyl (MRL value = 0.05, 0.068, 0.093 and 0.11 mg/kg) in cauliflower and two (8%) out of 25 samples, contained residues of imidacloprid (MRL value = 0.046 and 0.079 mg/kg) in cabbage above MRL values.

Habib (2016) monitored the pesticide residues of seven organophosphorus pesticides (acephate, diazinon, dimethoate, malathion, fenitrothion, chlorpyrifos and quinalphos) in eggplant and cauliflower samples collected from different markets. The result indicated that, out of 50 samples, 9 samples (18%) contained pesticide residues and 41 samples (82%) contained no detectable residues of the sought pesticides. Among 10 samples of eggplant collected from Mirpur-1 area, 2 samples contained dimethoate at the level of 0.052 mg/kg and 0.132 mg/ kg respectively, which were above the MRL (0.02 mg/kg) set by the European Commission and another 2 samples contained chlorpyriphos at the level of 0.980 mg/kg and 0.470 mg/kg which were also above MRL (0.40 mg/kg) set by the European Commission.

Tasnim (2016) conducted an experiment to analyze pesticide residues in 3 common vegetables (country bean, cauliflower and yard long bean) from 5 different markets of Gazipur and Narsingdi. The result reported that out of 15 samples of country bean, 2 samples contained pesticide residues above MRL in Gazipur, whereas in Narsingdi, only 3 samples were above MRL and remaining samples were reported with no detectable residues of the sought pesticides. In case of cauliflower, 2 samples from each location contained pesticide residues above MRL and rest of the samples had no detectable pesticide residues. From 15-yard-long bean samples, pesticide residues above MRL were identified and quantified in 3 samples from each region. No pesticide residues were found in rest of the samples.

Alam (2017) conducted a study to analyse pesticide residues in three common vegetables (cauliflower, eggplant and yard long bean) collected from five local markets of Mymensingh (Bangladesh) during November 2017 to January 2018. The result indicated that out of 30 samples of cauliflower, 5 samples (17%) contained residues of dimethoate, chlorpyrifos and quinalphos, whereas 1 sample contained multiple residues and 3 samples contained residue above MRLs. Out of 30 samples of eggplant, 5 samples (17%) contained residues of chlorpyrifos, quinalphos, and dimethoate, whereas only one sample contained residue above MRL. On the other hand, out of 30 samples of yard long bean, 3 samples (10%) contained residue of quinalphos and 2 samples contained residues above MRL.

Fosu *et al*. (2017) conducted a study to monitor the pesticide residues in food commodities of plant like fruits and vegetables. A total of 3483 samples were purchased in notable markets within Accra Metropolis and analysed for pesticide residues, employing the modified QuEChERS procedure. The results indicated that almost all the fruits and vegetables had residues above MRLs. The commodities with the greatest concentrations exceeding the European Union (EU) MRLs were long green beans (60.6%) and lettuce (57.1%) whereas watermelon (10%) and green pepper (8.6%) having the least contamination. The relative occurrence of the pesticides was fenvalerate 11.3%, fenitrothion 5.6%, lambda cyhalothrin 3.6%, dimethoate 3.2%, permethrin 2.7% and deltamethrin 2.2%.

Parven (2017) conducted a study to analyse the pesticide residues in two common vegetables (country bean and yard long bean) collected from five different areas (Raja Bazaar, Gabtali Bazar, Sonatola Bazar, Mohasthangor Bazar and Shibganj Bazar) of Bogura District from November, 2017 to February, 2018 and analysed by using QuEChERS method. The result indicated that quinalphos and dimethoate were dominating in most of the contaminated country bean and yard long bean samples, while chlorpyrifos was also detected. Among the 35 analysed samples of country bean, 4 samples (11%) contained pesticide residues of quinalphos. Among these 4 samples, 2 had residues above the Maximum Residue Limit (MRL) and 2 had residues below the MRL set by European Commission. Similarly, out of 35 samples of yard long bean, 5 samples (14%) contained pesticide residues of chlorpyrifos, dimethoate and quinalphos. Among these 5 samples, 2 had residues above the MRL and 2 had residues below the MRL set by European Commission and 1 sample contained two pesticide residues such as dimethoate and chlorpyrifos. The level of detected dimethoate residue was above the MRL, while the level of detected chlorpyrifos residue was below the MRL in this contaminated sample.

Prapamontol *et al*. (2021) conducted a survey series on pesticide residues in vegetable and fruit samples sourced from markets in urban and rural areas of upper northern Thailand during 2007-2013. They collected 16 different vegetables (n=412) and 11 different fruits (n=301) and analysed for 43 pesticide residues including 20 organophosphates (OP), 6 synthetic pyrethroids, 12 carbamates, 2 abamectins, imidacloprid, dithiocarbamates, and carbendazim. The result indicated that out of the 412 vegetable samples, 235 samples (57%) had pesticide residues and 185 samples (45%) had pesticide residues that exceeded the maximum residue limits (MRLs). The vegetable samples also had multiple synthetic pyrethroid residues and higher levels of residues than organophosphate and other pesticides. Among the organophosphate pesticides, chlorpyrifos was the most frequently detected pesticide.

Tripathy *et al*. (2022) conducted a study to monitor the pesticide residues in 2319 samples of fruiting vegetables namely, tomato (416), capsicum (363), brinjal (448), and cucurbits (1092) grown in the Northern and Western regions of India. The samples were extracted using QuEChERS method and analyzed for the residues of 155 multi–class pesticides by gas chromatography–mass spectrometry and/or liquid chromatography–tandem mass spectrometry. The result reported that the residues of 56 pesticides were detected in vegetables with the highest percentage of positive samples in capsicum (69.7%) followed by brinjal (36.6%), cucurbits (34%), and tomato (30.3%). Residues of acetamiprid, profenofos, imidacloprid, metalaxyl, chlorpyrifos, and tebuconazole were most frequently detected.

2.2 To evaluate the performance of some newer insecticides against pod borer in pea

a. Performance of some newer insecticides against pod borer in pea

Yadav et al. (2000) tested the bio-efficacy of 12 insecticides i.e., monocrotophos 0.04%, endosulfan 0.07%, quinalphos 0.05%, malathion 0.05%, carbaryl 0.15%, chlorpyrifos 0.05%, cypermethrin 0.006%, deltamethrin 0.002%, fluvalinate 0.008%, fenvalerate 0.006%, triazophos 0.06% and Neem [*Azadirachta indica*] 0.5%, against pod borer complex of field pea, *Pisum sativum*, for two consequent *rabi* seasons (1991/92 and 1992/93) in Hisar, Haryana, India. The pod borer complex consisted of the blue butterfly (*Lampoides boeticus*), the pea pod borer (*Etiella zinckenella*) and the gram pod borer (*Helicoverpa armigera*). All the insecticides were found effective in controlling pod borers and reduced pod damage from 10.28 to 19.73%, compared with 41.48% in control. Fenvalerate-treated plots registered the highest yield (25.34 q/ha) followed by cypermethrin (24.07 q/ha). The synthetic pyrethroids were better than the other treatments in controlling yield loss due to insect pests but were at par with endosulfan and quinalphos.

Sushil et al. (2006) conducted an experiment to evaluate the efficacy of various insecticides against pests of garden pea in Northwest Himalayas. The treatments included *Ha* NPV @ 250 LE/ha, *Bacillus thuringiensis* @ 1 kg/ ha, Batain (*Melia azedarach*) seed kernel extract (BSKE) @ 10%, azadirachtin @ 0.03%, endosulfan @ 0.07%, *Trichogramma chilonis* @ 50000 insects per ha per release. The result reported that application of BSKE against pod borers, *H. armigera* and *Lampoides boeticus* were found most promising followed by azadirachtin, *Ha* NPV at 250 LE/ha, and *B. thuringiensis*.

Singh *et al.* (2010) conducted an experiment to evaluate the efficacy of various bio-pesticides against stem fly and pod borer complex in field pea during *rabi* 2006-07. The treatments included *Beauveria bassiana* @ 2.0 kg/ha, *Metarrhizium anisopliae* @ 2.0 kg/ha, NSKE 5%, neemarin @ 3 l/ha, *Bt* @ 0.5 kg/ha and cartap hydrochloride 4G @ 15 kg/ha + endosulfan 35 EC @ 1.5 l/ ha. The result indicated that the treatment *Beauveria bassiana* @ 2.0 kg/ha was found to be the best with minimum pod borer infestation of 7.3%. However, the maximum yield of 17.54 q/ha, maximum net return of Rs. 13830/ha and highest cost benefit ratio (7.1) were obtained by the treatment cartap hydrochloride 4G + endosulfan 35 EC.

Dhaka *et al*. (2015) conducted a field experiment to determine the comparative efficacy of insecticides, *i.e*., lambda cyhalothrin 5 EC @ 500 ml/ha, carbosulfan 25 EC @ 1000 ml/ha, indoxacarb 14.5 SC @ 500 ml/ha, bifenthrin 20 EC @ 500 ml/ha, novaluron 10 EC @ 750 ml/ha, flubendiamide 39.35 EC @ 75 ml/ha, spinosad 45 SC @ 500 ml/ha and cypermethrin 20 EC @ 1000 ml/ha biopesticide, *viz*., *Bt* @ 1.5 kg/ha and botanical, *viz*., Neemarin 1500 ppm @ 3000 ml/ ha, which were sprayed on vegetable pea variety Arkel against pod borer, *Helicoverpa armigera* (Hubner) during *rabi* season of year 2010-11 and 2011-12. The result reported that flubendiamide was the best with lowest pod and seed infestation of 10.73 and 12.59 per cent, respectively and 95.84 q/ha yield followed by indoxacarb, spinosad, novaluron, carbosulfan, bifenthrin, lambda cyhalothrin, cypermethrin, neemarin and *Bt*, which gave 93.56, 91.63, 89.74, 83.22, 81.52, 79.42, 75.97, 72.78 and 68.99 q/ha yield, respectively.

Abhilasha (2016) studied the pest complex and integrated management of pod borer complex in pea. The study included flubendiamide 480 SC @ 0.5 ml/l, carbofuran 3G @ 12kg/ ha, acetamiprid 20 SP, imidacloprid 17.8 SL, acephate 75 SP, dimethoate 30 EC, *Lecanicilium lecani*, neem oil, cotton seed oil and NSKE. The result reported that flubendiamide 480 SC @ 0.5 ml/l and NSKE 5 % proved effective against pod borer complex viz., *Helicoverpa armigera*, *Cydia nigricana*, *Lampodies bioeticus* and *Spodoptera exigua* in pea. The highest avoidable loss (59.07 %), pod yield (39.82 q/ha) and per cent increase in yield over control was (144.58 %) recorded in fully protected plots treated with flubendiamide 480 SC @ 0.5 ml/l and carbofuran 3 G @ 12 kg/acre.

Krishna *et al*. (2019) conducted an experiment to evaluate the combinations of botanicals and insecticides against pod borer complex in field pea. The result indicated that among the various insecticides evaluated against pod borer complex in field pea, neem soap 5% + rynaxypyr 20 SC @ 25 g a.i./ha treated plot showed 100 per cent reduction in larval population and gave the highest crop yield of 19.55 q/ha. The efficacy of treatments in order of superiority were neem soap 5% + rynaxypyr 20 SC @ 25 g a.i./ha > neem soap 5% + indoxacarb 14.5 SC @ 60 g a.i./ha > neem soap 5% + indoxacarb 14.5 SC @ 50 g a.i./ha > neem soap 5% + rynaxypyr 20 SC @ 20 g a.i./ha > neem soap 5% + emamectin benzoate 5 SG @ 10 g a.i./ha > neem soap 5% + emamectin benzoate 5 SG @ 7 g a.i./ha > neem soap 5% @ 5 ml/l water. The maximum Cost: Benefit ratio of 1: 15.56 was obtained from neem soap 5% + rynaxypyr 20 SC @ 25 g a.i./ha.

Banerjee and Pal (2021) evaluated the bio-efficacy of some newer insecticides *viz.,* emamectin benzoate 5% SG, chlorantraniliprole 18.5% SC and indoxacarb 14.5% SC along with one botanical insecticide (Neem Seed Kernel Extract) against gram pod borer, *Helicoverpa armigera* in field pea during *rabi* season of two consecutive years (2019 and 2020). Among different insecticides evaluated, chlorantraniliprole 18.5 SC @ 25 g a.i./ha was the most effective insecticide in minimizing the larval population of pod borers and reducing pod borer damage besides recording highest grain yield with incremental benefit (Rs.19501/ha and Rs. 20094/ha during first and second year, respectively).

Sagar *et al.* (2022) evaluated eight different bio-pesticides *viz*., neem oil, garlic bulb extract, *Bacillus thuringiensis* (5% WP), castor oil, panchgavya, Neem Seed Kernel Extract (Crude extract), *Verticillium lecanii* (2x108 cfu), *Beauveria bassiana* against pea pod borer. The results revealed that *Beauveria bassiana* (6.74 larvae/5 plant) was found significantly more effective in reducing larval population per plant. *Bacillus thuringiensis* (7.62 larvae/5 plant), NSKE, neem oil, and *Verticillium lecanii* were found moderately effective whereas castor oil, panchgavya and garlic bulb extract proved significantly less effective.

Saiteja and Kumar (2022) conducted an experiment to evaluate the efficacy of some bio-pesticides *viz*., neem oil 2% @ 2ml/l, spinosad 45% SC @ 0.2ml/l, NSKE 5% @ 5ml/l, *Bacillus thuringiensis* 4% WSP @ ml/l, NSKE + *Ha* NPV + *Bt* @ 1ml/l, emamectin benzoate 5% SG @ 2ml/l, *Beauveria bassiana* @ 2ml/l against pod borer in garden pea, *Helicoverpa armigera*. Per cent pod damage revealed that emamectin benzoate 5% SG (10.57%) was found to be the most effective treatment in the reduction of *H. armigera* followed by spinosad 45% SC (15.21%), NSKE + *Ha* NPV + *Bt* (9.03%), *Beauveria bassiana* 1.5% SG (13.98%), NSKE 5% (16.41%), *Bacillus thuringiensis* 4% WSP (12.00%) and neem oil 2% (17.32%).

b. Performance of some newer insecticides against pod borer in other crops

Singh and Ali (2005) conducted an experiment to know the efficacy of nuclear polyhedrosis virus, *Ha* NPV-250 LE/ha, *Ha* NPV-350 LE/ha, *Ha* NPV-450 LE/ha, *Bacillus thuringiensis*, *Bt* (Biolep) 1%, Neem Seed Kernel Extract-NSKE 5% and endosulfan 0.07% against *Helicoverpa armigera* in chick pea cv. K-850. The result reported that maximum larval mortality (85%) was recorded in endosulfan 0.07% followed by *Bt* formulation 1% (80%) and *Ha* NPV-450 LE/ha (75%), while NSKE-5% was least effective.

Tohnishi *et al*. (2005) reported that flubendiamide showed extremely strong insecticidal activity especially against lepidopteran pests including resistant strains. Tomar *et al*. (2005) evaluated that flubendiamide 20 WDG at 50 g a.i./ha was found to be highly effective in minimizing the bollworm damage and increasing the yield of seed cotton and it was suggested that flubendiamide 20 WDG at 50 g a.i./ha could be considered as the optimum dose for controlling cotton bollworms.

Srinivasan and Durairaj (2007) conducted an experiment to evaluate the bio-efficacy of certain newer insecticides against gram pod borer, *Helicoverpa armigera* Hubner on pigeon pea. Experimental results showed that the least *Helicoverpa* larval population of 2.0/plant was recorded in spinosad 45 SC (73 g a.i./ha) treatment followed by indoxacarb 14.8 SC (2.4/plant) against a maximum population of 6.7 larvae/plant in the untreated check. Highest grain yield was recorded in bifenthrin treated plots (925.6 kg/ha) followed by indoxacarb (864.0 kg/ha) and spinosad 45 SC @ 73 g a.i/ha (841.1 kg/ha) as against the minimum yield of 432.7 kg/ha in the untreated control.

Ravi *et al*. (2008) conducted an experiment to test the efficacy of different sequential applications of microbials *viz*., nucleopolyhedrovirus of *Helicoverpa armigera* (Hübner) (*Ha* NPV @ $1.5x10^{12}$ OB/ha), *Bacillus thuringiensis* var. *kurstaki* Berliner (Delfin® 25 WG @1 kg/ha), spinosad 45 SC (@ 75 g a.i./ha) and neem (neemazol 1.2 EC @ 1000ml/ha) against *H. armigera* in comparison with sequential application of synthetic insecticides and untreated control on tomato F_1 hybrid Ruchi. Results of the field experiments showed that different sequential applications of microbials and neemazal were equally effective as that of sequential applications of synthetic chemical insecticides *viz*., endosulfan 35 EC (@ 350 g a.i./ha), quinalphos 25 EC (@ 250 g a.i./ha) and indoxacarb 14.5 SC (@ 75 g a.i./ha) in reducing *H. armigera* larval population and fruit damage.

Dodia *et al*. (2009) reported that flubendiamide 20 WDG at 50 g a.i./ha when sprayed against *H. armigera* infesting pigeon pea showed most effective results with 5.98 per cent pod damage. Kumar and Shivaraju (2009) reported that flubendiamide 480 SC @ 48 and 36 g a.i./ha recorded pod damage of 6.04 and 7.62 per cent by *Helicoverpa armigera.*

Tamboli and Lolage (2008) conducted a field experiment during *kharif* season of 2006 to evaluate the bio-efficacy of some newer insecticides like flubendiamide 20 WDG, spinosad 45 SC, indoxacarb 15 SC, thiacloprid 24% + flubendiamide 24% 480 SC, endosulfan 40 SC and novaluron 15 EC against pod borer, *Helicoverpa armigera* Hubner on pigeon pea. All insecticides except thiacloprid 240 SC were found effective in reducing the incidence of *H. armigera*. Spinosad 45 SC @ 90 g a.i./ha was the most potent insecticide in reducing the larval population (0.29 larvae/plant), pod damage (5.62%), grain damage (22.85 %) and highest grain yield of 1681 kg/ha. It was followed by flubendiamide 20 WDG @ 50 g a.i./ha, and novaluron 10 EC @ 75 g a.i/ha.

Kulhari *et al*. (2009) conducted an experiment to test the efficacy of insecticides/bio-pesticides against *H. armigera* (Hubner) in chickpea. The result revealed that out of ten treatments evaluated for the management of *H. armigera*, two sprays of indoxacarb (0.007%) and spinosad (0.01%) were found most effective with highest per cent yield increase (72.36% and 59.75 %) and least pod damage (4.49% and 5.45% respectively) followed by thiodicarb @ 0.07% (7.03% pod damage and 46.78% yield), endosulfan @ 0.07% (7.16% pod damage and 40.00% yield) and triazophos @ 0.06% (8.18% pod damage and 33.69% yield) as moderately effective and *Ha* NPV (10.36%

pod damage and 30.18 % yield) and *Bt* (11.04 % pod damage and 26.54% yield) as less effective in reducing pod borer population. Nimbecidine (0.5%) and Azacel (0.5%) were found least effective against pod borer.

Deshmukh *et al*. (2010) determined that flubendiamide @ 0.007 per cent in chickpea was found the most effective in reducing the *H. armigera* population and pod damage and showed the highest yield of 1850 kg/ha and cost benefit ratio of 1:6.10. Thilagam *et al*. (2010) evaluated that flubendiamide 60 g a.i./ha showed marked reduction in the *Helicoverpa* larval population and recorded up to 96.00 per cent reduction in damage in cotton.

Singh and Kumar (2012) conducted a field trial for evaluating various IPM modules on cv. 'JG-315' of chick pea. The result reported that Module M_5 (pheromone traps @ 20/ha, bird perch @ 40/ha, chlorantraniliprole @ 0.15 L/ha and water spray) followed by M_4 (pheromone traps @ 20/ha, bird perch @ 40/ha, emamectin benzoate 5 SG @ 0.15 kg/ha and *Ha* NPV @400 LE/ha + Teepol + sugar) and M_3 (pheromone traps @ 20/ha, bird perch @ 40/ha, flubendiamide 39.35 SC 0.08 lit/ha and *Ha* NPV @ 400 LE/ha + Teepol + sugar) were found effective in reducing the population of *H. armigera*. The highest yield (1592 kg/ha in 2009 and 1607 kg/ha in 2010) was obtained from M_5 followed by M_4 (1545 kg/ha in 2009 and 1558 kg/ha in 2010) in comparison to control and other modules including farmer's practice. The highest B:C ratio was obtained from M_5 (1:3.47) followed by M_3 (1:3.35), M_4 (1:3.18), M_1 (1:2.52), M_2 (1:2.28) and M_6-farmer practice (1:1.89) and the trend was almost similar in the succeeding year. Module M_5, was proved superior to other modules in respect of managing the pest infestation and B: C ratio.

Sreekanth and Seshamahalakshmi (2012) conducted an experiment during *rabi*, 2010 to evaluate the efficacy of different bio-pesticides against gram pod borer, *Helicoverpa armigera* (Hub.) and legume pod borer, *Maruca vitrata* (Geyer) on pigeon pea. The per cent inflorescence damage was lowest in spinosad 45% SC @ 73 g a.i/ha (4.74%), followed by *Bt* @ 1.5 kg/ha (10.52%) and *Beauveria bassiana* SC formulation @ 300mg/l (14.15%) with 80.9, 57.6 and 42.9 per cent reduction over control respectively as against control (24.79%). The highest grain yield was recorded in spinosad 45% SC @ 73 g.i/ha treated plots (831.0 kg/ha), followed by *Bt* @ 1.5 kg/ha (743.1 kg/ha) and *B. bassiana* SC formulation @ 300mg/l (694.4 kg/ha) with 104.0, 82.4 and 70.5 per cent increase over control respectively as against the minimum yield of 407.4 kg/ha in the untreated check.

Wakil *et al*. (2012) conducted an experiment to test the insecticidal efficacy of formulations of *Azadirachta indica*, a Nucleopolyhedrovirus (NPV), and new anthranilic diamide insecticide (chlorantraniliprole) against 2nd, through 5th larval instars of *H. armigera* collected from diverse geographical locations of Gunjranwala of Punjab province, Pakistan. The result revealed NPV, *A. indica* and chlorantraniliprole reported 45.86 ± 4.72, 40.70 ± 3.91 and 51.23 ± 2.94 per cent mortality.

Priyadarshini *et al*. (2013) conducted a field trial to evaluate comparative efficacy of six insecticides against pod borer complex in pigeon pea *viz*., gram pod borer (*Helicoverpa armigera* Hubner), pod fly (*Melanagromyza obtusa* Malloch), flower webber cum borer (*Maruca vitrata* Geyer), and plume moth (*Exelastis atomosa* Walsingham). Among all the chemicals, flubendiamide 480 SC at 60 g a.i./ha was found to be the most effective with a maximum reduction in lepidopteran pod borers with pod damage, grain damage and weight loss of 5.3, 3.3 and 2.9 per cent, respectively followed by lambda-cyhalothrin 5 EC at 25 g a.i./ha (8.0, 3.4 and 2.9%) and beta-cyfluthrin 25 SC at 18.8 g a.i./ha (10.3, 6.4 and 5.6%), respectively. The highest net profit was obtained from the treatment flubendiamide 480 SC at 60 g a.i./ha (Rs. 12,638) followed by lambda-cyhalothrin 5 EC at 25 g a.i./ha (Rs. 7092), beta-cyfluthrin 25 SC at 18.8 g a.i./ha (Rs. 6462.4), while lambda-cyhalothrin 5 EC at 25 g a.i./ha (1:7.5) recorded highest incremental cost benefit ratio followed by lambda-cyhalothrin 5 EC at 25 g a.i./ha (1:4.7) and quinalphos 25 EC at 250 g a.i./ha (1:4.4).

Patel and Patel (2013) conducted an experiment on bio-efficacy of newer insecticides against pod borer complex on pigeon pea during *Kharif* 2012-13. Among the various insecticides, chlorantraniliprole @ 30 g a.i./ha was the most effective insecticide against gram pod borer with lowest pod damage (21.06 %) and highest yield (1354.67 kg/ha). *B.t.* (*Bacillus thuringiensis*) recorded 26.62 per cent pod damage and 1088.67 kg of yield.

Chankapue *et al*. (2014) conducted the laboratory screening of new molecules of insecticide against *H. armigera* (Hub.) during 2010-11. Among the molecules tested, flubendiamide 39.35% SC @ 0.01% was superior with 96.66 per cent mortality after 168 hours of exposure, followed by rynaxypyr 18.5% SC @ 0.006 % (93.33 %), indoxacarb 14.5 SC @ 0.007% (80.00 %) and spinosad 45% SC @ 0.02% (76.66 %).

Kumar *et al*. (2014) conducted an experiment on bio-efficacy of insecticides and bio-pesticides against pod borer and jassids in cowpea. The result reported that all the treatments except *Bt*. var. *kurstaki* were effective against pod borer. The highest population reduction was recorded from imidacloprid 17.8 SL @ 0.003% treated plots followed by fipronil 5 SL @ 0.01%, acetamiprid 20 SP @ 0.004%, azadirachtin 1500 ppm@ 0.15% and *Bt*. var *kurstaki* 1500 ppm@ 0.1% against the jassid and pod borer in cowpea. The highest seed yield (1291.67 kg/ha) and cost benefit ratio (1: 10.37) was obtained from imidacloprid treatment.

Babar *et al*. (2015) conducted an experiment to test the bio-efficacy of newer molecules of insecticides against chickpea pod borer, *Helicoverpa armigera* using ten different insecticides. The result indicated that flubendiamide was superior over all other insecticides (0.07 larva per plant & 97.02% reduction in population over control) followed by rynaxypyr (0.17 & 92.76), emamectin and indoxacarb (0.20 & 91.47), spinosad (0.22 & 90.64), thiodicarb (0.29 & 87.66), novaluron and lufenuron (0.32 & 86.38). Endosulfan (1.11 & 69.36) was least effective. Based on per cent pod damage and per cent reduction in pod damage over control, the order of effectiveness was: flubendiamide (5.46 & 90.24) > emamectin (6.01 & 87.27) > indoxacarb (7.38 & 86.82) > thiodicarb (8.01 & 85.70) > spinosad (8.78 & 84.32) > lufenuron (9.45 & 83.12) > novaluron (9.59 & 82.87) > rynaxypyr (11.24 & 79.93) > endosulfan (13.21 & 76.41) > control (56.00) at green pod stage; while it was flubendiamide (7.10 & 87.96) > emamectin (7.19 & 88.76) > thiodicarb (9.16 & 85.68) > spinosad (9.52 & 85.12) > novaluron (10.18 & 84.09) > indoxacarb (10.57 & 83.48) > lufenuron (10.95 & 82.88) > rynaxypyr (13.26 & 79.27) > endosulfan (18.60 & 79.27) > control (63.98) at maturity stage.

Chavan *et al*. (2015) evaluated the bio-efficacy and economics of various insecticides for management of *Helicoverpa armigera* (Hubner) in chickpea. The result reported that minimum larval incidence (0.95) of *H. armigera* of (0.36 larva/m row length) was recorded in rynaxypyr 20 SC at 3 and 7 days after spraying, respectively followed by flubendiamide 48 SC (1.47 & 0.78 larvae/m row length) and emamectin benzoate 5 SG (1.55 & 0.89 larvae/m row length). The treatment with rynaxypyr 20 SC was found significantly effective in reducing the pod damage (3.5%) followed by flubendiamide 48 SC (4.8%) and emamectin benzoate 5 SG (6.05%). The highest (2590 kg/ha) yield was recorded in rynaxypyr 20 SC followed by flubendiamide 48 SC (2365 kg/ha) and emamectin benzoate 5 SG (2292 kg/ha).

Nithish *et al*. (2015) tested the bio-efficacy of eight newer insecticidal molecules, acetamiprid 20 SP @ 20 g a.i/ha, indoxacarb 14.5 SC @ 50g a.i/ha, acephate 75 SP @ 750g a.i/ha, spinosad 45 SC @ 73g a.i/ha, emamectin benzoate 5 WSG @ 9.5g a.i/ha, flubendiamide 20 WG @ 50g a.i/ha, rynaxypyr 18.5 SC @ 30g a.i/ha and thiamethoxam 25 WG @ 75g a.i/ha each at two sprays against gram pod borer *Helicoverpa armigera* in pigeon pea. The result reported that spinosad had least pod damage of 6.00% which was at par with indoxacarb (6.14%), whereas maximum pod damage of 10.03% was recorded by flubendiamide. Among the treatments, the minimum grain damage of 2.10% was recorded by spinosad and indoxacarb treated plots, which were at par with emamectin benzoate (2.63%), whereas the maximum grain damage of 4.26% was recorded in flubendiamide. The highest grain yield (1360.54 kg/ha) was recorded in spinosad 45 SC which was at par with indoxacarb 14.5 SC (1207.48 kg/ha), emamectin benzoate 5 WSG (1139.44 kg/ha) and acetamiprid 20 SP (1122.44 kg/ha), while the lowest grain yield (1037.41 kg/ha) was recorded in flubendiamide 20 WG.

Pandey and Das (2016) conducted a field experiment to evaluate various bio-pesticides against gram pod borer (*Helicoverpa armigera* Hub.) on pigeon pea during *kharif* season of 2012-13. Seven bio-pesticides were tested along with control. Among the bio-pesticides, *Beauveria bassiana* @ 1 l/ha (1x10^{12} spores/ml) was found to be the most effective bio-pesticide as it recorded lowest larval population (6.68 larvae/5 plants) and highest yield (1667.55 kg/ha). This was followed by *Verticillium lecanii* @ 1 kg/ha (1x10^{12} spores/ml) (1604.3 kg/ha) and *Bt* (PDBC-BT-1) 1.5 l/ha (1504.13 kg/ha) which were at par with each other. The next effective treatments were neem soap @ 1 kg/ha (10 g/l) (1486.55 kg/ha) followed by pongamia soap @ 1 kg/ha (10g/l) (1374.86 kg/ha), *M. anisopliae* @ 1 kg/ha (1x10^{12} spores /ml) (1272.74 kg/ha) and *P. fumosoreseus* @ 1 kg/ha (1x10^{12} spores/ml) (1025.21 kg/ha) and lowest yield was recorded in control plot (809.41 kg/ha).

Nitharwal *et al*. (2017) conducted an experiment in *rabi* 2014-2015 to study the relative efficacy of different insecticides against *Helicoverpa armigera* on chickpea. Among all the treatments, spinosad was superior with lowest larval population (2.85) and highest yield (17.45 q/ha). The next followed treatment was chlorpyriphos (3.40

larvae/plant, 16.24 q/ha yield), quinalphos (3.69 larvae/plant, 15.35q/ha yield), cypermethrin (3.95 larvae/plant, 13.92 q/ha yield). The treatment with fipronil (4.45 larvae/plant, 12.20 q/ha yield) and indoxacarb (4.63 larvae per plant, 11.90 q/ha yield) were statistically at par with each other whereas treatment with malathion (5.25 larvae/plant, 9.26 q/ha yield) recorded as least effective among the tested chemical insecticides.

Prasanthi *et al*. (2017) conducted an experiment on field efficacy of nine insecticides *viz*. chlorantraniliprole 18.5 SC @ 0.4 ml/l, indoxacarb 15.8 EC @ ml/l, fipronil 5 SC @ 2.0 ml/l, flubendiamide 480 SC @ 0.15 ml/l, bifenthrin 10 EC @ ml/l, azadirachtin 10000 ppm @ 1.0 ml/l, *Ha* NPV 0.43% AS @ 1.0 ml/l, novaluron 10 EC @ 1.0 ml/l and spinosad 2.5 SC @ 0.3 ml/l against gram pod borer of chickpea. The result revealed that the minimum mean larval population (1.32 larvae/plant), pod damage (1.3%), grain damage (1.0%), and higher yield (10.67 q/ha) was recorded in the plots treated with indoxacarb 15.8 EC @ 0.5 ml/l and which was followed by flubendiamide 480 SC @ 0.15 ml/l with 1.68 larvae/plant, 2.0 per cent pod damage, 1.6 per cent grain damage and 10.50q of grain yield/ha.

Kumar *et al*. (2018) studied bio-efficacy of four newer insecticides (buprofezin 5.65% + deltamethrin 0.72% EC, indoxacarb 15.8% EC, flubendiamide 480 SC and methomyl 40% SP), one conventional insecticide (quinalphos 25% EC), four biopesticides (*Metarhizium anisopliae*, *Beauveria bassiana*, *Ha* NPV and *Heterorhabditis indica* against pod borer, *Helicoverpa armigera* in chickpea crop during 2009-10 and 2010-11. The result indicated that application of flubendiamide @ 121.98 ml/ha was the most effective with highest grain yield 1833.33 kg/ha and 1802.77 kg/ha during 2009-10 and 2010-11, respectively. Among bio-pesticides, *Ha* NPV @ 500 LE was found more effective with highest net profit. The treatment of *Beauveria bassiana* recorded. maximum cost benefit ratio (1:7.09 and 1: 6.13) during 2009-10 and 2010-11, respectively.

Ahmad (2020) conducted a field experiment to evaluate the relative efficacy of different biopesticides against gram pod borer, *Helicoverpa armigera* (Hübner) and pod fly, *Melanogromyza obtusa* (Malloch) infesting pigeon pea during *kharif* season of 2018-19. The result reported that pod borer *H. armigera* was found lowest in the plot treated with chlorantraniliprole 18.5 SC @ 30 g a.i/ha (6.25%), followed by azadirachtin 1500 ppm @ 5.0 ml/l (7.33%) and *Bt* var. *kurastaki* @ 1.0 g/l (9.33%) as compared to control

(13.89%). Grain damage varied from minimum (3.35 %) due to pod borer, *H. armigera* with chlorantraniliprole 18.5 SC @ 30 g a.i/ha followed by azadirachtin 1500 ppm @ 5.0 ml/l (4.40 %), *Bt* var. *kurstaki* (4.46 %), *Beauveria bassiana* (4.74 %). Untreated control had highest per cent pod damage (18.41 %) and grain damage (13.89 %) due to *H. armigera*.

Jagtap *et al*. (2020) conducted an experiment to find out suitable and low-cost substitute for the management of *Helicoverpa armigera* (Hubner) on chickpea by using microbials and botanicals. The field trial was laid out during the *rabi*-2013-14. The result reported that the treatment spinosad 45 SC @ 0.01 % recorded the highest (76.17 %) per cent reduction in the larval population with minimum pod damage (18.64 %) and produced 15.23 q/ha of yield. *Beauveria bassiana* @ 2 ml/l and azadirachtin 1500 ppm reported 54.77 and 41.63 per cent reduction in larval population after 14 days of spray, respectively.

Rashmi *et al*. (2020) conducted an experiment to evaluate the bio-efficacy of various insecticides against pod borer complex in field bean. Among nine insecticide molecules tested, foliar sprays of chlorantraniliprole 18.5 SC @ 0.15 ml/l were found to be the most effective against *H. armigera* (0.53 larvae/ plant) and it was on par with spinosad @ 0.15 ml/l (0.65 larvae/ plant) and emamectin benzoate @ 0.2 g/l (0.78 larvae/ plant). Similarly, the least per cent pod damage was observed in chlorantraniliprole 18.5 SC treatment (12.57 %) followed by emamectin benzoate 5 SG (15.83 %) and spinosad 45 SC (17.60 %) which were statistically on par with each other.

Abbas *et al*. (2021) evaluated the efficacy of eight different insecticides *viz*., novaluron 10 EC, flubendiamide 480 SC, emamectin benzoate 1.9 EC, spinosad 240 SC, bifenthrin 10 EC, *Bacillus thuringiensis* (*Bt*), lufenuron 5 EC and Spinetoram 120 SC against the larvae of *H. armigera* in chickpea. The result reported that after 3 days of insecticidal application, bifenthrin and emamectin benzoate showed highest larval mortality (86.53%, 76.80%), and after 7 days of insecticidal application, *Bt* and lufenuron showed highest mortality percentages (84.97%, 77.33%) and after 14 days again *Bt* and lufenuron recorded highest mortality percentages (76.47%, 68.33%). The experiment suggested that *Bacillus thuringiensis*, bifenthrin and lufenuron are most effective insecticide while novaluron and flubendiamide were least effective insecticides for the control of *H. armigera.*

Agale *et al*. (2021) conducted a field experiment on efficacy of some bio-pesticides against *H. armigera* on pigeon pea under field condition at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Hyderabad, during 2016-2017 and 2017-2018. The treatment of spinosad 45 SC was found significantly superior, recording lower pod and seed damage (6.82%) by *H. armigera* followed by consortia (37.95%) and neem fruit powder (39.77%). The highest yield (1359 kg/ha) was recorded in Spinosad 45 SC followed by *Streptomyces* sp. (SAI-25) (762 kg/ha).

Warad *et al*. (2021) assessed the bio-efficacy of quinalphos 25 EC, emamectin benzoate 5% SG, indoxacarb 14.5% SC, chlorantraniliprole 18.5% SC, chlorpyriphos 20% EC, flubendiamide 39.35% SC, lambda cyhalothrin 5% EC against *Helicoverpa armigera* on pigeon pea. The result indicated that the treatments, chlorantraniliprole 18.5% SC and flubendiamide 39.35% SC were found to be the most effective against pod borer complex of pigeon pea with minimum per cent pod damage (3.64 % and 4.82 % respectively.), minimum grain damage (6.37 % and 8.02% respectively.) and higher yield (17.18 q/ha and 16.19 q/ha respectively).

Meena *et al*. (2022) evaluated the efficacy of various insecticides and bio-pesticides against *H. armigera* and *M. testularis* on green gram. The result reported that the spinosad 45 SC (0.01%) was the most effective in controlling the borers followed by indoxacarb 14.5 SC (0.01%), fipronil 5 SC (0.01%), whereas, treatments of neem leaf extract (10.00%), *Beauveria bassiana* 1.15 WP @ $1X10^8$ spore/l proved to be the least effective. The maximum seed yield of 9.13 q/ha was obtained from the plots treated with spinosad 45 SC (0.01%) followed by indoxacarb 14.5 SC @ 0.01% (8.89 q/ha), fipronil 5 SC @ 0.01% (8.60 q/ha).

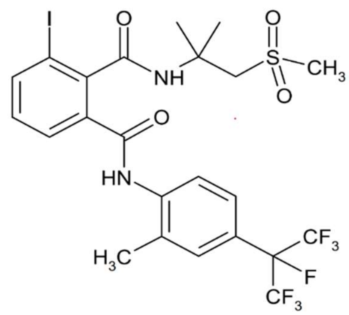
Sireesha and Kumar (2022) conducted an experiment to evaluate the efficacy of selected insecticides against pod borer [*Helicoverpa armigera* (Hubner)] on green gram. The result showed that, among all the treatments highest per cent reduction of gram pod borer was recorded in chlorantraniliprole 18.5 SC (74.31 %) followed by spinosad 45 SC (69.99), indoxacarb 14.5 SC (66.63 %), neem oil 2% (64.34 %). *Ha* NPV 250 LE (59.98 %), *Bacillus thuringiensis* 4% WSP (55.32 %) and *Beauveria bassiana* 1.15% WP (52.23 %) were found to be the least effective but comparatively superior over the control. The highest yield of 16.9 q/ha was obtained from chlorantraniliprole 18.5 SC.

2.3 To study the dissipation pattern of flubendiamide and chlorantraniliprole in pea

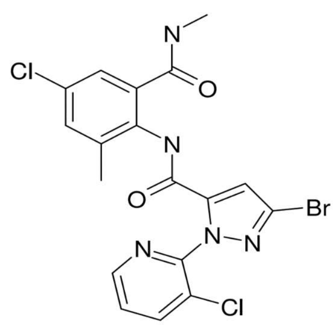
2.3.1 Technical information and dissipation pattern of pesticides

a. Flubendiamide

Chemically it is known *as* N^2-[1,1-Dimethyl-2-(methylsulfonyl) ethyl]-3-iodo-N^1-{2-methyl-4-[1,2,2,2-tetrafluoro-1-(trifluoromethyl) ethyl] phenyl} - 1,2 benzenedicarboxamide. Its empirical formula is $C_{23}H_{22}F_7IN_2O_4S$ with the following structure (sigmaaldrich.com).



b. Chlorantraniliprole



Chemically it is known as 3-Bromo-4′-chloro-1-(3-chloro-2-pyridyl)-2′-methyl-6′-(methylcarbamoyl) pyrazole-5-carboxanilide. Its empirical formula is $C_{18}H_{14}BrCl_2N_5O_2$ with the following structure (sigmaaldrich.com).

Flubendiamide and chlorantraniliprole are insecticides of the ryanoid class. It opens muscular calcium channels, in particular the ryanodine receptor, rapidly causing paralysis and ultimately death of sensitive species. The insecticide is very effective against range of pests belonging to the order lepidoptera and some other coleoptera, diptera and isoptera species.

The dissipation of the chemical insecticides after their application depends on various factors, including plant species, chemical formulation and application method

(Ebert *et al*., 1999), climatic conditions, physical phenomena (mainly volatilization) and chemical degradation, in which sunlight plays a prominent role (Garau *et al*., 2002; Minelli *et al*., 1996; Papadopoulos *et al*., 1995). Therefore, dissipation studies for a given crop in the specific conditions of each growing area are necessary to test if the established pre-harvest tie (PT) ensures that residues levels are below the maximum residue limit (MRL). The studies on dissipation of flubendiamide and chlorantraniliprole on pea are very scanty. Hence, the brief reviews of the dissipation of flubendiamide and chlorantraniliprole in other vegetable crops studied earlier are discussed here under.

a. Dissipation pattern of flubendiamide in pea

Sahoo *et al*. (2009) evaluated the dissipation kinetics of flubendiamide on chilli and soil. The result indicated that average initial deposits of flubendiamide on chilli were found to be 1.06 and 2.00 mg/kg respectively, following two applications of flubendiamide 480 SC at 60 and 120 g a.i./ha at 10 days interval. More than 80% of flubendiamide residues dissipated just after 3 days of the last application at both the dosages. Residues of flubendiamide dissipated below detectable level of 0.01 mg/kg in 7 and 10 days at single and double dosages, respectively. Half-life (t1/2) of flubendiamide on chilli was observed to be 0.96 and 0.91 days, respectively, at single and double dosages. Desiodo flubendiamide was not detected at 0.01 mg/kg level in chilli samples collected at different time intervals.

Singh *et al*. (2011) studied the disappearance trend of flubendiamide residues on chickpea under field conditions to ensure consumer safety. Average initial deposits of flubendiamide on chickpea pods were found to be 0.68 and 1.17 mg/kg, respectively, following three applications of flubendiamide 480SC @ 48 and 96 g a.i./ha at 7 days intervals. Half-life of flubendiamide on chickpea pods was observed to be 1.39 and 1.44 days, respectively, at single and double dosages whereas with respect to chickpea leaves, these values were found to be 0.77 and 0.86 days. Desiodo flubendiamide was not detected at 0.05 mg/kg level on chickpea samples collected at different intervals.

Chawla *et al*. (2011) conducted an experiment to check the dissipation pattern of flubendiamide in/on brinjal fruits following foliar application of fame 480 SC @ 90 (standard dose) and 180 (double dose) g a.i./ha. The result indicated that the residues of flubendiamide were reported as parent compound, and no des-iodo metabolites. The initial deposits of 0.17 and 0.42 μg/ g in/on brinjal fruits reached below determination level of 0.05 µg/ g on the 5th and 10th day at standard and double dose, respectively. The half-life of flubendiamide on brinjal fruits ranged from 2.68 to 2.55 days.

Das *et al*. (2012) conducted an experiment to evaluate the residue persistence of flubendiamide in/on okra fruits following foliar application of Belt 39.35% SC formulation at 24 (standard dose) and 48 (double dose) g a.i./ha. After HPLC analysis study revealed that residues of flubendiamide in/on okra persisted till 5th and 7th day after the last spray at standard and double dose, respectively. The residues of flubendiamide were reported as parent compound, and des-iodo flubendiamide, a metabolite (photo product) of flubendiamide, was not detected in/on okra at any time during the study period. The initial deposits of 0.28 and 0.53 µg/g in/on okra fruits reached below determination level of 0.01 µg/g on the 7th and 10th day at standard and double dose, respectively. The half-life of flubendiamide in/on okra fruits ranged from 4.7 to 5.1 days at standard and double dose, respectively.

Takkar *et al*. (2012) studied the dissipation pattern of flubendiamide in/on brinjal (*Solanum melongena* L.) with three applications of flubendiamide 480 SC at 7 days interval at 90 and 180 g a.i./ha in/on brinjal fruits. The result indicated that the initial deposit of 0.33 and 0.61 mg/kg of flubendiamide was observed respectively after application at single and double dosages. They also reported that residues of flubendiamide dissipated quickly at both the dosages, and after 3 days, the extent of dissipation was found to be about 76% and 79% at the single and double dosages, respectively. Brinjal fruit samples analysed at different time intervals did not show the presence of desiodo flubendiamide. The half-life of flubendiamide was observed to be 0.62 and 0.54 days at single and double dosages, respectively. The limit of determination of flubendiamide and desiodo flubendiamide was observed to be 0.05 mg/kg.

Sharma and Parihar (2013) evaluated the dissipation and persistence of the combination mixture of flubendiamide 24 % + thiacloprid 24 % (480 SC) at 48 and 96 g a.i./ ha in/on tomato. The result indicated that the residues of flubendiamide declined below detectable level of 0.01 mg/ kg after 5 and 7 days of application at lower and higher dose with RL_{50} of 0.72 and 1.32 days, respectively.

Paramasivam *et al*. (2014) conducted an open field trial to evaluate the dissipation pattern and risk assessment of flubendiamide in gherkin fruits following foliar application of Fame 480 SC at 60 and 120 g a.i./ha. Samples of gherkin fruits were drawn at different time intervals and quantified by HPLC-DAD. The result showed that the maximum initial deposits of flubendiamide on gherkin were 0.79 and 1.52 mg/kg, respectively, at recommended and double the recommended doses. The dissipation pattern of flubendiamide followed first-order kinetics with half-lives of 1.87 to 2.16 days at 60 and 120 g a.i./ha, respectively. The limit of quantification of flubendiamide and desiodo flubendiamide was observed to be 0.01 mg/kg for gherkin fruit.

Sharma *et al*. (2014) conducted a supervised trial at four different agroclimatic zones in India to evaluate the dissipation pattern and risk assessment of flubendiamide on tomato. Flubendiamide 480 SC was sprayed on tomato at 48 and 96 g a.i./ha. Samples of tomato fruits were drawn at 0, 1, 3, 5, 7, 10, 15, and 20 days after treatment. Quantification of residues was done on a high-performance liquid chromatography (HPLC) device with a photo diode array detector. Residues of flubendiamide were found below the determination limit of 0.01 mg/kg in 20 days at both the dosages in all the locations. The half-life of flubendiamide at an application rate of 48 g a.i./ha varied from 0.33 to 3.28 days and at 96 g a.i./ha ranged from 1.21 to 3.00 days.

Radhika *et al*. (2016) undertaken an investigation to compare the dissipation pattern of flubendiamide in capsicum fruits under poly-house and open field after giving spray applications at the recommended and double doses of 48 g a.i./ha and 96 g a.i./ha. Residues of flubendiamide and its metabolite, des-iodo flubendiamide, were analysed by high-performance liquid chromatography. Initial residue deposits of flubendiamide on capsicum fruits grown under poly-house conditions (0.977 and 1.834 mg/kg) were higher than that grown in the field (0.665 and 1.545 mg/kg). Flubendiamide residues persisted for 15 days in field-grown and for 25 days in poly-house-grown capsicum fruits. The residues were degraded with the half-lives of 4.3-4.7 and 5.6-6.6 days in field and poly-house respectively. Des-iodo flubendiamide was not detected in capsicum fruits or soil. The residues of flubendiamide degraded to below the maximum residue limit notified by Codex Alimentarius Commission (FAO/WHO) after 1 and 6 days in open field, and 3 and 10 days in poly-house.

Deepak *et al*. (2017) studied the dissipation pattern of flubendiamide on okra. The dissipation result showed that an initial deposit of 1.49 mg/kg was gradually dissipated to 0.84, 0.47, 0.10 and 0.01 mg/kg with the per cent dissipation of 43.30, 68.08, 93.14 and 98.88 on one, three, five and seven days, respectively. The residues fell below maximum residue limit (MRL) of 0.2 mg/kg in 4.19 days (T_{tol}) after the treatment. The half-life (RL_{50}) of flubendiamide was worked out to be 1.83 days.

Preethi *et al*. (2019) conducted two trials to study the dissipation of flubendiamide in cabbage during August 2018 to December 2018. Flubendiamide 39.35 SC @ 18.24 g a.i./ha and 36.48 g a.i./ha were sprayed twice at 10 days interval at 50 % head formation stage. Samples were collected at 0 (one hour after spraying), 1, 3, 5, 7, 10, 15 and 21 days after the second spray along with control samples. The mean initial deposit of flubendiamide after the second spray was 0.191 and 0.258 µg/g in Coimbatore and 0.195 and 0.281 µg/g in the Nilgiris at 18.24 g a.i./ha and 36.48 g a.i./ha doses, respectively. More than 80 per cent of flubendiamide residues were dissipated on 7 and 10 days after second spray (DAS) and recorded below detected level (0.01 mg/kg) on 10 and 15 DAS in Coimbatore and the Nilgiris, respectively. Dissipation of flubendiamide followed first order reaction kinetics and the calculated half-life was 2.8 to 2.9 days, in Coimbatore and 3.7 to 3.9 days in The Nilgiris.

Reddy *et al*. (2021) conducted field and laboratory experiments during *kharif*, 2015 to study the dissipation pattern of flubendiamide 480% SC @ 60 g a.i/ha by spraying thrice on dolichos bean. The samples were collected at regular intervals i.e., 0, 1, 3, 5, 7, 10 and 15 days after last spray and analyzed. The result of flubendiamide residues showed that, the initial deposits of 1.79 mg/kg were detected on field bean pods. The residues recorded at 1, 3, 5 and 7th day after third spraying were found to be 0.90, 0.51, 0.13 and 0.06 mg/kg, respectively and showing a dissipation per cent of 49.72, 71.51, 92.74 and 96.65 per cent, respectively. The residues were below determination level (BDL) after ten days showing hundred per cent dissipation.

b. Dissipation pattern chlorantraniliprole in pea

Malhat *et al*. (2012) conducted an experiment to understand the residue and persistence behaviour of new insecticide, chlorantraniliprole in tomato fruit and soil samples at recommended dose *i.e*., 60 ml/acre. The result indicated that chlorantraniliprole residues in/on tomato fruit reported to be 0.996, 0.620, 0.390, 0.115 and 0.10 mg/kg, at 3, 7, 10, 12 and 15 days after treatment, respectively. Samples taken 21 days after treatment contained no detectable amount of chlorantraniliprole (below the quantification limit 0.03 mg/kg) in tomato fruit. The dissipation rate of tomato fruit exhibited a first order kinetics. The half-life of chlorantraniliprole calculated in tomato fruit treated at recommended dose was 3.30 days and concluded that the pre harvest interval (PHI) of chlorantraniliprole on tomato was 8 days after the last treatment.

Kar *et al*. (2013) carried out research to study the dissipation pattern of chlorantraniliprole on cauliflower. Following three applications of chlorantraniliprole (coragen 18.5 SC) at recommended dose (9.25 g a.i./ha) and double the recommended dose (18.50 g a.i./ha), the average initial deposits of chlorantraniliprole were observed to be 0.18 and 0.29 mg/kg, respectively. These deposits were found to be less than the maximum residue limit of 2.0 mg/kg prescribed by the Codex Alimentarius Commission. These residues dissipated below the limit of quantification of 0.10 mg/kg after 3 and 5 days at recommended and double the recommended dosages, respectively. The half-life value ($T_{1/2}$) of chlorantraniliprole was worked out to be 1.36 days.

Vijayasree *et al*. (2015) studied the dissipation pattern of chlorantraniliprole (coragen 18.5 SC) in brinjal and okra fruits following field application at single and double doses of 30 and 60 g a.i./ha, and the residues of the insecticide were estimated using LC-MS/ MS. The result indicated that the initial residues of chlorantraniliprole at single and double doses on the fruits of brinjal were 0.72 and 1.48 mg/kg, while on okra fruits, the residues were 0.48 and 0.91 mg/kg, respectively. The residues reached below determination level of 0.01 mg/kg on the 10^{th} day. Half-life of chlorantraniliprole at 30 and 60 g a.i./ha on brinjal was 1.58 and 1.80 days with the calculated waiting period of 0.69 and 2.38 days, whereas on okra, the values were 1.60 and 1.70 and 0 and 1.20 days, respectively.

Ahlawat *et al.* (2019) studied the persistence of chlorantraniliprole in *Capsicum annum* using GC-MS/MS. The result indicated that the initial deposits of chlorantraniliprole at recommended (30 g a.i./ha) and double (60 g a.i./ha) the recommended doses revealed 3.16 and 4.18 mg/kg their respectively half-lives 1.18 and 2.05 days respectively. The residues persisted up to 7^{th} and 15^{th} day when sprayed at fruit setting stage.

Preethi *et al*. (2019) conducted an experiment to study the dissipation of chlorantraniliprole in cabbage during September 2018 to January 2019. Chlorantraniliprole 18.5 SC @ 10 g a.i./ ha and 20 g a.i./ ha was sprayed twice at 10 days interval at 50 per cent head formation stage. Samples were collected at 0 (one hour after spraying), 1, 3, 5, 7, 10, 15 and 21 days after the second spray along with control samples.

The result indicated that the mean initial deposit of chlorantraniliprole after the second spray was 0.24 and 0.41 mg/kg at 10 g a.i./ ha and 20 g a.i./ ha doses, respectively. Chlorantraniliprole residues reached BDL of 0.05 mg/kg on 7th and 10th day after application, respectively for recommended and double the recommended dose. Dissipation of chlorantraniliprole followed first order reaction kinetics and the calculated half-life was 2.29 to 2.53 days.

Sharma *et al*. (2019) studied the dissipation of chlorantraniliprole residues on tomato and brinjal fruits which was reported by high performance liquid chromatography and confirmed by liquid chromatograph-mass spectrometer. The average initial deposits of chlorantraniliprole (18.5 SC) were 0.03 and 0.04 mg/kg in tomato which dissipated to below the maximum residue limit (0.03 mg/kg) at 1 and 3 days after application of chlorantraniliprole @ 30 and 60 g a.i./ha respectively. In case of brinjal crop, the initial deposits were 0.19 and 0.40 mg/ kg after its application @ 40 and 80 g a.i./ha respectively, which dissipated to below the limit of quantification (0.03 mg/kg) after 7 days of spray.

Singla *et al*. (2020) studied the persistence and dissipation pattern of chlorantraniliprole, in okra and soil following the application at 25 and 50 g a.i./ha. High performance liquid chromatograph (HPLC) was used to estimate the residues. The average initial deposits of chlorantraniliprole in okra were 0.21 and 0.46 mg/kg at 25 and 50 g a.i./ha, respectively. At the recommended dose, the initial residues were below the MRL (0.3 mg/kg) in okra fruits. The residues dissipated below the limit of quantification (LOQ) of 0.03 mg/kg after 7 and 10 days of the application of insecticide at the two doses respectively. The half-lives ($t_{1/2}$) and waiting periods of chlorantraniliprole in okra were calculated to be 2.27 and 2.45 days, at the recommended and double the recommended dosages respectively.

Kansara *et al*. (2021) conducted a field trial to study dissipation and persistence behaviour of insecticides combination (Chlorantraniliprole 9.26 % + λ-cyhalothrin 4.63 % ZC) in/on pigeon pea at the recommended dose (RD) 30 g a.i./ha and double recommended dose 60 g a.i./ha (2RD). The quantitative analysis was performed using ultra-high performance liquid chromatography tandem mass spectrometry (UHPLC-MS/MS) for chlorantraniliprole and Gas chromatography with electron capture detector (GC-ECD) for λ-cyhalothrin. The chlorantraniliprole persisted up to 30 days at RD and 20 days at 2RD. The half-life (DT_{50}) of chlorantraniliprole was from 4.95 to 5.78 days at recommended and double recommended dose in pigeon pea.

Krishna *et al*. (2022) conducted a study to evaluate insecticide residues of chlorantraniliprole in pigeon pea succulent pods after foliar application. Chlorantraniliprole was sprayed at 0.6ml/l on pigeon pea crop at the pod formation stage to control pod borers like *Helicoverpa armigera* and *Maruca vitrata*. Samples were drawn at 0, 1, 5, 10, 15, 20, 25, and 30 days after spray. Dissipation of chlorantraniliprole was studied in first-order kinetic models (for which the coefficient of determination, R2 was 0.8684). Residues of chlorantraniliprole were 3.57, 3.16, 1.61, 1.13, 0.49, 0.21, 0.05 and 0.00mg/kg at 0, 1, 5, 10, 15, 20, 25 and 30 days after spraying. The residue level reached below the tolerance limit (MRL) (2mg/kg BW) of Codex Alimentarius Commission (CAC) on Pesticide Residues after 5 days of spray and below the detectable level after 25 days of spray in succulent pods and recorded a biological half-life of 4.36 days.

Paramasivam *et al*. (2022) studied the dissipation pattern of chlorantraniliprole in/on chilli. The result indicated that the degradation of chlorantraniliprole followed first-order kinetics with half-lives of 1.6 days for chilli fruits. Chlorantraniliprole residue quantified in the chilli fruit collected on 0 (2 h) day was 0.26 mg/kg at the recommended dose (30 g a.i./ha) was less than the MRL of 0.6 mg/kg. The residue of chlorantraniliprole was not detected at LOQ level of 0.01 mg/kg in chilli fruit after 7 days of treatment.

Kumar *et al*. (2022) studied the dissipation and persistence of chlorantraniliprole in tomato, by spraying twice at the recommended dose (30 g a.i./ ha), and double the recommended dose (60 g a.i./ ha). The initial deposit on tomato were 0.54 and 0.92 mg/kg. Residues further declined below Limit of Quantification (LOQ) of 0.05 mg/kg after 5^{th} day at both doses. The half-life of chlorantraniliprole on tomato after second spray was calculated to be 1.02 and 1.32 days, respectively.

Mawtham *et al*. (2022) studied the dissipation pattern of chlorantraniliprole 18.5% SC in/on bitter gourd by spraying twice at ten days intervals, at the recommended dose (25 g a.i./ ha), and double the recommended dose (50 g a.i./ ha). The initial deposit on bitter gourd was 0.72 and 1.41 mg/ kg and residues persisted up to 15 and 20 days with a half-life of 2.44 and 2.79 days at recommended and double the recommended doses, respectively.

3. MATERIALS AND METHODS

The study on "Evaluation of some newer insecticides against *Helicoverpa armigera* Hub. and their residues in pea (*Pisum sativum* L.)" was conducted under field as well as laboratory conditions during the year 2022-23. Field experiment was conducted at Experimental Farm of Department of Entomology, Post Graduate Institute and laboratory work was conducted at Pesticide Residue Laboratory, AINP on Pesticide Residues, Department of Entomology, M.P.K.V., Rahuri. The particulars of materials used and techniques employed in the conducting experiment are described in this chapter under different headings.

3.1 Monitoring of Insecticide Residues in Market Samples of Pea

3.1.1 Materials

3.1.1.1 Glassware

All the glassware used during the laboratory analysis were of A grade and washed properly with tap water followed by acetone and dried well in a hot air oven before put into use.

3.1.1.2 Apparatus and Equipments used during analysis

Apparatus/Equipment	Make	Model	Range and Accuracy
Weighing balance	Citizen	Cy-204	0.0001 to 220gm
Weighing balance	Citizen	CTG 302-300	0.02 to 300gm
Grinder	Robot Coupe	Blixer 6 v.v.	7L
Centrifuge	Remi	R-8-CHDLC-	--
Vortex shaker	Spinix	--	2000 to 3000 rpm
Deep freezer	TATA	Voltas/320L CF	Ambient to -20^{0}C
Micropipette	Eppendorf	--	100 to 1000 µl
Micropipette	Eppendorf	--	10 to 100 µl

3.1.1.3 Chemicals and Reagents

a. Ethyl acetate (HPLC Grade), Avantor Performance Materials India Limited, Thane, (M.S.).

b. Sodium sulphate anhydrous purified, SDFCL, Mumbai.

c. PSA (Primary Secondary Amine), Agilent Technology, Bangalore.

d. Acetone (Analytical Reagent Grade), Merck Specialties Private Limited, Mumbai (M.S.).

e. Toluene (Analytical Reagent Grade), Avantor Performance Materials India Limited, Thane, (M.S.).

3.1.1.4 Certified Reference Materials

The samples were monitored for presence of residues of 46 thermolabile insecticides belonging to organochlorine, organophosphate and synthetic pyrethroid group. Valid Certified Reference Materials (CRM's) of these insecticides were provided by Pesticide Residue Laboratory, AINP on Pesticide Residues, MPKV, Rahuri. The list of CRM's with their make and purity is mention in Table No 3.1.

3.1.2 Methods

3.1.2.1 Standard Preparation

An accurately weighed 10 mg Certified Reference Material of individual insecticide was dissolved in 10 ml volumetric flask using suitable solvent to prepare the standard stock solution of 1000 mg/kg. Standard stock solution of each insecticide was mixed in a group of 8 to 10 insecticides and further diluted to obtain intermediate lower concentrations of 100 and 10 mg/kg. From this, single mixture from all 46 insecticides under study was prepared using concentration of 5 mg/kg and further working standards of 0.10, 0.75, 0.05, 0.025 and 0.01 mg/kg were prepared by suitably diluting the intermediate solution in ethyl acetate and used as standard check in residue determination, linearity and recovery studies.

3.1.2.2 Sample Collection

Local markets of Ahmednagar, Pune and Satara districts where pea is predominantly grown were selected for monitoring studies. A total of 75 samples of peas were collected from all three locations. One sample consists of approximately one kg of mature pods and it was collected in separate clean transparent polyethylene bag. Each sample was properly labelled with sample number and source. All samples were properly packed and brought into laboratory for pesticide residue analysis. The details of samples regarding location, date of collection, etc. are presented in Table. 3.2.

3.1.2.3 Method Validation

Prior to sample analysis, the instrument method and extraction method were validated in the laboratory to confirm that the analytical procedure for a specific test is suitable for its intended use. Pesticide Residue Laboratory, AINP on Pesticide Residues has already validated the instrument method on GC-MS/MS for the insecticides under study. The validation parameters *viz*., LOD, LOQ, specificity, linearity, accuracy, repeatability and reproducibility were already studied by the laboratory hence only the linearity and accuracy were performed during the present study in order to ensure the suitability of the method for pea samples.

Table 3.1 List of Certified Reference Materials with their make and purity

Sr. No.	Name of CRM	Make	Purity (%)	Expiry Date (DD-MM-YY)
01	4-Bromo-2-Chlorophenol	Dr Ehrenstorfer	99.88	22-11-2024
02	Acephate	Dr Ehrenstorfer	98.47	28-11-2023
03	Alachlor	Dr Ehrenstorfer	99.34	22-11-2027
04	Aldrin	Dr Ehrenstorfer	96.98	05-05-2029
05	Alpha-Endosulfan	Dr Ehrenstorfer	98.15	06-10-2023
06	Alpha-HCH	Dr Ehrenstorfer	98.67	03-09-2024
07	Beta-Cyfluthrin	Dr Ehrenstorfer	99.08	06-11-2026
08	Beta-Endosulfan	Dr Ehrenstorfer	98.44	24-01-2028
09	Beta-HCH	Dr Ehrenstorfer	97.50	08-02-2027
10	Bifenthrin	Dr Ehrenstorfer	98.51	11-10-2025
11	Butachlor	Dr Ehrenstorfer	95.45	17-08-2025
12	Chlorpyrifos-methyl	Dr Ehrenstorfer	98.73	06-08-2024
13	Chlorpyrifos	Dr Ehrenstorfer	99.61	06-11-2024
14	Cypermethrin	Dr Ehrenstorfer	99.23	08-02-2027
15	Delta-HCH	Dr Ehrenstorfer	98.48	24-02-2027
16	Deltamethrin	Dr Ehrenstorfer	99.62	11-09-2024
17	Dichlorvos	Dr Ehrenstorfer	99.52	17-03-2025

18	Dicofol	Dr Ehrenstorfer	99.48	21-12-2026
19	Dimethoate	Dr Ehrenstorfer	99.21	25-05-2028
20	Edifenphos	Dr Ehrenstorfer	99.50	29-08-2026
21	Endosulfan sulphate	Dr Ehrenstorfer	99.64	08-01-2025
22	Ethion	Dr Ehrenstorfer	98.86	05-12-2025
23	Fenitrothion	Dr Ehrenstorfer	98.32	10-10-2023
24	Fenpropathrin	Dr Ehrenstorfer	98.36	25-05-2024
25	Fenvalerate	Dr Ehrenstorfer	98.93	25-02-2024
26	Fluchloralin	Dr Ehrenstorfer	98.00	12-06-2023
27	Fluvalinate	Dr Ehrenstorfer	99.90	05-08-2026
28	Gamma-HCH	Dr Ehrenstorfer	99.45	10-12-2024
29	Heptachlor	Dr Ehrenstorfer	99.05	20-04-2028
30	Heptachlor-exo-epoxide	Dr Ehrenstorfer	98.25	24-09-2025
31	Lambda-Cyhalothrin	Dr Ehrenstorfer	94.10	23-07-2026
32	Malathion	Dr Ehrenstorfer	98.33	16-01-2025
33	Malaoxan	Dr Ehrenstorfer	97.20	25-09-2023
34	Methamidophos	Dr Ehrenstorfer	98.69	25-03-2024
35	Monocrotophos	Dr Ehrenstorfer	99.60	09-12-2023
36	Omethoate	Dr Ehrenstorfer	98.70	13-04-2025
37	p,p-DDD	Dr Ehrenstorfer	99.24	30-03-2029
38	p,p-DDE	Dr Ehrenstorfer	99.47	22-07-2028
39	p,p-DDT	Dr Ehrenstorfer	99.85	22-06-2024
40	Parathion-Methyl	Dr Ehrenstorfer	98.44	29-06-2025
41	Phorate-sulfone	Dr Ehrenstorfer	98.27	16-07-2025
42	Phorate-sulfoxide	Dr Ehrenstorfer	97.49	08-09-2023
43	Phosalone	Dr Ehrenstorfer	99.02	18-11-2023
44	Profenophos	Dr Ehrenstorfer	95.80	06-03-2024
45	Quinolphos	Dr Ehrenstorfer	99.33	15-07-2023
46	Triazophos	Dr Ehrenstorfer	96.13	15-02-2025

Table 3.2 Details of sample collections

Sr. No.	Location	Number of samples collected	Date of collection	Tehsil
1.	Ahmednagar	25	5th January 2023	Akole
2.	Pune	25	10th January 2023	Narayangaon
3.	Satara	25	2nd February 2023	Phaltan

a. Recovery Studies

The analytical method used for estimation of residues of insecticides under study in mature pea grains was validated by conducting recovery studies using the samples from control plot. Ten gram of homogenized pea grain sample was taken in 50 ml centrifuge tubes in three replicates and each was spiked with mixture of insecticide standards at required fortification levels *i.e.*, 0.05 mg/kg, 0.25 mg/kg, and 0.5 mg/kg, by adding an appropriate volume of working standard of 10 mg/kg. This mixture was then shaken, in order to attain a proper homogeneity of insecticides in the samples. The extraction and cleanup procedure were followed as described in 3.1.2.4. Per cent recovery was calculated by using following formula.

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

b. Repeatability and Reproducibility

Repeatability or retest reliability was performed to check the variation in measurements taken by the same person on same instrument on the same substrate under the same conditions. Standards of flubendiamide and des-iodo (metabolite of flubendiamide) chlorantraniliprole were separately spiked into the control samples of pea at required fortification levels *i.e.,* 0.05 mg/kg, 0.25 mg/kg and 0.5 mg/kg.

Reproducibility was performed in similar way as that of repeatability only the difference is that it was performed by other person on the same instrument with same substrate under same conditions.

3.1.2.4 Extraction and Cleanup

Each sample was peeled and grains were separated from the pods. The whole sample was finely ground to a paste with robot coupe blixer. A representative 10 g homogenized sample was weighed in clean 50 ml polypropylene tube and tube was kept in deep freezer for 10 min. To this, 10 ml of ethyl acetate and 10 g of anhydrous sodium sulphate was added. The content was vigorously shaked on vortex shaker and centrifuged at 3500 rpm for 5 minutes. Supernatant (2ml) was transferred to the 15 ml tube containing 50 mg PSA and vortexed it for 30 seconds. These tubes then centrifuged at 2500 rpm for 2 minutes. The supernatant was filtered through 0.2 μ filter and filled in the vial for GC-MS analysis.

3.1.2.5 Residue Determination

The residue analysis of selected insecticides in pea samples collected was carried out with Shimadzu make Gas Chromatograph coupled with triple quadruple mass spectrometer (GCMS-TQ8040NX) with electron impact ionization (EI) equipped with auto sampler (SHIMADZU Analytical (India) Pvt. Ltd.) GCMS solution software was used as the data analysis system. The operating parameters of the instruments are shown in below Table 3.3.

Table 3.3 Gas chromatography conditions

Column Type	:	VF-5-MS-30 m × 0.25 μm × 0.25 mm
Column Temperature	:	@ 20^0 C/min 150^0 C … 1 min hold @ 10^0 C/min 210^0 C … 7 min hold @ 5^0 C/min 285^0 C … 5 min hold
Injector Temperature	:	250^0 C
Interface Temperature	:	285^0 C
Ion Source Temperature	:	250^0 C
Injection Volume	:	1 μl
Column Flow	:	1.20 ml^{-min}

Identification of insecticide residue was accomplished by retention time (RT) and compared with known standard (CRM) at same conditions. The quantities were calculated on peak area basis by using following formula.

$$\text{Residue (mg/kg)} = \frac{\text{Area of sample}}{\text{Area of standard}} \times \frac{\mu\text{l of sample injected}}{\mu\text{l of standard injected}} \times \frac{\text{Conc. of standard (ppm)}}{\text{Weight of sample}} \times 100$$

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

3.1.3 Statistical Analysis

Simple statistical analysis was carried out in the microsoft excel programme with the help of computer. The mean residues, standard deviation, regression equation, R^2 value and half-life were calculated in excel programme.

3.2 Evaluation of Performance of Some Newer Insecticides against Pod Borer in Pea

3.2.1 Materials

The materials such as pea seeds, insecticides, sprayer were required to conduct an experiment. Besides these, other materials such as card sheets, and fertilizers were required during the course of investigation.

3.2.1.1 Seed Material

Seed of pea purchased from the Department of Horticulture, PGI, M.P.K.V, Rahuri was used for sowing.

3.2.1.2 Insecticides

In this experiment, seven treatments including untreated control were maintained. All the chemical insecticides required for present studies were obtained from the local market. The bio-pesticides were obtained from Biocontrol Laboratory, Department of Entomology, PGI, MPKV, Rahuri. The details about the insecticides used in the present investigation with their common name, trade name, formulation and sources are given in Table 3.4.

Table 3.4 Particulars of insecticides evaluated against pea pod borer, *Helicoverpa armigera* Hub.

Technical Name	Trade name	Dose (g or ml/l)	Manufactures
1. Spinosad 45% SC	Tracer	0.25	Dow AgroSciences India Pvt. Ltd. Vikroli, Mumbai.
2. *Beauveria bassiana* 1.15% WP	Phule Beauveria	5.0	Biocontrol Laboratory, Department of Entomology, M.P.K.V. Rahuri
3. Flubendiamide 39.35% SC	Fame	0.20	Bayer Crop Science Ltd., Thane
4. *Bacillus thuringiensis* var. *kurstaki* (*Bt*)	Dipel	2.50	Sumitomo Chemical India Ltd. Kandivali (East), Mumbai.
5. Azadirachtin 10000 ppm	Nimbicidine	2.0	T. Stanes and Company Ltd. Race Course Road, Coimbatore.
6. Chlorantraniliprole 18.5% SC	Coragen	0.30	FMC Private Ltd, TCG Financial Centre, Bandra, Mumbai.

3.2.1.3 Equipments

The equipments such as sprayer (High volume knapsack spray pump of ASPEE make), measuring cylinder, weighing balance and other materials such as labels, thread and iron pegs required for conducting the field experiment were obtained from Department of Entomology, PGI, M.P.K.V., Rahuri,

3.2.1.4 Fertilizers

Recommended dose of urea, single super phosphate and muriate of potash was provided by Department of Entomology, PGI, M.P.K.V., Rahuri.

3.2.2 Methods

3.2.2.1 Land Preparation

The experimental field was ploughed thoroughly by tractor drawn mould board plough followed by two harrowing. The field was cleaned by removing all kinds of weeds and previous crop residues. Individual plots were cleaned and finally leveled with the help of a rotavator and then the trial was laid out as given in the plan of layout (fig 3.2).

3.2.2.2 Sowing of Seeds

The seeds of peas were sown manually by dibbling and the spacing of 30×10 cm was followed between rows and plants, respectively. The operations like thinning and gap filling were done at ten days after sowing to maintain a uniform plant population.

3.2.2.3 Fertilizer Application

The recommended dose of 120:80:70 kg of NPK per hectare was supplied through urea, single super phosphate, and muriate of potash. On the basis of the nutrient content of these fertilizers, the quantity to be applied was computed for one ha and then for the gross sowing plot. Half the dose of N, full dose of P and K were applied as basal dose at the time of sowing. Remaining nitrogen was top dressed at 30 DAS.

3.2.2.4 Irrigation

The first irrigation was given immediately after sowing for good germination and subsequent irrigations were given at regular intervals as per the requirement of the crop to avoid moisture stress.

3.2.2.5 Intercultural Operations

The manual weeding was done as and when required to keep the crop free from weeds and to ensure proper growth and development of the crop.

3.2.2.6 Experimental Details

Crop	:	Pea (*Pisum sativum*)
Variety	:	Phule Priya
Seed rate	:	75 to 80 kg/ha
Design	:	Randomized Block Design
Treatment	:	Seven

Replication	**:**	Three
Spacing	**:**	30 cm x 10 cm
Plot size	**:**	3 m x 3 m
Date of sowing	**:**	5th December, 2022
Fertilizer dose	**:**	N: P: K @ 120: 80: 70 kg/ha
Date of spraying	**:**	1st spray – 30/01/2023 2nd spray – 14/02/2023
Season	**:**	*Rabi* 2022
Location	**:**	Experimental Farm, Department of Entomology, PGI, MPKV, Rahuri

3.2.2.7 Spraying Interval and Number of Sprays

The chemical insecticides commonly used by the farmers and few ecofriendly insecticides were selected for foliar spraying against pea pod borer. Two sprays were given at an interval of 15 days, initiating first spray at pod development stage. Application of insecticides was carried out early in the morning by using hand operated knapsack sprayer (ASPEE make) using required quantity of water.

3.2.2.8 Preparation of Spray Solution

The quantity of spray solution required for spraying in each plot was calculated by spray given to untreated control plot of 3 m x 3 m with water. The quantity of insecticides required was calculated by using following formula and measured volume of the insecticide was dissolved in small quantity of water, mixed well and required concentration of spray solution was prepared by adding sufficient quantity of water to it. The due care was taken to wash the spray pump with water, in the beginning and while switching over from one insecticide to another.

$$\text{Quantity of insecticidal formulation required} = \frac{\text{Desired Strength}}{\text{Insecticide Formulation (\%)}} \times \text{Quantity of spray material required}$$

Table 3.5 Treatment details for evaluation of insecticides against pod borer, *Helicoverpa armigera* Hub. on pea

Treatments	Dose/ha	
	(gm/a.i.)	(ml/g)
T_1 - Spinosad 45% SC	68	150
T_2 - *Beauveria bassiana* 1.15% WP	-	2500
T_3 - Flubendiamide 39.35% SC	48	100
T_4 - *Bacillus thuringiensis* var. *kurstaki* (*Bt*)	-	750
T_5 - Azadirachtin 10000 ppm	-	500
T_6 - Chlorantraniliprole 18.5% SC	30	150
T_7 - Untreated control	-	-

3.2.2.9 Method of recording observations

In order to study the field efficacy of insecticides against pea pod borer, five plants from each plot were selected randomly for recording the observations. The data on per cent pod damage on number basis was recorded a day before spray and 1, 3, 7 and 14 days after each spray. For this, five plants were randomly selected and pod damage was noted by counting total pod, healthy pods and damaged pods. Per cent pod damage was worked out by using following formula (Birah *et al*., 2012).

$$\begin{matrix}\text{Per cent pod damage} \\ \text{(On number basis)}\end{matrix} = \frac{\text{Number of infested pods}}{\text{Total number of pods}} \times 100$$

In the case of pod damage on weight basis, the observations were recorded by weighing healthy pods, damage pods and total pods at each picking. Per cent pod damage on weight basis at each picking was calculated by using following formula (Birah *et al*., 2012).

$$\begin{matrix}\text{Per cent pod damage} \\ \text{(On weight basis)}\end{matrix} = \frac{\text{Weight of infested pods}}{\text{Weight of total number of pods}} \times 100$$

3.2.2.10 Harvesting

Pods were picked up as and when matured. Total three pickings were done in order to complete harvesting of the crop. The picked-up pods were stored separately as per treatment and replication. Due care was taken to avoid mixing of the pods among the treatments and replicates. Further, healthy pods and damaged pods among the replication was also counted and recorded. Based on this data, marketable yield of pea from each plot was recorded at the time of each picking and then total marketable yield from a plot (kg/plot) was converted to t/ha.

3.2.3 Statistical Analysis

The data on per cent pod damage on number basis as well as on weight basis infestation was translated into arc sin transformation and then subjected to statistical analysis as suggested by Panse and Sukhatme (1985) for RBD. The standard error (S.E.) and critical difference (C.D.) at 5 % level of probability were calculated to determine the efficacy of each insecticide treatment.

3.3 Dissipation Pattern of Flubendiamide and Chlorantraniliprole in Pea

Dissipation pattern of flubendiamide and chlorantraniliprole in pea was studies by conducting separate trial at experimental farm of Department of Entomology, PGI, M.P.K.V., Rahuri. As per standard protocol given by CIB & RC for dissipation study, two doses (X dose and 1.25X dose) were selected. The laboratory studies on dissipation of insecticides were carried out at All India Network Project on Pesticide Residues, Department of Entomology, M.P.K.V., Rahuri.

The pea crop variety Phule Priya was raised using standard package of practices except insecticides application. The related experimentation and methodology are detailed as below.

3.3.1 Materials

3.3.1.1 Insecticides

Same market formulations of the insecticides i.e., flubendiamide 39.35% SC and chlorantraniliprole 18.5% SC used for bio efficacy study were used for dissipation studies.

3.3.1.2 Chemicals and Reagents

1. Acetonitrile (HPLC Grade), Avantor Performance Material Ltd., Mumbai (M.S.)
2. Sodium sulphate anhydrous purified, SDFCL, Mumbai.
3. Magnesium sulphate (Analytical Reagent grade), Avantor Performance Material India Limited, Thane (M.S.)
4. Acetone (Analytical Reagent grade), Merck Specialities Private Limited, Mumbai.
5. Toluene (Analytical Reagent grade) Avantor Performance Material India Limited, Thane (M.S.)
6. η- Hexane (HPLC grade), Thermo Fisher Scientific India Pvt. Ltd. Mumbai.
7. Water (HPLC grade), Avantor Performance Material India Limited, Thane (M.S.)
8. PSA (Primary Secondary Amine) Agilent Technology, Bangalore.

3.3.1.3 Apparatus and Instruments

3.3.1.3.1 Apparatus

a. Analytical balance (Citizen make)
b. Grinder-Robot Coupe (Blixer 6 v.v)
c. Laboratory Centrifuge (Remi make)
d. Vortex shaker (Spinix)
e. Deep Freezer [-20^{0}C] (Sanyo)]

3.3.1.3.2 Instruments

High Performance Liquid Chromatography- Shimadzu- LC 20 AT

3.3.1.3.3 Appliances

Manually operated knapsack sprayer (ASPEE) with hollow cone nozzle was used for spraying of insecticides on pea crop.

3.3.2 Methods

3.3.2.1 Experimental Details

Crop	:	Pea (*Pisum sativum*)
Variety	:	Phule Priya
Seed rate	:	75-80 kg/ha
Design	:	Randomized Block Design
Treatment	:	Five
Replication	:	Three
Spacing	:	30 cm x 10 cm
Plot size	:	3 m x 3 m
Date of sowing	:	5^{th} December, 2022
Fertilizer dose	:	N: P: K @ 120: 80: 70 kg/ha
Season	:	*Rabi* 2022
Location	:	Experimental Farm, Department of Entomology, PGI, MPKV, Rahuri
No. of sprays	:	Two (30/01/2023 & 14/02/2023)
Sample collection	:	0, 1, 3, 5, 7, 10 and 15 days after 2^{nd}application

Table 3.6 Treatment details for studies on dissipation pattern of flubendiamide and chlorantraniliprole in pea

Sr. No.	Treatments	Dose	
		(gm/a.i./ha)	(ml/ha)
1.	Flubendiamide 39.35% SC - X Dose	48	100
2.	Flubendiamide 39.35% SC -1.25X Dose	60	125
3.	Chlorantraniliprole 18.5% SC - X Dose	30	150
4.	Chlorantraniliprole 18.5% SC – 1.25X Dose	37.5	187.5
5.	Untreated control	-	-

3.3.2.2 Application of insecticides

The spraying was done manually by hand operated knapsack sprayer fitted with hollow cone nozzle. Two foliar sprays of flubendiamide and chlorantraniliprole at standard dose and at 1.25 of standard dose were given to separate plots to study the dissipation pattern. First spray was given at pod initiation stage followed by second spray at 15 days interval. Due care was taken to wash the spray pump with water, in the beginning and while switching over from one insecticide to another during spraying. All sprayings were done during morning hours to avoid drift due to heavy wind from one treatment plot to other.

3.3.2.3 Residue Analysis for Dissipation Study

3.3.2.3.1 Standard Preparation

An accurately weighed 10 mg of individual Certified Reference Material of insecticide was dissolved in 10 ml volumetric flask using suitable solvent to prepare the standard stock solution of 1000 mg/kg. Standard stock solution of each insecticide was further diluted to obtain intermediate lower concentrations of 100 and 10 mg/kg. They were stored in a deep freezer at -20^{0}C. From intermediate standards, working standards of 0.50, 0.40, 0.25, 0.10 and 0.05 mg/kg were prepared by suitably diluting the stock solution in acetonitrile and were used as standard check in residue determination, linearity and recovery studies.

3.3.2.3.2 Method Validation

Prior to pesticide application and field sample analysis, the instrument method and extraction method were validated in the laboratory to confirm the suitability of analytical procedure for a specific test. Validation parameters *viz*., LOD, LOQ, specificity, linearity and recovery, repeatability and reproducibility were determined in the laboratory by adopting method validation protocol given by SANTE,2019.

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

The limit of detection (LOD) of the tested insecticides was determined resulting from signal-to-noise ratio with reference to the background noise (1:3) obtained from the blank sample. The limit of quantification (LOQ) determined as the lowest concentration of a given insecticide into sample giving a response that could be quantified with RSD lower than 20 per cent.

b. Specificity

Specificity studies were performed by spiking the pea sample and reagent blank with working standards of flubendiamide and chlorantraniliprole at the concentration of 0.05 mg/kg. The area of sample and reagent blank was compared with spiked matrix match area.

c. Linearity Studies

Linearity study was conducted by injecting five linear concentrations (0.50, 0.40, 0.25, 0.10 and 0.05 mg/kg) of working standards of flubendiamide, its metabolite *i.e.*, des-iodo and chlorantraniliprole in three replicates. The detector response was recorded and the graph of concentration of standard against detector response in the form of peak area was plotted. Linearity study was performed in solvent as well as matrix to consider the interference of the matrix effect in final calculations.

d. Recovery Studies

The analytical method for estimation of flubendiamide and chlorantraniliprole residues in mature pea grains was validated by conducting recovery studies using the samples from control plot. Fifteen gram of homogenized pea grain sample was taken in 50 ml centrifuge tubes in three replicates and each was spiked with flubendiamide and chlorantraniliprole separately at the required fortification levels *i.e.*, LOQ, 5 x LOQ and 10 x LOQ, by adding an appropriate volume of working standard of 10 mg/kg. This mixture was then shaken, in order to attain a proper homogeneity of insecticides in the samples. The extraction and cleanup procedure were followed as described below. Per cent recovery was calculated by using following formula.

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

e. Repeatability and Reproducibility

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

3.3.2.4 Sampling

Pods of pea (approximately 1 kg) were collected from each replication at an interval of 0 (2 hours after spray), 1, 3, 5, 7, 10 and 15 days, after second spray of insecticide. The samples were packed in polyethylene bags, labeled well and brought to laboratory for residue analysis. Each sample was peeled and grains were separated from pods. The samples were homogenized and kept at -20°C in deep freezer until used for analysis.

3.3.2.5 Extraction and Cleanup

The pea samples were extracted and cleaned up using QuEChERS methodology (acronym for quick, easy, cheap, effective, rugged and safe) (Anastassiades *et al*., 2003). A representative 15 g of homogenized sample was taken in a clean 50 ml polypropylene tube and tube was kept in deep freeze for 10 min. To this, added 30 ml of acetonitrile (v/v), homogenized the sample @ 1400-1500 rpm for 2-3 min and to that added 3.0 g anhydrous sodium chloride, shaked on vortex and centrifuged the content at 3000 rpm for 3 min. Then transferred 16 ml supernatant to tube containing 9 g anhydrous sodium sulphate. Then transfer 8 ml supernatant to a tube containing 40 mg PSA and 1.2 g magnesium sulphate (anhydrous). It was vortexed for 30 sec and centrifuged at 3000 rpm for 5 min. Then transfer 2 ml extract into a test tube and evaporate to dryness using LC nitrogen. Then reconstitute the volume with 1 ml acetonitrile and filtered through 0.2 μ filter for HPLC analysis (Anastassiades *et al.,* 2003).

3.3.2.6 Residue Determination

The analysis of samples for flubendiamide and chlorantraniliprole residues was carried out with Shimadzu make high-performance liquid chromatography system equipped with photodiode array detector and quaternary pump (LC-20 AT). LC solution software was used as the data analysis system. The operating parameters of the instruments are shown in below Table 3.7.

Identification of insecticide residue was accomplished by retention time (RT) and compared with known standard (CRM) at same conditions. The quantities were calculated on peak area basis by using following formula.

$$\text{Residue (mg/kg)} = \frac{\text{Area of sample}}{\text{Area of standard}} \times \frac{\mu\text{l of sample injected}}{\mu\text{l of standard injected}} \times \frac{\text{Conc. of standard (ppm)}}{\text{Weight of sample}} \times \text{Final volume (ml)}$$

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

Table 3.7 Liquid chromatography conditions

Column type	:	Purospher @ STAR (Hibar) RP 18(5µ) m-150-4.6
Mobile phase	:	Acetonitrile: Water (80:20)
Flow rate	:	Flubendiamide: 0.80 ml/min Chlorantraniliprole: 0.80 ml/min
Wavelength	:	Flubendiamide: 254 nm Chlorantraniliprole: 265 nm
Injector volume	:	20 µl
Retention time	:	Flubendiamide: 3.7 min Chlorantraniliprole: 4.4 min

3.3.3 Statistical Analysis

Simple statistical analysis was carried out in the Microsoft Excel Programme with the help of computer. The mean residues, standard deviation, regression equation, R^2 value and half-life were calculated in excel programme.

4. RESULTS AND DISCUSSION

The study on "Evaluation of some newer insecticides against *Helicoverpa armigera* (Hubner) and their residues in pea (*Pisum sativum* L.)" was conducted under field as well as laboratory conditions during the year 2022-23. The results obtained from the investigation have been presented and discussed below.

4.1 Monitoring of Insecticide Residues in Market Samples of Pea

A total of 75 samples of pea were collected during January 2023 to March 2023 from local markets of Ahmednagar, Pune and Satara districts. The collected samples were carried to the Pesticide Residue Laboratory, AINP on Pesticide Residues, M.P.K.V., Rahuri, for pesticide residue analysis.

4.1.1 Method Validation

Prior to analysis of the samples, validation parameters *viz*., linearity and accuracy were studied to determine the suitability of instrument method and extraction method. The results are presented in Table 4.1.

4.1.2 Status of Insecticide Residues in Ahmednagar Samples

The data pertaining to the status of insecticide residues in pea samples collected from Akole (Ahmednagar district) location is presented in Table 4.2. A total of 25 samples were collected and analyzed. The results revealed that 4 samples out of the 25 were found to have detectable residues. All 4 positive samples contained the residues of dimethoate. The levels of insecticide residues ranged from 0.04 mg/kg to 0.09 mg/kg and which is below the MRL value set by the FSSAI. None of the samples recorded multiple residues. The reported insecticide is not registered by CIB&RC for use in India on pea crop.

4.1.3 Status of Insecticide Residues in Pune Samples

The data pertaining to the status of insecticide residues in pea samples collected from market of Narayangoan (Pune district) location is presented in Table 4.3. Total 25 samples were collected out of which 02 samples were reported with detectable residues of dimethoate and remaining samples showed the residue levels below quantification limit. The samples with pesticide residues reported the levels below the MRL (2ppm) set by FSSAI. The data further revealed that only 1 insecticide *i.e.,* dimethoate was detected in all positive samples though it is not recommended by CIB&RC for use on pea in India. The levels of dimethoate residues ranged from 0.02 to 0.06 mg/kg. None of the **s**amples recorded multiple residues.

4.1.4 Status of Insecticide Residues in Satara Samples

The data pertaining to the status of insecticide residues in pea samples collected from Phaltan (Satara district) location is presented in Table 4.4. Off the 25 samples collected, 02 samples were reported with detectable residues which are below the MRL set by FSSAI. The data further revealed that only one of insecticide *i.e.,* dimethoate was detected in all the positive samples though it is off-label pesticide for pea in India. The levels of dimethoate residues ranged between 0.03 mg/kg to 0.06 mg/kg. Samples with multiple residues were not recorded.

Table 4.1 Result of linearity and accuracy studies

Sr. No.	Name of CRM	Linearity (R^2)	Recovery (%)		
			0.01 mg/kg	0.05 mg/kg	0.1 mg/kg
01	4-Bromo-2-Chlorophenol	0.9998	93	106	84
02	Acephate**	0.9916	79	93	102
03	Alachlor	0.9997	108	107	93
04	Aldrin	0.9998	94	110	92
05	Alpha-Endosulfan	0.9998	93	107	90
06	Alpha-HCH	0.9997	100	107	91
07	Beta-Cyfluthrin	0.9992	97	98	84
08	Beta-Endosulfan	0.9998	93	106	91
09	Beta-HCH	0.9997	92	107	88
10	Bifenthrin	0.9998	109	104	92
11	Butachlor	0.9998	99	105	91
12	Chloropyrifos-methyl	0.9997	97	106	89

13	Chloropyrifos	0.9998	92	106	92
14	Cypermethrin	0.9994	95	98	83
15	Delta-HCH	0.9997	97	108	89
16	Deltamethrin	0.9988	94	100	90
17	Dichlorvos	0.9998	82	102	89
18	Dicofol*	0.9994	109	88	94
19	Dimethoate	0.9991	88	107	91
20	Edifenphos	0.9994	90	101	89
21	Endosulfan sulphate	0.9997	93	104	90
22	Ethion	0.9982	105	107	91
23	Fenitrothion	0.9969	105	103	93
24	Fenpropathrin	0.9997	98	104	90
25	Fenvalerate	0.9994	101	100	93
26	Fluchloralin	0.9986	98	106	92
27	Fluvalinate	0.9989	99	98	86
28	Gamma-HCH	0.9997	87	106	87
29	Heptachlor	0.9996	114	106	90
30	Heptachlor-exo-epoxide	0.9997	94	110	92
31	Lambda-Cyhalothrin	0.9987	98	99	90
32	Malathion	0.9994	100	107	93
33	Malaoxan	0.9995	87	102	86

34	Methamidophos**	0.9986	113	101	96
35	Monocrotophos**	0.9957	90	88	105
36	Omethoate**	0.9909	114	97	102
37	p,p-DDD	0.9997	98	111	90
38	p,p-DDE	0.9998	95	107	89
39	p,p-DDT*	0.9932	78	88	95
40	Parathion-Methyl	0.9984	110	100	88
41	Phorate-sulfone	0.9996	108	107	90
42	Phorate-sulfoxide	0.9965	104	107	98
43	Phosalone	0.998	101	105	93
44	Profenophos	0.9996	75	104	94
45	Quinolphos	0.9925	96	108	90
46	Triazophos	0.9991	105	107	88

*LOQ value for pp-DDT and dicofol is 0.025 mg/kg, hence recovery was calculated at concentrations 0.025, 0.125, 0.25 mg/kg

**LOQ value for acephate, omethoate, methamidophos and monocrotophos was 0.05 mg/kg, hence recovery was calculated at concentrations 0.05, 0.25, 0.5 mg/kg

Table 4.2 Sample wise status of insecticide residues in pea collected from local markets of Akole (Ahmednagar district)

Sample ID	Pesticides detected	Concentration of residue (mg/kg)	Registration status	MRL (mg/kg)
ANG-01	Not detected	<LOQ	-	-
ANG-02	Not detected	<LOQ	-	-
ANG-03	Not detected	<LOQ	-	-
ANG-04	Not detected	<LOQ	-	-
ANG-05	Not detected	<LOQ	-	-
ANG-06	Not detected	<LOQ	-	-
ANG-07	Not detected	<LOQ	-	-
ANG-08	Not detected	<LOQ	-	-
ANG-09	Not detected	<LOQ	-	-
ANG-10	**Dimethoate**	**0.05**	**Not registered on pea**	**2.00**
ANG-11	Not detected	<LOQ	-	-
ANG-12	Not detected	<LOQ	-	-
ANG-13	**Dimethoate**	**0.09**	**Not registered on pea**	**2.00**
ANG-14	Not detected	<LOQ	-	-
ANG-15	Not detected	<LOQ	-	-
ANG-16	Not detected	<LOQ	-	-
ANG-17	Not detected	<LOQ	-	-
ANG-18	Not detected	<LOQ	-	-
ANG-19	Not detected	<LOQ	-	-
ANG-20	**Dimethoate**	**0.08**	**Not registered on pea**	**2.00**

ANG-21	Not detected	<LOQ	-	-
ANG-22	Not detected	<LOQ	-	-
ANG-23	Not detected	<LOQ	-	-
ANG-24	**Dimethoate**	**0.04**	**Not registered on pea**	**2.00**
ANG-25	Not detected	<LOQ	-	-

*LOQ – Limit of Quantification

** FSSAI & Codex MRL value for pea is not available hence FSSAI MRL mentioned for fruits and vegetable has been considered.

Table 4.3 Sample wise status of insecticide residues in pea collected from local markets of Narayangoan (Pune district)

Sample ID	Pesticides detected	Concentration of residue (ppm)	Registration status	MRL (mg/kg)
PN-01	Not detected	<LOQ	-	-
PN-02	Not detected	<LOQ	-	-
PN-03	Not detected	<LOQ	-	-
PN-04	Not detected	<LOQ	-	-
PN -05	Not detected	<LOQ	-	-
PN -06	Not detected	<LOQ	-	-
PN -07	Not detected	<LOQ	-	-
PN -08	Not detected	<LOQ	-	-
PN -09	**Dimethoate**	**0.02**	**Not registered on pea**	**2.00**
PN -10	Not detected	<LOQ	-	-
PN-11	Not detected	<LOQ	-	-
PN -12	Not detected	<LOQ	-	-

PN -13	Not detected	<LOQ	-	-
PN -14	Not detected	<LOQ	-	-
PN -15	Not detected	<LOQ	-	-
PN-16	Not detected	<LOQ	-	-
PN -17	**Dimethoate**	**0.06**	**Not registered on pea**	**2.00**
PN -18	Not detected	<LOQ	-	-
PN -19	Not detected	<LOQ	-	-
PN -20	Not detected	<LOQ	-	-
PN -21	Not detected	<LOQ	-	-
PN-22	Not detected	<LOQ	-	-
PN -23	Not detected	<LOQ	-	-
PN -24	Not detected	<LOQ	-	-
PN-25	Not detected	<LOQ	-	-

*LOQ – Limit of Quantification

** FSSAI & Codex MRL value for pea is not available hence FSSAI MRL mentioned for fruits and vegetable has been considered.

Table 4.4 Sample wise status of insecticide residues in pea collected from local markets of Phaltan (Satara district)

Sample ID	Pesticides detected	Concentration of residue (mg/kg)	Registration status	MRL (mg/kg)
STR-01	Not detected	<LOQ	-	-
STR -02	Not detected	<LOQ	-	-
STR -03	Not detected	<LOQ	-	-
STR -04	Not detected	<LOQ	-	-

STR -05	Not detected	<LOQ	-	-
STR -06	Not detected	<LOQ	-	-
STR -07	Not detected	<LOQ	-	-
STR -08	**Dimethoate**	**0.06**	**Not registered on pea**	**2.00**
STR -09	Not detected	<LOQ	-	-
STR -10	Not detected	<LOQ	-	-
STR -11	Not detected	<LOQ	-	-
STR -12	Not detected	<LOQ	-	-
STR -13	Not detected	<LOQ	-	-
STR -14	Not detected	<LOQ	-	-
STR -15	Not detected	<LOQ	-	-
STR -16	Not detected	<LOQ	-	-
STR -17	Not detected	<LOQ	-	-
STR -18	Not detected	<LOQ	-	-
STR -19	Not detected	<LOQ	-	-
STR -20	**Dimethoate**	**0.03**	**Not registered on pea**	**2.00**
STR -21	Not detected	<LOQ	-	-
STR -22	Not detected	<LOQ	-	-
STR -23	Not detected	<LOQ	-	-
STR -24	Not detected	<LOQ	-	-
STR -25	Not detected	<LOQ	-	-

*LOQ – Limit of Quantification

** MRL value for pea is not available hence MRL mentioned for fruits and vegetable has been considered.

Table 4.5 Overall status of insecticide residues in pea samples collected from local markets of Ahmednagar, Pune, and Satara

District	No. of Samples analysed	No. of Samples with residue	No. of Samples with Residue < MRL	No. of Samples with Residue > MRL	No. of Samples with Residue without MRL	No. of Samples with multiple residues
Ahmednagar	25	04	04	00	00	00
Pune	25	02	02	00	00	00
Satara	25	02	02	00	00	00
Total	**75**	**08 (10.66%)**	**08 (100.00%)**	00	00	00

Out of total 75 market samples, 08 samples reported to be contaminated with insecticide residues. The data on presence of positive samples revealed that, Ahmednagar location reported more number of positive samples compared to Pune and Satara location. As per as insecticides are concern only one insecticide *i.e.,* dimethoate was reported in all the positive samples. However, the levels of residues are very low (0.02 to 0.09 mg/kg). The presence of dimethoate residues in the samples may be because of its systemic nature and may be sprayed for the control of aphids in latter stage of the crop. It is also important to note that with the existing instrumentation facility, the analysis was specifically focused on organochlorine, organophosphate and synthetic pyrethroid group of insecticide. Additionally, another contributing factor may be that the analysis involved removing the outer pod covering, potentially preventing non systemic insecticides from penetrating the grains.

The present study is in accordance with, Dogheim *et al.* (1999) who reported dimethoate residues in 3 samples of green peas out of 13 samples. Dogheim *et al.* (2001) observed 5 green pea samples were showing dimethoate residues among 71 samples collected and monitored. Dogheim *et al.* (2002) found dimethoate residues in 6 samples of green peas out of 1222 samples. Srivastava *et al.* (2011) monitored pesticide residues in 20 different vegetables and quantified dichlorvos residues in 2 cabbage samples. Hasan *et al.* (2017) detected dimethoate residues in 8 market samples among 50 samples of country bean. Parven (2017) analysed 35 samples of yard long bean, in which 4 samples have detected with presence of dimethoate residues. Concha-Meyer *et al.* (2019) monitored 12 garden pea samples and no insecticide is quantified in all 12 samples. These findings are in close accordance with current findings.

4.2 Evaluation of Performance of Some Newer Insecticides against Pod Borer in Pea

During the investigation, six insecticides were evaluated for their effect against pod borer causing pod damage. Observations were recorded after each spray at one, three, seven- and fourteen-days interval. The results are presented here under.

4.2.1 Effect of Different Insecticides on Per Cent Pod Damage on Number Basis

4.2.1.1 Effect after First spray

The data on the effect of insecticides on per cent pod damage on number basis caused by pod borer in pea after first application are presented in Table 4.6.

The per cent pod damage recorded a day before spraying was varied from 19.59 to 20.52 per cent in various treatments which was non-significant indicating homogenous distribution of the pest in experimental plots.

The data displayed in table 4.6 shows that, one day after the first spray (1 DAS), all the insecticidal treatments resulted in significantly lower pod borer damage percentages as compare to the control. Among the treatments, chlorantraniliprole 18.5% SC @ 0.3 ml/l demonstrated the highest efficacy with the lowest pod damage of 14.69 per cent, and it was on par with flubendiamide 39.35% SC @ 0.2 ml/l (14.86%) and spinosad 45% SC @ 0.3 ml/l (15.49%). Following these, azadirachtin 10000 ppm @ 1 ml/l had a 17.84 per cent pod damage. *Beauveria bassiana* 1.15% WP @ 5 g/l and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l had similar pod damage rates of 19.81 per cent and 19.94 per cent, respectively. However, the untreated control recorded the highest pod damage of 21.68 per cent.

By the third day after initial spray (3 DAS), chlorantraniliprole 18.5% SC @ 0.3 ml/l and flubendiamide 39.35% SC @ 0.2 ml/l exhibited the lowest pod damage of 5.15 per cent and 5.59 per cent, respectively, and were statistically equivalent. It was followed by spinosad 45% SC @ 0.3 ml/l (7.27%). Azadirachtin 10000 ppm @ 1 ml/l proved the next effective treatment with 9.03 per cent pod damage. Subsequently, *Beauveria bassiana* 1.15% WP @ 5 g/l, and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, recorded

17.52 and 17.74 per cent pod damage, respectively. On the contrary, the untreated control had the highest (22.48%) pod damage.

The data collected at 7 DAS revealed that chlorantraniliprole 18.5% SC @ 0.3 ml/l proved to be the best treatment, showing minimal pod damage of 5.89 per cent. This result was statistically on par with flubendiamide 39.35% SC @ 0.2 ml/l, which recorded pod damage at of 6.05 per cent. Following closely was spinosad 45% SC @ 0.3 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, all exhibiting similar effectiveness with pod damage percentages of 8.69, 8.80, and 8.98, respectively. Azadirachtin 10000 ppm @ 1 ml/l recorded a pod damage of 10.67 per cent. In contrast, the untreated control experienced the highest (23.96%) pod damage.

On 14th day after spraying (14 DAS), similar trend of effectiveness was reported by different treatments as reported on 7th day after spray. Corresponding values of pod damage were 10.10, 10.35, 12.43, 13.11, 13.52 and 15.42 per cent for chlorantraniliprole 18.5% SC @ 0.3 ml/l, flubendiamide 39.35% SC @ 0.2 ml/l, spinosad 45% SC @ 0.3 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l and Azadirachtin 10000 ppm @ 1 ml/l, respectively. On the contrary, the untreated control exhibited the highest pod damage at 26.15 per cent.

Considering the average damage reported by pod borers after the first spray, it is evident that chlorantraniliprole 18.5% SC @ 0.3 ml/l maintained its superiority by recording the lowest pod damage of 8.96 per cent. Equally effective was flubendiamide 39.35% SC @ 0.2 ml/l, which registered a mean damage of 9.21 per cent. Following closely was spinosad 45% SC @ 0.3 ml/l, with a damage of 10.97 per cent. Azadirachtin 10000 ppm @ 1 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l exhibited similar results, all recording pod damage of 13.52 per cent, 14.81 per cent, and 15.04 per cent, respectively. In contrast, the untreated control experienced the highest pod damage, reaching to 23.57 per cent.

The data on percentage of reduction in pod damage over the control indicates that, chlorantraniliprole 18.5% SC @ 0.3 ml/l proved as superior, achieving the highest reduction of 61.99 per cent. Following closely was flubendiamide 39.35% SC @ 0.2 ml/l, which achieved 60.92 per cent reduction, and spinosad 45% SC @ 0.3 ml/l resulted in a 53.46 per cent reduction. Azadirachtin 10000 ppm @ 1 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l also displayed reductions in pod damage, with 42.64 per cent, 37.17 per cent, and 36.19 per cent, respectively.

Table 4.6 Evaluation of insecticides against pea pod borer, *Helicoverpa armigera* Hub. after first spray

Treatment details	Dosage/ha (gm/a.i.)	Pre-count (1 DBS)	Per cent pod damage (On number basis)				Mean	Mean per cent reduction over control
			1DAS	3 DAS	7 DAS	14 DAS		
T_1 - Spinosad 45% SC	68 gm a.i.	19.75 (26.38)	15.49 (23.17) [a]	7.27 (15.63) [b]	8.69 (17.13) [b]	12.43 (20.62) [b]	10.97 (19.34) [b]	53.46
T_2 - *Beauveria bassiana* 1.15% WP	2500 g	20.08 (26.61)	19.81 (26.42) [c]	17.52 (24.74) [d]	8.80 (17.23) [b]	13.11 (21.22) [b]	14.81 (22.63) [c]	37.17
T_3 - Flubendiamide 39.35% SC	48 gm a.i.	19.59 (26.26)	14.86 (22.67) [a]	5.59 (13.62) [a]	6.05 (14.23) [a]	10.35 (18.75) [a]	9.21 (17.66) [a]	60.92
T_4 - *Bacillus thuringiensis* var. *kurstaki (Bt)*	750 ml	20.18 (26.68)	19.94 (26.52) [c]	17.74 (24.90) [d]	8.98 (17.42) [b]	13.52 (21.57) [b]	15.04 (22.82) [c]	36.19
T_5 - Azadirachtin 10000 ppm	500 ml	20.39 (26.84)	17.84 (24.98) [b]	9.03 (17.47) [c]	10.67 (19.06) [c]	15.42 (23.12) [c]	13.52 (21.34) [c]	42.64
T_6 - Chlorantraniliprole 18.5% SC	30 gm a.i.	19.90 (26.49)	14.69 (22.52) [a]	5.15 (13.09) [a]	5.89[a] (14.03) [c]	10.10 (18.53) [a]	8.96 (17.41) [a]	61.99
T_7 - Untreated control	-	20.52 (26.93)	21.68 (27.75) [d]	22.48 (28.30) [e]	23.96 (29.31) [d]	26.15 (30.75) [d]	23.57 (29.04) [d]	-
S. Em (±)	-	0.54	0.40	0.58	0.53	0.44	0.49	-
C.D (5%)	-	NS	1.22	1.80	1.63	1.36	1.50	-

*Figures in the parentheses are arcsine transformed value

*DBS: Days before spray *DAS: Days after spray

*S. Em: Standard error mean *C. D: Critical difference

4.2.1.2 Effect after Second spray

Data obtained after second spray is presented in Table 4.7. The data recorded on 14 DAS after first spray was considered as the pre count data for second spray (1 DBS).

The data recorded at a day after second spray (1 DAS) indicates that all the insecticidal treatments recorded significantly lower per cent of pod damage over untreated control. Chlorantraniliprole 18.5% SC @ 0.3 ml/l was found to be effective treatment by recording minimum pod damage (7.22%), this was found at par with flubendiamide 39.35% SC @ 0.2 ml/l, which recorded 7.38 per cent pod damage. This was followed by Spinosad 45% SC @ 0.3 ml/l (9.69%). Next effective treatments were azadirachtin 10000 ppm @ 1 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, being at par with each other and recorded 12.60 per cent, 12.96 per cent and 13.29 per cent, pod damage respectively. Untreated control recorded highest pod damage of 26.56 per cent.

On third day after the second spray (3 DAS), chlorantraniliprole 18.5% SC @ 0.3 ml/l and flubendiamide 39.35% SC @ 0.2 ml/l exhibited the lowest pod damage, both at 3.27 per cent and 3.02 per cent, respectively, and were statistically equivalent. Following closely was spinosad 45% SC @ 0.3 ml/l, with a pod damage of 4.83 per cent. Azadirachtin 10000 ppm @ 1 ml/l showed the next best results with 7.69 per cent pod damage. Subsequently, *Beauveria bassiana* 1.15% WP @ 5 g/l and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l has similar levels of effectiveness, both recording pod damage percentages of 10.87 and 11.14 per cent, respectively. In contrast, the untreated control had the highest pod damage percentage of 27.24 per cent.

The data collected at 7 DAS revealed that chlorantraniliprole 18.5% SC @ 0.3 ml/l proved to be the most effective treatment, showing minimal pod damage of 4.86 per cent. This result was statistically on par with flubendiamide 39.35% SC @ 0.2 ml/l, which recorded pod damage of 5.08 per cent. Following closely was spinosad 45% SC @ 0.3 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, all exhibiting similar effectiveness with pod damage percentages of 7.07 per cent, 6.99 per cent, and 7.44 per cent, respectively. Azadirachtin 10000 ppm @ 1 ml/l recorded pod damage of 9.56 per cent. In contrast, the untreated control group experienced the highest pod damage, reaching 27.98 per cent.

On 14th day after spraying (14 DAS), chlorantraniliprole 18.5% SC @ 0.3 ml/l and flubendiamide 39.35% SC @ 0.2 ml/l demonstrated the lowest pod damage percentages, both at 7.34 and 7.45 per cent, respectively, and these results were statistically comparable. This was followed by spinosad 45% SC @ 0.3 ml/l with 9.94 per cent pod damage. Subsequently *Beauveria bassiana* 1.15% WP @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, and azadirachtin 10000 ppm @ 1 ml/l, all displayed similar levels of effectiveness with pod damage of 11.28 per cent, 11.53 per cent, and 13.21 per cent respectively. On the contrary, the untreated control exhibited the highest pod damage of 28.98 per cent.

The average data of second spray revealed that, chlorantraniliprole @ 0.3 ml/l maintained its superiority, recording lowest pod damage of 6.56 per cent. Similarly, flubendiamide 39.35% SC @ 0.2 ml/l performed well, with a mean damage of 6.66 per cent and statistically at par with chlorantraniliprole @ 0.3 ml/l. This was followed by spinosad 45% SC @ 0.3 ml/l with damage of 8.79 per cent. The next treatments in the order of effectiveness were *Beauveria bassiana* 1.15% WP @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, and azadirachtin 10000 ppm @ 1 ml/l, being at par with each other and recorded 11.04 per cent, 11.38 per cent and 11.70 per cent pod damage respectively. The highest (27.38%) pod damage was recorded in untreated control.

Data on per cent reduction of pod damage over control during second spray indicated that, chlorantraniliprole 18.5% SC @ 0.3 ml/l was superior over control by recording highest (76.04%) per cent reduction. It was followed by flubendiamide 39.35% SC @ 0.2 ml/l with 75.68 per cent reduction. The subsequent treatments are spinosad 45% SC @ 0.3 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, and azadirachtin 10000 ppm @ 1 ml/l, with reduction of 67.90 per cent, 59.68 per cent, 58.44 per cent, 57.27 per cent respectively.

Table 4.7 Evaluation of insecticides against pea pod borer, *Helicoverpa armigera* Hub. after second spray

Treatment details	Dosage/ha (gm/a.i.)	Pre-count (1 DBS)	Per cent pod damage (On number basis)				Mean	Mean per cent reduction over control
			1DAS	3 DAS	7 DAS	14 DAS		
T1 - Spinosad 45% SC	68 gm/a.i.	12.43 (20.62) [b]	9.69 (18.12) [b]	4.83 (12.67) [b]	7.07 (15.41) [b]	9.94 (18.36) [b]	8.79 (17.24) [b]	67.90
T2 - *Beauveria bassiana* 1.15% WP	2500 g	13.11 (21.22) [b]	12.96 (21.10) [c]	10.87 (19.21) [d]	6.99 (15.31) [b]	11.28 (19.60) [c]	11.04 (19.41) [c]	59.68
T3 - Flubendiamide 39.35% SC	48 gm/a.i.	10.35 (18.75) [a]	7.38 (15.74) [a]	3.02 (9.94) [a]	5.08 (13.00) [a]	7.45 (15.82) [a]	6.66 (14.95) [a]	75.68
T4 - *Bacillus thuringiensis* var. *kurstaki (Bt)*	750 ml	13.52 (21.57) [b]	13.29 (21.37) [c]	11.14 (19.49) [d]	7.44 (15.81) [b]	11.53 (19.85) [c]	11.38 (19.72) [c]	58.44
T5 - Azadirachtin 10000 ppm	500 ml	15.42 (23.12) [c]	12.60 (20.78) [c]	7.69 (16.08) [c]	9.56 (18.00) [c]	13.21 (21.31) [c]	11.70 (20.00) [c]	57.27
T6 - Chlorantraniliprole 18.5% SC	30 gm/a.i.	10.10 (18.53) [a]	7.22 (15.58) [a]	3.27 (10.99) [a]	4.86 (12.71) [a]	7.34 (15.68) [a]	6.56 (14.83) [a]	76.04
T7 - Untreated control	-	26.15 (30.75) [d]	26.56 (31.01) [d]	27.24 (31.46) [e]	27.98 (31.94) [d]	28.98 (32.57) [d]	27.38 (31.55) [d]	-
S. Em (±)	-	0.44	0.50	0.64	0.53	0.56	0.53	-
C.D (5%)	-	1.36	1.54	1.97	1.64	1.72	1.65	-

*Figures in the parentheses are arcsine transformed values

*DBS: Days before spray *DAS: Days after spray

*S. Em: Standard error mean *C. D: Critical difference

4.2.1.3 Cumulative effect of two sprays

The data pertaining to cumulative effect of different insecticides against mean pod damage after two sprays are presented in table 4.8. It could be seen that all insecticidal treatments are significantly superior over untreated control.

The mean data revealed that, chlorantraniliprole 18.5% SC @ 0.3 ml/l was consistently proved to be the most promising insecticide against pod borer *Helicoverpa armigera* Hub. by recording lowest per cent damage of pods (7.62%) and this was found at par with flubendiamide 39.35% SC @ 0.2 ml/l, which recorded 7.79 per cent pod damage. The next treatments in the order of effectiveness were spinosad 45% SC @ 0.3 ml/l, azadirachtin 10000 ppm @ 1 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l with pod damage percentage of 9.76, 12.38, 12.72 and 13.01 per cent, respectively.

Cumulative data of two sprays consistently proved that chlorantraniliprole 18.5% SC @ 0.3 ml/l was superior over control by recording highest (70.34%) per cent reduction. It was followed by flubendiamide 39.35% SC @ 0.2 ml/l with 69.68 per cent reduction. Next in the order of reduction in per cent pod damage was spinosad 45% SC @ 0.3ml/l with 62.01 per cent reduction. The reduction in per cent damage was 51.81, 50.48 and 49.36 per cent in azadirachtin, *Beauveria bassiana* and *Bacillus thuringiensis* var. *kurstaki*, respectively.

Table 4.8 Cumulative effect of insecticides against pea pod borer, *Helicoverpa armigera* Hub.

Treatment details	Dosage/ha (gm/a.i.)	Per cent pod damage (On number basis)		Mean	Mean per cent reduction over control
		I Spray	II Spray		
T_1 - Spinosad 45% SC	68 gm/a.i.	10.97 (19.34) [b]	8.79 (17.24) [b]	9.76 (18.20) [b]	62.01
T_2 - *Beauveria bassiana* 1.15% WP	2500 g	14.81 (22.63) [c]	11.04 (19.41) [c]	12.72 (20.89) [c]	50.48
T_3 - Flubendiamide 39.35% SC	48 gm/a.i.	9.21 (17.66) [a]	6.66 (14.95) [a]	7.79 (16.21) [a]	69.68
T_4 - *Bacillus thuringiensis* var. *kurstaki (Bt)*	750 ml	15.04 (22.82) [c]	11.38 (19.72) [c]	13.01 (21.14) [c]	49.36
T_5 - Azadirachtin 10000 ppm	500 ml	13.52 (21.34) [c]	11.70 (20.00) [c]	12.38 (20.60) [c]	51.81
T_6 - Chlorantraniliprole 18.5% SC	30 gm/a.i.	8.96 (17.41) [a]	6.56 (14.83) [a]	7.62 (16.03) [a]	70.34
T_7 - Untreated control	-	23.57 (29.04) [d]	27.38 (31.55) [d]	25.69 (30.45) [d]	-
S. Em (±)	-	0.49	0.53	0.51	-
C.D (5%)	-	1.50	1.65	1.58	-

*Figures in the parentheses are arcsine transformed value

*S. Em: Standard error mean *C. D: Critical difference

4.2.2 Effect of Different Insecticides on Per cent Pod Damage on Weight Basis

The data on the effect of insecticides on per cent pod damage (on weight basis) caused by pod borer in pea after first, second and third picking is presented in Table 4.9. The per cent pod damage by pod borer was considerably lower in all the treatments as compared to untreated control at each picking.

At first picking chlorantraniliprole 18.5% SC @0.3 ml/l recorded 8.37 per cent pod damage, which was found at par with flubendiamide 39.35% SC @ 0.2 ml/l (8.60%). This was followed by spinosad 45% SC @ 0.3 ml/l with 10.37 per cent pod damage. The subsequent treatments in order of effectiveness are *Beauveria bassiana* 1.15% WP @ 5 g/l, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, and azadirachtin 10000 ppm @ 1 ml/l with 12.28 per cent, 12.43 per cent and 13.10 per cent pod damage respectively. The highest damage was recorded in untreated control with 24.78 per cent pod damage.

At second picking, chlorantraniliprole 18.5% SC @ 0.3 ml/l recorded 3.35 per cent pod damage, which was at par with flubendiamide 39.35% SC @ 0.2 ml/l (3.49%). This was followed by spinosad 45% SC @ 0.3 ml/l with 4.97 per cent damage. Azadirachtin 10000 ppm @ 1 ml/l recorded 7.37 per cent damage. The next treatments in the order of effectiveness were *Beauveria bassiana* 1.15% WP @ 5 g/l and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l with 11.60 per cent and 11.88 per cent pod damage respectively. The highest damage was recorded in untreated control with 27.55 per cent pod damage.

At third picking, the similar trend was followed with chlorantraniliprole 18.5% SC @ 0.3 ml/l recorded 7.37 per cent pod damage, which was found at par with flubendiamide 39.35% SC @ 0.2 ml/l (7.54%). This was followed by spinosad 45% SC @ 0.3 ml/l with 9.87 per cent pod damage. The next treatments in the order of effectiveness are *Beauveria bassiana*1.15% WP @ 5 g/l, and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, with 11.50 per cent and 11.69 per cent pod damage respectively. Azadirachtin 10000 ppm @ 1 ml/l was the next effective treatment with 13.59 per cent pod damage. The highest damage was recorded in untreated control with 29.82 per cent pod damage.

The mean data of all the three pickings revealed that, all the insecticidal treatments recorded significantly lesser amount of pod damage as compared to untreated control. Chlorantraniliprole 18.5% SC @ 0.3 ml/l recorded 6.36 per cent damage and at par with flubendiamide 39.35% SC @ 0.2 ml/l (6.54%). Whereas spinosad 45% SC @ 0.3 ml/l recorded 8.40 per cent pod damage. The next treatments in the order of effectiveness were azadirachtin 10000 ppm @ 1 ml/l, *Beauveria bassiana* 1.15% WP @ 5 g/l and *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l, being at par with each other and recorded 11.35 per cent, 11.79 per cent and 12.00 per cent pod damage respectively. The highest (27.38%) pod damage was recorded in untreated control.

The data of three pickings consistently proved that chlorantraniliprole 18.5% SC @ 0.3 ml/l was superior over control by recording highest (76.77%) per cent reduction. It was followed by flubendiamide 39.35% SC @ 0.2 ml/l with 76.11 per cent reduction. Next in the order of effectiveness were spinosad 45% SC @ 0.3 ml/l with 69.32 per cent reduction in damage. The reduction in per cent damage by per cent in *Bacillus thuringiensis* var. *kurstaki*, *Beauveria bassiana* and azadirachtin was in the range of by 56.17 to 58.55.

In the present study, among different treatments chlorantraniliprole and flubendiamide were found as most effective treatments in management of pod borer followed by spinosad. These findings are in corroboration with Deshmukh *et al*. (2010) who reported that flubendiamide 0.007 per cent, spinosad 0.009 per cent were found the most effective in reducing the *H. armigera* population and pod damage in chickpea. Singh *et al*. (2013) observed bioefficacy of spinosad 45 SC@ 100 g a.i./ha against *Helicoverpa armigera* (Hubner) on chickpea and reported 81.2 per cent reduction in larval population over control. Chavan *et al.* (2015) found that the rynaxypyr 20 SC significantly effective in reducing the pod damage (3.5%) followed by flubendiamide 48 SC (4.8%) in chickpea. Dhaka *et al.* (2015) reported minimum pod damage by pod borer in the treatment of flubendiamide 39.35% SC @ 75 ml/ha with 10.73 per cent pod damage, followed by spinosad 45% SC @ 500 ml/ha on pea. Patel *et al.* (2015) investigated that chlorantraniliprole 18.5 % SC @ 30 g a.i./ha registered the lowest pod damage due to pod borer in pigeon pea. Abhilasha (2016) reported flubendiamide @ 0.5 ml/l as most effective for control of pod borer in pea. Patel and Chaudhari (2016) pod damage recorded at harvest was lowest in the treatment of chlorantraniliprole (0.46 per cent), followed by flubendiamide (1.02%). Chitralekha *et al.* (2018) found chlorantraniliprole 18.5 SC was the best treatment in management of pod borer with minimum pod damage (20.23%) in chickpea. Waseem and Thakur (2019) found that flubendiamide maintained its superiority throughout the experiment with lowest pod damage (5.25%) in chickpea.

Table 4.9 Evaluation of insecticides against pea pod borer, *Helicoverpa armigera* Hub. on weight basis

Treatment details	Dosage/ha (gm/a.i.)	Per cent pod damage (On weight basis)			Mean	Mean per cent reduction over control
		I Picking	II Picking	III Picking		
T_1 - Spinosad 45% SC	68 gm/a.i.	10.37 (18.78) [b]	4.97 (12.85) [b]	9.87 (18.30) [b]	8.40 (16.85) [b]	69.32
T_2 - *Beauveria bassiana* 1.15% WP	2500 g	12.28 (20.51) [c]	11.60 (19.90) [d]	11.50 (19.81) [c]	11.79 (20.08) [c]	56.94
T_3 - Flubendiamide 39.35% SC	48 gm/a.i.	8.60 (17.03) [a]	3.49 (10.75) [a]	7.54 (15.90) [a]	6.54 (14.82) [a]	76.11
T_4 - *Bacillus thuringiensis* var. *kurstaki (Bt)*	750 ml	12.43 (20.64) [c]	11.88 (20.15) [d]	11.69 (19.98) [c]	12.00 (20.27) [c]	56.17
T_5 - Azadirachtin 10000 ppm	500 ml	13.10 (21.21) [c]	7.37 (15.74) [c]	13.59 (21.62) [d]	11.35 (19.68) [c]	58.55
T_6 - Chlorantraniliprole 18.5% SC	30 gm/a.i.	8.37 (16.80) [a]	3.35 (10.47) [a]	7.37 (15.72) [a]	6.36 (14.60) [a]	76.77
T_7 - Untreated control	-	24.78 (29.85) [d]	27.55 (31.66) [e]	29.82 (33.09) [e]	27.38 (31.55) [d]	-
S. Em (±)	-	0.50	0.57	0.48	0.56	-
C.D (5%)	-	1.55	1.76	1.48	1.74	-

*Figures in parentheses are arcsine transformed values

*S. Em: Standard error mean *C. D: Critical difference

Yadav *et al.* (2019) reported that flubendiamide 480 SC @ 30 g a.i./ha gave 87.78 per cent reduction, which was at par with rynaxypyr 20SC @ 40 g a.i./ha (83.33%). Banerjee and Pal (2021) observed that chlorantraniliprole 18.5 SC @ 25 g a.i./ha was the most effective in control of pod borer damage in field pea. Saiteja and Kumar (2022) recorded spinosad 45% SC @ 0.2 ml/l (15.21%) as effective treatment in control of pod borer in pea.

4.2.3 Influence of Different Insecticides on Pea Yield

The result pertaining to the yield as influenced by different insecticides used for pod borer management were presented in table 4.10. All the insecticide treatments were found superior over untreated control in terms of yield.

The study indicated that T_6 (chlorantraniliprole @ 18.5 Sc) registered highest yield of 11.90 t/ha with maximum per cent increase over untreated control (74.48%). This was followed by T_3 (flubendiamide @ 39.35 SC) registering 11.46 t/ha with 68.03 per cent increase over untreated control. Treatments T_1 (spinosad, 10.84 t/ha), T_5 (azadirachtin, 10.22 t/ha), T_2 (*Beauveria bassiana*, 10.03 t/ha), and T_4 (*Bacillus thuringiensis* var. *kurstaki*, 9.96 t/ha) were next to follow in the order. Untreated plot has recorded 6.82 t/ha yield.

The present findings are in close agreement with Dhaka *et al.* (2015) who reported highest pea yield (95.84 q/ha) in the plot treated with flubendiamide 39.35% SC @ 75 ml/ ha, it was followed by spinosad 45% Sc @ 500 ml/ha (91.63 q/ ha), neemarin 1500 ppm (72.78 q/ha), and *Bacillus thuringiensis* (68.99 q/ha). Banerjee and Pal (2021) observed that the highest yield of garden pea was obtained from the plot treated with chlorantraniliprole 18.5 SC @ 25 g a.i./ha. Saiteja and Kumar (2022) recorded that the plot treated spinosad 45% SC @ 0.2 ml/l has recorded comparatively higher yield (16.40 q/ha) of garden pea, followed by *Beauveria bassiana* 1.5% SG and *Bacillus thuringiensis* with 13.25 q/ha and 11.80 q/ha, respectively.

Table 4.10 Influence of insecticides on yield of pea

Treatment details	Dosage/ha (gm/a.i.)	Average yield		Per cent increase yield over control
		Kg/ plot	t/ ha	
T_1 - Spinosad 45% SC	68 gm/a.i	9.76	10.84	58.94
T_2 - *Beauveria bassiana* 1.15% WP	2500 g	9.03	10.03	47.07
T_3 - Flubendiamide 39.35% SC	48 gm/a.i	10.31	11.46	68.03
T_4 - *Bacillus thuringiensis* var. *kurstaki (Bt)*	750 ml	8.96	9.96	46.04
T_5 - Azadirachtin 10000 ppm	500 ml	9.19	10.22	49.85
T_6 - Chlorantraniliprole 18.5% SC	30 gm/a.i	10.71	11.90	74.48
T_7 - Untreated control	-	6.14	6.82	-
S. Em (±)		0.18	-	-
C.D. at 5 %		0.54	-	-

*S. Em: Standard error mean C.D: Critical difference

4.2.4 Incremental Cost Benefit Ratio of Different Treatments in Pea

The comparative analysis of economics of various insecticidal treatments is presented in Table 4.11. The present investigation included six insecticides against pea pod borer, *Helicoverpa armigera* Hub. under field conditions and all the treatments were effective in reducing pod borer damage and recorded increased yield over control.

Highest cost of plant protection/ha was recorded in the treatment spinosad 45% SC @ 0.3 ml/l, while minimum cost was incurred in *Beauveria bassiana* 1.15% WP @ 5 g/l which was Rs. 9800/ha and Rs. 3000/ha for two sprays. The highest ICBR ratio was obtained from plot treated with *Beauveria bassiana* 1.15% WP @ 5 g/l (1:41.80) followed by *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l and azadirachtin 10000 ppm @ 1 ml/, reported ICBR ratio 1:27.54 and 1:26.20 rupees, respectively. Besides that, chlorantraniliprole 18.5% SC @ 0.3 ml/l, flubendiamide 39.35% SC @ 0.2 ml/l, and spinosad 45% SC @ 0.3 ml/l, reported ICBR ratio 1:25.68, 25.51 and 15.41 rupees, respectively.

Table 4.11 Incremental cost benefit ratio of different treatments on pea

Treatment details	Dosage/ha (gm/a.i.) (A)	Quantity of insecticide/ha (g/ml) (B)	Yield (t/ha) (C)	Increase inyield over control (t/ha) (D)	Value of increase in yield (Rs. /ha) (E)	Cost of insecticides for 2 applications (Rs. /ha) (F)	Application cost for two applications (Rs. /ha) (G)	Total cost of application (H= F+G)	Net profit (Rs. /ha) (I=E-H)	ICBR (J=I/H)
T_1 - Spinosad 45% SC	68	150	10.84	4.02	160800	7800	2000	9800	151000	1:15.41
T_2 - *Beauveria bassiana* 1.15% WP	-	2500	10.03	3.21	128400	1000	2000	3000	125400	1:41.80
T_3 - Flubendiamide 39.35% SC	48	100	11.46	4.64	185600	5000	2000	7000	178600	1:25.51
T_4 - *Bacillus thuringiensis* var. *kurstaki (Bt)*	-	750	9.96	3.14	125600	2400	2000	4400	121200	1:27.54
T_5 - Azadirachtin 10000 ppm	-	500	10.22	3.40	136000	3000	2000	5000	131000	1:26.20
T_6 - Chlorantraniliprole 18.5% SC	30	150	11.90	5.08	203200	5700	2000	7700	195500	1:25.68
T_7 - Untreated control	-	-	6.82	-	-	-	-	-	-	-

Total cost = Cost of insecticides + Application cost

Spinosad 45% SC	:	1950 Rs. /75ml	*Beauveria bassiana* 1.15% WP	:	200 Rs. /Kg
Flubendiamide 39.35% SC	:	2500 Rs. /100ml	*Bacillus thuringiensis* var. *kurstaki* (*Bt*)	:	1600 Rs. /L
Azadirachtin 1.00% EC	:	3000 Rs. /L	Chlorantraniliprole 18.5% SC	:	1900 Rs. /100ml
Number of applications	:	Two	Two Labour charges	:	1000 Rs. /Application
Average market price	:	40000 Rs. /t			

4.3 Dissipation Pattern of Flubendiamide and Chlorantraniliprole in Pea

In order to study dissipation pattern of flubendiamide 39.35% SC and chlorantraniliprole 18.5 % SC, a field experiment was conducted at experimental farm of Department of Entomology, PGI, M.P.K.V., Rahuri. The laboratory analysis was carried out at Pesticide Residue Laboratory, All India Network Project on Pesticide Residues, Department of Entomology, M.P.K.V., Rahuri as explained under chapter 3 (Materials and methods).

4.3.1 Method validation

Validation parameters *viz*., LOD, LOQ, linearity, accuracy and precision were determined before analysis of samples and results are presented here under.

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

The limit of detection (LOD) of the tested insecticide was 0.01 mg/kg resulting from signal-to-noise ratio of insecticide with reference to the background noise (3:1) obtained from the blank sample. The limit of quantification (LOQ) determined as the lowest concentration of insecticide of interest into sample giving a response that could be quantified with RSD lower than 20 per cent, was 0.05 mg/kg for both the insecticides.

4.3.1.2 Linearity

A linearity study was performed to determine the performance of the detector and validity of instrument. Linearity line was established with concentrations of standard and corresponding peak area. The results of linearity study both in solvent as well as matrix revealed that response of both the insecticides was linear over the range tested and regression coefficient (R^2) values were greater than 0.99 over the range tested which proved validity of instrument method for analysis of insecticides of interest.

4.3.1.3 Recovery

Accuracy of the analytical method was determined by recovery studies. Precision of the method was reflected into the relative standard deviation.

The recovery percentages and relative standard deviation values are presented in Table 4.12. The data revealed that the recovery of flubendiamide (94.98, 93.42 and 95.99%), des-iodo flubendiamide (100.17, 98.10 and 98.38%) and chlorantraniliprole (88.35, 102.90, and 99.80%) in pea at different levels of fortification was observed to be in the range of acceptable limit (70 to 120 %) as mentioned in SANTE (2017) guidelines. This proved the suitability of analytical method for the extraction and cleanup of pea sample.

Table 4.12 Recovery of flubendiamide, its metabolite des-iodo and chlorantraniliprole in pea

Substrate	Fortification level (mg/kg)	Recovery (%)											
		Flubendiamide				Des-iodo flubendiamide (Flubendiamide metabolite)				Chlorantraniliprole			
		R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean
Pea	**0.05**	95.37	96.75	92.83	94.98 (±2.15)	98.70	102.44	99.36	100.17 (±2.00)	85.35	93.23	86.45	88.35 (±4.88)
	0.25	94.04	96.05	90.16	93.42 (±3.26)	99.30	98.59	96.42	98.10 (±1.50)	99.31	101.47	107.92	102.90 (±5.02)
	0.50	94.17	97.37	96.43	95.99 (±1.82)	99.73	98.52	99.33	98.38 (±1.03)	98.13	101.06	100.20	99.80 (±1.80)

4.3.1.4 Repeatability and Reproducibility

The results of repeatability and reproducibility studies showed that the recovery ranged between 80-110 per cent and the methodwas found valid.

The results of method validation parameters showed that the QuEChERS method employed for the extraction and clean-up of pea samples was found accurate and precise as mean recovery percentage and relative standard deviation (RSD) were within the limit prescribed by SANTE, 2017. According to SANTE, 2017 guidelines, analytical method which records mean recovery in the range of 70-120 per cent with RSD below 20 per cent is accurate and precise.

4.3.2 Residues of insecticides in pea

Dissipation of flubendiamide, des-iodo flubendiamide and chlorantraniliprole was studied after two applications at the standard dose and 1.25X of the standard dose in pea crop.

4.3.2.1 Dissipation of flubendiamide and its metabolite des-iodo in pea

Dissipation of residues in plant depends upon climatic condition, type of application, doses and interval between application and time of harvest.

Overall result of analysis of pea grains after 2nd application of flubendiamide 39.35 SC @ 48 and 60 g a.i./ha are presented in Table 4.13. The mean initial residues of flubendiamide were 0.05 and 0.06 mg/kg. The residues of flubendiamide reached to below determination level of 0.05 mg/kg on one day after the spray at both recommended dose and 1.25X of recommended dose. Metabolite of flubendiamide *i.e.,* des-iodo flubendiamide, was not detected in any of the sample (Table 4.14).

In current study, it has been observed that flubendiamide residues dropped below the determination level (BDL) just one day after the second spray application. This phenomenon may have multiple underlying reasons. Firstly, our analysis involved the removal of the outer pod cover, which raises the possibility that the insecticides did not penetrate the seeds due to flubendiamide's nature as a contact insecticide. Additionally, flubendiamide, as a green labeled molecule, has shorter persistence.

The present findings are found closely in line with Kooner *et al.* (2009) who reported that flubendiamide residues reached to below its determination limit (0.01 mg/kg) on 3rd day (48 g a.i./ha) and 5th day (96 g a.i./ha) after its third application in tomato. Chawla *et al*. (2011) reported flubendiamide @ 90 g a.i./ha and @ 180 g a.i./ha residues in brinjal fruits dissipated to below determination limit of 0.05 mg/kg after 3 days and 5 days, respectively. Takkar *et al*. (2012) found that residues of flubendiamide @ 90 g a.i./ha and @ 180 g a.i./ha in brinjal fruits were reached to below determination limit (0.05 mg/kg) on 3rd day and on 5th day, respectively. Sharma and Parihar (2013) studied the persistence of flubendiamide in tomato following application of flubendiamide @ 46 g a.i./ha and 96 g a.i./ha and reported that the residues were dissipated to below LOQ (0.01 mg/kg) on 5th day and 7th day, after the 3rd spray. Sharma *et al*. (2014) found that flubendiamide residues in cabbage were found only up to one day @ 24 g a.i./ha and up to 3rd day @ 48 g a.i./ha after the 2nd spray. There after it reached to below determination limit (0.01 mg/kg).

4.3.2.1 Dissipation of chlorantraniliprole in pea

Dissipation of chlorantraniliprole 18.5 SC was studied @ 30 and 37.50 g a.i./ha in pea. The results pertaining to this study are described under here in Table 4.15.

In the present study, the mean initial residues of chlorantraniliprole were found to be 0.08 and 0.09 mg/kg. These residues dissipated to 0.05 and 0.06 mg/kg after a day at standard and 1.25X of the standard doses, respectively. The residues of chlorantraniliprole reached below its LOQ of 0.05 mg/kg on 3rd day at both standard dose and 1.25X of standard dose.

As regarding the residues of chlorantraniliprole, the residues were observed only up to one day after the 2nd spray thereafter on 3rd day it reached to below determination level. This phenomenon may have multiple underlying reasons. Firstly, our analysis involved the removal of the outer pod cover, which raises the possibility that the insecticides did not penetrate the seeds due to chlorantraniliprole's nature as a contact insecticide. Additionally, chlorantraniliprole, as a green-labeled molecule, has a shorter persistence.

The current findings are supported by Kar *et al.* (2013) who reported that chlorantraniliprole @ 9.25 g a.i./ha and 18.5 g a.i./ha declined to below determination level of 0.01 mg/kg after 3 days and 5 days with RL_{50} of 1.36 and 1.25 days, respectively in cauliflower. Sharma *et al.* (2019) observed that initial deposit of chlorantraniliprole were 0.03 mg/kg and 0.04 mg/kg in tomato following application of chlorantraniliprole @ 30 g a.i./ha and 60 g a.i./ha, respectively. These deposits dissipated to below determination level (0.03 mg/kg) after 1 day and 3 days with half-life of 1.95 and 1.55 days, respectively for the recommended and double the recommended doses. Sheoran *et al.* (2023) reported that chlorantraniliprole 18.5% SC residues with initial deposit of 0.083 mg/kg and 0.144 mg/kg after application of chlorantraniliprole @ 125 ml/ha and @ 250 ml/ha in okra fruits and it reached to LOQ (0.01 mg/kg) on the 7th day and 10th day respectively. All these findings found in line with the current findings.

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

Table 4.13 Dissipation of flubendiamide residues at different intervals in pea

Interval between last application andsampling	Residues mg/kg											
	Untreated control				Flubendiamide @ 48 g a.i/ha				Flubendiamide @ 60 g a.i./ha			
	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean
0 Day	ND	ND	ND	ND	0.052	0.051	0.052	0.05 (± 0.001)	0.065	0.060	0.064	0.06 (± 0.003)
1 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
3 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
5 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
7 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
10 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
15 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
DT_{50} (Days)	_				-				-			

*<LOQ = Limit of Quantification (0.05 mg/kg)

*ND= Not Detected

*DT = Dissipation time

Table 4.14 Dissipation of des-iodo (metabolite of flubendiamide) residues at different intervals in pea

Interval between last application andsampling	Residues mg/kg											
	Untreated control				Des-iodo flubendiamide @ 48 g a.i/ha				Des-iodo flubendiamide @ 60 g a.i./ha			
	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean
0 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
1 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
3 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
5 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
7 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
10 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
15 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
DT_{50} (Days)	-				-				-			

*<LOQ = Limit of Quantification (0.05 mg/kg)

*ND= Not Detected

*DT = Dissipation time

Table 4.15 Dissipation of chlorantraniliprole residues at different intervals in pea

Interval between last application andsampling	Residues mg/kg											
	Untreated control				Chlorantraniliprole @ 30 g a.i/ha				Chlorantraniliprole @ 37.50 g a.i./ha			
	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean	R_1	R_2	R_3	Mean
0 Day	ND	ND	ND	ND	0.087	0.079	0.084	0.08 (±0.004)	0.092	0.91	0.096	0.09 (± 0.01)
1 Day	ND	ND	ND	ND	0.053	0.055	0.056	0.05 (± 0.005)	0.063	0.058	0.065	0.06 (± 0.002)
3 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
5 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
7 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
10 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
15 Day	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
DT_{50} (Days)	_				**1.47**				**1.71**			

*<LOQ = Limit of Quantification (0.05 mg/kg)

*ND= Not Detected

*DT = Dissipation time

5. SUMMARY AND CONCLUSION

5.1 Summary

5.1.1 Monitoring of Insecticide Residues in Market Samples of Pea

The local market samples of pea were collected from Akole (Ahmednagar), Narayangoan (Pune), Phaltan (Satara) and analysed for residues by adopting the validated QuChERS multiresidue method. Out of 75 samples, 67 samples did not record detectable residues and 08 samples were recorded with insecticide residues. None of the samples were recorded with insecticide residues above MRL values prescribed by FSSAI.

Dimethoate was the only insecticide detected in all positive samples from all three locations. The range of dimethoate residues was 0.02 mg/kg to 0.09 mg/kg and not exceeded the FSSAI MRL.

5.1.2 Evaluation of Performance of Some Newer Insecticides against Pod Borer in Pea

Considering the performance of insecticides (on number basis), chlorantraniliprole 18.5% SC @ 0.3 ml/l was proved to be highly effective by recording lowest per cent pod damage (7.62%) and maximum reduction in pod damage over control (70.34%). This was found at par with flubendiamide 39.35% SC @ 0.2ml/l with 7.79 per cent pod damage and 69.68 per cent reduction in pod damage over control. Spinosad 45% SC @ 0.3 ml/l was next in the order of effectiveness with 9.76 % pod damage and 62.01 % reduction in pod damage over control. Next treatments to follow were azadirachtin 10000 ppm @ 1 ml/l (12.38% pod damage & 51.81% reduction in pod damage over control), *Beauveria bassiana* 1.15% WP @ 5 g/l (12.72% pod damage & 50.48% reduction in pod damage over control), *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l (13.01% pod damage & 49.36% reduction in pod damage over control).

Considering the performance of insecticides (on weight basis), chlorantraniliprole 18.5% SC @ 0.3 ml/l was proved to be highly effective by recording lowest per cent pod damage (6.36%) and maximum reduction of pod damage over control (76.77%). This was found at par with flubendiamide 39.35% SC @ 0.2ml/l with 6.54 per cent pod damage and 76.11 per cent reduction over control. This was followed by spinosad 45% SC @ 0.3 ml/l (8.40% pod damage & 69.32% reduction in pod damage over control). Next treatments to follow were azadirachtin 10000 ppm @ 1 ml/l (11.35% pod damage & 58.55% reduction in pod damage over control), *Beauveria bassiana* 1.15% WP @ 5 g/l (11.79% pod damage & 56.94% reduction in pod damage over control), *Bacillus thuringiensis* var. *kurstaki* @ 1.5 ml/l (12.00 % pod damage & 56.17% reduction in pod damage over control).

Chlorantraniliprole registered highest yield of 11.90 t/ha with maximum per cent increase over control (69.65%). Highest incremental cost benefit ratio (ICBR) was obtained from *Beauveria bassiana* 1.15% WP @ 5 g/l (1:41.80). However, chlorantraniliprole 18.5% SC recorded highest net profit (Rs. 195500/ha) over control.

5.1.3 Dissipation Pattern of Flubendiamide and Chlorantraniliprole in Pea

The mean initial residues of flubendiamide @ 48 and 60 g a.i./ha in pea were found to be 0.05 and 0.06 mg/kg which dissipated below LOQ on 1st day after 2nd spray. Des-iodo flubendiamide, a metabolite was not detected in any of the pea samples.

In case of chlorantraniliprole @ 30 and 37.5 g a.i./ha, the initial residues were 0.08 and 0.09 mg/kg. This was reached to below LOQ on 3rd day after 2nd spray. The half-life values calculated were 1.47 and 1.71 days for both the doses, respectively.

5.2 Conclusions

Off the 75 samples of pea analyzed for presence of pesticide residues, only 08 samples (10.66 %) were detected with residues of insecticide and the levels of residues are less that FSSAI MRLL.

Residues of dimethoate was detected in pea samples although this insecticide is not registered in India for use in this crop.

Chlorantraniliprole @ 30 g a.i./ha proved to be the most effective treatment by reducing pod borer damage (74.34%) with highest yield of pea (11.90 t/ha) and this was followed by flubendiamide (11.46 t/ha). Though the highest ICBR was registered by *Beauveria bassiana* (1:41.80), the chlorantraniliprole @ 30 g a.i./ha registered highest net profit.

The data generated on dissipation pattern of flubendiamide and chlorantraniliprole will be useful for determination of safe waiting periods for insecticides in pea crop and for fixing MRL by regulatory authorities. At present no MRL is prescribed for flubendiamide and chlorantraniliprole in pea, Considering LOQ of 0.05 mg/kg for flubendiamide and chlorantraniliprole pre harvest interval (PHI) of three days can be recommended to harvest residue free pea.

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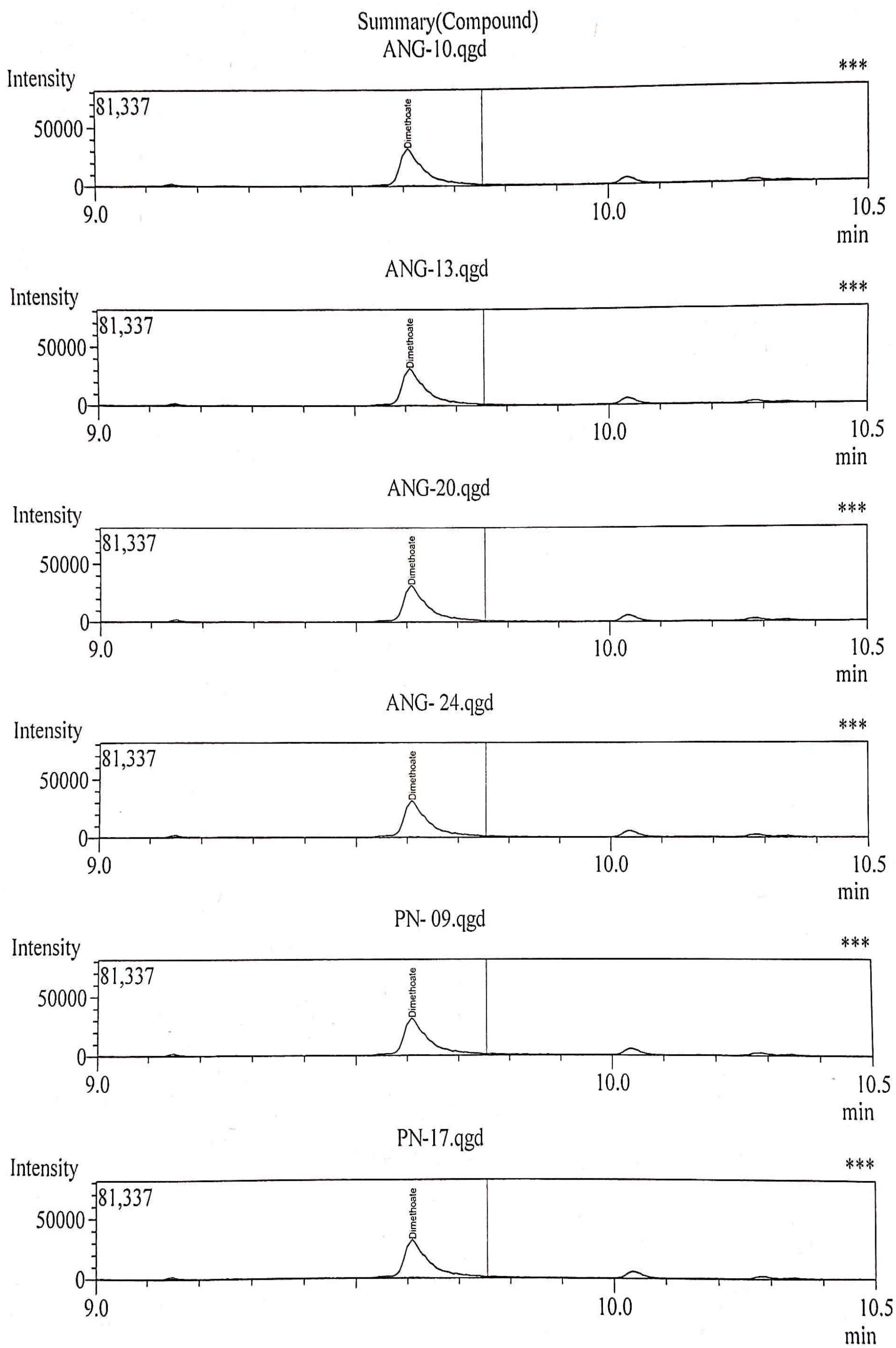
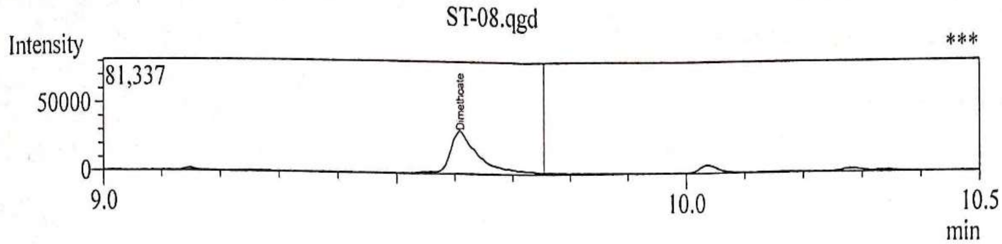
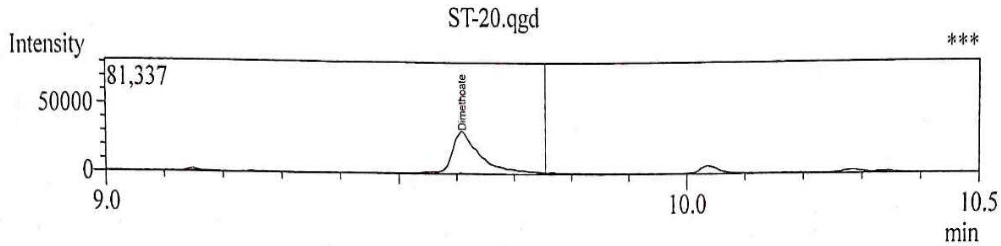
7. APPENDICES

APPENDIX I
Chromatograph Showing Detection of Pesticide Residue in Pea Samples



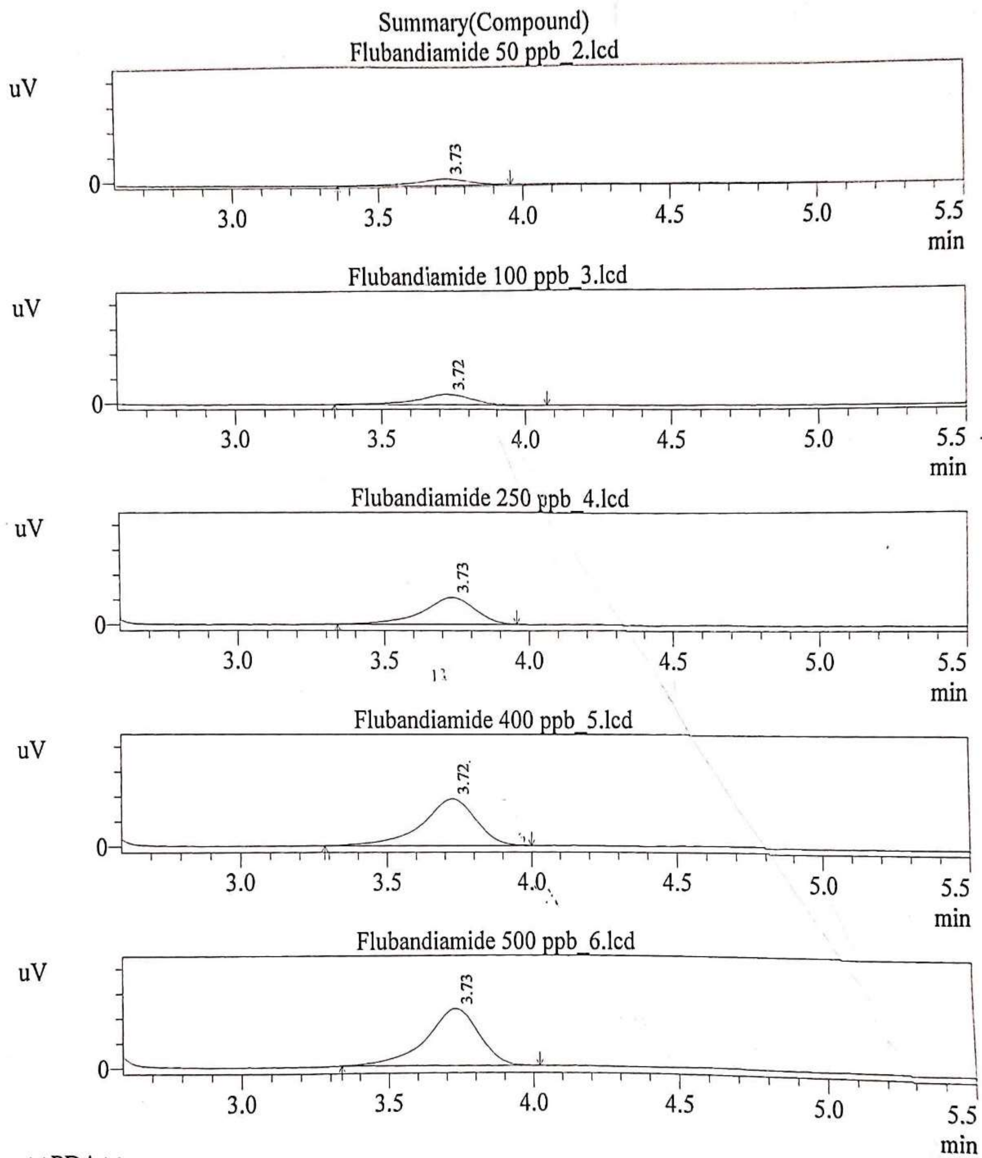




[MS] ID1 Compound Name:Dimethoate

Title	Ret. Time	Area	Height
ANG-10.qgd	9.609	12503	8470
ANG-13.qgd	9.609	21675	10655
ANG-20.qgd	9.609	20608	10504
ANG- 24.qgd	9.609	9885	7270
PN- 09.qgd	9.609	6229	5699
PN-17.qgd	9.609	17653	9956
ST-08.qgd	9.609	16096	9628
ST-20.qgd	9.609	8083	6683

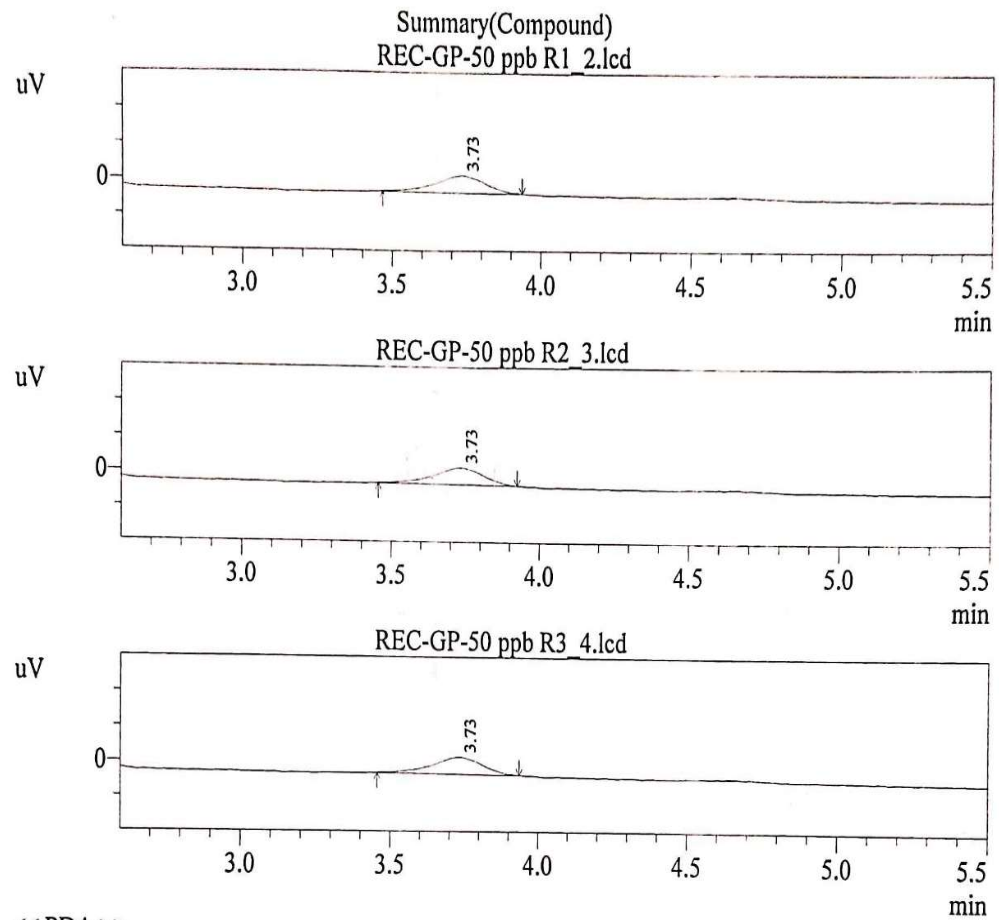
APPENDIX II
Chromatograph Showing Linearity of Flubendiamide



<< PDA >>
ID#1 Compound Name: FLUBENDIAMIDE

Title	Ret. Time	Area	Height
Flubandiamide 50 ppb_2.lcd	3.727	6178	497
Flubandiamide 100 ppb_3.lcd	3.722	10721	821
Flubandiamide 250 ppb_4.lcd	3.728	27219	2164
Flubandiamide 400 ppb_5.lcd	3.722	49043	3793
Flubandiamide 500 ppb_6.lcd	3.726	58137	4604

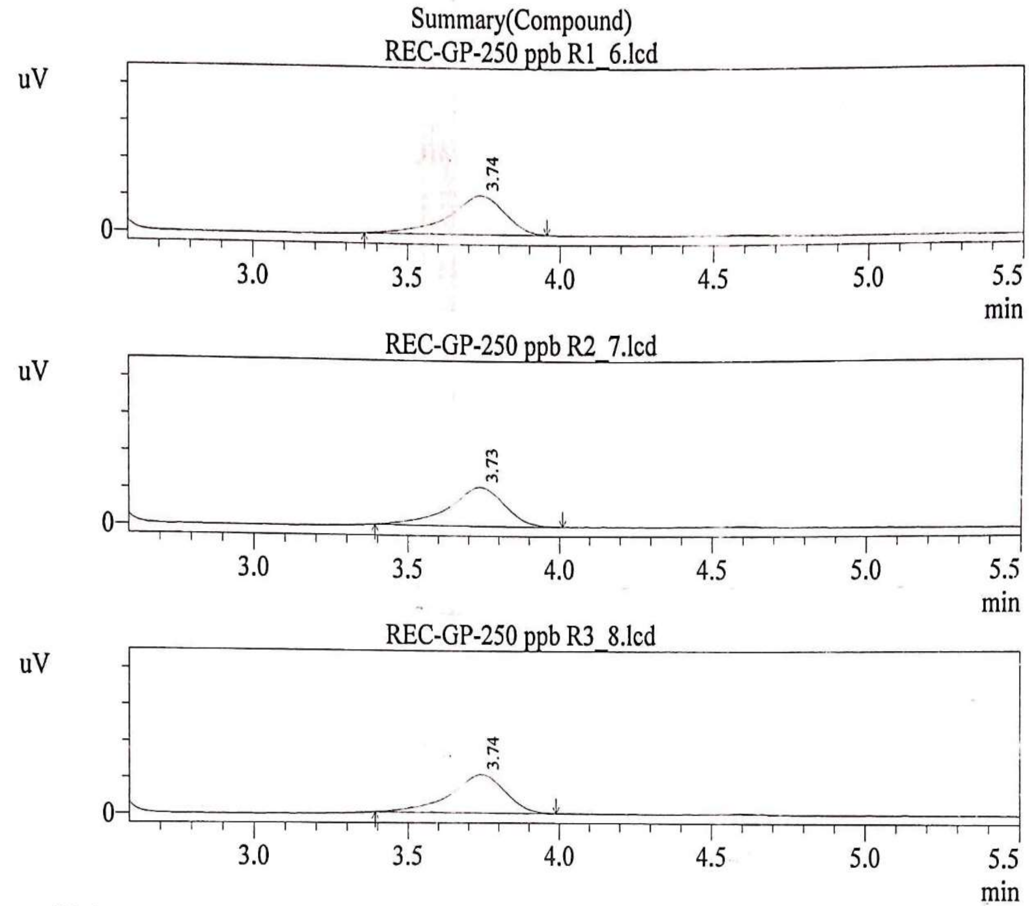
APPENDIX III
Chromatograph Showing Recovery of Flubendiamide



<< PDA >>

ID#1 Compound Name: Flubendiamide

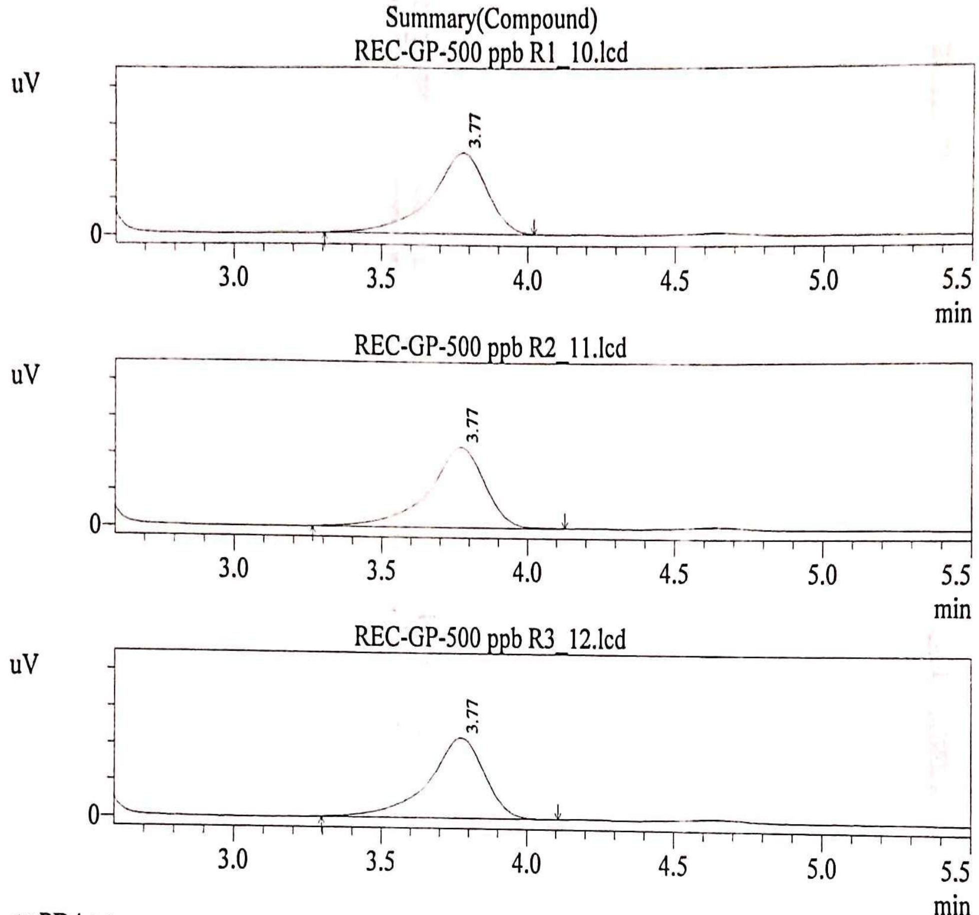
Title	Ret. Time	Area	Height
REC-GP-50 ppb R1_2.lcd	3.727	5729	484
REC-GP-50 ppb R2_3.lcd	3.727	5613	479
REC-GP-50 ppb R3_4.lcd	3.727	5725	484



<< PDA >>

ID#1 Compound Name: Flubendiamide

Title	Ret. Time	Area	Height
REC-GP-250 ppb R1_6.lcd	3.735	27032	2110
REC-GP-250 ppb R2_7.lcd	3.733	26791	2119
REC-GP-250 ppb R3_8.lcd	3.737	26779	2126

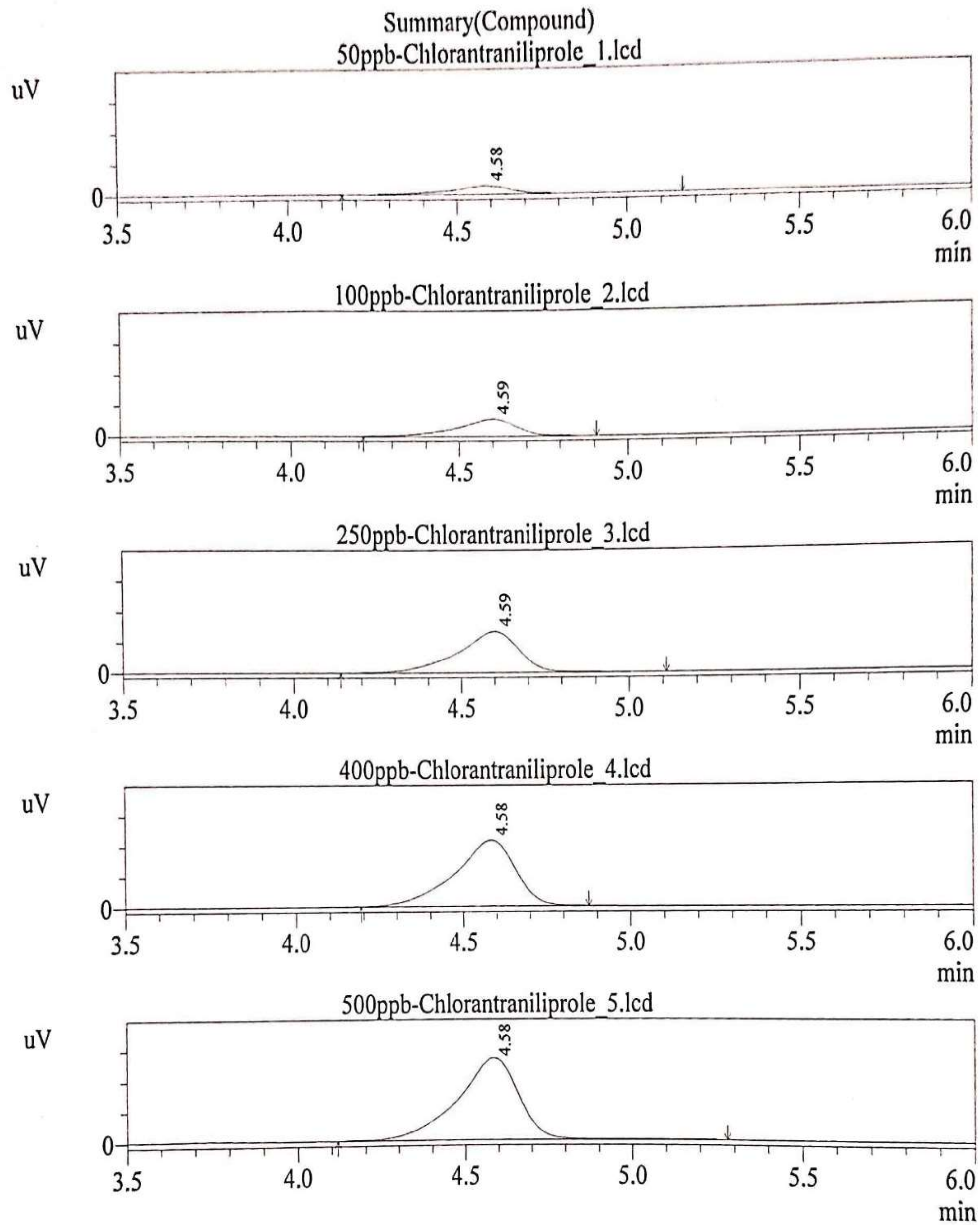


<< PDA >>

ID#1 Compound Name: Flubendiamide

Title	Ret. Time	Area	Height
REC-GP-500 ppb R1_10.lcd	3.775	57320	4342
REC-GP-500 ppb R2_11.lcd	3.767	58751	4383
REC-GP-500 ppb R3_12.lcd	3.768	58266	4378

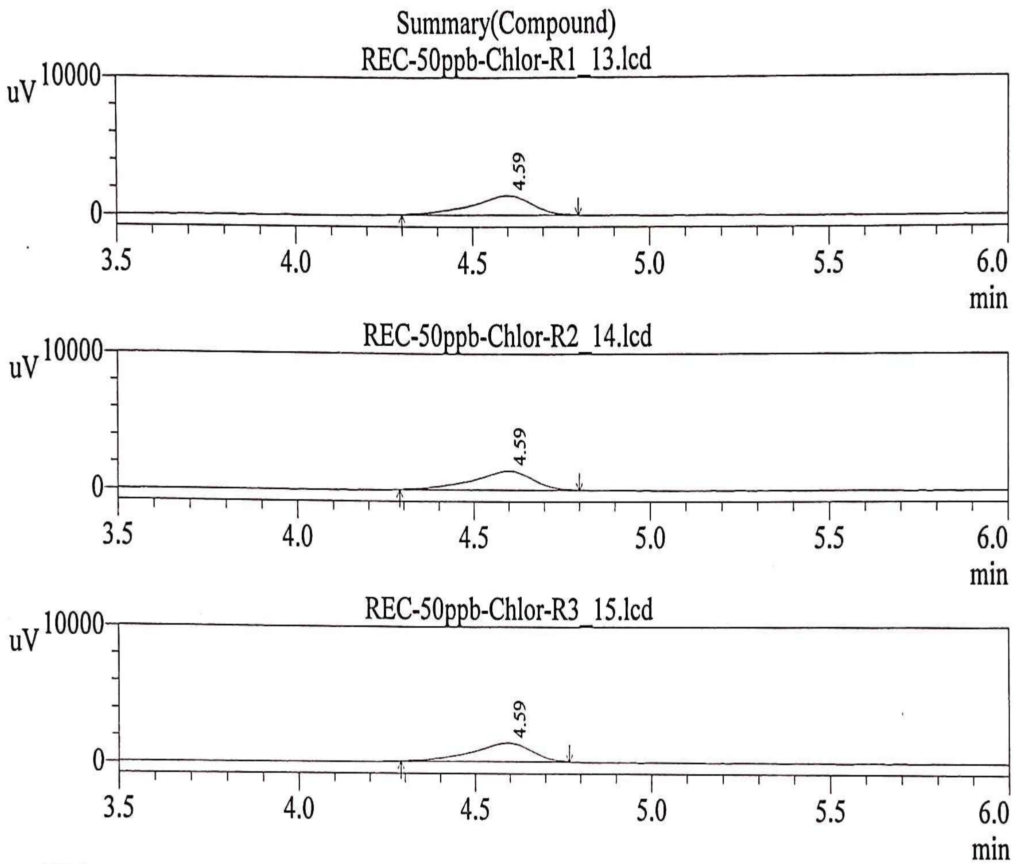
APPENDIX IV
Chromatograph Showing Linearity of Chlorantraniliprole



<< PDA >>
ID#1 Compound Name: Chlorantraniliprole

Title	Ret. Time	Area	Height
50ppb-Chlorantraniliprole_1.lcd	4.580	17718	1393
100ppb-Chlorantraniliprole_2.lcd	4.593	35136	2784
250ppb-Chlorantraniliprole_3.lcd	4.594	87447	6823
400ppb-Chlorantraniliprole_4.lcd	4.579	138137	10937
500ppb-Chlorantraniliprole_5.lcd	4.581	174120	13567

APPENDIX IV
Chromatograph Showing Recovery of Chlorantraniliprole



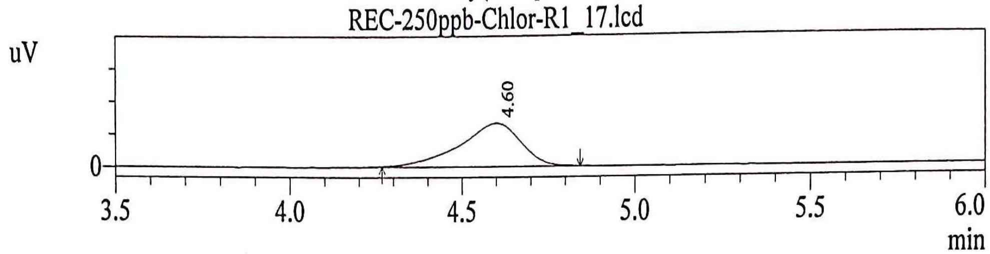
<< PDA >>

ID#1 Compound Name: Chlorantraniliprole

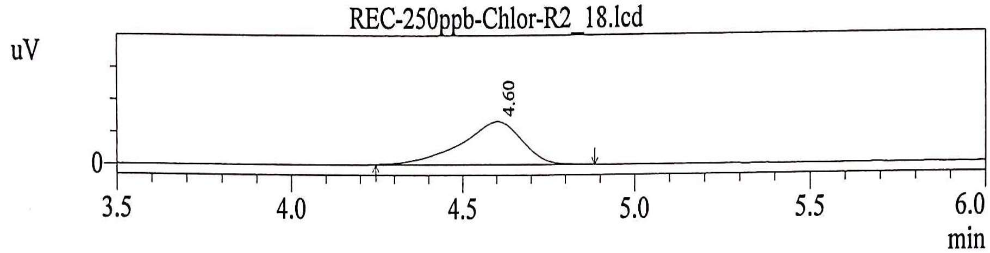
Title	Ret. Time	Area	Height
REC-50ppb-Chlor-R1_13.lcd	4.595	16898	1405
REC-50ppb-Chlor-R2_14.lcd	4.594	17142	1421
REC-50ppb-Chlor-R3_15.lcd	4.589	16448	1387

Summary(Compound)

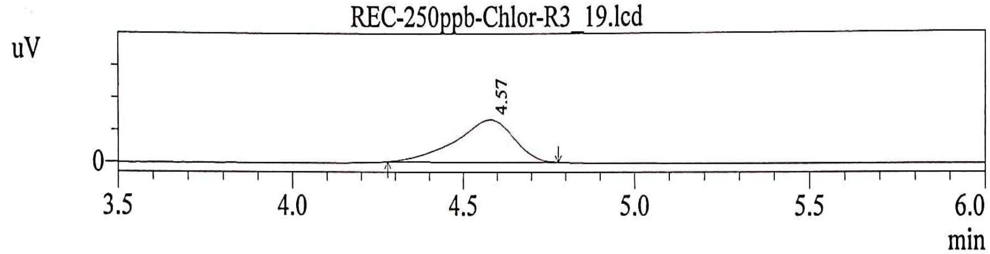
REC-250ppb-Chlor-R1_17.lcd



REC-250ppb-Chlor-R2_18.lcd



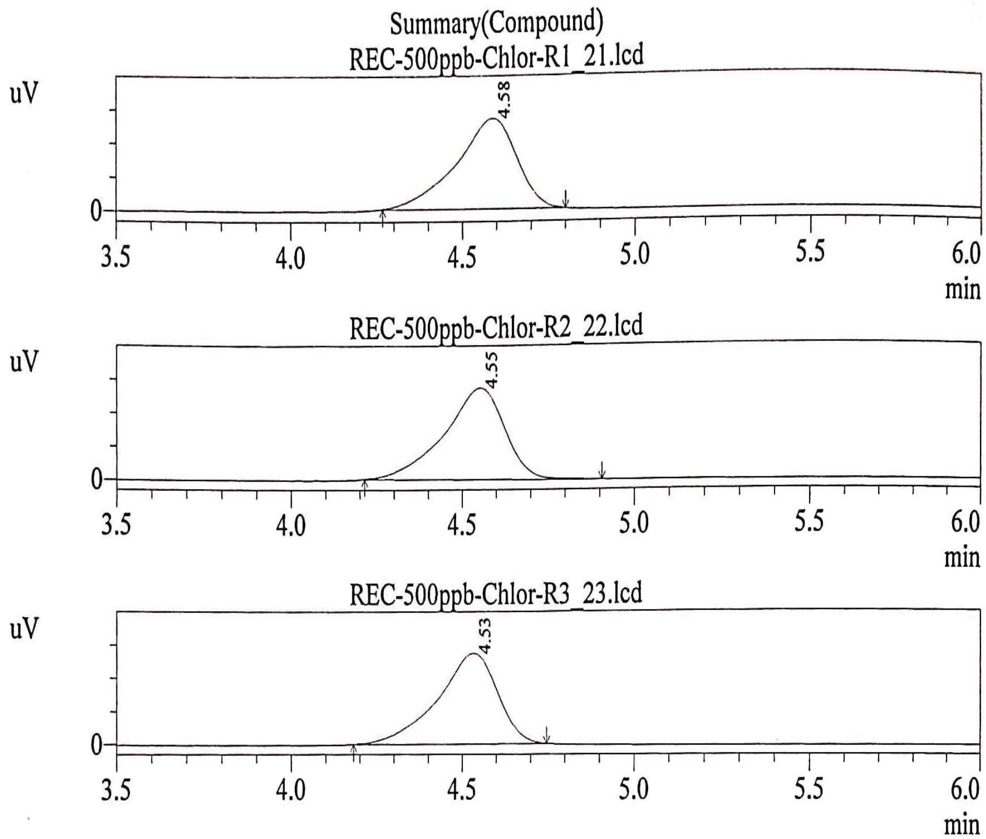
REC-250ppb-Chlor-R3_19.lcd



<< PDA >>

ID#1 Compound Name: Chlorantraniliprole

Title	Ret. Time	Area	Height
REC-250ppb-Chlor-R1_17.lcd	4.595	82235	6638
REC-250ppb-Chlor-R2_18.lcd	4.597	83989	6678
REC-250ppb-Chlor-R3_19.lcd	4.574	78845	6615



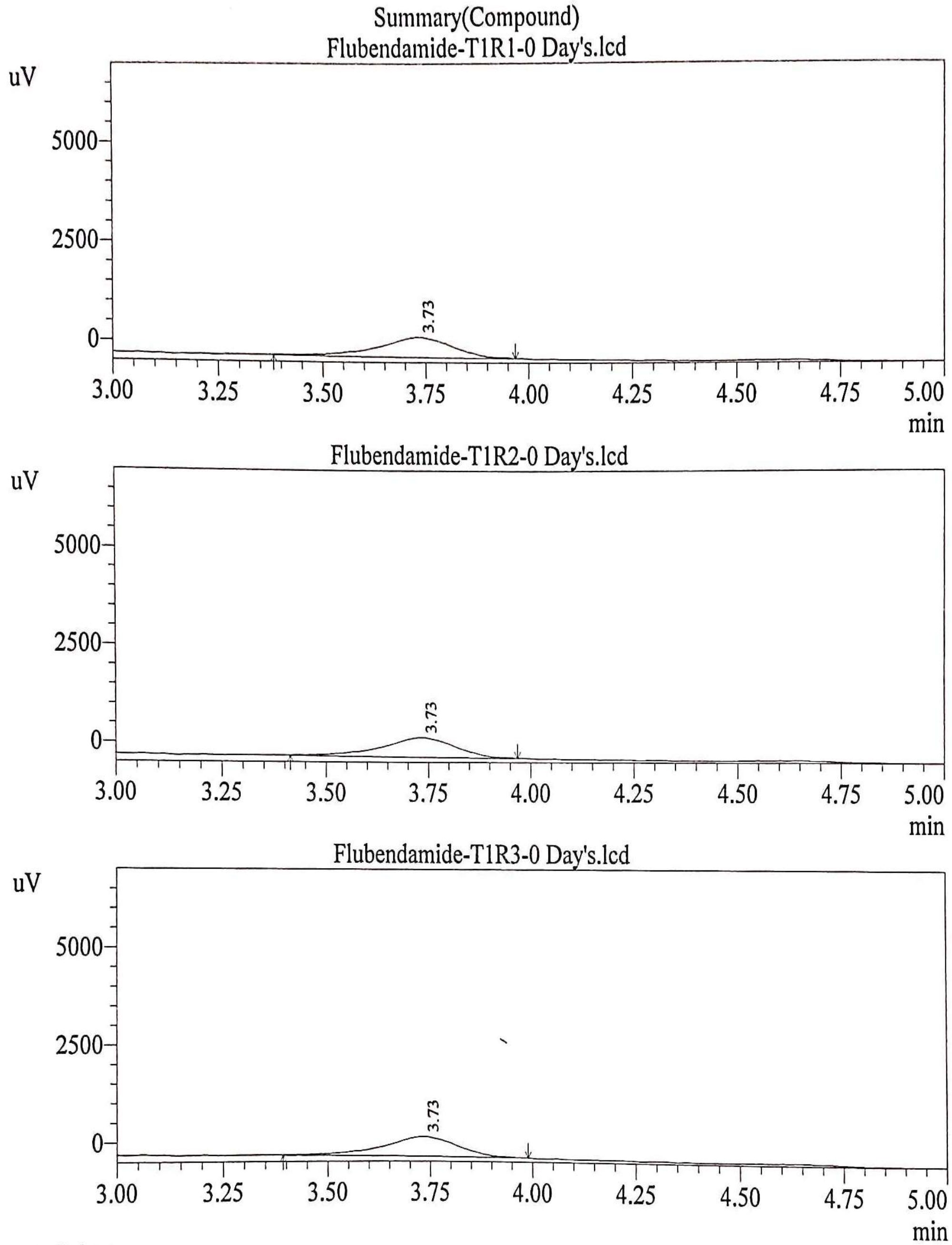
<< PDA >>

ID#1 Compound Name: Chlorantraniliprole

Title	Ret. Time	Area	Height
REC-500ppb-Chlor-R1_21.lcd	4.583	163977	13403
REC-500ppb-Chlor-R2_22.lcd	4.547	169542	13759
REC-500ppb-Chlor-R3_23.lcd	4.528	167896	13752

APPENDIX VI

Chromatograph Showing Dissipation of Flubendiamide



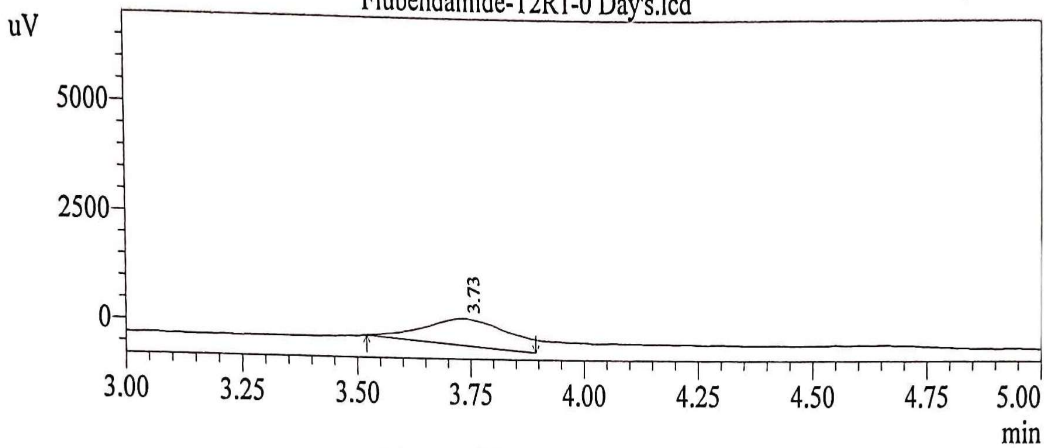
<< PDA >>

ID#1 Compound Name: FLUBENDIAMIDE

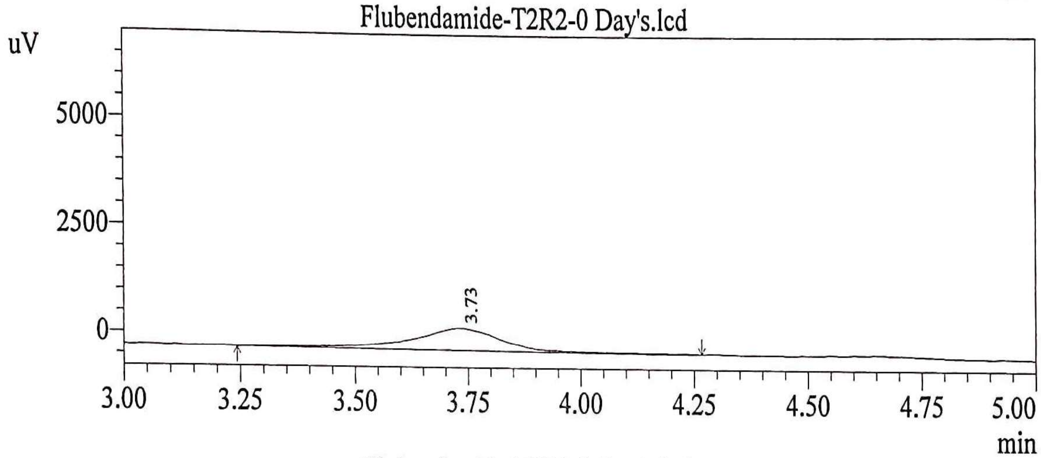
Title	Ret. Time	Area	Height
Flubendamide-T1R1-0 Day's.lcd	3.727	6399	503
Flubendamide-T1R2-0 Day's.lcd	3.727	6259	500
Flubendamide-T1R3-0 Day's.lcd	3.727	6365	502

Summary(Compound)

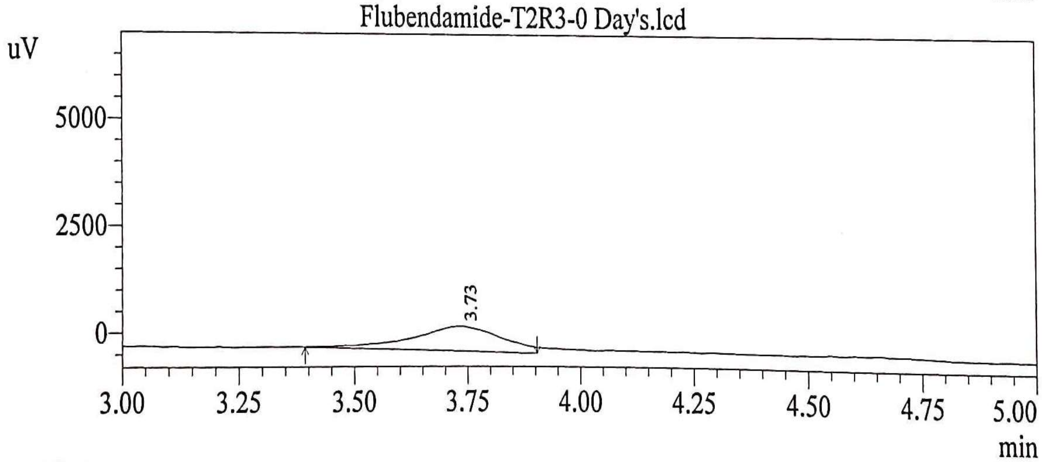
Flubendamide-T2R1-0 Day's.lcd



Flubendamide-T2R2-0 Day's.lcd



Flubendamide-T2R3-0 Day's.lcd

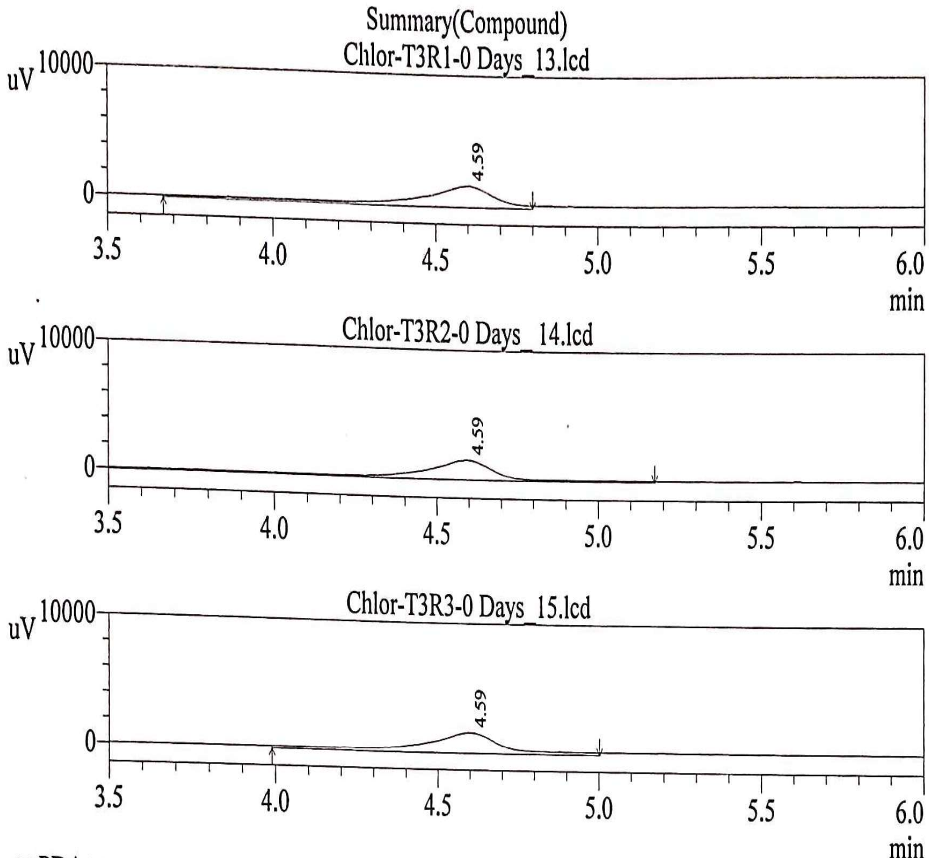


<< PDA >>

ID#1 Compound Name: FLUBENDIAMIDE

Title	Ret. Time	Area	Height
Flubendamide-T2R1-0 Day's.lcd	3.727	8008	605
Flubendamide-T2R2-0 Day's.lcd	3.727	7400	524
Flubendamide-T2R3-0 Day's.lcd	3.727	7915	571

APPENDIX VII
Chromatograph Showing Dissipation of Chlorantraniliprole



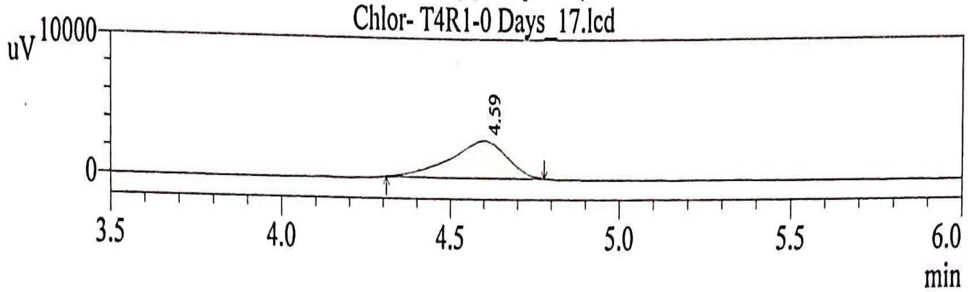
<< PDA >>

ID#1 Compound Name: Chlorantraniliprole

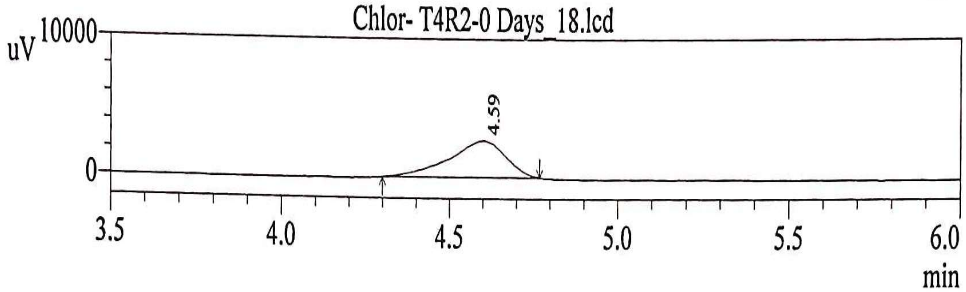
Title	Ret. Time	Area	Height
Chlor-T3R1-0 Days_13.lcd	4.594	29753	1651
Chlor-T3R2-0 Days_14.lcd	4.589	27245	1531
Chlor-T3R3-0 Days_15.lcd	4.595	28936	1627

Summary(Compound)

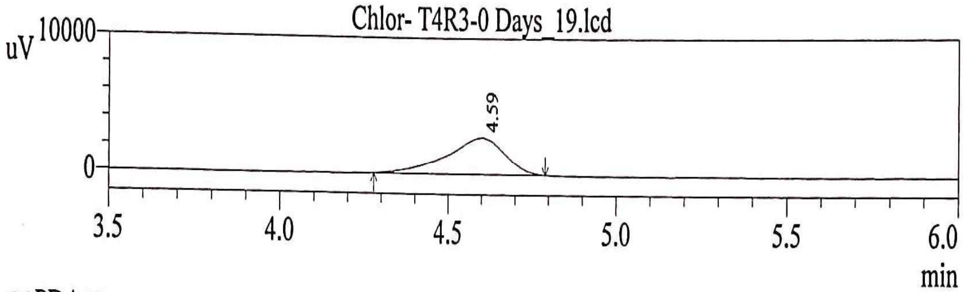
Chlor- T4R1-0 Days_17.lcd



Chlor- T4R2-0 Days_18.lcd



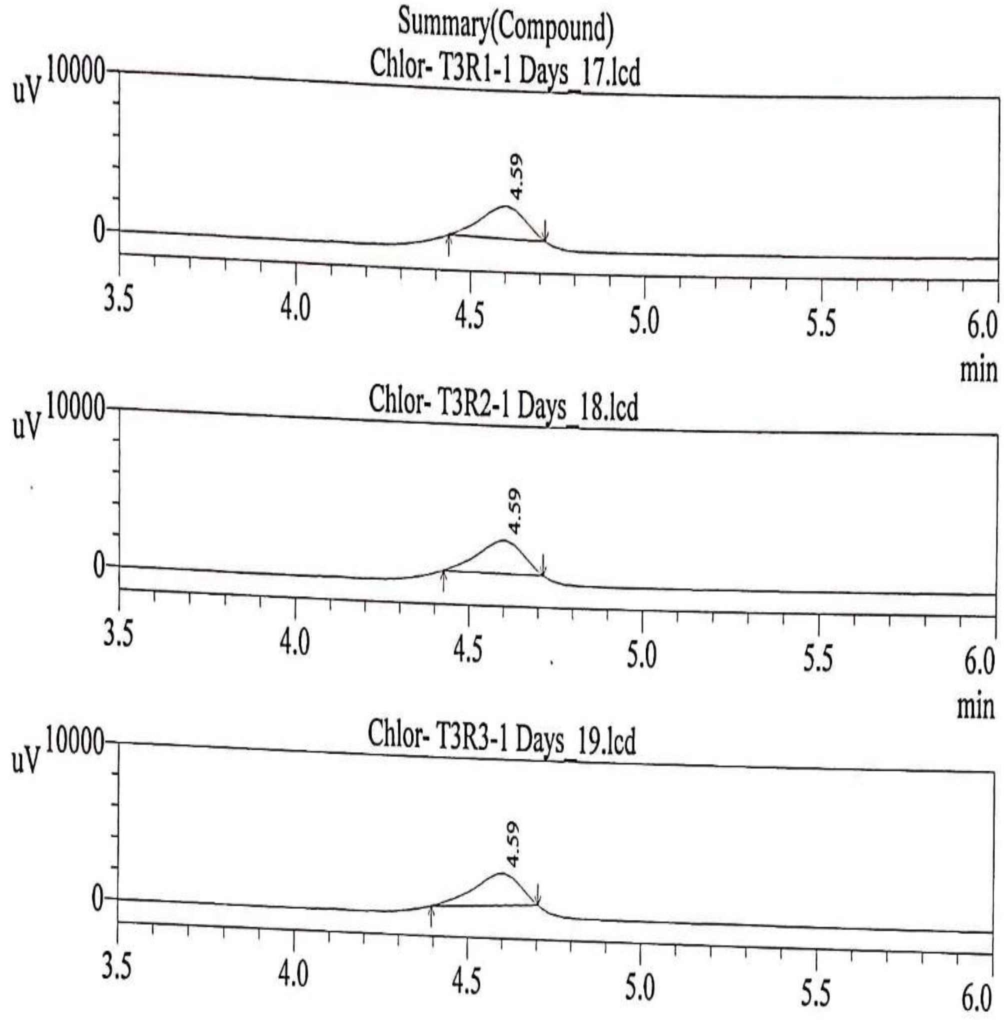
Chlor- T4R3-0 Days_19.lcd



<<PDA>>

ID#1 Compound Name: Chlorantraniliprole

Title	Ret. Time	Area	Height
Chlor- T4R1-0 Days_17.lcd	4.593	31562	2675
Chlor- T4R2-0 Days_18.lcd	4.593	31300	2657
Chlor- T4R3-0 Days_19.lcd	4.593	32997	2719

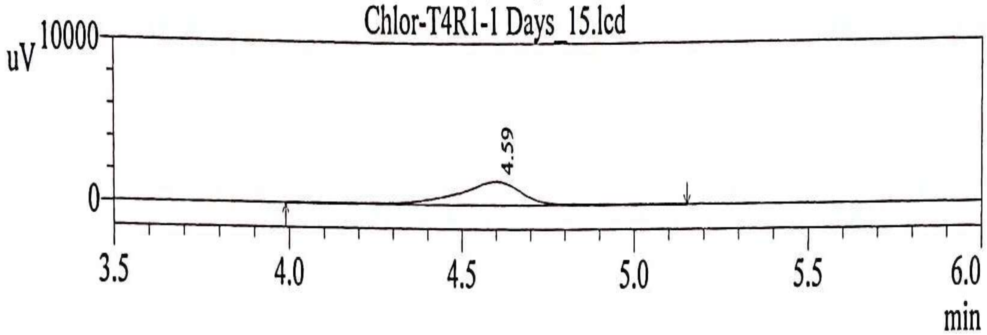


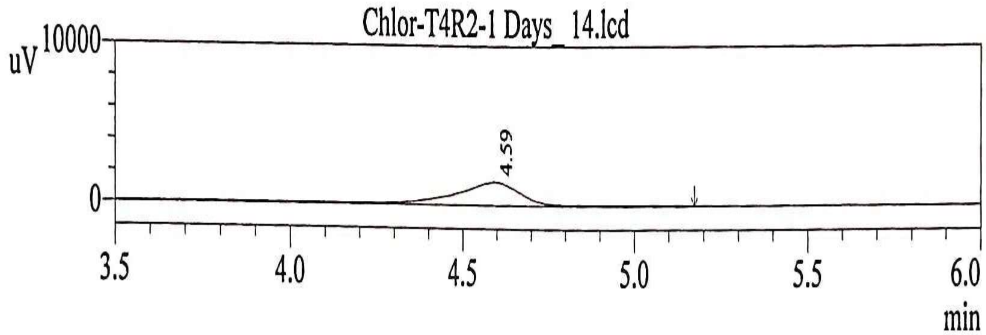
<< PDA >>

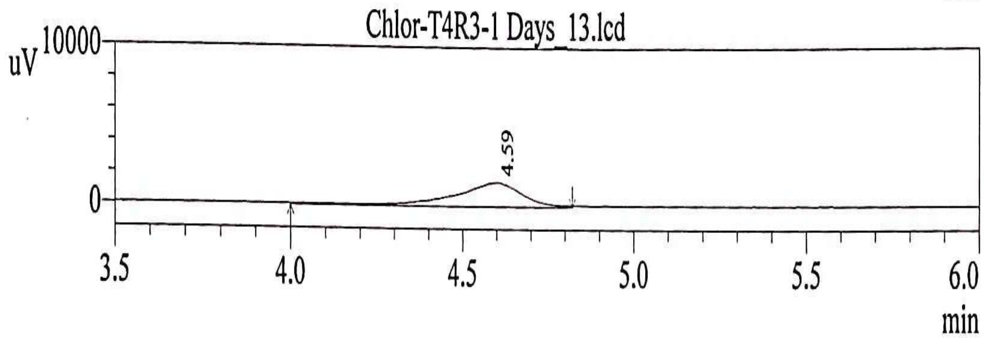
ID#1 Compound Name: Chlorantraniliprole

Title	Ret. Time	Area	Height
Chlor- T3R1-1 Days_17.lcd	4.593	18000	2060
Chlor- T3R2-1 Days_18.lcd	4.593	18830	2101
Chlor- T3R3-1 Days_19.lcd	4.593	19225	2070

Summary(Compound)







<< PDA >>

ID#1 Compound Name: Chlorantraniliprole

Title	Ret. Time	Area	Height
Chlor-T4R1-1 Days_15.lcd	4.595	19721	1465
Chlor-T4R2-1 Days_14.lcd	4.589	21560	1482
Chlor-T4R3-1 Days_13.lcd	4.594	22243	1526

8. VITAE

Mr. Mahesh G Koulagi

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL ENTOMOLOGY

2023

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