BIO-EFFICACY OF CONVENTIONAL INSECTICIDES AGAINST FALL ARMYWORM *Spodoptera frugiperda* (J E Smith) AND THEIR DISSIPATION IN/ON MAIZE

by

Miss. Vishaka Sadanand Kamble
(Reg. No. 019/143)

A thesis submitted to the

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

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH
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APPROVED BY

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RAHURI - 413 722, DIST - AHMEDNAGAR
MAHARASHTRA, INDIA
2022

CANDIDATE'S DECLARATION

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

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Date: /01/ 2022

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This is to certify that the thesis entitled, **"BIO-EFFICACY OF CONVENTIONAL INSECTICIDES AGAINST FALL ARMYWORM *Spodoptera frugiperda* (J E Smith) AND THEIR DISSIPATION IN/ON MAIZE"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist - Ahmednagar (M.S.) in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **VISHAKA SADANAND KAMBLE,** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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

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Date: /01/ 2022

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS

a.i.	:	Active ingredient
ADI	:	Acceptable Daily Intake
AICRP	:	All India Cordinated Research Project
AINP	:	All India Network Project
BDL	:	Below Detection Limit
BQL	:	Below Quantification Limit
CD	:	Critical Difference
Cm	:	centimeter
CRM	:	Certified Reference Material
Con.	:	concentration
DAS	:	Days After Spraying
EC	:	Emulsifiable Concentrate
ETL	:	Economic Threshold Level
et al.	:	*et alli* (and other)
etc.	:	Et cetera (and so on)
EU	:	European Union
FAO	:	Food and Agriculture Organisation
FAW	:	Fall Armyworm
Fig.	:	Figure (s)
G	:	Gram (s)
GC-MS/MS	:	Gas Chromatography Mass Spectrometry Mass Spectrometry
ha	:	Hectare (s)
Hrs	:	Hour (s)
ICBR	:	Incremental Cost Benefit Ratio
i.e.	:	*Id est* (that is)
IPM	:	Integrated Pest Management
IUPAC	:	International Union of Pure and Applied Chemistry
kg	:	Kilogram(s)
lit./L	:	Litre (s)
LOD	:	Limit of Detection
LOQ	:	Limit of Quantification

Ltd	:	Limited
$MgSO_4$	:	Magnesium sulphate
m	:	Meter(s)
mg	:	Milligram(s)
min.	:	Minute(s)
ml	:	Milliliter(s)
mm	:	Millimeter(s)
M.P.K.V	:	Mahatma Phule Krishi Vidyapeeth
MRL	:	Maximum Residue Limit
MT	:	Metric Tonne(s)
Na_2SO_4	:	Sodium sulphate
ND	:	Not Detected
nm	:	Nanometer(s)
PGI	:	Post Graduate Institute
PHI	:	Pre Harvest Interval
ppm	:	Parts Per Million
PSA	:	Primary Secondary Amine
Pvt.	:	Private
Q/q	:	Quintal(s)
QEChERS	:	Quick Easy Cheap Effective Rugged Safe
R	:	Regression coefficient
RL_{50}	:	Residual life 50
rpm	:	Revolution Per Minute
Rs.	:	Rupee(s)
RBD	:	Randomized Block Design
RSD		Relative Standard Deviation
RT	:	Retention Time
SE(m)	:	Standard Error of Mean
T	:	Tonne(s)
Tr. No.	:	Treatment Number
µg	:	Microgram(s)
µl	:	Microliter(s)
viz.	:	Videlicet(Namely)

Vol.	:	Volume
Wt.	:	Weight
>	:	Greater than
%	:	Per cent
@	:	At the rate
+	:	Plus
^{0}C	:	Degree celcius

ABSTRACT

BIO-EFFICACY OF CONVENTIONAL INSECTICIDES AGAINST FALL ARMYWORM *Spodoptera frugiperda* (J E Smith) AND THEIR DISSIPATION IN/ON MAIZE

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2022

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

The present investigation entitled "Bio-efficacy of conventional insecticides against fall armyworm *Spodoptera frugiperda* (J E Smith) and their dissipation in/on maize" was conducted at Instructional farm of Post Graduate Institute M.P.K.V, Rahuri during *Rabi* 2020-21. The efficacy was studied in the field while the dissipation studies were carried out in laboratory at AINP on Pesticide Residues, Department of Education, M.P.K.V, Rahuri.

The field experiment on bioefficacy of insecticide consisted eight treatments *viz*., bifenthrin 10% EC @ 50 g a.i./ha, deltamethrin 2.8% EC @ 15 g a.i./ha, lambda cyhalothrin 5%EC 15 g a.i./ha, cypermethrin 10% EC @ 50 g a.i./ha, ethion 50% EC @ 500 g a.i./ha, fevalrate 10% EC @ 75 g a.i./ha, profenofos 50% EC @ 500 g a.i./ha and untreated control. These treatments were evaluated in Randomized Block Design in three replications. Observations were recorded as number of larvae per 30 plants and per cent infestation of fall armyworm larvae. Total number of three sprays were given at 10 days interval starting from the time when sufficient pest population was observed.

Among all the tested insecticides, the treatment of profenofos 50% EC @ 500 g a.i./ha expressed its superiority over rest of the treatments disclosing itself to be the most promising treatment with mean larval population of 4.61 and per cent infestation of 9.77. The range of mean larval population for other treatments varied from 7.27 to 28.86 and that for per cent infestation varied from 12.52 to 46.04 per cent. The next treatments to follow profenofos 50%

Abstract contd…. **Miss. Kamble V. S.**

EC @ 500 g a.i./ha were lambda cyhalothrin 5% EC @ 15 g a.i./ha and cypermethrin 10% EC @ 50 g a.i./ha. Further, profenofos 50% EC @500 g a.i. /ha proved effective with the cob yield of 8.5 T/ha with maximum ICBR of 1:8.60.

The studies on dissipation pattern of lambda cyhalothrin and cypermethrin were performed using two sprays of each insecticide separately at an interval of 10 days, the first spray being given at cob initiation stage. In the immature maize cobs, the mean initial residues of lambda cyhalothrin @ 15 and 30 ga.i./ha were found to be 0.584 and 0.892 mg/kg respectively, which dissipated to BQL after 10th and 15th day respectively, after second spray. The half-life values were 2.22 and 2.66 days for recommended and double the recommended doses respectively. The mean initial residue for cypermethrin @ 50 and 100 ga.i./ha was recorded to be 0.271 and 0.478 mg/kg, which gradually decreased to BQL after 7th and 10th day respectively. The half-life values calculated for recommended and double the recommended doses were 2.10 and 2.42 days respectively.

Pages 1 to 62

1. INTRODUCTION

Maize (*Zea mays*), also known as "Queen of Cereals" is the world's third most important cereal crop after rice and wheat. The crop is used as human and poultry feed, as well as livestock fodder. It is also an important input for corn starch industry, corn oil production, baby corns, *etc*. Globally, India ranks 4th in area and 7th in production of maize contributing approximately 4% and 2% of global area and production of maize, respectively (DACNET 2020). In India, area under maize crop is 9.63 million hectare with production and productivity of 25.90 million tones and 2.68 T/ha respectively during 2016-17 (Anon., 2018). Of the total production of maize, poultry feed accounts for approximately 47 per cent, whereas the remaining produce is used for livestock feed and food (13%), industrial purposes (12%), starch industry (14%), processed food (7%), export and other purposes (6%). In India, Madhya Pradesh has the highest area under maize (14.22%) followed by Karnataka (13.3 %), Maharashtra (11.91%), Rajasthan (9.54%), Telangana (8.33%) and Uttar Pradesh (7.67%). Maharashtra has the highest state productivity (3 T/ha) (Anon., 2018). Maize is principally grown in India during two seasons: *Kharif* and *Rabi*. *Kharif* maize accounts for approximately 83 per cent of maize area in India, while *Rabi* maize accounts for 17 per cent of maize area. Over 70% of *Kharif* maize area is grown under rainfed conditions.

Maize, just like many other cereal crops is vulnerable to both abiotic as well as biotic factors, insect pest incidence being one of them. There are 139 insect species in India attacking maize crop and causing damage of variable degrees to it. Fortunately, there are only a few insect pest species that cause serious damage from sowing to storage (Kumar and Alam, 2017).

Since 2018, maize crop production in India has been threatened by the arrival of a new pest, *Spodoptera frugiperda* (J E Smith). The pest is native to the Americas' tropical and subtropical regions, and it is also found in Argentina, Brazil, Mexico, and the United States (Prowell *et al.* 2004; Clark *et al.* 2007). It harms a variety of crops including maize, soybean, cotton (Pogue 2002; Nagoshi *et al.* 2007; Bueno et al. 2010) rice, other grasses, and feeds on a number of weeds (Nabity *et al.* 2011). The incursion of fall armyworm as an invasive pest into Asia was reported for the first time from India on maize during May 2018 (Sharanabasappa *et al.* 2018a). Later, it has spread in other states of India on maize (Mahadevaswamy*et al.* 2018; Sharanabasappa *et al.* 2018b). It was first reported in Maharashtra in September 2018 in Tandulwadi village, Solapur district by the farmer Ganesh Babar (Khergamker, 2019). Fall armyworm is abbreviated as FAW. A female moth lays approximately 1000 hair- covered eggs in single or multiple clusters. The newborn larvae disperse from the hatching site ingroups and feed on the epidermal layers of the lower surface of tender leaves. The larvae grow through six stages of development known as instars before pupating. The larva feed by scraping the leaf surface, forming elongated papery windows of various sizes that are spread across the leaves of nearby plants. Larva causes ragged-edged round to oblong holes. The size of the holes on the leaves grow with the larva, and it feeds voraciously on the leaves, causing a larger area of leaves to be lost.

In severe cases, it defoliates the leaves extensively and produces a large amount of fecal matter. Tassels and corn ears are vulnerable parts to be damaged during the reproductive stage. According to Sena(2003), the loss caused by fall armyworm observed by using digital color images was found to be 94.72% of 720 images. This signifies the importance of this pest in maize crop production.

The economic importance of the crop compelled farmers to use insecticidal sprays to protect the crop from the pest. At present, the Central Insecticide Board and Registration Committee recommends the use of chlorantraniliprole 18.5 SC, thiamethoxam 12.6% + lambda cyhalothrin 9.5 % ZC, and spinetoram 11.7 SC for fall armyworm management (DPPQS 2019). In India, maize is primarily grown by farmers who do not have access to reliable irrigation. As a result, these rainfed farmers prefer conventional and less expensive insecticides, which they also use on other crops. This necessitates an evaluation of the various commonly used insecticides against fall armyworm. Furthermore, the use of insecticides to protect crops from pest attack may result in the accumulation of insecticide residues in edible crop parts. Good agricultural practices (GAP) necessitate the use of insecticides while keeping safe withholding periods in mind. Studies on dissipation of insecticides are crucial under different agro climatic conditions and for each crop before making recommendations on waiting period for specific insecticides and crops as the weather conditions and host plant play an important role in the dissipation of insecticide residues. However, a review of the literature revealed that very little research has been conducted on the bio-efficacy of insecticides against maize fall armyworm and their dissipation in/on maize. As a result, the current study was designed with the following goals in mind:

1. To evaluate the efficacy of conventional insecticides against S*podoptera frugiperda*
2. To study the dissipation pattern of selected insecticides on maize

2. REVIEW OF LITERATURE

The literature pertaining to the bio-efficacy of conventional insecticides against fall armyworm, *Spodoptera frugiperda* (J E Smith) and their dissipation in maize and cropped soil is very scanty, hence the literature on bio-efficacy and dissipation of insecticides against FAW on maize as well as on other crops and other lepidopteran pests has been reviewed here under different headings.

2.1 Efficacy of Conventional Insecticides against *S. frugiperda*

2.1.1 Efficacy of Conventional Insecticides against *S. frugiperda* in Maize and Other Cereals

Young (1986) observed that when a combination of chlorpyriphos (0.26-0.56 kg a.i./ ha) and a pyrethroid (permethrin, fenvalerate or cypermethrin 0.056 kg a.i./ ha) was chemigated, excellent control of FAW was obtained on spring and summer grown sweet corn.

All *et al*. (1986) reported that pyrethroid insecticides fenvalerate; permethrin and cypermethrin were not highly effective on FAW at rates labeled for other sweet corn pests. Tank mixing of fenvalerate with methomyl or chlorpyrifos resulted in control of FAW damage and verified laboratory studies indicating synergism of these mixtures. Several new pyrethroid insecticides showed promise in controlling the fall armyworm in sweet corn including cyhalothrin.

Guillebeau and All (1991) illustrated through the field trials of all rates tested of pyrethroid insecticides trailomethrin, flucythrinate and cyhalothrin to be as effective as manufacturer`s recommendation rate of chlorpyriphos and methomyl against FAW in whorl stage sweet corn, field corn and sorghum. Permethrin, cypermethrin, fenvalerate and cyfluthrin gave erratic control of FAW injury in field corn and sweet corn compared with chlorpyriphos and methomyl; these insecticides were comparable with other treatments against FAW in whorl stage sorghum.

Smith (2009) checked upon the efficacy of lambda cyhalothrin against fall armyworm in maize. According to registered outcomes, the number of larvae per 10 plants noted on 3rd, 8th and 15th day after treatment were 9.0, 7.3 and 4.5 whereas that for methomyl 2.4 SL + lambda cyhalothrin 2.08 EC were 8.3, 6.0 and 2.5 respectively.

Belay *et al.* (2012) reported the effects of spinosad, chlorantraniliprole and cyhalothrin on the mortality of FAW to be intermediate among all the treatments considered at 16 hrs after application under laboratory condition. Cyhalothrin showed an increased larval mortality at 48 hrs that was equivalent to spinetoram and acephate. At 96 h after application, all insecticides except methoxyfenozide and bifenthrin resulted in more than 80% FAW larval mortality. Indoxacarb, flubendiamide and lambda cyhalothrin required longer (≥ 96 hrs) to achieve higher levels of mortality of FAW.

Dal *et al.* (2012) carried out an experiment in the field with six treatments, one of it being - spinosad, lufenuron, thiamethoxam + lambda cyhalothrin and deltamethrin (in sequence at 10 days interval). The caterpillar population (20.9-21.7 larvae/plot) observed in corn plants were significantly lower in treated plots as compared to the untreated control and the same was observed in case of index of damage (1.2-1.7).

Hardke *et al*. (2011) checked four insecticides and five commercial standards (including lambda cyhalothrin). The consequences of the field trial against native FAW infestation in sorghum depicted that lambda cyhalothrin and methoxyfenozide treated plots reduced the number of infested whorls below that in non treated control within three days after treatment (DAT). In residual efficacy studies, exposure of FAW to lambda cyhalothrin treated tissue resulted in significantly greater mortality as compared to non-treated tissues at 7 DAT.

Fernandes *et al.* (2018) deliberated the performance of individual and combined insecticides for the control of FAW caterpillars under laboratory conditions. The outcome stated that by residual contact after 72 hours, chlorfenapyr + zeta cypermethrin treatment had 100% efficacy in mortality of both the instars. When applied via direct contact after 72 hours later, the combined treatment exhibited the efficacy to be above 80%. However, for an IPM, where it was recommended the association of different control tactics, the management of insecticides with chlorfenapyr + cypermethrin was effective with 100% control efficacy in both instars.

Satya Narayan (2018) explained the different methods to control the fall armyworm in maize in India. In chemical method of control, he recommended the use of thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC for managing second and third instar larvae having more than 10 % foliar damage.

Worku and Ebabuye (2019) reported that profenofos + lambda cyhalothrin and profenofos + cypermethrin recorded maximum larval mortality during bioassay study. In field experiment, only profenofos + cypermethrin and spinosad were effective giving maximum mortality of sixth instar larva in the whorls, these were followed by profenofos + lambda cyhalothrin and indoxacarb.

Sisay *et al.* (2019) tested nine synthetic insecticides belonging to different chemical groups for their efficacy against fall armyworm under laboratory, greenhouse and field conditions. In laboratory, Radiant, Tracer, Karate and Ampligo caused over 90 % larval mortality at 72 hours after application.

Kammo *et al*. (2019) publicized that synthetic insecticides, lambda cyhalothrin and cypermethrin were applied to maize at one and two weeks intervals at the recommended doses of 2 L/ha and 1.5 L/ha respectively. The consequences of his study unveiled that maize treated with lambda cyhalothrin at 1 week interval had very low percentage of dead heart prevalence (38%). It was the second best treatment followed by lambda cyhalothrin at 2 week interval.

Bharadwaj *et al.* (2020) analyzed the treatments of various insecticides including lambda cyhalothrin 5% EC @ 0.025%, chlorantraniliprole 9.3% + lambda cyhalothrin 4.6 ZC @ 0.008 +

0.002% and thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC @ 0.003 + 0.002% against FAW. The outcome disclosed that the treatment of lambda cyhalothrin 5% EC reported 44.04% reduction in larval population while chlorantraniliprole 9.3+ lambda cyhalothrin 4.6 ZC and thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC reported 77.35 and 54.98% reduction in larval population, respectively.

Deshmukh *et al*. (2020) assessed insecticides with variable mode of action for managing second instar larvae under field condition and also by leaf dip bioassay method. Through his paper he declared that lambda cyhalothrin 5% EC @ 25g a.i./ ha reduced the larval count per plant from 2.33 on day after treatment to 1.17 on third day after treatment and 1.07 on 10^{th} day after treatment. After the second spray his findings included the presence of 0.27 larvae per plant on third day which gradually rose to 0.47 larvae per plant.

Kumari *et al.* (2020) tested the bio-efficacy of insecticides like cypermethrin 5% EC, chlorpyrifos 50 + cypermethrin 5% EC, chlorpyrifos 50% + cypermethrin 5% EC, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, cypermethrin 10% + indoxacarb 10% SC, cypermethrin + indoxacarb 10% SC and found their percent reduction over control to be 51.11, 42.96, 44.44, 65.92, 51.11 and 40.74 after first spray;78.48, 58.22, 49.36, 83.54, 60.75and 58.22 after second spray and 59.30, 63.95, 61.62, 84.88, 59.30 and 54.65 after third spray, respectively.

Omprakash (2021) interpreted the field efficacy of lambda cyhalothrin 5% EC and profenofos 50% against FAW in maize. He noted the pest incidence after first spray in *Rabi* 2018-19 for lambda cyhalothrin 5% EC to be 18.3 and that for profenofos 50% EC to be 25. After second spray the values changed to 15 and 20 and after third spray to 11.7 and 18.3 for lambda cyhalothrin and profenofos, respectively. In *Kharif 2019*, he noted the incidence per cent to be 18.3, 15.0 and 11.7 for lambda cyhalothrin and for profenofos to be 25, 23.3 and 18.3 per cent after first, second and third spray, respectively.

2.1.2 Efficacy of Insecticides against Fall Armyworm in the Crops Other than Maize and Cereals

Adamczyk *et al.* (1999) tested the efficacy of conventional and experimental insecticides against the fall armyworm, *Spodoptera frugiperda* (J E Smith) in cotton and evaluated it in laboratory bioassay. The mortality of first instar larvae was observed to be greater on leaves treated with chlorfenapyr, lambda cyhalothrin or thiodicarb as compared to the untreated control at 24 hours after infestation .

Cook *et al*. (2009) studied occasional pest of cotton and soybean - beet armyworm *Spodoptera exigua* (Humne) and fall armyworm *Spodoptera frugiperda* (Smith). The outcome indicated that the LC_{50} values of indoxacarb and pyridalyl for fall armyworm adults exceeded 100 µg per vial (highest concentration tested). The LC_{50} value for cypermethrin (31.0 µg per vial) was significantly lower than spinosad (69.3 µg per vial) against fall armyworm adults. The

LC_{50} values of indoxacarb, pyridalyl for fall armyworm exceeded 100 μg per vial (highest concentration tested).

2.1.3 Efficacy of Insecticides against Lepidopterian Pests in Maize

Kumar and Alam (2017) studied the bio-efficacy of some new insecticides including deltamethrin 2.8 EC against maize stem borer, *Chilo partellus*. He observed that the mean per cent reduction over control obtained by treating the plot with deltamethrin 2.8 EC was 81.06% for plant infestation and 72.97% for dead hearts.

2.1.4 Efficacy of Insecticides against Lepidopterian Pests on the Crops Other than Maize

Mustak *et al.* (2007) researched upon the occurrence of insecticide resistance in field populations of *Spodoptera litura* (Lepidoptera : Noctuidae) in Pakistan using organophosphates like profenofos and pyrethroids like bifenthrin and found the resistance levels for both profenofos and bifenthrin to be between very low to low.

Hole *et al*. (2009) studied the bio-efficacy of insecticides (including cypermethrin and profenofos) against *Spodoptera litura* infesting soybean. He noted that treatments with profenofos 0.1% gave maximum protection and showed significant superiority in controlling larval population, reducing leaf damage and thereby increasing grain yield.

Bhatti *et al* (2013) studied the pyrethroids and new chemistry insecticide mixtures against *Spodoptera litura* (Lepidoptera: Noctuidae) under laboratory condition. He observed that pyrethroids (deltamethrin and bifenthrin) were least effective due to their high LC_{50} values as compared to the new chemistry insecticides.

Waykule *et al.* (2020) interpreted the efficacy of cypermethrin 10 EC, profenofos 50 EC, along with some other insecticides and notified the mean larval population of *Spodoptera litura* on groundnut which was 14.13 on the day before spraying which reduced to 5.67 on the third day, 8.33 on the seventh day and 9.33 on fourteenth day after spraying in case of cypermethrin. Further he reported the mean larval population of *Spodoptera litura* which was 15.40 on the day before spraying to come down to 6.33, 9 and 9.47 on third, seventh, fourteenth day after spraying respectively in case of profenofos after first spray. After second spray the observations that he mentioned regarding the mean larval population were 15.67 on the day before spraying to 5.33, 7.67 and 8.67 for cypermethrin and 13.40 on the day before spraying to 5.93, 8.27 and 10 after 3, 7 and 14 days after spraying.

Kumar *et al* (2010) published the relative efficacy of cypermethrin and few other pesticides against chili pod borer in Manipur. He mentioned the larval population per 5 plants to be 0.92 in 2004 and 1.11 in 2005 in case of cypermethrin 0.01% treated plot. He declared cypermethrin to have maximum larval population just after dimethoate than rest of the treatments under consideration.

Nagal *et al.* (2016) unfolded his strategy for the management of *Spodoptera litura* on bell pepper. He mentioned the use of bifenthrin 0.005% and noted the number of larvae per plot to be 17.67 one day before treatment while 2.67, 0.67 and 0.33 on 1, 3 and 7 days after treatment, respectively. He mentioned the reduction in *Spodoptera litura* to be 85.25, 96.17 and 98.24 per centafter 1, 3 and 7 days after treatment, respectively.

Ramzan *et al.* (2019) compared the efficacy of profenofos and two other insecticides against *Plutella xylostella* and *Spodoptera litura*. He disclosed profenofos to be the second most significant and efficient treatment against *Spodoptera litura* and *Plutella xylostella*.

2.2 To Study the Dissipation Pattern of Lambda cyhalothrin and Cypermethrin on Maize

2.2.1 Dissipation Pattern in Vegetables

Dikshit *et al.* (2001) worked on residue studies and bio-efficacy of beta cyfluthrin and lambda cyhalothrin in brinjal fruits and reported that on spraying lambda cyhalothrin @ 35 g a.i./ ha. The half-life observed was 1.45 - 2.54 days.

Jayakrishnan *et al.* (2005) evaluated the dissipation of lambda cyhalothrin in tomato and found the initial deposit to be 0.385 to 0.526 mg/kg and 0.690 to 0.958 mg/kg from 15 and 30 g a.i./ ha which persisted up to 7-10 days. The residues were found to have the half-life of 3.6-4.5 days and 3.7-3.9 days from 1st and 2nd spray, respectively.

Nath *et al.* (2005) determined the persistence and dissipation of ready-mix formulation Polythrin 44% (profenofos40% + cypermethrin 4% EC) and Spark 36% EC (triazophos35% + deltamethrin 1%) in/on okra fruits. In cypermethrin he noted the maximum dissipation of 73.50% on seventh day and found it's half-life to be 4.11 days.

Barik *et al.* (2010) evaluated the persistence behavior of thiamethoxam and lambda cyhalothrin in transplanted paddy and he concluded that there wasn't any residue detected in harvested Paddy, straw, grain and soil sample.

Kaur *et al.* (2011) established the persistence of cypermethrin and decamethrin residues in /on brinjal fruits. The average initial deposit of cypermethrin was reported to be 0.600 and 1.095 mg/kg on single application of Cymbush 25% EC @ 43.75 and 87.50 g a.i./ ha. On the third and seventh day, the residues were below the maximum residue limit value and found to be 0.2 and 0.05 mg/kg and half-life values were worked out to be 1.16, 1.18 days for cypermethrin.

Nahar *et al.* (2012) researched on dissipation pattern of cypermethrin in tomato and through experimental results showed that when cypermethrin (Ripcord 10 EC) was sprayed at recommended and double the recommended dose the residues were found below MRL (0.5 ppm) after one day of application.

Samriti and Reena (2012) undertook the experiment to check the residue and decontamination, the samples from okra crop treated with pre-mix insecticides (cypermethrin 5% + chlorpyrifos

50%) were collected after spraying of insecticides @ 275 g a.i./ ha and 550 g a.i./ ha. The results revealed 2.74 days and 3.07 days to be the half-life values of cypermethrin at suggested and it's double dose, respectively.

Gupta *et al*. (2013) assessed the persistence of insecticides in ready-mix formulations of Rocket 44 EC (profenofos 40 % + cypermethrin 5%) and Action 505 (chlorpyrifos 50% + cypermethrin 5% EC) and their efficacy against *Lipaphis erysimi* (kalt) in cauliflower and suggested the safety waiting period of 3 days. Half-life of cypermethrin was 1.5-2.1 days.

Jyot *et al.*(2013) interpreted the dissipation of cypermethrin in chili giving 3 applications of combination formulation of Nurelle-D 505 (chloropyriphos 50 % + cypermethrin 5%) at 1 and 2 l/ha at an interval of 15 days. The estimated half-life value of cypermethrin was observed to be 2.51 and 2.64 days. The residues of cypermethrin were found to be dissipated to the extent of more than 70 % in 7 days. The soil samples collected after 15 days of the last application did not show the presence of cypermethrin at the determination limit of 0.01 mg/kg. The safe waiting period suggested was 1 day.

Chandra *et al.* (2014) researched upon the persistence pattern of chlorpyriphos, cypermethrin and monocrotophos in okra. He studied the persistence of cypermethrin following the application at dose of 200 g a.i./ ha. He observed the initial residue of cypermethrin to be between 0.378 - 0.862 mg/kg and noted the pesticide residue to fall below detection limit in 17 days.

Singh *et al.* (2015) assessed the persistence and risk of cypermethrin residues on chili and recorded average initial deposit of cypermethrin to be 1.46 and 3.11 mg/kg with half-life of 4.43 days and 4.70 days at recommended and double the recommended dosage respectively.

Cherukuri *et al.* (2015) determined the dissipation dynamics and risk assessment of profenofos, triazophos and cypermethrin residues on tomato. He detected the fruit samples with deposits of 0.158 mg/kg cypermethrin to dissipate below determination level by fifth day. Maximum residue limit of 0.4 mg/kg and pre harvest interval of one day for cypermethrin is suggested through this literature.

Rahman *et al*. (2015) analysed cypermethrin residues in brinjal fruit and soil samples. The results showed that cypermethrin residues determined from fruit and soil sample sprayed @1 ml/L in field was above MRL up to three days after spraying (0.762 ppm) in fruit samples and up to five days after spraying in soil sample (0.6 ppm) while it was above MRL up to seven days after spraying (0.768 ppm) in fruit and five days after spraying (0.753 ppm) in soil when sprayed @ 2ml/L respectively.

Gupta *et al*. (2015) established the dissipation pattern and decontamination of lambda cyhalothrin residues in brinjal. According to him, the initial deposits of lambda cyhalothrin were 0.138 mg/kg which dissipated to 92.75 per cent on 10^{th}day with half-life value of 2.65 days.

Tao *et al.* (2016) assessed the dissipation of cypermethrin in cabbage and found half-life to be 2.14 – 2.56 days. From the experimentation, it was concluded that the ultimate residues of cypermethrin were less than MRL (5 mg/kg) when harvested 3 days after spraying.

Malhat *et al.* (2016) determined the dissipation pattern and undertook the risk assessment of the synthetic pyrethroid lambda cyhalothrin applied on tomatoes under dry land conditions. He reported the lambda cyhalothrin residues to decline very quickly following first order kinetics with half-life of 3.12 days. At the time of harvesting, 14 days after final application, the remaining residues of lambda cyhalothrin were below CODEX maximum residue limit (MRL) of 0.05 mg/kg.

Mayannawar *et al.* (2017) tested the persistence of acephate and cypermethrin was applied @ 50 and 100 g a.i./ ha twice at an interval of 10 days. The initial residue dissipated with 2.38 and two days in case of cypermethrin at recommended and double the recommended dose. Pre harvest interval of five days can be suggested for cypermethrin for safe consumption of okra fruits.

Reddy *et al.* (2017) assessed the dissipation pattern of lambda cyhalothrin 15 % EC in chilli. The initial deposit of 1.20 mg/kg was recorded at 2 hrs after last spray and dissipated to 0.78, 0.36 and 0.09 mg/kg at 1,3 and 5 days after last spray, respectively and BDL by 7th day.

Kelageri *et al.* (2017) estimated the residue persistence of lambda cyhalothrin from tomato fruits. Estimation of residues was done till the residues reached BDL (0.05 mg/kg). Initial deposits of 0.18 mg/kg from polyhouse and 0.13 mg/kg from open fields were detected which dissipated to BDL by 7th and 5th day respectively.

Shalaby *et al.* (2017) determined the residues of lambda cyhalothrin on sweet pepper fruits. The initial deposit was found to be 0.253 mg/kg and 1.896 mg/kg on fruits and leaves respectively. Whereas the half-life was estimated to be 2.68 and 3.45 days in fruits and leaves, respectively.

Raghu *et al.* (2017) analyzed the dissipation pattern of lambda cyhalothrin on chilli both in polyhouse as well as in open field. The initial deposits of 0.37 mg/kg obtained from chilli samples collected from polyhouse dissipated to BDL by 10th day with half-life of 19.8 days whereas in open fields, the deposits of 0.16 mg/kg dissipated to BDL by 7th day with half-life of 34.65 days.

Tanuja and Patyal (2017) interpreted the dissipation of cypermethrin in cauliflower in Himachal Pradesh. Cypermethrin @ 50 g a.i./ ha and 100 g a.i./ ha was applied. The half-life of cypermethrin was observed to be 1.31-1.71 days while applied individually but when applied in ready-mix formulation with chlorpyrifos, it was found to be 1.38-1.69 days. The residues of cypermethrin were below the determination limit in 10th day sampling.

Sharma *et al.* (2018) observed the persistence of imidacloprid, indoxacarb and lambda cyhalothrin on tomato under protected cultivation. Single spray of lambda cyhalothrin (0.004%) was given on tomato crop and initial deposit was found to be 0.550 mg/kg with half-life value for lambda cyhalothrin to be 3.06 days.

Parmar *et al.* (2018) studied the dissipation and decontamination of some pesticides in/on okra. The average initial deposit of cypermethrin was found to be 0.172 mg/kg which dissipated to 0.020 (88.37%) mg/kg on fifth and seventh day. The half-life was notices to be 2.59 days.

Yeasmin *et al.* (2019) analyzed cypermethrin residues in brinjal. According to the observations for the varieties BARI-8 and UTTARA, the respective initial deposits were 0.052 and 0.050 mg/kg which persisted up to 7 days and was found to be below MRL thereafter.

Pandey *et al.*(2019) assessed the dissipation of lambda cyhalothrin in okra and declared it's initial deposit to be 2.45 ppm which persisted up to 10^{th} day when the residue was noted to be 0.25 ppm and was below detectable limit thereafter.

2.2.2 Dissipation Pattern in Fruits

Awasti (1989) evaluated the persistence of cypermethrin on mango. He found cypermethrin to persist for 3 weeks with half-life value of 5.83 days and recommended the safe waiting period of 3.45 days.

Kadam *et al.* (2015) determined the residues of lambda cyhalothrin in pomegranate fruits @ 12.5 and 25 g a.i./ ha. The initial deposit was found to be 0.120 and 0.170 mg/kg which persisted till 7^{th} and 10^{th} day for recommended and double the recommended dose respectively with half-life values of 2.59 and 3.11 days, respectively.

Hem *et al.* (2010) evaluated the residues of lambda cyhalothrin in pomegranate. The residue level of lambda cyhalothrin after 2 sprays twice was found to be 0.011 and 0.004 mg/kg after 3 sprays twice was found to be 0.011 and 0.014 mg/kg and after 4 sprays twice was found to be 0.016 and 0.010 mg/kg, respectively. The residues of lambda cyhalothrin determined from treatedpomegranate sample and its LOD level was much lower than the MRL (0.5 mg/kg).

3. MATERIALS AND METHODS

Present investigation entitled, "Bio-efficacy of conventional insecticides against fall armyworm *Spodoptera frugiperda* (J E Smith) and their dissipation in/on maize" was carried out to study the effectiveness of some commonly used synthetic pyrethroids and organophosphate insecticides against fall armyworm and to evaluate the dissipation pattern of lambda cyhalothrin and cypermethrin in/on maize. The field experiment was conducted during Rabi 2020 at Instructional Farm of Post Graduate Institution, MPKV, Rahuri. The dissipation and harvest time residues of selected insecticides was studied at Pesticide Residue Laboratory, AINP on Pesticide Residues, Department of Entomology, MPKV, Rahuri.

3.1 Materials

3.1.1 Maize Seeds

Maize seed of variety - ECO-97 Parmeshwar was procured from local market and was used for sowing.

3.1.2 Insecticides

In this experiment, five synthetic pyrethroids and two organophosphates were evaluated for their bio-efficacy. Particulars of evaluated insecticides *viz*., common name, chemical name, formulation and manufacturer of product/source are presented in Table 1. The treatment details *viz.*, common name as well as trade name of insecticide, its formulation, dose in g a.i./ ha and concentration of spray solution are given in Table 2.

3.1.3 Glasswares

All of the glass items were of 'A' grade and cleaned with an aqueous soap solution, thoroughly rinsed with tap water and oven dried prior to use.

3.1.4 Chemicals and Reagents

a. Ethyl Acetate, Avantor Performance Materials India Limited, Thane (MS)
b. Sodium Sulphate Anhydrous Purified, SAFAL, Mumbai
c. PSA (Primary Secondary Amine), Agilent Technology, Bangalore
d. Acetone (Analytical Reagent grade), Merck Specialties Private Limited, Mumbai.
e. Water, Avantor Performance Materials India Limited, Thane (MS)
f. Certified Reference Material of Cypermethrin and Lambda cyhalothrin

3.1.5 Apparatus

a. Analytical balance-Citizen
b. Grinder-Robot Coupe (Blixer 6v.v.)
c. Laboratory Centrifuge, Remi make
d. Vortex-Spinix
e. Refrigerator- SANYO (-20°C)

Table 3.1 Particulars of the insecticides

Tr. No.	Common Name	IUPAC name	Trade Name	Manufacturer
1.	Bifenthrin	(2-methyl-3-phenylphenyl)methyl 3-[(z)-2-chloro-3,3,3-trifluoroprop-1-enyl]-2,2-dimethylcyclopropane-1-carboxylate	Markar 10 EC	M/s.Dhanuka Agritech
2.	Deltamethrin	[(S)-cyano-(3-phenoxyphenyl)methyl](1S,3R) -3-(2,2-dibromoethenyl)-2,2-dimethylcyclopropane-1-carboxylate	Decis 2.8 EC	M/s. Bayer Crop Science India ltd, Thane M/s.
3.	Lambda cyhalothrin	[(R)-cyano-(3-phenoxyphenyl)methyl](1S,3S)-3-[(Z)-2-chloro-3,3,3-trifluoroprop-1-enyl]-2,2-dimethylcyclopropane-1-carboxylate	Karate 5 EC	M/s.AGRO SHOPY Syngenta, India Ltd.,
4.	Cypermethrin	[cyano-(3-phenoxyphenyl)methyl] 3-(2,2-dichloroethenyl)2,2-dimethylcyclopropane-1-carboxylate -	Cymbush 10 EC	M/s. Syngenta, India Ltd.,
5.	Ethion	1-[diethoxyphosphorylsulfanylmethylsulfanyl(ethoxy)phosphoryl]oxyethane	Fosmite 50 EC	M/s. PI Industries Ltd., Gujarat
6.	Fenvalerate	[cyano-(3-phenoxyphenyl)methyl]2-(4-chlorophenyl)-3-methylbutanoate	Tatafen 10 EC	Rallis India Ltd., Mumbai.
7.	Profenofos	4-bromo-2-chloro-1-[ethoxy(propylsulfanyl)phosphoryl]oxybenzene	Curacon 50 EC	M/s. Syngenta, India Ltd., Mumbai.

Table 3.2 Treatment details

Tr. No.	Treatment	Trade Name	Dose (g a.i./ha)	Dose (ml formulation /L of water)
1.	Bifenthrin 10% EC	Markar 10 EC	50	1
2.	Deltamethrin 2.8% EC	Decis 2.8 EC	15	1
3.	Lambda cyhalothrin 5% EC	Karate 5 EC	15	0.6
4.	Cypermethrin 10 % EC	Cymbush 10 EC	50	1
5.	Ethion 50% EC	Fosmite 50 EC	500	2
6.	Fenvalerate 10% EC	Tatafen 10 EC	75	1.5
7.	Profenofos 50% EC	Curacon 50 EC	500	2
8.	Untreated control	--	--	--

3.1.6 Instruments

a. Gas Chromatography-MS (GCMS-TQ8040NX)

3.1.7. Appliances

Insecticides were sprayed on maize crop using a manually operated knapsack sprayer (Aspee brand) with a hollow cone nozzle.

3.2 Methods:

3.2.1 Bio-efficacy Study

3.2.1.1 Raising of the Crop

During *Rabi* 2020, the experiment was conducted using a locally available variety of maize. The study used a randomized block design (RBD) with three replications and eight treatments. The crop was grown using all the agronomical practices recommended by the university. The experimental details are mentioned below:

1.	Treatment	:	8
2.	Replication	:	3
3.	Plot size	:	4 m X 3m
4.	Spacing	:	75 cm X 20 cm
5.	Variety	:	ECO-97 Parmeshwar
6.	Date of sowing	:	03/12/2020
7.	Time of application	:	When sufficient pest population was observed
8.	Number of applications	:	3 applications at 10 days interval
9.	Dates of application	:	18/01/2021, 28/01/2021 and 07/02/2021

3.2.1.2 Application of Insecticides

Conventional insecticides from synthetic pyrethroid and organophosphate group were chosen, and the treatments were applied as foliar spray against the fall armyworm on maize using a knapsack sprayer with a hollow cone nozzle. Three sprays of each treatment were performed at 10 day intervals, with the first spray initiated upon the appearance of fall armyworm incidence. The amount of spray fluid required per plot was determined by spraying the untreated control plot with water at the recommended rate of 500 lit/ha. The known amount of water was poured into a bucket and the required amount of insecticide formulation according to the application rate was thoroughly mixed to obtain the required concentration of spray fluid, which was poured into a sprayer and applied with a knapsack sprayer. Water was used to clean the spray pump both at the start and when switching from one insecticide to another during spraying. All sprayings were done in the early morning hours, with special care taken to avoid drift from one treatment plot to the next.

3.2.1.3 Method of Recording Observation

The effectiveness of the treatment was ascertained on the basis of reduction in larval population and reduced per cent infestation due to each treatment. Hence, total number of larvae and percentage of FAW infestation from randomly selected 30 plants from each treatment plot was counted a day before spray (Pre count) and 3, 5, 7 and 10 days after each spray. Yield from each plot was recorded separately and expanded in T/ha. Further, ICBR was calculated considering the cost of plant protection.

3.2.1.4 Statistical Analysis for Bio-efficacy

The efficacy data was statistically analyzed as per Panse and Sukhatme (1985) for RBD. The significance of treatments was determined by calculating the critical difference (C.D.) at the 5% level of significance.

3.2.2 Dissipation Study

3.2.2.1. Raising of the Crop

The crop was grown on Instructional Farm, Department of Entomology, PGI, M.P.K.V., Rahuri in *Rabi* 2020. The field was prepared by deep ploughing and harrowing. The seed of locally available variety ECO-97 Parmeshwar was used and the crop was raised using all agronomical practices for maize with the spacing of 75cm × 20 cm in a plot of 4m × 3m. In a random block design five treatments were administered in 3 replications.

3.2.2.2 Application of Insecticides

Quantity of spray fluid required per plot was calculated by spraying control plot with water. The spraying was done manually by hand operated knapsack sprayer fitted with hollow cone nozzle. As per the protocol for residue and dissipation study, the insecticides under study were evaluated at two different doses i.e. at recommended dose and double the recommended dose. A total of two sprays were given at an interval of 10 days initiating the first spray at cob initiation stage. The due care was taken to wash the spray pump with water in the beginning and while switching over from one treatment to another during spraying. All sprayings were done during morning hours to avoid drift due to heavy winds from one treatment plot to other. Treatment details are as below.

Table No 3.3: Treatment details for dissipation study

Tr. No.	Treatments	Dose (ml formulation /L of water)
1.	Cypermethrin 10 % EC @ 50 g a.i./ha	1
2.	Cypermethrin 10 % EC @ 100 g a.i./ha	2
3.	Lambda cyhalothrin 5 % EC @ 15 g a.i./ha	0.6
4.	Lambda cyhalothrin5 % EC @ 30 g a.i./ha	1.2
5.	Untreated control	

3.2.2.3. Standard Preparation

To prepare the standard stock solution of 1000 ppm, an accurately weighed 10 mg of an individual insecticide reference material was dissolved in 10 ml volumetric flask separately in ethyl acetate. Each insecticide standard stock solution was further diluted to obtain intermediate lower concentrations of 100 and 10 ppm. They were kept in a refrigerator at -20^{o}C. Working standards of 0.010, 0.025, 0.050, 0.080, 0.125, 0.250 and 0.500 ppm were prepared from intermediate standards by suitably diluting the stock solution in n-hexane and were used for method validation *i.e.* as standard checks in linearity and recovery studies and in residue determination.

3.2.2.4 Method Validation

Prior to sample analysis, the linearity of insecticides was determined using GC-MS/MS. The methods' accuracy and precision was measured using percent mean recovery and percent relative standard deviation.

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

The limit of detection (LOD) of insecticide was calculated using a signal-to-noise ratio of three in comparison to the background noise obtained for the blank sample. The limit of quantification (LOQ) was determined as three times the limit of detection (LOD).

3.2.2.4.2 Linearity Study

Seven linear concentrations of (0.010, 0.025, 0.050, 0.080, 0.125, 0.250 and 0.500 mg/kg) cypermethrin and lambda cyhalothrin, were injected in triplicate in order to determine instrument's calibration range. The linearity curve was created by plotting the detector response graph against concentration.

3.2 2.4.3 Recovery Study

The analytical method for estimating residues of lambda cyhalothrin and cypermethrin in maize was validated through recovery studies using untreated control maize and soil samples. In 50 ml centrifuge tubes, a 10g blended sample of maize cob and soil was taken in three replicates and spiked with the insecticides under study 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 ppm.

This mixture was shaken to ensure that the insecticide in the sample was homogeneous. The extraction and cleanup procedure was carried out exactly as described hereunder. Percent recovery was calculated by using following formula,

$$\textbf{Percent recovery} = \frac{\text{Quantity of insecticide recovered}}{\text{Quantity of insecticide added}} \times 100$$

3.2.2.5. Sample Collection and Sample Preparation:

3.2.2.5.1 Sample Collection:

Immature cobs (about 1 kg) were randomly collected from each replicate of the treated and control plots separately at regular time intervals of 0 (2 hr after spraying),1, 3, 5, 7, 10, 15, and 20 days after the second spray, whereas mature cobs and soil samples were collected from each treatment plot at final harvest. The collected samples were immediately transported to the laboratory in an ice box. The samples were homogenised and stored in a deep freezer at -20°C until analysed. The dates of collection of maize cob and soil samples are mentioned below:

Substrate	Interval between last application and sampling	Date of sample collection
Immature cob	0 day	28 February 2021
	1 day	1 March 2021
	3 day	3 March 2021
	5 day	5 March 2021
	7 day	7 March 2021
	10 day	10 March 2021
	15 day	15 March 2021
Mature cob	20 day	20 March 2021
Soil	45 day	13 April 2021

3.2.2.5.2 Sample Preparation:

The homogenized samples were extracted using the laboratory validated QuEChERS method (Anastassiades *et al.*, 2003) with certain modification.

3.2.2.5.3 Extraction and Cleanup of Maize Cob:

The entire laboratory sample was thoroughly crushed in a grinder, and approximately 10g homogenized sample was weighed in a 50 ml polypropylene tube, which was then placed in a deep freezer for 10 minutes. Homogenized sample was extracted with 10 ml ethyl acetate in the presence of 10 g anhydrous sodium sulphate (Na_2SO_4) and centrifuged for 5 minutes at 3500 rpm. The supernatant (2 ml) was then transferred into a 15ml tube containing 50 mg PSA. The content was vortexed for 30 seconds before being centrifuged for 2 minutes at 2500 rpm. The supernatant was filtered through a 0.2 µ filter before GC-MS/MS analysis.

3.2.2.5.4 Extraction and Cleanup of Cropped Soil:

In a 50 ml polypropylene tube, a representative 10 g soil sample was weighed. It was filled with 25 ml of acetonitrile and vigorously shaken for 1 minute. To this, 4.0 g anhydrous magnesium sulphate ($MgSO_4$) and 1 g sodium chloride was added, and the mixture was centrifuged at 3500 rpm for 2 minutes. A supernatant (10 ml) was transferred to a 15 ml tube containing 1.5 g $MgSO_4$ and 0.250 mg PSA. It was then shaken for a few minutes and sonicated for 1 minute. It was then centrifuged again for 2 minutes at 2500 rpm. At 40°C, 3ml of this aliquot was evaporated to dryness using a nitrogen concentrator (water bath temp.). The dry residues were reconstituted in 1.5 ml of ethyl acetate, filtered through a 0.2 μ filter in GC vials, and GC-MS/MS analysis was performed.

3.2.2.6 Residue Determination

The residues of lambda cyhalothrin and cypermethrin were estimated using GC-MS/MS. The insecticide residues were identified using retention time and compared to a known standard under the same conditions. The following formula was used to calculate the quantities on a peak area basis.

$$\textbf{Residues (mg/kg)} = \frac{\text{Area of sample}}{\text{Area of standard}} \times \frac{\text{μl of standard injected}}{\text{μl of sample injected}} \times \frac{\text{Conc. of standard (mg/kg)}}{\text{Wt. of sample (g)}} \times \text{Final Vol. (ml)}$$

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

3.2.2.6.1 GC-MS/MS Analysis:

Residues of lambda cyhalothrin and cypermethrin were analysed using a Gas Chromatography Mass Spectrometry - TQ8040NX with an automatic injection system (Plate 3). The software data analysis system was GC-MS/MS solution software. The following are typical GC-MS/MS conditions for analysis:

Column Type	SH - Rxi - 5SilMS-30cm ×0.25μm×0.25mm
Oven programming	0 80°C ....0 min hold @40°C/min 180°C....... 1 min hold @20°C/min 285°C...... 5 min hold
Detector	Interface temperature - 285°C
	Ion source temperature - 250°C
	Mass range (M/Z) - 40-400°C
Injector	Injector temperature - 250°C
	Injection volume - 1 μl
	Injection mode - split less
Column flow	1.20 ml/min
Carrier gas	Helium (99.999%)
Retention time	Lambda cyhalothrin- 10.22min Cypermethrin- 11.94min

3.2.2.7 Statistical Analysis

A simple statistical analysis in Microsoft Excel was used to calculate the mean residues, standard deviation, regression equation, R^2 value, and half-life.

4. RESULTS AND DISCUSSION

At the Instructional Farm of Department of Agricultural Entomology of Post Graduate Institute of Mahatma Phule Krishi Vidyapeeth, Rahuri, the study on “Bio-efficacy of conventional insecticides against fall armyworm *Spodoptera frugiperda* (J E Smith) and their dissipation in/on maize" was conducted. There were two objectives for the conduction of this study. The first one being the evaluation of bio-efficacy of conventional insecticides against fall armyworm while the second one being the establishment of dissipation pattern of lambda cyhalothrin and cypermethrin in/on maize. The results of the study are presented hereunder with appropriate headings.

4.1. Efficacy of Conventional Insecticides against Fall Armyworm *S. frugiperda*

Effectiveness of seven insecticides *viz*., bifenthrin @ 50 g a.i./ha, profenofos @ 500 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha, ethion @ 500 g a.i./ha, fenvalerate @ 75 g a.i./ha and lambda cyhalothrin @ 15 g a.i./ha was evaluated against *S. frugiperda*. The results obtained are elaborated and discussed in the Table No 4.1 to 4.8.

4.1.1 Larval Population

Table No. 4.1- 4.4 depicts the data on larval population of *Spodoptera frugiperda* after conducting three consecutive sprays at 10 days interval. The plot was observed and the results were noted for each insecticide, 2 hrs before and on 3, 5, 7 and 10 days after each spraying. Based on this data, the cumulative effect of all the three sprayings was derived.

4.1.1.1 First Spray

The data recorded through observations after first spray is mentioned in Table 4.1 and Fig. 4.1. On the day before spraying the field with insecticides, there was more or less uniform pest incidence in the field.

Third day after spraying showed drastic change in the population of fall armyworm. The plots sprayed with insecticides showed high larval mortalities whereas the untreated plot showed increase in the larval population up to 20 larvae per 30 plants. The treatment of profenofos @ 500 g a.i./ha expressed its superiority over all the other treatments with remarkable reduction to 9.00 larvae per 30 plants as against 18.67 larvae per 30 plants on the day before spraying. Succeeding it were lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha and had the larval count values of 11.67 and 12.00 per 30 plants, respectively, indicating these two treatments to be at par. Next to it were the treatments of deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha with the larval counts of 15.33 and 15.67 per 30 plants, respectively, and these too were at par. The larva populations on 30 plants as registered by ethion

@ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha were 18.67 and 19.00, respectively, which displayed much proximity in their values and revealed them to be atpar and also to be the least effective insecticide treatment on this day.

Day fifth observations disclosed the pairs of treatments at par and in accordance with the order of effectiveness to be in the sequence - lambda cyhalothrin @ 15 g a.i./ha (7.67 larvae/30 plants) and cypermethrin @ 50 g a.i./ha (8.00 larvae/30 plants), deltamethrin @ 15 g a.i./ha (11.33 larvae/30 plants) and bifenthrin @ 50 g a.i./ha (11.67 larvae/30 plants) as well as ethion @ 500 g a.i./ha (14.67 larvae/30 plants) and fenvalerate @ 75 g a.i./ha (15.00 larvae/30 plants), with profenofos @ 500 g a.i./ha having larval count of 5.00 per 30 plants being the supreme treatment while the least effective one being the untreated control with larval population of 22.00 larvae per 30 plants.

On the seventh day after spraying there was increase in the larval count in all the plots. Even if so, the plot treated with profenofos @ 500 g a.i./ha maintained its superiority over all the other treatments. The larval count closest but less than it was that of lambda cyhalothrin @ 15 g a.i./ha with 8.33 larvae per 30 plants with much lesser difference between itself and cypermethrin @ 50 g a.i./ha (8.67 larvae/ 30 plants) disclosing them to be at par. Untreated control plot was still the least effective having 23 larvae per 30 plants. Tenth day after spraying showcased much higher incidence than the previous days of observation. The highest incidence of 24.67 larvae per 30 plants was seen in the control plot. The lowest incidence was recorded in the Profenofos 50% EC treated plot with 8.33 larvae per 30 plants. Remaining treatments fall in the range of 11 to 18.33 with the sequence of lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha, ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha.

The mean values calculated after the first spray presented profenofos @ 500 g a.i./ha to be the leading treatment in controlling FAW with the mean larval count of 7 larvae per 30 plants. The values of mean for number of larvae per 30 plants for lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha were 9.67 and 10 respectively, which confirmed these two to be at par and also to be the next in the order of effectiveness. Chasing it were the mean larval populations of deltamethrin @ 15 g a.i./ha (13.33 larvae/30 plants) and bifenthrin @ 50 g a.i./ha (13.67 larvae/30 plants) whose mean larval population per 30 plants could be referred to, to present these treatments to be at par. The treatment of ethion 500 g a.i./ha (16.67 larvae/30 plants) was at par with that of fenvalerate @ 75 g a.i./ha (17.00 larvae/30 plants) and at the bottom of the list of order of effectiveness concerning the insecticide treated plots. Highest mean value was again the value of untreated control plot.

4.1.1.2 Second Spray

After the second spray, the data obtained pertaining to the larval population of fall armyworm is presented in Table 4.2 and Fig.4.2. The range of larval population recorded on the third day was between 4 and 26 larvae per 30 plants. Minimum larval population was registered from the treatment plot of profenofos @ 500 g a.i./ha while the maximum was spotted in untreated plot. Next to the best was the treatment of lambda cyhalothrin @ 15 g a.i./ha with larval population of 6.67 which was detected to be at par with the treatment of cypermethrin @ 50 g a.i./ha with 7 larvae per 30 plants being it's larval population. Up next were the treatments of deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha with larval population of 10.33 and 10.67 per 30 plants respectively and ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha with larval population of 13.67 and 14.00, respectively, which were viewed to be at par.

Day fifth after spraying reflected decrease in the fall armyworm incidence. The sequence of treatments from the most to least effective as witnessed on this day along with their respective larval population per 30 plants is profenofos @ 500 g a.i./ha (1.67), lambda cyhalothrin 15 g a.i./ha (4.33), cypermethrin @ 50 g a.i./ha (4.67), deltamethrin @ 15 g a.i./ha (8.00), bifenthrin @ 50 g a.i./ha (8.33), ethion @ 500 g a.i./ha (11.34), fenvalerate @ 75 g a.i./ha (11.67) and untreated control (27.00).

On the seventh day after spraying, the superior most treatment was profenofos @ 500 g a.i./ha with larval population of 3.33 per 30 plants followed by at par treatments of lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha with 6.00 and 6.33 larvae per 30 plants. Highest larval incidence of 28.67 per 30 plants was noticed in untreated control plot.

On the tenth day after spraying, the larval population per 30 plants was ranged between 6.00 and 31.33. The highest control(6.00) was observed from profenofos @ 500 while the highest larval population (31.33) from untreated control. Lambda cyhalothrin @ 15 g a.i./ha (8.66) and cypermethrin @ 50 g a.i./ha (9.00) were discovered to be at par and next to profenofos @ 500 g a.i./ha in the order of effectiveness. The nearness in the values of deltamethrin @ 15 g a.i./ha(12.33) and bifenthrin @ 50 g a.i./ha (12.67) ruled them to be at par, succeeding the priorly mentioned treatments in this para. Ethion@ 500 g a.i./ha (15.66) and fenvalerate @ 75 g a.i./ha (16.00) were also ascertained to be at par, following in theorder of effectiveness.

The mean values obtained after second spray held high the treatment of profenofos @ 500 g a.i./ha (3.75 larvae/30 plants) and at par treatments of lambda cyhalothrin 15 g a.i./ha (6.42 larvae/30 plants) and cypermethrin @ 50 g a.i./ha (6.75 larvae/30 plants) as was the order of effectiveness. Other treatments succeeding these and perceived to be at par were deltamethrin @

15 g a.i./ha with 10.08 larvae per 30 plants and bifenthrin 50 g a.i./ha with 10.42 larvae per 30 plants as well as ethion @ 500 g a.i./ha with 13.42 larvae per 30 plants and fenvalerate @ 75 g a.i./ha with 13.75 larvae per 30 plants. Maximum larval population of 28.25 per 30 plants was observed from untreated control.

4.1.1.3 Third Spray

The data obtained from observing the treatment plots after third spray is displayed in Table No. 4.3 as well as Fig. 4.3. Significant reduction in the fall armyworm incidence was detected in the treatment plots as compared to the untreated plot. On 3, 5, 7 and 10 days after third spray, the order of effectiveness of treatments was analyzed and it was found to be similar to that of first and second spray but with larval population variation from 3.67 - 33.00, 1.33 - 35.00, 3.00 - 36.67 and 4.33 - 39.00 larvae per 30 plants respectively.

The treatment of profenofos @ 500 g a.i./ha., was witnessed to be the best on the third, fifth, seventh and tenth day after third spray with larval population of 3.67, 1.33, 3.00 and 4.33 larvae per 30 plants.

On all the days, the subsequent treatments according to the order of effectiveness were lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha; deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha; ethion 500 g a.i./ha and fenvalerate @ 75 g a.i./ha which were concluded to be at par in pairs as mentioned.

By calculating the mean values in respect of larval population of the treatments, the order of effectiveness was – profenofos @ 500 g a.i./ha (3.08 larvae/30 plants), lambda cyhalothrin @ 15 g a.i./ha (5.75larvae/30 plants), cypermethrin @ 50 g a.i./ha (6.08 larvae/30 plants), deltamethrin @ 15 g a.i./ha (9.42 larvae/30 plants), bifenthrin @ 50 g a.i./ha (9.75 larvae/30 plants), ethion @ 500 g a.i./ha (12.75 larvae/30 plants), fenvalerate @ 75 g a.i./ha (13.08 larvae/30 plants) and untreated control plot (35.92 larvae/30 plants) .

Table 4.1: Effect of different treatments on larval population of FAW, *S. frugiperda* on maize (First Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Larval count of FAW, *S. frugiperda* per 30 plants					
			Precount	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	**Mean**
1	Bifenthrin 10 % EC	50	18.67 (4.43)	15.67 (4.07)	11.67 (3.55)	12.33 (3.65)	15.00 (4.00)	13.67 (3.82)
2	Deltamethrin 2.8 % EC	15	18.33 (4.39)	15.33 (4.06)	11.33 (3.50)	12.00 (3.60)	14.67 (3.96)	13.33 (3.78)
3	Lambda cyhalothrin 5 % EC	15	19.00 (4.47)	11.67 (3.56)	07.67 (2.93)	08.33 (3.05)	11.00 (3.46)	09.67 (3.25)
4	Cypermethrin 10 % EC	50	18.33 (4.40)	12.00 (3.60)	08.00 (3.00)	08.67 (3.11)	11.33 (3.51)	10.00 (3.31)
5	Ethion 50 % EC	500	20.33 (4.62)	18.67 (4.43)	14.67 (3.96)	15.33 (4.04)	18.00 (4.36)	16.67 (4.20)
6	Fenvalerate 10 % EC	75	20.67 (4.65)	19.00 (4.47)	15.00 (4.00)	15.67 (4.08)	18.33 (4.40)	17.00 (4.24)
7	Profenofos 50 % EC	500	18.67 (4.43)	09.00 (3.16)	05.00 (2.44)	05.67 (2.58)	08.33 (3.05)	07.00 (2.81)
8	Untreated control	--	18.33 (4.39)	20.00 (4.58)	22.00 (4.80)	23.00 (4.90)	24.67 (5.07)	22.42 (4.84)
SE (m) ±			0.12	0.12	0.14	0.06	0.08	0.07
CD @ 5 %			NS	0.37	0.43	0.18	0.25	0.20

Figures in the parenthesis are $\sqrt{X+0.5}$ transformed values, DAS- Days After Spraying

Table 4.2: Effect of different treatments on larval population of FAW, *S. frugiperda* on maize (Second Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Larval count of FAW, *S. frugiperda* per 30 plants					
			Precount	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	**Mean**
1	Bifenthrin 10% EC	50	15.00 (4.00)	10.67 (3.41)	08.33 (3.05)	10.00 (3.31)	12.67 (3.70)	10.42 (3.37)
2	Deltamethrin 2.8% EC	15	14.67 (3.96)	10.33 (3.36)	08.00 (3.00)	09.66 (3.26)	12.33 (3.65)	10.08 (3.32)
3	Lambda cyhalothrin 5% EC	15	11.00 (3.46)	06.67 (2.77)	04.33 (2.31)	06.00 (2.64)	08.66 (3.11)	6.42 (2.71)
4	Cypermethrin 10 % EC	50	11.33 (3.51)	07.00 (2.83)	04.67 (2.38)	06.33 (2.70)	09.00 (3.16)	6.75 (2.77)
5	Ethion 50 % EC	500	18.00 (4.36)	13.67 (3.83)	11.34 (3.51)	13.00 (3.74)	15.66 (4.08)	13.42 (3.79)
6	Fenvalerate 10% EC	75	18.33 (4.40)	14.00 (3.87)	11.67 (3.56)	13.33 (3.79)	16.00 (4.12)	13.75 (3.84)
7	Profenofos 50% EC	500	08.33 (3.05)	04.00 (2.23)	01.67 (1.63)	03.33 (2.08)	06.00 (2.64)	03.75 (2.15)
8	Untreated control	--	24.67 (5.07)	26.00 (5.19)	27.00 (5.29)	28.67 (5.45)	31.33 (5.69)	28.25 (5.41)
SE (m) ±			0.08	0.12	0.08	0.10	0.07	0.05
CD @ 5 %			0.25	0.36	0.25	0.31	0.23	0.15

Figures in the parenthesis are $\sqrt{X+0.5}$ transformed values, DAS- Days After Spraying

Table 4.3: Effect of different treatments on larval population of FAW, *S. frugiperda* on maize (Third Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Larval count of FAW, *S. frugiperda* per 30 plants					
			Precount	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	**Mean**
1	Bifenthrin 10% EC	50	12.67 (3.70)	10.33 (3.37)	08.00 3.00	9.67 (3.27)	11.00 (3.46)	9.75 (3.28)
2	Deltamethrin 2.8% EC	15	12.33 (3.65)	10.00 (3.31)	07.67 (2.94)	9.33 (3.21)	10.67 (3.42)	9.42 (3.22)
3	Lambda cyhalothrin 5% EC	15	08.66 (3.11)	06.33 (2.71)	04.00 (2.23)	05.67 (2.58)	07.00 (2.83)	05.75 (2.59)
4	Cypermethrin 10% EC	50	09.00 (3.16)	06.67 (2.77)	04.33 (2.31)	06.00 (2.64)	07.33 (2.89)	06.08 (2.65)
5	Ethion 50% EC	500	15.66 (4.08)	13.33 (3.79)	11.00 (3.46)	12.67 (3.70)	14.00 (3.87)	12.75 (3.71)
6	Fenvalerate 10 % EC	75	16.00 (4.12)	13.67 (3.83)	11.33 (3.51)	13.00 (3.74)	14.33 (3.92)	13.08 (3.75)
7	Profenofos 50% EC	500	06.00 (2.64)	03.67 (2.16)	01.33 (1.52)	03.00 (1.99)	04.33 (2.31)	03.08 (2.00)
8	Untreated control	--	31.33 (5.69)	33.00 (5.83)	35.00 (6.00)	36.67 (6.14)	39.00 (6.32)	35.92 (6.07)
SE (m)			0.07	0.06	0.09	0.08	0.09	0.05
CD @ 5%			0.23	0.18	0.28	0.24	0.26	0.16

Figures in the parenthesis are arc sin transformed values, DAS- Days After Spraying

4.1.1.4 Cumulative Effect of Three Sprays

Table 4.4 as well as Fig.4.4 represents the cumulative data on larval population after three sprays. All the treatments were notably superior over the untreated control in reducing the population of fall armyworm in maize. The range of larval population was between 4.61 and 14.61 larvae per 30 plants as observed in treatment plots against 28.86 larvae per 30 plants in untreated control. The treatment of profenofos @ 500 g a.i./ha excelled over other treatments in minimizing the larval population (4.61 larvae per 30 plants). Lambda cyhalothrin 5% EC was witnessed as the next effective treatment recording 7.27 larvae per 30 plants and was at par with cypermethrin @ 50 ga.i/ha with the larval population of 7.61 per 30 plants. The larval populationper 30 plants for at par treatments of deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha was 11.22 and 11.25 while that for ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha was 14.28 and 14.61, respectively following the sequence of order of effectiveness after cypermethrin @ 50 g a.i./ha.

According to the data, significant variations in the per cent reduction were observed among various treatments in comparison with control. The variation was ranged from 49.38 to84 per cent reduction in mean larval population over control. The maximum reduction of 84.03 per cent was recorded by profenofos 50% EC while the lowest reduction of 49.38 per cent was registered by fenvalerate @ 75 g a.i./ha.

Table 4.4: Cumulative effect of different treatments on larval population of FAW, *S. frugiperda* on maize

Tr. No.	Treatment	Larval count of FAW, *S. frugiperda* per 30 plants				
		I spray	**II spray**	**III spray**	**Mean**	**Percent reduction over untreated control**
1	Bifenthrin 10% EC	13.67 (3.82)	10.42 (3.37)	09.75 (3.28)	11.25 (3.49)	61.02
2	Deltamethrin 2.8% EC	14.17 (3.78)	10.08 (3.32)	09.42 (3.22)	11.22 (3.44)	61.11
3	Lambda cyhalothrin 50% EC	09.67 (3.25)	06.42 (2.71)	05.75 (2.59)	07.27 (2.85)	74.81
4	Cypermethrin 10% EC	10.00 (3.31)	06.75 (2.77)	06.08 (2.65)	07.61 (2.91)	73.63
5	Ethion 50% EC	16.67 (4.20)	13.42 (3.79)	12.75 (3.71)	14.28 (3.90)	50.52
6	Fenvalerate 10% EC	17.00 (4.24)	13.75 (3.84)	13.08 (3.75)	14.61 (3.94)	49.38
7	Profenofos 50% EC	7.00 (2.81)	3.75 (2.15)	03.08 (2.00)	04.61 (2.32)	84.03
8	Untreated control	22.42 (4.84)	28.25 (5.41)	35.92 (6.07)	28.86 (5.44)	-
SE (m) ±		0.07	0.05	0.05	0.05	-
CD @ 5%		0.20	0.15	0.16	0.16	-

Figures in the parenthesis are arc sin transformed values, DAS- Days After Spraying

4.1.2. Percent Infestation:

The data on percent infestation of *Spodoptera frugiperda* after three spray is presentedin Table 4.5 to 4.8. The observations were recorded a day before and 3, 5, 7 and 10 days after each spraying and cumulative data after all three sprays are discussed here under.

4.1.2.1. First Spray

The data on percent infestation of *Spodoptera frugiperda* after spraying is displayed in Table 4.5 and Fig.4.5. On the day before conducting the spraying, there was more or less uniform infestation of fall armyworm in the experimental plots. However, the situation of experimental plots changed gradually after conducting the spraying.

On the third day after spraying, major changes were observed in almost all the plots. Minimum infestation of 19.98 per cent was seen in the plots treated with profenofos 500 g a.i./ha indicating it to be the superior treatment followed by lambda cyhalothrin @ 15 g a.i./ha (23.33 %) and cypermethrin @ 50 g a.i./ha (24.74%) treated plots which were at par. Thereafter in the sequence was the plot treated with deltamethrin @ 15 g a.i./ha showing 28.39 per cent infestation and that treated with bifenthrin @ 50 g a.i./ha showing 29.33 per cent infestation indicating these two treatments to be at par. Next to it was ethion @ 500 g a.i./ha treated plot with 32.22 per cent infestation being at par with fenvalerate @ 75 g a.i./ha treated plot which had infestation percentage of 32.41. Maximum infestation of 38.43 per cent was observed in the untreated control plot.

Percent infestation on fifth day ranged from 10.29 to 40.13%. profenofos @ 500 g a.i./ha was the best treatment observed on this day with 10.29 per cent infestation. The untreated control plot was the least effective with 40.13 per cent infestation. The plots treated with lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha were at par and the next treatments after profenofos @ 500 g a.i./ha with mean of 13.76 per cent infestation and 14.30 per cent respectively, followed by the plots treated with deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha which too were at par with mean 18.66 percent infestation and 18.77 per cent infestation respectively. Treatment plots of ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha had similar percent infestation i.e. 22.65 and 22.57 indicating these two to be at par and least effective insecticide treatments observed on this day.

On the seventh and the tenth day after spraying, similar trend of effectiveness of the treatments was observed. The sequence of effectiveness of treatments was profenofos @ 500 g a.i./ha, lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha, bifenthrin @ 50 g a.i./ha, ethion @ 500 g a.i./ha and fenvalerate 75 g a.i./ha with corresponding values of per cent infestation being -11.51,15.56, 16.49, 20.50, 21.09, 23.82 and 24.34 on seventh day after spraying and 15.16, 18.59, 19.79, 23.57, 24.27, 27.41 and 27.75 on tenth day after spraying respectively.

Mean of first spray as calculated were – 14.23, 17.81, 18.83, 22.78, 23.36, 26.53, 35.01 and 41.11 per cent for profenofos @ 500 g a.i./ha, lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin@ 15 g a.i./ha, bifenthrin @ 50 g a.i./ha, ethion @ 500 g a.i./ha, fenvalerate @ 75 g a.i./ha and untreated control respectively.

4.1.2.2 Second Spray

The data on percent infestation of FAW after second spray is presented in Table 4.6 and Fig.4.6. The per cent infestation readings obtained through observing the different treatments on third day after spraying ranged between 10.61 and 45.75 per cent. Minimum infestation was observed in the plot sprayed with profenofos @ 500 g a.i./ha followed by lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha, bifenthrin @ 50 g a.i./ha, ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha with corresponding infestation of 10.61, 13.14, 14.29, 18.16, 19.33, 21.36 and 21.98 per cent, respectively.

The data collected through observation on the fifth day after spraying revealed that there was significant reduction in the per cent infestation of the plots treated with insecticides as compared to the untreated control plot with per cent infestation of 47.47. The highest control was observed in the plot treated with profenofos @ 500 g a.i./ha with infestation per cent as low as 7.34. Chasing it were the treatments of lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha with per cent infestation figures of 10.78 and 11.54. Thedeltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha treated plots were at par with the values of percent infestation of 15.08 and 16.37, respectively which were just below cypermethrin @ 50 g a.i./ha in the order of effectiveness of treatments under consideration. Per cent infestation observed in the plots treated with ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha was 20.07 and 20.82 disclosing these two treatments to be at par and at the bottom of order of effectiveness of insecticide treated plots.

On the seventh day after treatment the percent infestation values of 7.91, 10.19, 11.11, 15.68, 16.94, 21.31, 21.96 and 48.02 were observed in the treatment plots of profenofos @ 500 g a.i./ha, lambda cyhalothrin @15g a.i./ha, cypermethrin @ 50g a.i./ha, deltamethrin @ 15 g a.i./ha, bifenthrin @ 50 g a.i./ha, ethion @ 500 g a.i./ha, fenvalerate @ 75 g a.i./ha and Untreated control, respectively. There was slight increase in the infestation percentage of the pest on tenth day after spraying, indicating the effect of insecticide to be lower than the previous days. Even if so, the per cent infestation in the plot treated with profenofos @ 500 g a.i./ha was as low as 11.58 followed by lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha treated plots with per cent infestation of 13.18 and 14.25 whose proximity discloses them to be at par. Followed by it and with similar proximity in the per cent infestation values could be seen in case of deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha and ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha with per cent infestation values of 18.66 and 19.84 and 24.23 and 24.86, respectively, revealing these two pairs to be at par, respectively. The infestation per cent of untreated control yet remained the highest with the value of 49.16 per cent.

The mean per cent infestation in the plot treated with profenofos @ 500g a.i./ha wasas low as 9.36, followed by lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha treated plots with per cent infestation of 11.82 and 12.80 which were at par. Chasing it and with close proximity in the per cent infestation values could be seen in case of deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha and ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha with mean per cent infestation values of 16.89 and 18.12 and 21.74 and 22.40 respectively, revealing these two pairs to be at par, respectively. The infestation per cent of untreated control yet remained the highest with the mean value of 47.60 per cent .

4.1.2.3. Third Spray

The data on the per cent infestation of *Spodoptera frugiperda* in each treatment plot after third spray is presented in Table 4.7 and Fig.4.7. The results revealed that there was significant reduction in the pest infestation in the insecticide treated plots over untreated control plots. The order of effectiveness of different treatments a day before and on 3, 5, 7and 10 days after third spray was similar to the order observed in the first and second spray.

Noticeable control was observed in the per cent infestation of FAW on the third day after spraying. The maximum infestation (51.41) was observed in untreated control plot while minimum one (7.20) was observed in profenofos @ 500 g a.i./ha treated plot. Among the remaining treatments, there were three pairs of treatments which were at par. The treatments in the order of effectiveness from the most effective to least effective are - and cypermethrin @50 g a.i./ha (10.45) and lambda cyhalothrin @ 15 g a.i./ha (9.57); bifenthrin @ 15 g a.i./ha (15.18) and deltamethrin @ 15 g a.i./ha (14.44) and fenvalerate @75 g a.i./ha (20.82) and ethion @ 500 g a.i./ha (20.24) ;

The observations noted on the fifth day after spraying displayed greater control of the pest than the previous days. However, the plot with maximum per cent infestation of FAW

(51.98) was that of untreated control.The best treatment observed was that of profenofos @ 500 g a.i./ha with 4.21 percent infestation. Chasing it were the at par treatment pairs oflambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha as well as fenvalerate 75 g a.i./ha and ethion @ 500 g a.i./ha with the corresponding per cent infestation of 6.57 and 6.59%; 11.10 and 11.66% and 17.29 and 17.28% respectively.

On the seventh and the tenth day after spraying, similar trend in the effectiveness of treatments was observed. On the basis of effectiveness, the treatments can be queued as profenofos @ 500 g a.i./ha, lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha, ethion @ 500 g a.i./ha, fenvalerate @ 75 g a.i./ha and Untreated control with the corresponding values of per cent infestation being 4.78, 5.98, 6.04, 12.61, 13.42, 19.07, 20.23 and 52.55 on the seventh day while 6.64, 9.58, 10.42, 16.39, 16.94, 22.66, 23.70 and 53.67 on the tenth day after spraying, respectively.

On the basis of effectiveness based on mean per cent infestation, the treatments can be queued as profenofos @ 500 g a.i./ha, lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i./ha, deltamethrin @ 15 g a.i./ha, bifenthrin @ 50g a.i./ha, ethion @ 500 g a.i./ha, fenvalerate @ 75 g a.i./ha and Untreated control with the corresponding values of mean per cent infestation being 5.70, 7.92, 8.37, 13.63, 14.30, 19.81, 20.51 and 52.40, respectively. The pairs of treatments at parwere lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 g a.i./ha ; deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha ; ethion @ 500 g a.i./ha and fenvalerate @ 75 g a.i./ha.

Table 4.5: Effect of different treatments on per cent infestation of FAW, *S. frugiperda*on maize (First Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of FAW, *S. frugiperda*					
			Precount	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	**Mean**
1	Bifenthrin 10 % EC	50	32.06 (34.47)	29.33 (32.77)	18.77 (25.65)	21.09 (27.31)	24.27 (29.49)	23.36 (32.42)
2	Deltamethrin 2.8 % EC	15	31.47 (34.11)	28.39 (32.18)	18.66 (25.56)	20.50 (26.90)	23.57 (29.43)	22.78 (32.24)
3	Lambda cyhalothrin 5 % EC	15	31.72 (34.26)	23.33 (28.87)	13.76 (21.76)	15.56 (23.22)	18.59 (25.52)	17.81 (29.85)
4	Cypermethrin 10 % EC	50	31.87 (34.25)	24.74 (29.81)	14.30 (22.15)	16.49 (23.93)	19.79 (26.39)	18.83 (30.33)
5	Ethion 50 % EC	500	33.89 (35.58)	32.22 (34.57)	22.65 (28.41)	23.82 (29.20)	27.41 (31.56)	26.53 (33.76)
6	Fenvalerate 10 % EC	75	34.05 (35.67)	32.41 (34.67)	22.57 (28.31)	24.34 (29.54)	27.75 (31.77)	35.01 (33.85)
7	Profenofos 50 % EC	500	31.54 (34.15)	19.98 (26.54)	10.29 (18.70)	11.51 (19.82)	15.16 (22.90)	14.23 (27.90)
8	Untreated control	--	32.01 (34.45)	38.43 (38.29)	40.13 (39.29)	41.81 (40.27)	44.06 (41.57)	41.11 (39.13)
SE (m) ±			0.558	0.701	0.817	0.520	0.542	0.43
CD @ 5 %			NS	2.146	2.502	1.592	1.66	1.28

Figures in the parenthesis are arc sin transformed values, DAS- Days After Spraying

Table 4.6: Effect of different treatments on per cent infestation of FAW, *S. frugiperda* on maize (Second Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of FAW, *S. frugiperda*					
			Precount	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	**Mean**
1	Bifenthrin 10 % EC	50	24.27 (29.49)	19.33 (26.06)	16.37 (23.82)	16.94 (24.29)	19.84 (26.43)	18.12 (30.64)
2	Deltamethrin 2.8 % EC	15	24.17 (29.43)	18.16 (25.19)	15.08 (22.84)	15.68 (23.31)	18.66 (25.57)	16.89 (30.14)
3	Lambda cyhalothrin 5 % EC	15	19.77 (26.39)	13.14 (21.22)	10.78 (19.16)	10.19 (18.59)	13.18 (21.24)	11.82 (27.45)
4	Cypermethrin 10 % EC	50	19.79 (26.39)	14.29 (21.91)	11.54 (19.85)	11.11 (19.45)	14.25 (22.16)	12.80 (27.90)
5	Ethion 50 % EC	500	27.41 (31.56)	21.36 (27.50)	20.07 (25.88)	21.31 (27.48)	24.23 (29.48)	21.74 (32.16)
6	Fenvalerate 10 % EC	75	27.75 (31.77)	21.98 (27.94)	20.82 (26.57)	21.96 (27.93)	24.86 (29.89)	22.40 (32.45)
7	Profenofos 50 % EC	500	15.16 (22.90)	10.61 (18.73)	7.34 (15.61)	7.91 (16.21)	11.58 (19.81)	9.36 (25.53)
8	Untreated control	--	44.06 (41.57)	45.75 (42.55)	47.47 (43.53)	48.02 (43.85)	49.16 (44.50)	47.60 (41.07)
SE (m) ±			0.43	0.71	0.72	0.58	0.58	0.40
CD @ 5 %			1.30	2.16	2.19	1.77	1.75	1.16

Figures in the parenthesis are arc sin transformed values, DAS- Days After Spraying

Table 4.7: Effect of different treatments on per cent infestation of FAW, *S. frugiperda*on maize (Third Spray)

Tr. No.	Treatment	Dose (g a.i./ha)	Per cent infestation of FAW, *S. frugiperda*					
			Precount	**3 DAS**	**5 DAS**	**7 DAS**	**10 DAS**	**Mean**
1	Bifenthrin 10 % EC	50	19.84 (26.43)	15.18 (22.91)	11.66 (19.94)	13.42 (21.47)	16.94 (24.28)	14.30 (28.63)
2	Deltamethrin 2.8 % EC	15	18.66 (25.57)	14.44 (22.28)	11.10 (19.42)	12.61 (20.75)	16.39 (24.36)	13.63 (28.26)
3	Lambda cyhalothrin 5 % EC	15	13.18 (21.34)	9.57 (18.31)	06.57 (14.82)	05.98 (14.12)	09.58 (18.00)	7.92 (24.52)
4	Cypermethrin 10 % EC	50	14.25 (22.16)	10.45 (18.84)	06.59 (14.87)	06.04 (14.20)	10.42 (18.78)	8.37 (24.85)
5	Ethion 50 % EC	500	24.23 (29.48)	20.24 (26.71)	17.28 (24.51)	19.07 (25.85)	22.66 (28.38)	19.81 (31.27)
6	Fenvalerate 10 % EC	75	24.86 (29.89)	20.82 (27.13)	17.29 (25.03)	20.23 (26.70)	23.70 (29.11)	20.51 (31.65)
7	Profenofos 50 % EC	500	11.58 (19.81)	07.20 (15.53)	04.21 (11.81)	04.78 (11.00)	06.64 (14.92)	5.70 (22.36)
8	Untreated control	--	49.16 (44.50)	51.41 (45.79)	51.98 (46.11)	52.55 (46.45)	53.67 (47.09)	52.40 (42.68)
SE (m) ±			0.57	0.54	0.60	0.75	0.80	0.47
CD @ 5 %			1.75	1.67	1.83	2.31	2.45	1.38

Figures in the parenthesis are arc sin transformed values, DAS- Days After Spraying

4.1.2.4 Cumulative Effect of Three Sprays

The cumulative data on the per cent infestation after three sprays is presented in Table 4.8 and Fig.4.8. The data clearly showed that all the treatments were significantly superior over untreated control in minimizing the fall armyworm infestation. For the untreated plot, the per cent infestation was 47.04, while that for the plot treated with profenofos @ 500 g a.i./ha was 9.77. The treatments of lambda cyhalothrin @ 15 g a.i./ha and cypermethrin @ 50 ga.i/ha were next to the best and at par with per cent infestation values of 12.52 and 13.33 respectively, followed by 17.77 and 18.63 per cent infestation as was observed in the plot treated with deltamethrin @ 15 g a.i./ha and bifenthrin @ 50 g a.i./ha, the close values indicating these treatments to be at par. Next to it was the plots treated with ethion @ 500 g a.i./ha that had per cent infestation of 22.70 and was at par with the one treated withfenvalerate @ 75 g a.i./ha with 25.98 per cent infestation. The overall data on the effect of various treatments on reduction of percent infestation in maize indicated that treatments with profenofos @ 500 g a.i./ha was the most effective among all the treatments followed by lambda cyhalothrin @ 15 g a.i./ha, cypermethrin @ 50 g a.i/ha and d eltamethrin @ 15 ga.i/ha. Fenvalerate @ 75 g a.i./ha was least effective treatment amongst all the insecticide treatments.

The current investigation is in accordance with the findings of Worku and Ebabuye (2019) who declared the supremacy of profenofos + cypermethrin in the field experiment. Hole *et al* who researched on bio-efficacy of profenofos and other insecticides against *Spodoptera litura* in soybean publicized that profenofos 0.1% EC gave highest degree of protection as compared to other insecticides.

Table 4.8: Cumulative effects of different treatments on per cent infestation of FAW, *S. frugiperda* on maize

Tr. No.	Treatment	Per cent infestation of FAW, *S. frugiperda*				
		I spray	**II spray**	**III spray**	**Mean**	**Percent reduction over untreated control**
1	Bifenthrin 10 % EC	23.36 (30.08)	18.12 (30.87)	14.30 (28.77)	18.60 (25.41)	60.46
2	Deltamethrin 2.8 % EC	22.78 (29.84)	16.89 (30.42)	13.63 (28.41)	17.77 (24.76)	60.22
3	Lambda cyhalothrin 5 % EC	17.81 (27.74)	11.82 (27.83)	7.92 (24.95)	12.52 (20.39)	73.38
4	Cypermethrin 10 % EC	18.83 (27.86)	12.79 (28.22)	8.37 (25.29)	13.33 (21.07)	71.66
5	Ethion 50 % EC	26.52 (31.90)	21.74 (32.33)	19.81 (31.34)	22.70 (28.37)	51.74
6	Fenvalerate 10 % EC	26.77 (32.16)	22.40 (32.60)	20.51 (31.69)	25.98 (30.39)	44.77
7	Profenofos 50 % EC	14.23 (25.68)	9.36 (25.86)	5.70 (22.89)	9.77 (17.82)	79.23
8	Untreated control	41.11 (38.23)	47.60 (40.98)	52.40 (42.60)	47.04 (43.20)	-
SE (m) ±		0.43	0.40	0.45	0.708	-
CD @ 5%		1.28	1.03	1.28	2.097	-

Figures in the parenthesis are arc sin transformed value

4.1.3. Marketable Yield of Maize Cobs

Table 4.9 constitutes the judgments concerning the marketable yield of maize cobs. The quality and quantity of yield displays the fruitfulness of the treatments in/on maize. In terms of yield, the data depicts that treatment of profenofos @ 500 g a.i./ha exhibited highest yield of 10.20 kg/plot with maximum increase over control of 59.18% and was noticed to be better than all other insecticidal treatments. Next to it was lambda cyhalothrin 5% EC @ 15 g a.i./ha yielding 9.24 kg/plot with 44.19% increase over control. Following it was cypermethrin 10% EC @ 50 ga.i/ha with total yield of 7.86 kg/plot. It's percent increase in yield over control was 22.66. Succeeding it was deltamethrin 2.8% EC @15 g a.i./ha with 20.78 per cent increase over control and the total yield per plotof 7.74 kg/plot.

In accordance with the yield received from each treatment, the sequence in descending order is as given below:

Profenofos 50% EC > Lambda cyhalothrin 5% EC > Cypermethrin 10% EC > Deltamethrin 2.8% EC > Bifenthrin 10% EC > Ethion 50% EC > Fenvalerate 10%EC > untreated control.

It is observed that there is considerable yield advantage of 3.80 kg/plot over control due to effective control of *Spodoptera frugiperda* in maize particularly through the use of profenofos 50% EC @ 500 g a.i./ha.

These findings are in agreement with those reported earlier by Hole *et al.* (2009) who obtained highest yield of soybean (27.46 q/ha) from the profenofos 0.1% EC treated plot.

4.1.4. Incremental Cost Benefit Ratio (ICBR)

The productiveness of insecticides under study was assessed through net profit and incremental cost benefit ratio (ICBR) which is illustrated in Table 4.10.The cost of control offall armyworm due to various insecticides varied from Rs.61.89 to Rs.63.03 per plot which includes the cost of insecticides for three sprayings and labour cost @ Rs. 165/plot/application. Among all the treatments under consideration, the highest protection cost of Rs.63.03 per plot was incurred in the treatment of lambda cyhalothrin @ 15 g a.i./ha while the lowest was observed in deltamethrin @ 15 g a.i./ha treatment which was merely Rs. 61.89 per plot.

In comparison with untreated control, maximum rise in yield was noted due to the application of profenofos @ 500 g a,.i./ha while the minimum rise in yield was registered due to fenvalerate @ 75g a.i./ha.

The net monetary returns due to different insecticides are clearly illustrated in the data.

The highest net return of Rs. 127.78 was noted from profenofos 50% EC @ 500 g a.i./ha, closely chasing it was lambda cyhalothrin 5% EC @ 15 g a.i./ha (Rs.108.83) followed by cypermethrin 10% EC @ 50 g a.i./ha (Rs.84.26) and deltamethrin 2.8%EC @ 15 g a.i./ha(Rs.82.07). It was found minimum, just Rs. 73.53 in fenvalerate 10% EC @ 75 g a.i./ha. All the insecticides gave higher monetary returns than untreated control.

The range of ICBR for different insecticide treatments that were calculated lied between 1:1.18 and 1:2.06. The highest ICBR was registered by profenofos @ 500 g a.i./ha (1:2.06) followed by lambda cyhalothrin @ 15 g a.i./ha(1:1.73), cypermethrin @ 50 g a.i./ha (1:1.36) and deltamethrin @ 15 g a.i./ha(1:1.33). The least ICBR was seen in fenvalerate @ 75 g a.i./ha which was 1:1.18 only.

Table 4.9: Effect of conventional insecticides on marketable cob yield of maize

Tr. No.	Treatments	Dose (g a.i./ha)	Marketable yield kg/plot	Percent increase over control
T1	Bifenthrin 10% EC	50	7.59	18.54
T2	Deltamethrin 2.8% EC	15	7.74	20.78
T3	Lambda cyhalothrin 5% EC	15	9.24	44.19
T4	Cypermethrin 10% EC	50	7.86	22.66
T5	Ethion 50% EC	500	7.46	16.10
T6	Fenvalerate 10% EC	75	7.29	13.85
T7	Profenofos 50% EC	500	10.20	59.18
T8	Untreated control		6.40	
	SE(m) ±		0.19	
	CD @ 5%		0.57	

Table 4.10: Economics of FAW control through conventional insecticides

Tr. No.	Treatment	Dose (ga.i./ha)	Quantity of insecticide/ plot/application (ml)	Yield (kg/plot)	Increase in yield over control (kg/plot)	Value of increase in yield (Rs/plot)	Treatment cost for 3 applications (Rs/plot) (A)	Net profit (Rs/plot) (B)	ICBR (B/A)
T1	Bifenthrin 10%EC	50	0.06	7.59	1.19	22.13	62.15	79.02	1:1.27
T2	Deltamethrin 2.8% EC	15	0.018	7.74	1.34	24.92	61.89	82.07	1:1.33
T3	Lambda cyhalothrin 5% EC	15	0.6	9.24	2.84	52.82	63.03	108.83	1:1.73
T4	Cypermethrin 10 % EC	50	0.06	7.86	1.46	27.16	61.94	84.26	1:1.36
T5	Ethion 50% EC	500	0.6	7.46	1.06	19.72	62.51	76.25	1:1.22
T6	Fenvalerate 10% EC	75	0.09	7.29	0.89	16.55	62.06	73.53	1:1.18
T7	Profenofos 50 % EC	500	0.018	10.20	3.80	70.68	61.94	127.78	1:2.06
T8	Untreated control	--	--	6.40	--	--	--	--	--

***Treatment cost= Cost of insecticide + Charges of insecticide application (Labour charges)**

Bifenthrin10 EC = Rs.1480/ L **Lambda cyhalothrin 5 EC = Rs.640/L**

Cypermethrin10 EC= Rs. 320/L **Deltamethrin 2.8 EC = Rs.227**

Ethion 50 EC= Rs.350 **Fenvalerate 10 EC=Rs.660/L**

Labour charges/application = Rs.165 **No.of applications = 3**

Average market price = Rs.18.6/kg **Plot size = 4 x 3 m = 12 m^2 (for 3 replications = 36 m^2)**

4.2. Residues of Lambda cyhalothrin and Cypermethrin in/on Maize Cobs and Cropped Soil

Dissipation of lambda cyhalothrin and cypermethrin was established by undertaking a supervised field during rabbi 2020 at the Instructional farm of PGI, MPKV, Rahuri. Insecticides were sprayed twice at an interval of 10 days, the first been given at cob initiation stage. The samples of cobs were collected at 0, 1, 3, 5, 7, 10, 15 and 20 days after insecticide application and subjected to QuEChERS method of analysis as explained under section 3.2.2.2.3 of the chapter third (Materials and Methods). During the period of experimentation, the relevant metrological data *viz.,* temperature, relative humidity and rainfall were recorded and are mentioned in appendix - I

4.2.1 Method Validation

Method validation refers to the process used to confirm the suitability of analytical method employed for specific test and it is an integral part of any good analytical procedure (Huber, 2007). Validation parameter *viz.,* linearity, LOD, LOQ, accuracy and precision were determined.

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

The limit of detection (LOD) of the tested insecticides was 0.003 mg/kg resulted by considering a signal-to-noise ratio of compound with reference to the background noise (1:3) obtained for the blank sample. The limit of quantification (LOQ) determined as the lowest concentration of a given compound giving a response that could be quantified with RSD lower than 20 per cent, was 0.01 mg/kg for both the insecticides.

4.2.1.2 Linearity Study

Seven linear concentrations (0.010, 0.025, 0.050, 0.080, 0.125, 0.250 and 0.500 ppm) of each working standard *i.e*. lambda cyhalothrin and cypermethrin were injected three times andthe linearity lines were drawn which are presented in Fig.4.11 and 4.12. The response was linear over the range tested and R^2 values were 0.990 and 0.995 for lambda cyhalothrin and cypermethrin, respectively. The results indicated that the GC-MS/MS analysis is a valid methodfor residue determination of tested insecticides.

4.2.1.3 Recovery Study

Recovery studies are used to define the accuracy of analytical method. The accuracy of the method was ascertained by the mean recovery obtained from the studies.

Recovery experiment was conducted on untreated maize cobs and soil fortified in triplicate concentrations *i.e.* 0.01, 0.05 and 0.10 mg/kg of individual insecticides. The extraction and clean-up was done as prescribed earlier. The recovery percentages are illustrated in Table 4.11 and 4.12.

The mean recovery of lambda cyhalothrin carried out at the levels of 0.01, 0.05 and 0.10 mg/kg were 84.69, 91.98 and 91.33per cent for immature cobs, 91.33, 83.52 and 92.14 per cent for mature cobs and 83.92, 86.03 and 97.12 per cent for soil respectively.

The mean recovery of cypermethrin worked out at the levels of 0.01, 0.05 and 0.10 mgkg on immature cobs, mature cobs and soil were 85.44, 101.96 and 91.53 per cent while that for mature cobs were 91.53, 83.87 and 99.15 per cent and that for cropped soil was 105.18, 87.13 and 97.24 per cent, respectively. The analytical method employed for the extraction and clean-up of maize cobs and soil samples was found accurate and precise as mean recovery percentage were within the limits prescribed by SANTE (2017). According to SANTE (2019) guidelines, analytical method which records mean recovery in the range of 70-120 per cent is accurate and precise. The outcomes pointed out that the QuEChERS method is valid method for residue determination of the tested insecticides in maize cobs and soil.

Table 4.11: Recovery of lambda cyhalothrin in immature cobs, mature cobs and cropped soil

Substrate	Fortification level (mg/kg)	Recovery (%)			
		R1	R2	R3	Mean (±SD)
Immature cobs	0.01	83.99	83.14	86.94	84.69 (±1.99)
	0.05	92.55	91.42	91.98	91.98 (±0.56)
	0.10	92.47	89.71	91.82	91.33 (±1.44)
Mature cobs	0.01	82.28	83.20	85.09	83.52 (±1.43)
	0.05	91.98	92.55	91.89	92.14 (±0.36)
	0.10	89.39	92.47	89.71	90.52 (±1.69)
Soil	0.01	84.88	81.93	84.94	83.92 (±1.72)
	0.05	85.96	85.75	86.37	86.03 (±0.31)
	0.10	99.40	96.44	95.51	97.12 (±2.03)

Table 4.12: Recovery of cypermethrin in immature cobs, mature maize cobs and cropped soil

Substrate	Fortification level (mg/kg)	Recovery (%)			
		R1	R2	R3	Mean (±SD)
Immature maize cobs	0.05	85.82	85.10	85.39	85.44 (±0.36)
	0.25	102.96	102.96	99.95	101.96 (±1.74)
	0.50	91.49	90.66	92.44	91.53 (±0.89)
Mature maize cobs	0.05	81.53	85.35	84.73	83.87 (±2.05)
	0.25	99.95	97.56	99.95	99.15 (±1.38)
	0.50	105.65	103.69	106.21	105.18 (±1.32)
Soil	0.05	87.10	87.57	86.72	87.13 (±0.43)
	0.25	97.56	95.84	98.33	97.24 (±1.27)
	0.50	89.38	90.66	91.49	90.51 (±1.06)

4.2.2. Dissipation of Insecticides in Maize Cobs and Soil

Dissipation of lambda cyhalothrin and cypermethrin was accessed after two applications at the recommended dose (15 and 50 g a.i./ha) and double the recommended dose (30 and 100 g a.i./ha) respectively, on maize cobs and soil. The outcomes established that residues decreased with different day intervals after application. In maize, the dissipation of residues relies on climatic conditions, insecticide application, type of application, interval between application, dosage of application and harvesting time.

4.2.2.1 Persistence and Dissipation of Lambda cyhalothrin in Maize Cobs.

In case of lambda cyhalothrin 5% EC @ 15 g a.i./ha and 30 g a.i./ha the initial deposits noticed were 0.584 and 0.892 mg/kg which subsequently decrease and seem to be less than the limit of quantification (LOQ) on 15 and 20 days respectively. The half-life values were 2.22 and 2.66 days respectively. (Table 4.13 and 4.14) The residues dissipated up to 95.86 per cent and 97.75 per cent at both the doses. The samples of mature cob taken from control plot contained no noticeable amounts of lambda cyhalothrin residues, below the quantification limit.

Owing to the paucity of data on residues of lambda cyhalothrin in maize, the current outcomes are narrated in consideration with residues and persistence of lambda cyhalothrin in other crops. The outcomes are in agreement with the findings of Pandey *et al.* (2019) who notified the mean residue of lambda cyhalothrin 15 g a.i./ha on okra to be 0.25 on 10th day and perish thereafter. Jayakrishnan *et al.* (2005) found the initial deposit to be 0.385 to 0.526 mg/kg and 0.690 to 0.958 mg/kg from 15 and 30 g a.i./ ha which persisted up to 7-10 days. The residues were found to have the half-life of 3.6-4.5 days and 3.7-3.9 days from 1st and 2nd spray respectively. His findings are also in line with our findings. The outcomes obtained by Raghu *et al.* (2017) who analyzed the dissipation pattern of lambda cyhalothrin and observed it to have theinitial deposits of 0.37 mg/kg in chili samples collected from polyhouse to dissipate by 10th day with the half-life of 19.8 days and that in open fields, with the initial deposits of 0.16 mg/kg to dissipate to BDL by 7th day, too are in accordance with our findings.

4.2.2.2 Persistence and Dissipation of Cypermethrin in/on Maize Cobs

The initial deposits observed were 0.271 and 0.478 mg/kg at recommended and double the recommended dose, respectively. The residues of cypermethrin were lower than LOQ on 10th and 15th day, respectively. The residual half-life values calculated were 2.10 and 2.42 days, while the residues of cypermethrin were dissipated to 92.25 per cent and 95.18 per cent at recommended and double the recommended dose, respectively. (Table 4.15 and 4.16)

With respect to all these aspects, the PHI of 10 days is advisable for cypermethrin.

Owing to the paucity of data on residues of cypermethrin in maize, the current outcomesare narrated in consideration with residues and perseverance of cypermethrin in other crops. Theoutcomes of current investigation are in accordance with the findings of Mayannavar *et al.*(2017) who publicized the recommended dose of cypermethrin (50 g a.i./ha) to persist up to 7days and the double the recommended dose (100 g a.i./ha) to persist up to 10 days on okra cropwhich is similar to our findings. The results obtained by Chandra *et al.* (2014) while studying onthe residues of cypermethrin (100 g a.i/ha) on okra are very close to the results that we obtained. Similarly the results obtained by Nath *et al.* (2005) who noted cypermethrin to have maximumdissipation of 73.50% on seventh day and found the half-life value of cypermethrin to be 4.11days are in accordance with our findings. Tanuja and Patyal (2017) who interpreted thedissipation of cypermethrin @ 50 g a.i./ ha and 100 g a.i./ ha to have the half-life of 1.31-1.71days while applied individually but when applied in ready-mix formulation with chlorpyrifos,found it to be 1.38-1.69 days. According to her, the residues of cypermethrin were below thedetermination limit in 10^{th} day sampling. These results too are in line with our findings.

4.2.2.3. Residues of Lambda cyhalothrin in Mature Cobs and Soil

Mature cobs and soil samples were collected at the harvest for the residues of lambda cyhalothrin and the judgments are displayed in Table 4.13. No residues above the limit of quantification were detected in untreated samples. The residues of lambda cyhalothrin in mature cobs and soil at harvest were realized to be lower than the LOQ in both the dosages.

4.2.2.4 Residues of Cypermethrin in Mature Cobs and Soil

Due considerations on residues of cypermethrin disclosed that the residues in mature cobs and soil at harvesting time for both the recommended as well as double the recommended dose were below than limit of quantification (Table 4.14).

Table 4.13: Residues and dissipation of lambda cyhalothrin in/on maize cobs and cropped soil

Days after last spray	Residues of lambda cyhalothrin (mg/kg)											
	Control				X-dose @ 15 g a.i./ha				2X-dose @ 30 g a.i./ha			
	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean
Immature cobs												
0	ND	ND	ND	ND	0.593	0.555	0.604	0.584	0.887	0.905	0.884	0.892
1	ND	ND	ND	ND	0.387	0.412	0.389	0.396	0.618	0.637	0.641	0.632
3	ND	ND	ND	ND	0.228	0.207	0.222	0.219	0.449	0.451	0.456	0.452
5	ND	ND	ND	ND	0.170	0.179	0.167	0.172	0.376	0.391	0.388	0.385
7	ND	ND	ND	ND	0.065	0.059	0.062	0.062	0.120	0.128	0.121	0.123
10	ND	ND	ND	ND	0.022	0.024	0.026	0.024	0.075	0.073	0.077	0.075
15	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	0.015	0.019	0.020	0.018
20	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Mature cobs	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Soil at harvest	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
$RL_{50 (Days)}$	-				2.22				2.66			
Regression Equation					y=-0.1363x+27734 (R^2=0.9825)				Y=-0.1097x+2.9675 (R^2=0.9762)			

LOQ = 0.01 $mgkg^{-1}$

Table 4.14: Percent dissipation of lambda cyhalothrin in/on maize cobs and cropped soil

Interval between last application and sampling	Lambda cyhalothrin 5% EC (15 ga.i./ha)		Lambda cyhalothrin 5% EC (30 ga.i./ha)	
	Mean Residue (mg/kg)	Dissipation (%)	Mean Residue (mg/kg)	Dissipation (%)
0	0.584	-	0.892	-
1	0.396	31.03	0.632	29.21
3	0.219	62.07	0.452	49.44
5	0.172	70.69	0.385	56.18
7	0.062	89.66	0.123	86.52
10	0.024	95.86	0.075	91.01
15	<LOQ	-	0.018	97.75
Mature cobs	<LOQ	-	<LOQ	-
Soil (at harvest)	<LOQ	-	<LOQ	-
Half-life	2.22		2.66	

LOQ = 0.01 mgkg^{-1}

Table 4.15: Residue and dissipation of cypermethrin in/on maize cobs and soil

Days after last spray	Residues of of cypermethrin(mg/kg)											
	Control				X-dose @ 50 g a.i./ha				2X-dose @ 100 g a.i./ha			
	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean
Immature cobs												
0	ND	ND	ND	ND	0.278	0.282	0.252	0.271	0.491	0.512	0.431	0.478
1	ND	ND	ND	ND	0.131	0.126	0.124	0.127	0.283	0.260	0.243	0.262
3	ND	ND	ND	ND	0.092	0.114	0.092	0.099	0.154	0.145	0.172	0.157
5	ND	ND	ND	ND	0.056	0.052	0.051	0.053	0.091	0.082	0.011	0.094
7	ND	ND	ND	ND	0.020	0.023	0.020	0.021	0.058	0.061	0.057	0.059
10	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	0.022	0.023	0.021	0.023
15	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
20	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Mature cobs	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Soil at harvest	ND	ND	ND	ND	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
RL_{50} (Days)	-				2.10				2.42			
Regression equation					y=-0.1428x+2.3728 (R^2=0.9584)				y=-0.124x+2.6039 (R^2=0.9891)			

LOQ = 0.01 $mgkg^{-1}$

Table 4.16: Per cent cent dissipation of cypermethrin in/on maize cobs and cropped soil

Interval between last application and sampling	Cypermethrin 10% EC(50 g a.i./ha)		Cypermethrin 10% (100 ga.i./ha)	
	Mean Residue (mg/kg)	Dissipation (%)	Mean Residue (mg/kg)	Dissipation (%)
0	0.271	-	0.478	-
1	0.127	53.14	0.262	45.19
3	0.099	63.47	0.157	67.15
5	0.053	80.44	0.094	80.33
7	0.021	92.25	0.059	87.66
10	<LOQ	-	0.023	95.18
15	<LOQ	-	<LOQ	-
Mature cobs	<LOQ	-	<LOQ	-
Soil (at harvest)	<LOQ	-	<LOQ	-
Half-life	2.10		2.42	

LOQ = 0.01 mgkg^{-1}

5. SUMMARY AND CONCLUSIONS

The current studies on bio-efficacy of conventional insecticides against fall armyworm *Spodoptera frugiperda* (J E Smith) and it's dissipation in/on maize was conducted during 2020-21. The efficacy was studied in the field while the dissipation studies were carried out in laboratory at AINP on Pesticide Residues, Department of Entomology, MPKV., Rahuri.

5.1. Summary

5.1 Efficacy of Conventional Insecticides against *Spodoptera frugiperda* in/on Maize

5.1.1.1. Larval Population

The treatments of profenofos 50% EC @ 500 g a.i./ha expressed its superiority over rest of the treatments disclosing itself to be the most promising treatment with mean larval population of 4.61. The range of mean larval population for other treatments varied from 7.27 to 28.86, the highest being from untreated plot.

5.1.1.2. Per cent infestation

According to the observations recorded, the treatment of profenofos 50 % EC @ 500 g a.i./ha was found to be the most effective in significantly reducing the pest infestation by 79.23% as compared to the untreated control after conduction of three sprays. Per cent infestation in the treatment plot of cypermethrin 10% EC and lambda cyhalothrin 5% EC was found to be better than the rest accounting for 73.38 and 71.66 per cent reduction over control respectively. Range of per cent reduction for other treatments varied from 44.77 to 60.46. Untreated control plot recorded significantly high 47.04 per cent infestation.

5.1.1.3. Marketable Cob Yield

The difference in the effectiveness of treatments was reflected on the yield of maize as well which ranged from the highest yield of 10.20 kg/plot from profenofos treated plots to the lowest 6.40 kg/plot from untreated plot.

5.1.1.4. Incremental Cost Benefit Ratio (ICBR)

The cost effectiveness of all the treatments under consideration was analyzed. The highest ICBR was reaped from profenofos 50% EC @ 500 g a.i./ha (1:2.06) followed by lambda cyhalothrin 5% EC @ 15 g a.i./ha (1:1.73) and cypermethrin 10% EC @ 50 g a.i./ha (1:1.36) and the corresponding net profit were Rs.127.78, Rs.108.83 and Rs.84.26 per plot.

5.2. Residues of Lambda cyhalothrin and Cypermethrin in/on maize cobs or cropped soil

5.2.1Method Validation

The mean percent recovery for lambda cyhalothrin as well as cypermethrin in all the matrices was within the acceptable range of 70-120 per cent at all the fortified concentrations.

This indicates the suitability of the extraction methods for estimation of residues of the insecticides under study.

5.2.1.2. Persistence and dissipation studies of lambda cyhalothrin and cypermethrin in/on maize and cropped soil

In the immature maize cobs, the mean initial residues of lambda cyhalothrin 5% EC @ 15 and 30 g a.i./ha were found to be 0.584 and 0.892 mg/kg respectively, which dissipated up to 95.86 and 97.75 per cent on 10^{th} and 15^{th} day in both the doses respectively, thereafter the residue observed to be less than limit of quantification. The half-life values were 2.22 and 2.66 days for both the doses respectively. The residues of lambda cyhalothrin were found to be BQL in mature maize cobs and soil at harvest at both the doses respectively.

The mean initial residue for cypermethrin 10% EC @ 50 and 100 g a.i./ha was recorded to be 0.271 and 0.478 mg/kg, which gradually decreased BQL after 10^{th} and 15^{th} day respectively. with 92.25 and 95.18 per cent loss of initial residues on 7^{th} and 10^{th} day respectively. The half-life values calculated for both the doses 2.10 and 2.42 days respectively. The residues of cypermethrin were found to be BQL in mature cobs and soil at harvest at both the doses respectively.

Conclusions

Profenofos 50% EC @ 500 g a.i./ha reported as the best treatment for the management of fall armyworm with 84.03 per cent reduction over control in larval population per 30 plants and 79.23 per cent reduction in infestation per plot. Further, the treatment profenophos 50 % EC @ 500 g a.i./ha registered highest yield (8.5 T/ha) with maximum ICBR 1:8.60) as compared to rest of the treatments.

The residues of lambda cyhalothrin on maize with initial deposit of 0.584 mg/kg and 0.892 mg/kg was dissipated below the determination level after 15^{th} and 20^{th} day with half-life of 2.22 and 2.66 days for recommended dose (15 g a.i./ha) and double the recommended dose (30 g a.i./ha) respectively, considering 0.01 mg/kg as default MRL, Pre Harvest Interval of 15 days can be suggested to avoid any type of health hazards to consumers.

The residues of cypermethrin on maize with initial deposit of 0.271 mg/kg and 0.478 mg/kg was dissipated below the determination level after 10^{th} and 15^{th} day with half-life of 2.10 and 2.42 days for recommended dose (50 g a.i./ha) and double the recommended dose (100g a.i./ha) respectively, considering 0.01 mg/kg as default MRL, Pre Harvest Interval of 10 days can be suggested to avoid any type of health hazards to consumers.

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8. VITAE

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MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL ENTOMOLOGY

2022

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