`INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN COWPEA

by

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(2016-11-051)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

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COLLEGE OF AGRICULTURE

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DECLARATION

I, hereby declare that this thesis entitled **"INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN COWPEA"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,

18-06-2018.

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CERTIFICATE

Certified that this thesis entitled **"INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN COWPEA"** is a record of research work done independently by Mr. Banka Kanda Kishore Reddy under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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(Banka Kanda Kishore Reddy)

Dedicated to my father

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LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
ADI	Acceptable daily intake
a.i.	Active ingredient
BDL	Below detectable level
BQL	Below quantification level
bw d^{-1}	Body weight per day
CIB & RC	Central Insecticide Board and Registration committee
C.D.	Critical Difference
DAS	Days after spraying
EC	Emulsifiable concentrate
et al	And others
FAO	Food and agriculture organisation
g	Gram
GC-MS	Gass chromatograph mass spectroscopy
ha^{-1}	per hectare
HPLC	High performance liquid choromatgography
IRAC	Insecticide resistance action commiittee
IRM	Insecticide resistance management
KAU	Kerala Agricultural University
kg	Kilogram
L	Litre
LC-MS	Liquid choramatography-Mass Spectroscopy
LOQ	Limit of Qunatification
Mg	Milligram
mL	Millilitre
MPI	Maximum permissible intake
MRM	Mutilple Reaction Monitoring
ppm	Parts per million
QuEChERS	Quick, easy, cheap, effective, rugged and safe
RBD	Randomized block design

RSD Relative standard deviation

SC Suspension concentrate

SG Water soluble granules

TMRC Theoretical maximum residue concentration

SL Soluble Liquid

SP Soluble Powder

SD Standard deviation

sp Species

viz., Namely

WHO World health organisation

WG Wettable granules

ZC Zeon capsules

Introduction

1. INTRODUCTION

Cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.) commonly termed as yard long bean is a nutritionally important legume crop grown in semi-arid and sub-humid tropics of Asia for both vegetables and pulses. In India, cowpea is grown as sole, inter-crop, mix-crop and in agro-forestry combinations. Inspite of all improvement brought in cultivation of cowpea, its productivity is still very low due to insect-pests attack. An array of pests attack this crop which includes pod borers, leaf feeders, sap sucking insects etc which infest the crop simultaneously especially at the pod bearing stage. Farmers' resort to spray various insecticides with short intervals resulted in resistance, secondary pest outbreak and pest resurgence along with destruction of natural enemies and environmental pollution. Resistance typically develops due to the continuous use of single insecticide with similar mode of action or chemistries in the presence of common detoxification pathways.

Insecticide mixtures are the best alternative to address the above problems and to mitigate insecticide resistance. Combining insecticides with different properties such as contact or systemic action can be advantageous for containing both chewing and sucking pests simultaneously. Mixtures may enhance the overall target spectra allowing the control of a wide range of pests when they are present on the crop at the same time. Recently, different pesticide firms have formulated various insecticide mixtures which can take care of sucking pests as well as leaf feeders/ chewing pests. According to Central Insecticide Board and Registration Committee, there are insecticide mixtures registered in India till date. Mixtures of insecticides provide technical advantages for controlling pests in a broad range of settings, typically by increasing the level of target pest control and/or broadening the range of pests to be controlled (IRAC, 2018).

Studies have demonstrated that insecticide mixtures increase efficacy against insect pests such as jassids, aphids and thrips in okra (Mallapur *et al.*, 2012), thrips in chilli (Tatagar *et al.*, 2014), whiteflies and borers in brinjal (Sunda *et al.*, 2015), borers in pigeon pea (Swami *et al.*, 2017) etc. compared to separate applications of each pesticide. In Kerala, study conducted by Sreelakshmi *et al.*, (2016) revealed that indoxacarb 14.5 % + acetamiprid 7.7% SC @ 100 g a.i ha^{-1} was found effective in managing the resistant population of cowpea pod borer, *Maruca vitrata* Fabricius. Pesticide mixtures may enhance the suppression of arthropod pest population due to either synergistic interaction or potentiation between or among pesticides that are mixed together. However, studies on the bio efficacy of insecticide mixtures against pests of cowpea are so meagre in Kerala. Moreover, studies on pesticide residues in cowpea pods based on the dissipation studies would ensure the safety of the products to the end users. Keeping this view in backdrop, the research project entitled "Insecticide mixtures for the management of pest complex in cowpea" was undertaken with the following objectives,

- To evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of cowpea
- To determine the persistence and dissipation rate of insecticide mixtures in cowpea

Review of literature

2. REVIEW OF LITERATURE

Cowpea is known for its flexibility and better adaptability to warm and dry conditions because of proven drought tolerance and appropriate crop in current environmental changing scenario of global warming. Cowpea is known as vegetable meat due to high amount of protein in the grain and it contains 26.61 per cent protein, 3.99 per cent lipid, 56.24 per cent carbohydrates, 8.60 per cent moisture, 3.84 per cent ash, 1.38 per cent crude fibre, 1.51 per cent gross energy and 54.85 per cent nitrogen free extract (Owolabi *et al.,* 2012). Insect pests are considered to be the menace of cowpea as their attack can result in 90 - 100 per cent yield reduction (Oyewale and Bamaiyi, 2013). The important pests affecting cowpea include, aphids (*Aphis craccivora* Koch), pod borers (*Maruca vitrata* Fabricius and *Lampides boeticus* L), leaf eating caterpillar, *Spodoptera litura* Fabricius, pod bug, *Riptortus pedestris* Fabricius, leaf miners, whiteflies (*Bemisia tabaci* Gennadius), leafhoppers (*Empoasca* sp.), mites (*Tetranychus* spp.), thrips (*Megalurothrips sjostedti* Trybom), *Clavigralla* sp., etc. Farmers used to spray different insecticides to contain these pests and injudicious use of chemical insecticides with similar mode of action leads to the development of insecticide resistance, destruction of natural enemies, and the presence of high level of pesticide residues in the produce. One of the alternatives for tackling the problem is the use of insecticide mixtures.

As cowpea is infested with a complex of pests *viz.*, pod borers, aphids, pod bug and leaf eating caterpillars, application of insecticide mixture will play a vital role in reducing the infestation of pest complex and also minimize pesticide load in the environment.

2.1. Insecticide mixtures

Insecticide mixtures are combinations of two or more pesticides having different mode of action in a single spray solution which expose insects to each insecticide simultaneously (Tabashnik, 1989; Hoy, 1998). Mixtures of insecticides provide technical advantages for controlling pests in a broad range of settings, typically by increasing the level of target pest control and/or broadening the range of pests controlled (IRAC, 2018).

The mixtures help to delay the development of insecticide resistance (Skylakakis, 1981; Mani, 1985; Mallet, 1989), reduce the number of applications, decreases labour costs, control pests in a broad range, effective against certain life stages of insects, more efficacy and less dosage (Cabello and Canero, 1994). Insecticide mixtures may be in the form of tank-mix or pre-mix formulation that entails exposing individuals in a pest population to each of the active ingredient simultaneously. However, tank mixing is an unscientific way of mixing insecticides and may cause phytotoxicity and incompatibility of insecticides. Pre-mix formulation (Ready mix formulation) have promising option that has the potential to increase the commercial lives of pesticides through their use in combinations, lowering their selection pressure, broadening the spectrum of activity, simultaneously control two pest species, overcoming pest resistance to individual pesticide.

2.2 Action of insecticide mixtures:

Das (2014) explained the action of insecticide mixtures in four ways *viz.*, similar effect, additive effect, synergism and antagonism.

Synergism is the major action taken place in majority of mixtures. Synergism may occur when one pesticide interferes with the metabolic detoxification of another pesticide. Certain organophosphate insecticides bind to the active site associated with esterase enzymes responsible for detoxification of pyrethroid-based insecticides and so organophosphate insecticides may be considered useful synergists for pyrethroids (Kulkarni and Hodgson, 1980). This is one of the main reasons why manufacturing companies formulate organophosphate and pyrethroid-based insecticide mixtures to manage arthropod pest complexes and counteract resistance (Ahmad, 2004). When synthetic pyrethroids were applied alone, these synthetic pyrethroids were detoxified by esterase enzymes present in the insect nervous system. But, when synthetic pyrethroids were applied in combination with organophosphates, those esterase enzymes were detoxified by the organophosphates and then synthetic pyrethroids will act upon the nervous system which causes hyper excitation of nerve membrane resulting in the death of the insect.

IRAC (2018) has given guidelines for using mixtures in Insecticide Resistance Management (IRM) *viz.,* individual insecticides selected should be highly effective and be applied at the rates at which they are individually registered for use against the target species, mixtures with components having the different mode of action should be recommended, not to use component molecules having cross resistance.

2.3 Efficacy of insecticide mixtures against pests of crops

Consistent use of single insecticide facilitates development of resistance and accumulation of insecticide in environment. The use of combination products with different modes of action has provided potential and viable alternatives to insect infestation. Currently, farmers are widely using insecticide mixtures for tackling the problem of pest complex occurring simultaneously in crops. In 2013, the number of insecticide mixtures registered under CIB & RC was 17, but now the number has increased to 33 (www.cibrc.nic.in) which revealed the wider acceptance of insecticide mixtures among scientific and farming community. Several research works have been conducted on efficacy of insecticide mixtures against pests of crops and these works have been summarised in Table 1.

2.4 Efficacy of single insecticides against pests of pulses

Various conventional insecticides were used against pests of pulses and the experimental results stated that lambda cyhalothrin @ 0.005 % was reported as the best chemical against *M. vitrata* in reducing pod damage in black gram (Sonune *et al.,*2010) and aphid in mustard (Ghule and Badge, 2016).

Flubendiamide 20 WDG @ 60 g a.i ha^{-1} was evaluated along with other conventional insecticides against *S. litura* in various crops and revealed that it was effective against pod borer in pigeon pea (Priyadarshi *et al.,* 2013; Wadaskar *et al.,* 2013) and in soybean (Manu *et al.,* 2014; Patil *et al.,* 2015a).

Table 1. Efficacy of insecticide mixtures against pests of crops

Sl. No.	Insecticide mixture	Concentration	Pest	Crop	Reference
1.	Lambda cyhalothrin 4.6 % + Chlorantraniliprole 9.3 % ZC	300 mL ha^{-1}	*Helicoverpa armigera*	Cotton	Reghupathy and Satyaseelan, 2011
2.	Flubendiamide 4% + Buprofezin 20% SC	875 mL ha^{-1}	*Scirpophaga incertulas, Orseolia oryzae, Cnaphalocrocis medinalis Hydrellia sasakii, Nilaparvata lugens*	Rice	Kartikeyan *et al.*, 2012
3.	Indoxacarb 14.5 + acetamiprid 7.7 SC	300 mL ha^{-1}	*Amrasca bigittula bigittula, Aphis gossypii, Scirtothrips dorsalis, Earias vitella*	Okra	Mallapur *et al.*, 2012.
4.	Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30 g a.i ha^{-1}	*Maruca vitarta Euchrysopscn ejus*	Pigeon pea	Patel and Patel, 2013
5.	Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5 g a.i ha^{-1}	*Chrysodeixisa cuta, Diachrysia orichalcea*	Soybean	Sridhar and Sharma, 2013
6.	Acephate 0.15% + monocrotophos 0.0612%	1000 g + 850 mL ha^{-1}	*Amrasca bigittula bigittula, Aphis gossypii*	Cotton	Dhere *et al.*, 2014
7.	Chlorpyriphos 50% + cypermethrin 5 % EC	100 mL ha^{-1}	*Earias vitella*	Okra	Kamble *et al.*, 2014

	Indoxacarb 14.5 % + acetamiprid 7.7 % SC	400 mL ha^{-1}			
8.	Flubendiamid 24 % + thiacloprid 24 % SC	48+48 g a.i ha^{-1}	*Scirtothrips dorsalis*	Chilli	Tatagar *et al.*, 2014
9.	Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	60 g a.i ha^{-1}	*Helicoverpa armigera*	Cotton	Bajya *et al.*, 2015
10.	Spirotetramat 11.01% + imidacloprid 11.015 SC	75+75g a.i ha^{-1}	*Bremisia tabaci, Amrasca bigittula bigittula, Leucinodes orbonalis*	Brinjal	Sunda *et al.*, 2015
11.	Cypermethrin 10 % + indoxacarb 10 % SC	200+200 g a.i ha^{-1}	*Aphis gossypii, Scirtothrips dorsalis*	Cotton	Surpam *et al.*, 2015
12.	Indoxacarb 14.5 %+ acetamiprid 7.7% SC	100 g a.i ha^{-1}	*Maruca vitrata*	Cowpea	Sreelakshmi *et al.*, 2016
13.	Imidacloprid 17.8 SL + spinosad 45 SC Acetamiprid 20 SP + spinosad 45 SC	0.005% +0.014% 0.006%+0.014 %	*Maruca vitrata*	Cowpea	Kattula *et al.*, 2017
14.	Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	35 g a.i ha^{-1}	*Leucinodes orbonalis*	Brinjal	Sen *et al.*, 2017
15.	Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	180 mL ha^{-1}	*Maruca vitrata Aphis carccivora*	Cowpea	Roy *et al.*, 2017
16.	Chlorantraniliprole 9.6% + lambda cyhalothrin 4.6% ZC	300 mL ha^{-1}	*Helicoverpa armigera*	Pigeon pea	Swami *et al.*, 2017

17.	Acetamiprid 0.4%+cypermethrin 2% EC Acetamiprid 0.4%+chlorpyrifos 20 % EC	40+200g a.i ha^{-1} 40+2000 g a.i ha^{-1}	Bollworm complex	Cotton	Bhamare and Wadnerkar, 2018
18.	Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	0.4 mL L^{-1}	Bollworm complex	Cotton	Borude *et al.*, 2018

Chlorantraniliprole 18.5 SC @ 30 g a.i ha^{-1} was found to be an effective insecticide against different pests *viz.*, and *M.vitrata* in green gram (Kumar *et al.*, 2014a), in red gram (Kumar *et al.*,2015b), *S. litura* in ground nut (Kumar *et al.*, 2015a), in pigeon pea (Jakhar *et al.*, 2016). Thiamethoxam 25 WG @ 25 g a.i ha^{-1} was recorded as the best insecticide against various pests in different crops *viz.*, aphid in urdbean (Rajawat *et al.*, 2017), aphid and whitefly in green gram (Sujatha and Bharpoda, 2017). Thiacloprid 240 SC @ 75 g a.i ha^{-1} was proved to be safer insecticide to natural enemies and effective against pests in pulses *viz.*, *M.vitrata* and *H. armigera* in pigeon pea (Srujana and Keval, 2014), whitefly in urdbean (Rajawat *et al.*, 2017).

For the effective management of *M. vitrata* in mung bean (Bairwa and Singh, 2015), *S. litura* and *M. vitrata* in blackgram (Yadav *et al.*, 2015). indoxacarb 14.5 SC @ 65 g a.i ha^{-1} was the effective insecticide.

Patel *et al.*, (2012) tested the efficacy of different insecticides as seed dressers against leaf hoppers, whiteflies and thrips in cowpea and concluded that imidacloprid 70 WS @ 5g kg^{-1} was effective for managing thrips and thiamethoxam 70 WS @ 5g kg^{-1} was found effective in reducing leaf hopper and whitefly population. They also reported that emamectin benzoate 5 SG @ 3 g/10 L^{-1} recorded highest mortality per cent of *M. vitrata* and less pod damage. Reddy *et al.*, (2014b) studied the efficacy of new generation insecticides against aphid, *A.craccivora* in cowpea and stated that imidacloprid 17.8 SL @ 0.005 % was found potent with high mortality rate. Imidacloprid 17.8 % SL @ 0.003 % was found effective against jassid, *A.bigittula biguttula* and pod borer, *M.vitrata* followed by fipronil 5 SL and acetamiprid 20 % SP (Kumar *et al.*, 2014b).

Spinosad 45% SC @ 0.2 mL L^{-1} was recorded as the highly effective chemical with 80.70 per cent larval mortality of *M.vitrata* in cowpea (Yadav and Singh, 2014; Randhawa and Saini 2015; Kaushik *et al.*, 2016). Acetamiprid 20 SP was highly potent against aphid with mortality of 98.75 per cent against *A.craccivora* in cowpea (Gowtham *et al.*, 2016). However, Choudhary *et al.*, (2017) confirmed that thiamethoxam 25 WG @ 0.005 %, imidacloprid @ 0.005 %

and dimethoate @ 0.03 % were found superior in decreasing the aphid, *A. craccivora* in cowpea.

Laboratory study on evaluation of insecticides by two methods *viz.*, leaf dip and direct spray revealed that imidacloprid @ 0.5 mL L^{-1} was effective followed by thiamethoxam @ 0.5 mg L^{-1}. But, in case of direct spray method, spiromesifen 22.9 SC @ 0.8 mL L^{-1} was superior followed by thiamethoxam @ 0.5 mg L^{-1} (Patil *et al.*, 2017). Imidacloprid 17.8 SL @ 0.03 mL L^{-1} proved to be effective and gave maximum control of both aphids and leaf hoppers in cowpea (Soratur *et al.*, 2017).

2.5 Dissipation and persistence of insecticide mixtures in crops.

Dissipation of any insecticide depends on various factors including plant matrix, chemical formulation, agroclimatic conditions, physical phenomenon, application method and chemical degradation in which sunlight place an important role (Bhattacharya *et al.*, 2017). The objective of the study of dissipation of insecticide is to develop an efficient residue analytical method and determine safety parameters of insecticide mixtures for safety of end users. Research works conducted on dissipation/persistence of insecticide mixtures in various crops are reviewed under Table 2.

2.6 Risk assessment of insecticide mixtures

Safety parameters of flubendiamide 24% + thiacloprid 24 % 480 SC was assessed by Parmar *et al.* (2016) in red gram and revealed that insecticide mixture does not pose any harmful effect on the consumers. Bhattacharyya *et al.* (2017) studied the risk assessment of insecticide mixture emamectin benzoate 1.5% + fipronil 3.5% EC in chilli and reported that insecticide mixture was safe to the consumers when the insecticide was applied at recommended dose in chilli.

Table 2. Dissipation of insecticide mixtures in crops.

Sl. No	Crop	Insecticide mixture	Dosage (g a.i ha^{-1})	Initial concentration (mg kg^{-1})	Days taken to reach LOQ	Half-life (days)	Reference
1.	Tomato	Beta cyfluthrin +imidacloprid	20	1.22	20	2.00	Dharumarajan *et al.*, 2009
			20	1.45	20	1.90	
2.	Brinjal	Beta cyfluthrin +imidacloprid	18	-	-	-	Singh *et al.*, 2009
			42	0.03	5	1.81	
3.	Paddy	Thiamethoxam +lambda cyhalothrin	33	0.50	>15	5.19	Barik *et al.*, 2010
			33	0.26	5	-	
4.	Tomato	Flubendiamide +thiacloprid	48	0.08	3	0.33	Kooner *et al.*, 2010
			20	0.16	5	1.18	
5.	Brinjal	Beta cyfluthrin + imidacloprid	18	0.07	5	1.74	Mandal *et al.*, 2010
			42	0.24	10	2.31	
6.	Chilli	Flubendiamide +thiacloprid	60	0.24	3	1.12	Parmar *et al.*, 2012
			60	0.16	5	2.17	
7.	Okra	Beta cyfluthrin +imidacloprid	18	0.18	3	0.60	Patel *et al.*, 2012
			42	0.30	3	0.49	
8.	Red gram	Flubendiamide +thiacloprid	48	0.602	1	0.73	Parmar *et al.*, 2016
			48	0.18	10	13.68	

LOQ-Limit of quantitation

Materials and Methods

3. MATERIALS AND METHODS

The studies on the evaluation of the efficacy of new generation insecticide mixtures against the major pests of cowpea and assessment of residues in cowpea pods were conducted in the farmers field at Kalliyoor Panchayath, Thiruvananthapuram. Estimation of residues of these new generation insecticide mixtures in cowpea was conducted at Pesticide Residue Research and Analytical Laboratory, Department of Agricultural Entomology, College of Agriculture, Vellayani. The materials used and the methods adopted are detailed here under.

3.1 EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES AGAINST THE PEST COMPLEX IN COWPEA

The experiment was conducted in the farmers field located at Kalliyoor during August, 2017 – November, 2017 to study the infestation of pests of cowpea (Plate.1). The crops were raised according to the Package of practices suggested by KAU (2016).

Design – RBD

Treatment-9 ·

Replication – 3

Variety- Vellayani Jyothika

The new generation insecticide mixtures and single insecticides were sprayed at their recommended doses in cowpea as and when 10 per cent infestation of all pests was noticed. No second spray was given since there is no reoccurrence of pest complex. The details of the treatments are presented in Table.3

3.1.1 Sucking Pests Infesting Cowpea

3.1.1.1 Pod Bug, R. pedestris

The pods, flowers, leaves and stem were closely inspected for pod bug nymphs and adults and the mean number present in each plant was observed (5 plants

Plate 1. View of experimental plot

Table 3. Details of insecticide mixtures used for the bio efficacy studies against pests of cowpea under field conditions

Sl. No	Details of insecticides				
	Chemical name	Trade name	Chemical group	Mode of action as per IRAC, 2018	Dosage (g a.i. ha^{-1})
1.	Chlorantraniliprole 8.8 % + Thiamethoxam 17.5 % SC	Voliumflexi	Diamide + Neonicotinoid	Ryanodine receptor modulators + Nicotinic acetylcholine receptor competitive modulators	150
2.	Lambda cyhalothrin 4.6 % + Chlorantraniliprole 9.3 % ZC	Ampligo	Synthetic pyrethroid + Diamide	Sodium channel modulators + Ryanodine receptor modulators	30
3.	Thiamethoxam 12.6 % + Lamda cyhalothrin 9.5 % ZC	Alika	Neonicotinoid + Synthetic pyrethroid	Nicotinic acetylcholine receptor competitive modulators + Sodium channel modulators	27.50
4.	Beta cyfluthrin 8.49 %+ Imidacloprid 19.81 % SC	Solomon	Synthetic pyrethroid + Neonicotinoid	Sodium channel modulators + Nicotinic acetylcholine receptor competitive modulators	15.75+36.70
5.	Flubendiamide19.92%	Belt expert	Diamide+ Neonicotinoid	Ryanodine receptor modulators +	48+48

	w/w +Thiacloprid 19.92% w/w SC			Nicotinic acetylcholine receptor competitive modulators	
6.	Hand mixing (Tank mixing) of Chlorantraniliprole 18.5 % SC +Thiamethoxam 25 % WG (1:1)	Coragen+Arrow	Diamide + Neonicotinoid	Ryanodine receptor modulators + Nicotinic acetylcholine receptor competitive modulators	--
7.	Chlorantraniliprole 18.5 % SC	Coragen	Diamides	Ryanodine receptor modulators	30
8.	Thiamethoxam 25 % WG	Arrow	Neonicotinoids	Nicotinic acetylcholine receptor competitive modulators	30

replication^{-1}) before treatment and 1, 3, 5, 7, 10 and 15 days after treatment (Thamilarasi, 2016).

3.1.1.2 Cowpea Aphid, A. craccivora

Counting Method

The number of aphids from each plant was assessed from 15 cm of the terminal twig with unopened leaves and two opened leaves (5 plants/replication) before treatment and 1, 3, 5, 7, 10 and 15 days after treatment (Thamilarasi, 2016).

Scoring Method

Aphid population was assessed by scoring method as described by Banks, (1954) and Rani (2001). In each plant, the terminal twig up to 15 cm length with the unopened leaves and two opened leaves were observed for aphid 1, 3, 5, 7, 10 and 15 days after treatment.

Based on the severity of infestation, twigs were grouped into different classes as shown below

0	Zero (0)	No aphids.
1	Very light (V)	From one aphid to a small colony, confined to the very youngest leaves of the crown
2	Light (L)	Several aphid colonies are present on the stem and not confined to the uppermost leaves
3	Medium (M)	Aphids present in large numbers, not in recognizable colonies but diffuse and infesting a large proportion of leaves and stem.

4	Heavy (H)	Aphids present in large numbers, very dense, infesting all the leaves and stem, the latter usually being black with aphids

3.1.2 Leaf Eating Caterpillars and Borers Infesting Cowpea

3.1.2.1 Leaf Eating Caterpillar, S. litura

Population of Larvae in Plants

Five plants per replication were selected and number of larvae present in each plant was counted before treatment and 1, 3, 5, 7, 10 and 15 days after treatment.

Leaf Damage

Total number of leaves and number of infested leaves were counted from five plants/replication before treatment and 1, 3, 5, 7, 10 and 15 days after treatment. Percent leaf damage was calculated by using the following equation (Thamilarasi, 2016).

$$\text{Per cent of damage} = \frac{\text{Number of leaves infested}}{\text{Total number of leaves plant}^{-1}} \times 100$$

3.1.2.2 Spotted Pod Borer, M. vitrata

Population of Larvae in Flowers

Five plants per replication were selected and number of larvae present in flowers of each plant were counted before treatment and 1, 3, 5, 7, 10 and 15 days after treatment.

Population of Larvae in pods

Five plants per replication were selected and number of larvae present in pods of each cowpea plant was counted before treatment and 1, 3, 5, 7, 10 and 15 days after treatment. Percent infestation was calculated as follows:

$$\text{Per cent infestation} = \frac{\text{Number of pods damaged}}{\text{Total number of pods plant}^{-1}} \times 100$$

3.2 PERSISTENCE AND DEGRADATION OF RESIDUES OF INSECTICIDES IN COWPEA

The studies on the persistence and degradation of the insecticide mixtures and single insecticides in cowpea pods were done in the Pesticide Residue Research and Analytical Laboratory, Department of Agricultural Entomology, College of Agriculture, Vellayani.

3.2.1 Method Validation

3.2.1.1 Preparation of Standard Insecticides

Certified reference materials of pesticides *viz.,* imidacloprid, thiamethoxam, thiacloprid, chlorantraniliprole, flubendiamide, lambda cyhalothrin and beta-cyfluthrin with 99.9, 99.3, 99.9, 97.84, 98.6, 98.7 and 99.3 per cent purity respectively were procured from M/s Sigma Aldrich. Stock solutions (1000 µg mL^{-1}) of the insecticides were prepared by dissolving a weighed quantity of the analytical grade material in HPLC grade methanol. The stock solutions were serially diluted to prepare an intermediate stock of 100 µg mL^{-1}. The intermediate stock solutions were further diluted with HPLC grade methanol to prepare working standard mixtures (10 µg mL^{-1}) of the insecticides to be analysed by positive electro spray ionozation (imidacloprid, thiamethoxam, thiacloprid, chlorantraniliprole, lambda cyhalothrin and beta cyfluthrin) and by negative electro spray ionization (flubendiamide). The working standard mixtures were serially diluted to obtain 1.00, 0.50, 0.25, 0.10, 0.075, 0.05, 0.025, 0.01 and 0.005 µg mL^{-1} of analytical grade insecticides.

3.2.1.2 Fortification and Recovery Experiment

Cowpea (500 g) pods harvested from control plots were chopped and ground to a fine paste. Five replicates of 25 g representative samples of the fruits were taken in 50 mL centrifuge tubes and spiked with 0.05, 0.25 and 0.50 mL of 10 µg mL^{-1} working standard mixtures of the insecticides. The extraction and clean-up were done following the QuEChERS method (Anastassiades *et al.*, 2003) and quantified using UPLC-MS/MS under optimized conditions. The method which gave recovery of insecticides in the range of 70-120 per cent with a relative standard deviation less than 20 was considered to be the ideal method, the lowest spiking level of which was considered as LOQ.

3.2.2 Estimation of Persistence and Degradation of Residues

3.2.2.1 Sampling

Cowpea pods (2 kg each) sprayed with insecticides were collected from each plot at two hours, one, three, five, seven, ten and fifteen days after spraying and brought to the laboratory and processed immediately for residue analysis.

3.2.2.2 Residue Extraction

The multiresidue estimation procedure recommended for vegetables as per QuEChERS method with suitable modification was adopted for extraction and cleanup of residues in cowpea. The harvested fruits were macerated as such in a high-speed blender (BLIXER 6 vv Robot Coupe) for three times and a representative sample of 25g of ground cowpea was taken in a 250 mL centrifuge tube. HPLC grade acetonitrile (50 mL) was added to the samples and homogenised with a high-speed tissue homogenizer (Heidolph Silent Crusher-M) at 14000 rpm for three minutes. This was followed by the addition of 10 g activated sodium chloride (NaCl) and vortexing for two minutes for separation of the acetonitrile layer. The samples were then centrifuged for five minutes at 2500 rpm and 12 mL of the clear upper layer was transferred into 50 mL centrifuge tubes containing 6 g pre-activated sodium sulphate and vortexed for two minutes. The acetonitrile extracts were subjected to clean up by dispersive solid phase extraction (DSPE). For this, 8 mL of the upper layer was transferred into centrifuge tubes (15 mL) containing 0.20 g PSA and 1.20 g magnesium sulphate. The mixtures were then shaken in vortex for two minutes and again centrifuged for five minutes at 2500 rpm. The supernatant liquids (5 mL each) were transferred to turbovap tube and evaporated to dryness under a gentle steam of nitrogen using a Turbovap set at 40 °C and 7.5 psi nitrogen flow. The residues were reconstituted in 2 mL of methanol for imidacloprid, thiamethoxam, thiacloprid, chlorantraniliprole, flubendiamide (LC-compounds) and in 2 mL of n-hexane for lambda cyhalothrin and beta-cyfluthrin (GC-compounds), filtered through a 0.2-micron filter (PVDF) prior to estimation in LC-MS/MS and GC-MS respectively.

3.2.3 Instrumentation

3.2.3.1 LC-MS/MS

The chromatographic separation was achieved using Waters Acquity UPLC system equipped with a reversed phase Atlantis d C-18 (100 ×2.1 mm, 5 μm particle size) column. The moisture phase consists of gradient system involving the following two eluent components: (A) 10 % methanol in water + 0.1 % formic acid + 5 mM ammonium acetate; (B) 10 % water in methanol + 0.1 % formic acid + 5 mM ammonium acetate was used as mobile phase for the separation of residues. The gradient elution was done as follows: 0 min isocratic 20 % B, increased to 90 % in 4 min, then raised to 95 % with 5 min and increased to 100 % B in 9 min, decreased to the initial composition of 20 % B in 10 min and hold to 12 min for re-equilibration. The flow rate remains constant at 0.8 mL min^{-1} and injection volume was 10 μL. The column temperature was maintained at 40 °C. The effluent from the LC system was introduced into triple quadrupole API 3200 MS/MS system equipped with an electrospray ionization interface (ESI), operating in the positive ion mode. The source parameters were temperature 600 °C, ion gas (GSI) 50 psi, ion gas (GS2) 60 psi, ion spray voltage 5,500 V, curtain gas 13 psi.

3.2.3.2 GC-ECD

Estimation of residues of lambda cyhalothrin and beta-cyfluthrin were performed using Gas Chromatograph (Shimadzu 2010 AT) equipped with Electron Capture Detector (ECD). Operating conditions of GC are, Column, DB-

5 capillary (0.25μm film thickness X 0.25 mm X 30 m), carrier gas- Nitrogen, column flow- 0.79 mL/min., injector temperature -250 ° C and detector temperature used was 300 ° C. The residues of lambda cyhalothrin and beta-cyfluthrin were confirmed in GC-MS (Shimadzu GC- MS QP 2010 Plus) with retention time of 50.25 min and 61.10 min respectively. Helium was used as carrier gas in GC-MS operated with Electron Impact Ionization (70eV). In GC-MS, injector temperature, column, column flow was similar to that of GC.

The MS/MS conditions were optimized using direct infusion in to ESI source in positive mode to provide highest signal/noise ratio for the quantification ion of each analyte. Two MS/MS transitions were made in case of chemical interferences observed in the quantitation ion chromatogram and for qualitative purpose. The ion source temperature was 550 ° C with ion spray voltage of 5500 V. Chromatographic elution zones were divided into appropriate number of time segments. In each segment corresponding MS/MS transitions were monitored using multiple reactions – monitoring (MRM) mode.

3.2.4 Residue Quantification

Based on the peak area of the chromatogram obtained for various insecticides, the quantity of residue was determined as detailed below.

Pesticide residue (mg kg^{-1}) = Concentration obtained from chromatogram by using calibration curve × Dilution factor

$$\text{Dilution factor} = \frac{\text{Volume of the solvent added} \times \text{Final volume of extract}}{\text{Weight of sample} \times \text{Volume of extract taken for concentration}}$$

The persistence of insecticides is generally expressed in terms of half-life (DT50) *i.e.*, time for disappearance of pesticide to 50 per cent of its initial concentration.

3.3 RISK ASSESSMENT OF INSECTICIDE MIXTURES IN COWPEA

Calculation of theoretical maximum residue concentration involves the assumptions that all the pesticides legally allowed on a particular commodity will always be applied, that all residues are present at tolerance levels and that there is no post-harvest effect on residue levels. Therefore, to evaluate the risk assessment of insecticides, the TMRC was calculated by multiplying the maximum residue levels with average per capita daily consumption in the Indian context. Safety parameters were evaluated by comparing the Theoretical Maximum Residue Concentration (TMRC) with Maximum Permissible Intake (MPI) (Bhattacharya *et al.*, 2017). If TMRC value is less than MPI, the particular insecticide will not cause any health impact.

TMRC= Maximum residue level obtained at recommended dose on 0^{th} day of application X total intake of food per day

MPI= Acceptable daily intake X average body weight (55) Kg of an adult of human being

Daily consumption value of cowpea was considered as 90 g d^{-1} (Huan *et al.*, 2016).

The prescribed ADI values of insecticides were given by FAO/WHO.

3.4 STATISTICAL ANALYSIS

Data on each experiment were analyzed, applying appropriate methods of analysis (Panse and Sukhatme, 1967). Suitable transformations were applied and significant results were equated on the basis of critical differences.

Results

4. RESULTS

4.1 EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES AGAINST THE PEST COMPLEX IN COWPEA

4.1.1 Sucking Pests Infesting Cowpea

4.1.1.1 Pod bug

The effectiveness of insecticide mixtures against population of pod bug in cowpea is shown in Table 4 and Plate 2.

Significantly lower population was recorded in thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (0.33) and it was on par with hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (0.67), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (0.67), beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (1.00), thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (1.00) flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (1.00) after first day of spraying. The highest population was found in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (1.67), lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (1.33) which were statistically on par.

More or less similar result was obtained on third day after spraying and no bug was seen in plants treated with mixtures prepared by hand mixed of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (0.00) and it was significantly different from thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (0.33). Whereas, population of bug in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 30 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} treated plants were one. The population in plants treated with thiamethoxam 12.6

Table 4. Effect of insecticide mixtures on the population of pod bug, *Riptortus pedestris*

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	*Number of bugs per plant (DAS)					
			1	3	5	7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	1.67 (1.46)	1.00 (1.22)	0.00 (0.70)	0.00 (0.70)	0.67 (1.05)	0.67 (1.05)
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	1.33 (1.34)	1.00 (1.22)	1.00 (1.22)	1.33 (1.34)	1.67 (1.46)	2.33 (1.68)
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	1.00 (1.22)	0.67 (1.05)	0.33 (0.88)	0.00 (0.70)	0.00 (0.70)	1.33 (1.34)
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	1.00 (1.22)	1.00 (1.22)	0.00 (0.70)	0.00 (0.70)	1.33 (1.34)	2.00 (1.56)
Flubendiamide19.92% +thiacloprid 19.92% SC	48+48	0.50	1.00 (1.22)	1.00 (1.22)	1.33 (1.34)	2.00 (1.55)	2.00 (1.55)	2.33 (1.68)
Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)	1:1	0.30	0.67 (1.05)	0.00 (0.70)	0.00 (0.70)	1.00 (1.22)	1.00 (1.18)	1.67 (1.46)
Chlorantraniliprole18.5%SC (check)	30	0.30	0.67 (1.05)	0.67 (1.05)	1.00 (1.22)	1.67 (1.44)	2.00 (1.56)	2.67 (1.77)
Thiamethoxam 25 % WG (check)	30	0.40	0.33 (0.89)	0.33 (0.88)	0.00 (0.70)	1.00 (1.22)	1.33 (1.29)	2.00 (1.56)
Control			4.67 (2.28)	5.00 (2.34)	5.67 (2.48)	5.67 (2.48)	6.33 (2.60)	6.00 (2.54)
CD (0.05)			0.352	0.276	0.336	0.449	0.494	0.405

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAS- Days after spraying, *Mean of fifteen plants

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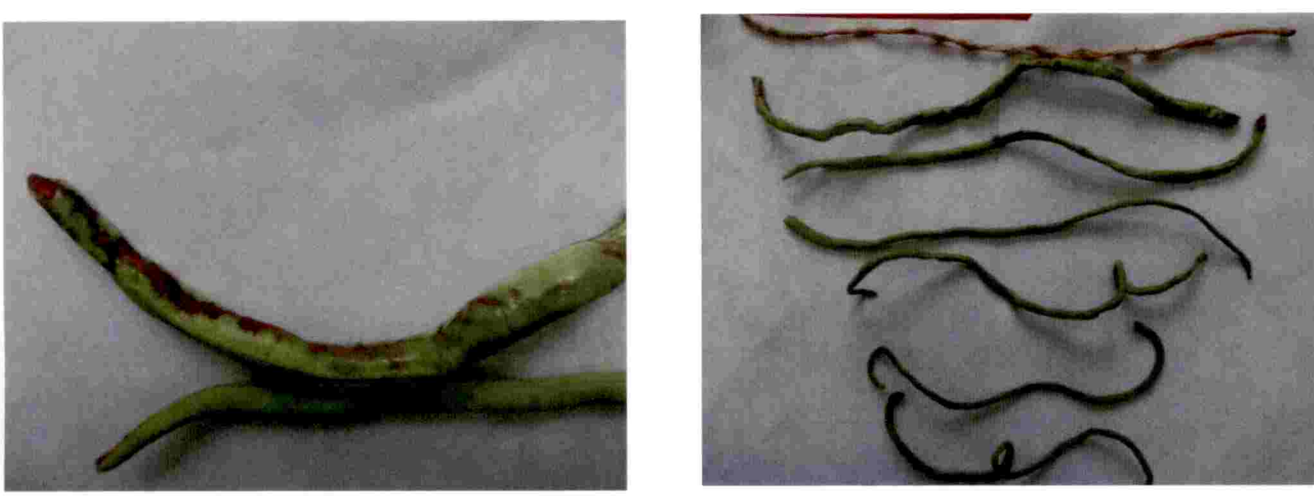
a. *Ripotortus pedestris*



b. Damage symptom on pods

Plate 2. Pod bug and its infestation in cowpea pods

% + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (0.67) and chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (0.67) were significantly on par.

No pod bug was found in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (0.00), beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (0.00), hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (0.00), thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (0.00) which were on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (0.33) after five days of spraying. Significantly the highest population was seen in uncontrolled treatment (5.67) followed by flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (1.33).

After seven days of spraying, more or less similar trend was observed. No insects were recorded in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC 150 g a.i ha^{-1} (0.00), thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (0.00) beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC@ 15.75+36.7 g a.i ha^{-1}treated plants. Whereas, more number of insects were recorded in flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.00) followed by chlorantraniliprole18.5 %SC @ 30 g a.i ha^{-1} (1.67), lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (1.33), hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (1.00) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (1.00) and they were significantly different.

Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (0.00) recorded no population of pod bugs followed by chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (0.67), hand mixed product of chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG @ (1:1) (1.00) after tenth day of spraying. Whereas, higher population was found in flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.00), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (2.00) followed by lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (1.67), beta cyfluthrin 8.49 %+

imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (1.33), thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (1.33) and they were on par with each other.

More or less similar result was obtained on fifteen days after treatment and lower population was observed in the treatments plants of chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (0.67) and thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 30 g a.i ha^{-1} (1.33) which were significantly on par. While, higher population was observed in chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (2.67) followed by flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.33), lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (2.33), beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC@ 15.75+36.7 g a.i ha^{-1} (2.00), thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (2.00) and they were significantly on par. The untreated control plot infested with (6.00) number of bugs.

4.1.1.2 Cowpea Aphid, A. craccivora

4.1.1.2.1 Population of aphids (Count method)

The results on the efficacy of new generation insecticide mixtures against the population of cowpea aphids, *A. craccivora* are given in Table 5 and Plate 3.

No aphid was observed in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} after first day of spraying. However significant population of aphid was present in control plot (121.67) which was on par with chlorantraniliprole 18.5 % SC (30.00).

Table 5. Effect of insecticide mixtures on the population of cowpea aphid, *Aphis craccivora* (Count method)

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	*Number of aphids per 15 cm shoot (DAS)					
			1	3	5	7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	0 (0.70)	0 (0.70)	0 (0.70)	13.67 (3.77)	30.00 (5.51)	50.00 (7.06)
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	21.00 (0.70)
Flubendiamide19.92 % +thiacloprid 19.92 % SC	48+48	0.50	0 (0.70)	0 (0.70)	0 (0.70)	26.67 (5.21)	36.67 (6.09)	51.67 (7.23)
Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)	1:1	0.30	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)
Chlorantraniliprole18.5 % SC (check)	30	0.30	30.00 (5.51)	24.00 (4.92)	33.33 (5.80)	41.67 (6.49)	63.33 (7.98)	121.00 (10.49)
Thiamethoxam 25 % WG (check)	30	0.40	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)
Control			121.67 (11.04)	169.33 (13.01)	178.33 (13.34)	178.33 (13.34)	196.67 (14.01)	211.67 (14.54)
CD (0.05)			0.399	0.613	0.602	0.682	0.689	1.041

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAS- Days after spraying, *Mean of fifteen plants

a. Leaf infestation

b. Flower infestation

Plate 3. Infestation of cowpea aphid, *A.craccivora* in cowpea

More or less similar result was found on third day after spraying. No population of aphid was observed in the plants treated with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1}. While, plants sprayed with chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} alone showed presence of aphid (24.00) and it was significantly different from control (169.33).

Similar trend was observed five days after spraying. Number of aphids present in chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} was 33.33 which was significantly different from control plot (178.33).However, aphid population appeared in flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} treated plants (26.67) which was significantly different from chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (41.67) treated plants and control (178.33) after seven days of spraying. No aphids were seen in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} treated plants.

After ten days of spraying, the highest population was noticed in chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (63.33) followed by flubendiamide 19.92 % w/w + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (36.67) and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (30.00). Whereas, no population was detected in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 %

ZC @ 27.5 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG @ (1:1) and thiamethoxam 25 % WG @30 g a.i ha^{-1}

On fifteen days after spraying, the highest population was found in chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (121.00) which is significantly different from other treatments. Flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} was recorded a population of 51.67 which was on par with lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (50.00). While, the lowest population was recorded in beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (21.00)

4.1.1.1.2 Population of aphids (Scoring method)

The results of the study on effect of insecticide mixtures against *A. craccivora* under field conditions in terms of scores are presented in Table. 6

Zero score was recorded in all treatments except in chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (1.22) first day after spraying with 2.77 score in control. More or less similar trend was observed three and five days after spraying. The score observed in chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} treated plots were 0.88 and 1.66 after 3 and 5 days of spraying respectively.

After seven days of spraying, the highest score was reported in chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (1.77) followed by flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.11) lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (1.33). Damage scores were less in plants treated with insecticides when compared to untreated control (2.55).

More or less same observations were recorded at ten days after spraying with higher score in chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} and untreated control (2.88 each) followed by flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.00) and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (1.44).

Table 6. Effect of insecticide mixtures on the population of cowpea aphid, *Aphis craccivora* (Score card method)

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	Scores* (DAS)					
			1	3	5	7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	0	0	0	0	0	0
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	0	0	0	1.33	1.44	2.44
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	0	0	0	0	0	0
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	0	0	0	0	0	1.22
Flubendiamide19.92% +thiacloprid 19.92% SC	48+48	0.50	0	0	0	2.11	2.00	2.22
Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)	1:1	0.30	0	0	0	0	0	0
Chlorantraniliprole18.5%SC (check)	30	0.30	1.22	0.88	1.66	1.77	2.88	2.55
Thiamethoxam 25 % WG (check)	30	0.40	0	0	0	0	0	0
Control			2.77	2.77	2.66	2.55	2.88	2.88

* Mean of fifteen plants

After fifteen days of spraying, the damage score in different treatments were chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (2.55), lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (2.44), flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.22), beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (1.22). whereas, higher score was noticed in control plot with 2.88 score.

4.1.2 Leaf Feeders and Borers Infesting Cowpea

4.1.2.1 Spodoptera litura

The results on evaluation of insecticide mixtures on population of *S.litura* in cowpea is presented in Table 7 and Plate 4.

After first day of spraying, no population of *S.litura* was found in flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} treated plot followed by chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (2.33) and it was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, thiamethoxam 25 % WG @ 30 g a.i ha^{-1} with 2.67, 2.67, 3.00, 3.00 larvae respectively. The treatments lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} and hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) recorded equal population with 3.67 larvae and these were on par with each other. However, the highest larval count was recorded in control plot with 5.67 larvae which is significantly different from all other treatments.

No *S.litura* larvae found in plants treated with flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} after three days of spraying. More or less similar number of *S.litura* larvae was observed in plants treated with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1)

Table 7. Effect of insecticide mixtures on the population of leaf eating caterpillar, *Spodoptera litura*

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	*Larval population (DAS)					
			1	3	5	7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	2.67 (1.77)	1.67 (1.46)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	3.67 (2.04)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	2.67 (1.77)	1.67 (1.46)	0.67 (1.05)	0.67 (1.05)	0.00 (0.70)	0.67 (1.05)
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	3.00 (1.86)	2.33 (1.65)	2.00 (1.55)	1.00 (1.18)	1.67 (1.46)	2.33 (1.68)
Flubendiamide19.92% +thiacloprid 19.92 % SC	48+48	0.50	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.67 (1.05)	1.33 (1.34)
Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)	1:1	0.30	3.67 (2.04)	1.67 (1.46)	1.00 (1.18)	0.00 (0.70)	0.00 (0.70)	1.33 (1.34)
Chlorantraniliprole18.5 % SC (check)	30	0.30	2.33 (1.68)	1.67 (1.46)	0.67 (1.05)	0.00 (0.70)	0.67 (1.05)	1.66 (1.38)
Thiamethoxam 25 % WG (check)	30	0.40	3.00 (1.86)	2.33 (1.68)	2.33 (1.68)	2.00 (1.58)	2.67 (1.77)	3.33 (1.95)
Control			5.67 (2.43)	6.33 (2.60)	7.00 (2.73)	7.67 (2.85)	8.00 (2.91)	8.33 (2.97)
CD (0.05)			0.338	0.385	0.421	0.327	0.315	0.467

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAS- Days after spraying, *Mean of fifteen plants

a. Larva of *S.litura*

b. Leaf damage by *S.litura*

Plate 4. Infestation of leaf eating caterpillar, *Spodoptera litura* in cowpea

@ 150 g a.i ha^{-1}, chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (1.67 each) which was par on with beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (2.33 each). All the treatments were found to be superior when compared to control plot which showed larval count of 6.33 larvae.

More or less similar pattern was observed five days after spraying. lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} treated plants. Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} showed 0.67 larval population and these were statistically on par with the above treatments. Population of *S.litura* in hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (1.00), beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (2.00) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (2.33) were on par with each other. However, all the tested insecticide mixtures including chlorantraniliprole, thiamethoxam were found to be significantly different from control plot (7.00).

After seven after spraying, no *S.litura* was observed in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} treated plants. Whereas, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} and beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} recorded 0.67,1.00 larvae respectively they were on par each other. All the treatments were found superior to control plot which recorded a population of 7.67 larvae.

More or less same trend was recorded after ten days of spraying. No *S.litura* was found in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, hand mixing of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) treated plants and found to be significant and superior to other treatments followed by flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (0.67), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (0.67), beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (1.67) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (2.67) which were significantly different. The highest population of *S. litura* was found in untreated control (8.00).

Even after fifteen days of spraying, no *S. litura* larvae was reported from chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}. Larval population thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (0.67), flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (1.33) and hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (1.33) were significantly on par. Whereas, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC@ 15.75+36.7 g a.i ha^{-1} and chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} showed 2.33 and 3.33 larvae respectively and these were statistically on par. All the treatments were found to be superior in reducing larval population over the control (8.33).

4.1.2.2 Leaf Damage

The results on evaluation of insecticide mixtures on leaf damage caused by *S.litura* in cowpea is presented in Table 8.

The lowest leaf damage was found in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (21.04 %) and it was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (24.00 %) which was on par with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (27.63 %) after seven days of spraying. The hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) recorded 33.47

Table 8. Effect of insecticide mixtures on leaf damage by *Spodoptera litura*

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	Leaf damage % (DAS)*		
			7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	27.63 (31.70)	30.20 (33.31)	34.56 (36.00)
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	21.04 (27.29)	25.03 (30.04)	27.87 (31.86)
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	24.00 (29.29)	26.46 (30.93)	28.67 (34.34)
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	35.53 (36.58)	33.73 (35.47)	38.33 (38.24)
Flubendiamide19.92% +thiacloprid 19.92 % SC	48+48	0.50	40.47 (39.49)	44.76 (41.98)	45.74 (42.54)
Hand mixing of Chlorantraniliprole 18.5 % SC +hiamethoxam 25 % WG (1:1)	1:1	0.30	33.47 (35.31)	36.23 (36.98)	37.30 (37.63)
Chlorantraniliprole18.5% SC (check)	30	0.30	37.33 (37.65)	43.30 (41.12)	41.76 (40.26)
Thiamethoxam 25 % WG (check)	30	0.40	44.45 (41.80)	47.24 (43.41)	49.21 (44.55)
Control			83.34 (66.02)	87.61 (69.45)	85.66 (67.77)
CD (0.05)			3.262	4.443	3.739

Figures in parentheses are arc sign transformed values, DAS- Days after spraying. * Mean of fifteen plants per cent damage which was significantly on par with beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (35.53 %), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (37.33 %). While the treatments flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (40.47 %) and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (44.45 %) showed higher damage over other treatments and statistically on par. The per cent leaf damage was found in untreated control (83.34 %) after seven days of spraying.

More or less similar trend of damage was observed after ten days of spraying. The treatments lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (25.03 %), thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (26.46 %) recorded lower per cent of damage and they were on par in their effect with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (30.20 %). Similarly, the treatment beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} recorded with 33.73 per cent leaf damage which was on par with hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1) @ 150 g a.i ha^{-1} (36.23 %). Whereas, relatively higher leaf damage was found in thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (47.24 %) followed by flubendiamide19.92 % + thiacloprid 19.92 % @ 48+48 g a.i ha^{-1} (44.76 %), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (43.30 %) and the above treatments were significantly on par. All the treatments shown their efficacy in reducing leaf damage by *S.litura* when compared with untreated control (87.61 %).

At fifteen days of spraying, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} recorded the lowest per cent damage with 27.87 per cent and it was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (28.67 %) which was on par with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (34.56 %).Similarly, the damage found in plants treated with prepared hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1) @ 150 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, chlorantraniliprole18.5 % SC

@ 30 g a.i ha^{-1} were 37.30, 38.33, 41.76 per cent respectively and the above treatments were significantly on par with each other. Whereas, moderately higher damage per cent age was found in thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (49.21 %) which was on par with flubendiamide 19.92 % SC + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (45.74 %). All the insecticide mixtures including checks chlorantraniliprole and thiamethoxam were showed their efficacy in reducing leaf damage over the control plot (85.66 %).

4.1.2.3 Cowpea pod borer, M.vitrata

The results on evaluation of insecticide mixtures on population of *M.vitrata* in cowpea is presented in Table 9 and Plate 5.

The lowest number of larvae was found in plants treated with hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1) @150 g a.i ha^{-1} (1.00) after first day of spraying and it was significantly different from other treatments. Larval population was found in plants treated with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} were 2.00 each. Higher population of larvae was recorded in thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (3.67), thiamethoxam 25 % WG @30 g a.i ha^{-1} (3.67) followed by flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (3.33) and they were significantly different as compared to control (5.67).

Infestation was reduced after three days of treatment and lower number of larvae was observed in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (0.33) and it was statistically on par with plants treated with hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (0.67), chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (1.00), chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (1.00). Similarly, number of larvae found in thiamethoxam 25 % WG @ 30 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, beta

Table 9. Effect of insecticide mixtures on the population of spotted pod borer, *Maruca vitrata*

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	* Number of larvae per plant (DAS)					
			1	3	5	7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	2.00 (1.41)	1.00 (1.22)	0 (0.70)	1.33 (1.34)	1.67 (1.46)	2.00 (1.58)
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	2.00 (1.41)	0.33 (0.87)	0 (0.70)	0 (0.70)	0 (0.70)	0 (0.70)
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	3.67 (1.91)	2.67 (1.77)	2.67 (1.77)	2.00 (1.55)	1.00 (1.22)	1.33 (1.34)
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	2.67 1.62)	2.00 (1.58)	2.00 (1.58)	1.33 (1.34)	0.67 (0.99)	1.00 (1.17)
Flubendiamide19.92% +thiacloprid 19.92 % SC	48+48	0.50	3.33 (1.82)	1.33 (1.34)	0.67 (1.05)	1.67 (1.46)	2.00 (1.58)	2.33 (1.67)
Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)	1:1	0.30	1.00 (1.00)	0.67 (1.05)	1.33 (1.34)	1.00 (1.22)	1.67 (1.46)	1.67 (1.46)
Chlorantraniliprole18.5% SC (check)	30	0.30	2.00 (1.41)	1.00 (1.17)	0.67 (1.05)	1.33 (1.34)	2.00 (1.57)	2.67 (1.77)
Thiamethoxam 25 % WG (check)	30	0.40	3.67 (1.91)	2.67 (1.77)	3.33 (1.95)	3.67 (2.03)	3.67 (2.03)	3.67 (2.03)
Control			5.67 (2.37)	6.33 (2.61)	6.67 (2.67)	6.33 (2.60)	6.33 (2.60)	6.67 (2.67)
CD (0.05)			0.221	0.388	0.338	0.323	0.320	0.359

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAS- Days after spraying, *Mean of fifteen plants

a. Flower infestation

b. Pod infestation

c. Seed infestation

Plate 5. Infestation of pod borer, *Maruca vitrata* in cowpea

cyfluthrin 8.49 %+ imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} were 2.67, 2.67, 2.00 respectively and they were significantly different when compared to untreated control (6.33).

After five days of spraying, no larvae was found in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} followed by flubendiamide19.92 % +thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (0.67), chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (0.67), hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (1.33). While, the treatment thiamethoxam 25 % WG @ 30 g a.i ha^{-1} shown a population of 3.33 and it was statistically on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (2.67) followed by beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @15.75+36.7 g a.i ha^{-1} (2.00).

No larva was recorded from plants treated with lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (0.00) treated plot after seven days of spraying and it was significantly different from the other treatments. The treatment, hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1) recorded a population of 1.00 and it was on par with chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (1.33), chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (1.33), beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (1.33), flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (1.67). Whereas, number of larvae in thiamethoxam 25 % WG @ 30 g a.i ha^{-1} and thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} recorded 3.67, 2.00 respectively and they were significantly different when compared with untreated control (6.33).

After ten days of spraying lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} showed no population of *M.vitrata* and it was on par with beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (0.67) which was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (1.00). The plants treated with chlorantraniliprole 8.8 % +

thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, hand mixed product of chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG @ (1:1) showed 1.67 larvae and they were on par with flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.00), chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (2.00). Thiamethoxam 25 % WG @ 30 g a.i ha^{-1} showed 3.67 larvae which is significantly different from all other treatments including with untreated control (6.33).

No larva was observed in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} after 15 days of spraying and it was significantly different from other treatments. beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} showed 1.00 larva and it was on par with treatment hand mixed product of chlorantraniliprole 18.5 % SC +Thiamethoxam 25 % WG (1:1) @ 150 g a.i ha^{-1} (1.67), thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (1.33). More or less similar number of larvae were found in thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (3.67), chlorantraniliprole18.5 %SC @ 30 g a.i ha^{-1} (2.67), flubendiamide19.92 % +thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (2.33), chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (2.00) and they were statistically on par with each other. The highest population was found in untreated control (6.67).

4.1.2.4 Pod damage

The results on evaluation of insecticide mixtures on pod damage caused by *M.vitrata* in cowpea is presented in Table 10.

Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} treated plot recorded the lowest damage (9.76%) on seventh day after spraying which was significantly different from all other treatments followed by chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (19.92%), chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} (23.16%), hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @(1:1) (24.09 %), thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (26.92 %)

Table 10. Effect of insecticide mixtures on the pod damage by spotted pod borer, *Maruca vitrata*

Insecticide mixtures	Dosage (g a.i ha^{-1})	Field dose (mL or g L^{-1})	Pod damage % (DAS)		
			7	10	15
Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC	150	0.30	19.92 (26.25)	14.39 (22.21)	29.92 (33.08)
Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC	30	0.50	9.76 (14.99)	14.53 (22.24)	15.82 (23.31)
Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC	27.5	0.30	26.92 (31.24)	23.06 (28.44)	36.67 (37.22)
Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC	15.75+36.7	0.40	45.15 (42.20)	34.44 (35.90)	28.18 (32.05)
Flubendiamide19.92% thiacloprid 19.92% SC	48+48	0.50	42.67 (40.76)	37.57 (37.70)	48.48 (44.12)
Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)	1:1	0.30	24.09 (29.34)	18.09 (24.90)	27.60 (31.62)
Chlorantraniliprole18.5%SC (check)	30	0.30	23.16 (28.72)	18.78 (25.68)	28.61 (32.22)
Thiamethoxam 25 % WG (check)	30	0.40	49.03 (44.44)	61.61 (51.87)	64.64 (53.61)
Control			70.83 (58.06)	76.92 (62.03)	81.14 (65.29)
CD (0.05)			9.367	9.956	9.085

Figures in parentheses are arc sign transformed values, DAS- Days after spraying.

and these were on par with each other. Whereas, the treatments flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, thiamethoxam 25 % WG @ 30 g a.i ha^{-1} recorded 42.67, 45.15, 49.03 per cent respectively and were on par. The unsprayed control plot showed the highest per cent damage (70.83 %).

After ten days of spraying the infestation in pods was significantly lower in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (14.39 %) followed by lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (14.53 %), hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (18.09 %), chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (18.78 %), thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (23.06 %) and they were significantly on par. Whereas, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}, flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} recorded 34.44 and 37.57 per cent respectively and have significantly no difference. While, thiamethoxam 25 % WG @ 30 g a.i ha^{-1} recorded 61.61 per cent damage and significantly different from all other treatments. All the treatments were effective in reducing pod damage when compared with untreated control (76.92).

The lowest pod damage was recorded in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (15.82 %) and it was on par with hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG @ (1:1) (27.60), beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} (28.18), chlorantraniliprole18.5 % SC @ 30 g a.i ha^{-1} (28.61) after fifteen days of spraying. The treatments chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} recorded 29.92 and 36.67 per cent respectively and have no significant difference. While, flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (48.48%), thiamethoxam 25 % WG @ 30 g a.i ha^{-1} (64.64%) were recorded higher damage over other chemicals. The control plot showed higher pod damage (81.14%) and it was superior over all other treatments.

4.2 PERSISTENCE AND DISSIPATION OF INSECTICIDE RESIDUES IN COWPEA

4.2.1 Method validation for the Pesticide Residue Analysis in Cowpea

The results of the validation for the estimation of the different insecticides in cowpea fruits proved satisfactory recovery for all the compounds fortified. Method validation was accomplished with good linearity and acceptable recoveries. The mean recovery of all the insecticides under study was within the acceptance range of 70-120 per cent at three levels of fortification. The repeatability of the recovery results as indicated by the relative standard deviations, RSD < 20 per cent, confirmed that the method was sufficiently reliable for pesticide analysis and the results are presented in Table 11.

The mean per cent recovery of chlorantraniliprole at three different fortification levels *viz,* 0.05, 0.25 and 0.50 mg kg^{-1} were 102.67, 97.33 and 74.00, respectively with relative standard deviation 2.98, 2.37 and 14.04 per cent respectively. The mean per cent recovery of thiamethoxam was 84.00, 101.33 and 77.83, respectively at three fortification levels with relative standard deviation of 8.25, 4.56 and 12.22 per cent respectively. However, in flubendiamide the mean recoveries were 110.67, 120.00 and 104.67 per cent respectively at three fortification levels with 5.52, 5.77 and 10.52 per cent relative standard deviation respectively. In case of imidacloprid the mean per cent recoveries were 96.00, 84.00.00 and 84.00 with RSD of 2.08, 4.17 and 4.76 per cent respectively.

The fortification studies of thiacloprid at three fortification level of 0.05, 0.25 and 0.50 mg kg^{-1} showed that the mean per cent recoveries were 85.67, 89.33 and 77.33 with accepted relative standard deviation was in the range of 1.78, 2.59 and 5.29 per cent. In case of lambda cyhalothrin had a recovery of 120, 120 and 115 per cent for three fortification levels with 1.67 to 5.91 per cent relative standard deviation respectively. While, beta cyfluthrin had a recovery of 74,76 and 84 per cent with RSD of 0.5, 2.6 and 1.8 per cent respectively.

Table 11. Per cent recovery of insecticides in cowpea pods

Insecticides	Fortification levels (mg Kg^{-1})					
	0.05		0.25		0.50	
	Mean recovery (%)	RSD (%)	Mean recovery (%)	RSD (%)	Mean recovery (%)	RSD (%)
Chlorantraniliprole	102.67	2.98	97.33	2.37	74.00	14.04
Thiamethoxam	84.00	8.25	101.33	4.56	77.83	12.22
Flubendiamide	110.67	5.52	120.00	5.77	104.67	10.52
Imidacloprid	96.00	2.08	84.00	4.17	84.00	4.76
Thiacloprid	85.67	1.78	89.33	2.59	77.33	5.29
Lambda cyhalothrin	120	1.67	120	5.88	115	5.91
Beta cyfluthrin	74	0.5	76	2.6	84	1.8

Limit of quantification (LOQ) – 0.05 mg Kg^{-1}, RSD – Relative Standard Deviation

4.2.2 Estimation of Persistence and Degradation of Residues

The mean residue, dissipation per cent and their half-lives of combination insecticides in cowpea pods were presented in Table 12-15.

4.2.2.1 Chlorantraniliprole 8.8 % + Thiamethoxam 17.5 % SC

Chlorantraniliprole

The initial deposit of chlorantraniliprole (two hours after spraying) was 0.27 mg kg^{-1}. One day after spraying, the residue reduced to 0.24 mg kg^{-1}, with a reduction of 11.11 per cent. On third day after spraying, the residue content was degraded to 0.15 mg kg^{-1} with a reduction of 44.44 per cent. The residues of chlorantraniliprole were 0.14, 0.11 mg kg^{-1} after 5 and 7 days after spraying with a dissipation % of 48.14 and 59.25 respectively. However, on tenth day after spraying, the residues reached below quantification level 0.05 mg kg^{-1}. The half-life recorded was 5.34 days.

Thiamethoxam

Thiamethoxam resulted in an initial deposit of 0.64 mg kg^{-1} on cowpea pods after two hours of spraying. One day after spraying, the residue degraded to 0.58 mg kg^{-1} with a reduction per cent of 9.37 per cent from the initial residue. The 57.81 per cent of the residue degraded on third day and the concentration of residue recorded being 0.27 mg kg^{-1}. However, on the fifth and seventh day after spraying the residue content degraded to 0.20 and 0.14 mg kg^{-1} respectively with a dissipation per cent of 68.75 and 78.12 respectively. The half-life of thiamethoxam calculated as 3.01 days.

4.2.2.2 Lambda cyhalothrin 4.6 % + Chlorantraniliprole 9.3 % ZC

Lambda cyhalothrin

The initial deposit of lambda cyhalothrin after two hours of spraying was 0.12 mg kg^{-1} on cowpea fruits. On the next day the residue degraded to 0.09 mg kg^{-1}, indicating 25.00 per cent loss of residues. On the third day, 33.33 per cent

Table 12. Residue of Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC in cowpea pods

Days after Spraying (DAS)	Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC				Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC			
	Chlorantraniliprole		Thiamethoxam		Lambda cyhalothrin		Chlorantraniliprole	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	0.27±0.01		0.64±0.023		0.12±0.02		0.21±0.02	
1	0.24±0.02	11.11	0.58±0.03	9.37	0.09±0.03	25 .00	0.19±0.01	9.52
3	0.15±0.01	44.44	0.27±0.02	57.81	0.08±0.02	33.33	0.18±0.02	14.28
5	0.14±0.01	48.14	0.20±0.02	68.75	BQL		0.16±0.03	23.80
7	0.11±0.02	59.25	0.14±0.01	78.12	BQL		BQL	-
10	BQL	-	BQL	-	BQL		BQL	-
Half-life (Days)	5.34		3.01		5.48		13.67	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg Kg^{-1}, SD – Standard Deviation reduction of residue was observed and the residues being 0.08 mg kg^{-1}. On fifth day of spraying residue of lambda cyhalothrin reached below quantification level with half-life of 5.48 days.

Chlorantraniliprole

The initial deposit of chlorantraniliprole after two hours of spraying was 0.21 mg kg^{-1}. On first day, the residue dissipated to 0.19 mg kg^{-1} and the dissipation per cent age was 9.52 per cent. An average deposit of 0.18 mg kg^{-1} was recorded on third day with dissipation per cent age of 14.28 per cent. On the fifth day, 0.16 mg kg^{-1} of residue was recorded on the cowpea pods with a dissipation per cent of 23.80 and the half-life was calculated as 13.67 days. By the seventh day, the residue reached below quantification of 0.05 mg kg^{-1}.

4.2.2.3 Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5 % ZC

Thiamethoxam

The initial deposit of thiamethoxam was reported as 0.43 mg kg^{-1} on cowpea fruits two hours after spraying. On the first day after spraying the residue dissipated to 0.19 mg kg^{-1} with a dissipation per cent age of 55.81. The per cent dissipation observed after third day of spraying was 74.41 and the residue recorded from the fruits being 0.11 mg kg^{-1}. On the fifth day, the residue reached below the quantification level. The half life of thiamethoxam was worked out to be 1.58 days.

Lambda cyhalothrin

The cowpea fruits recorded an average initial deposit of 0.23 mg kg^{-1} two hours after spraying which dissipated to 0.13 mg kg^{-1} on the first day after spraying, indicating 43.47 per cent dissipation. The residue level was 0.06 mg kg^{-1} on third day with the dissipation per cent of 73.91 which reached below quantification level on the fifth day of spraying with a half-life period of 1.53 days.

Table 13. Residue of Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC and beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC in cowpea pods

Days after Spraying (DAS)	Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC				Beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC			
	Thiamethoxam		Lambda cyhalothrin		Beta cyfluthrin		Imidacloprid	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	0.43±0.02		0.23±0.02		0.08±0.03		0.07±0.01	
1	0.19±0.01	55.81	0.13±0.03	43.47	BQL	-	BQL	-
3	0.11±0.02	74.41	0.06±0.02	73.91	BQL	-	BQL	-
5	BQL	-	BQL	BQL	BQL	-	BQL	-
7	BQL	-	BQL	BQL	BQL	-	BQL	-
10	BQL	-	BQL	BQL	BQL	-	BQL	-
Half-life (Days)	1.58		1.53		-		-	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg Kg-1, SD – Standard Deviation

4.2.2.4 Beta cyfluthrin 8.49 % + Imidacloprid 19.81 % SC

Beta cyfluthrin

The initial deposit of beta cyfluthrin on cowpea fruits was 0.08 mg kg^{-1} after two hours of spraying. After one day, the residue got reduced to below quantification limit.

Imidacloprid

The initial deposit of imidacloprid on cowpea pods was 0.07 mg kg^{-1} after two hours of spraying. After one day, the residue degraded to below quantification level.

4.2.2.5 Flubendiamide 19.92 %+ Thiacloprid 19.92 % SC

Flubendiamide

An initial deposit of 1.18 mg kg^{-1} was recorded on cowpea fruits immediately two hours after spraying. One day after spraying the residue was 0.84 mg kg^{-1} with a dissipation per cent of 28.81. On the third day the residue level was 0.73 mg kg^{-1} and the dissipation per cent was 38.13. On the fifth day, the residue level was 0.23 mg kg^{-1} with a dissipation per cent of 80.50 which reached to 0.06 mg kg^{-1} with dissipation per cent of 94.91 on seventh day of spraying and had a half-life period of 1.67 days.

Thiacloprid

The initial deposit of thiacloprid on cowpea fruits was found to be 0.35 mg kg^{-1}, which got dissipated to 0.29 mg kg^{-1} one day after spraying with a dissipation per cent age of 17.41. On the third day, 25.71 per cent of the initial residue dissipated and the residue level became 0.26 mg kg^{-1} with half-life of 8.79 days. The residue level reached below quantification on fifth day.

Table 14. Residue of Flubendiamide19.92 % + thiacloprid 19.92 % SC and hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1) in cowpea pods

Days after Spraying (DAS)	Flubendiamide19.92 % + thiacloprid 19.92 % SC				Hand mixing of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1)			
	Flubendiamide		Thiacloprid		Chlorantraniliprole		Thiamethoxam	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	1.18±0.02		0.35±0.04		0.60±0.03		0.81±0.02	
1	0.84±0.02	28.81	0.29±0.02	17.41	0.56±0.02	6.66	0.61±0.02	24.69
3	0.73±0.01	38.13	0.26±0.03	25.71	0.27±0.01	55.00	0.25±0.01	69.13
5	0.23±0.02	80.50	BQL		0.17±0.02	71.66	0.13±0.02	83.95
7	0.06±0.01	94.91	BQL		BQL		BQL	
10	BQL		BQL		BQL		BQL	
Half-life (Days)	BQL		8.79		2.52		1.81	
	BQL							

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg Kg-1, SD – Standard Deviation

4.2.2.6 Hand mixed Product of Chlorantraniliprole 18.5 % SC + Thiamethoxam 25 % WG (1:1)

Chlorantraniliprole

Two hours after spraying, an initial deposit of 0.60 mg kg^{-1} recorded on cowpea pods after one day residue degraded to 0.56 mg kg^{-1} with a dissipation per cent of 6.66. On third day, the residue reached to 0.27 mg kg^{-1} with a dissipation of 55.00 per cent. The residue level was 0.17 mg kg^{-1} on fifth day with the dissipation per cent of 71.66. From the seventh day onwards, the residue was reached below quantification and the half-life was reported to be 2.52days.

Thiamethoxam

The initial deposit of 0.81 mg kg^{-1} was recorded in cowpea fruits two hours after spraying which dissipated to 0.61 mg kg^{-1} on the next day, indicating 24.69 per cent dissipation. The residue level was 0.25 mg kg^{-1} on the third day with the dissipation per cent age of 69.13. On fifth day, the residue content was dissipated to 0.13 mg kg^{-1} with a dissipation per cent age of 83.95 which reached below quantification level on seventh day and recorded a half-life of 1.81days.

Chlorantraniliprole (Sprayed as Single insecticide)

The initial deposit of chlorantraniliprole on cowpea fruits following application at the rate of 0.30 mL L^{-1} was found to be 0.42 mg kg^{-1}, which dissipated to 0.29 mg kg^{-1} on the first day of spraying, the extent of dissipation being 30.95 per cent. On the third day, 78.57 per cent of initial residue dissipated and the residue level became 0.09 mg kg^{-1}. The dissipation continued at a slower pace and on the fifth day, the residue reduced to 0.06 mg $kg^{-1}$with a dissipation per cent age of 85.71 which reached below quantification level on seventh day and recorded a half-life of 1.66 days.

Thiamethoxam (Sprayed as Single insecticide)

Two hours after spraying, an average initial deposit of 0.53 mg kg^{-1} was observed. On the next day 43.39 per cent of the residues got dissipated and the

Table 15. Residue of Chlorantraniliprole 18.5 % SC and thiamethoxam 25 % WG in cowpea pods

Days after Spraying (DAS)	Chlorantraniliprole18.5 % SC (Check)		Thiamethoxam 25 % WG (Check)	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL	
0 (2 h after spraying)	0.42±0.02		0.53±0.01	
1	0.29±0.01	30.95	0.30±0.02	43.39
3	0.09±0.01	78.57	0.12±0.01	77.35
5	0.06±0.02	85.71	BQL	-
7	BQL	-	BQL	-
10	BQL	-	BQL	-
Half-life (Days)	1.66		1.37	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg Kg^{-1}, SD – Standard Deviation level reached 0.30 mg kg^{-1}. Fruits collected on the third day recorded an average residue level of 0.12 mg kg^{-1} with dissipation per cent age of 77.35 which degraded to below quantification level on fifth day and reported half-life was 1.37 days.

4.3 Risk Assessment of Various Insecticide Mixtures in Cowpea

Risk assessment of various insecticide mixtures in cowpea pods were calculated and presented in Table 16-23.

4.3.1 Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC

Chlorantraniliprole

ADI of chlorantraniliprole is 2 mg kg^{-1}. The mean residue of chlorantraniliprole in cowpea fruits from 0^{th} to 5^{th} day after spraying followed as 0.27, 0.24, 0.15, 0.14 and 0.11 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 110000 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 7^{th} day after spraying were 24.3, 21.6, 13.5, 12.6 and 9.9 μg kg^{-1} bw d^{-1} respectively which were lower than the MPI of chlorantraniliprole (Table.16)

Thiamethoxam

ADI of thiamethoxam is 0.08 mg kg^{-1}. The mean residue of thiamethoxam in cowpea fruits from 0^{th} to 5^{th} day after spraying followed as 0.64, 0.58, 0.27, 0.20 and 0.14 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 4400 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0th to 7th day after spraying were 57.6, 52.2, 24.3, 18 and 12.6 μg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiamethoxam. Thus, the application of thiamethoxam in cowpea at the recommended dose does not pose any adverse health effect on the consumers.

Table 16. Risk assessment of chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC in cowpea pods

ADI (mg kg^{-1} bw d^{-1})		Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})		Average residue (µg g^{-1})		TMRC (µg person $^{-1}$ day^{-1})	
Chlorantraniliprole	Thiamethoxam				Chlorantraniliprole	Thiamethoxam	Chlorantraniliprole	Thiamethoxam	Chlorantraniliprole	Thiamethoxam
2	0.08	55	0	90	110000	4400	0.27	0.64	24.3	57.6
2	0.08	55	1	90	110000	4400	0.24	0.58	21.6	52.2
2	0.08	55	3	90	110000	4400	0.15	0.27	13.5	24.3
2	0.08	55	5	90	110000	4400	0.14	0.20	12.6	18.0
2	0.08	55	7	90	110000	4400	0.11	0.14	9.9	12.6
2	0.08	55	10	90	-	-	BDL	BDL	-	-

* MPI= ADI × Average body weight × 1000

4.3.2 Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC

Lambda cyhalothrin

ADI of lambda cyhalothrin was 0.08 mg kg^{-1}. The mean residue of lambda cyhalothrin in cowpea fruits from 0^{th} to 3^{rd} day after spraying followed as 0.12, 0.09 and 0.08 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 1100 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 3^{rd} day after spraying were 10.8, 8.1 and 7.2 μg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiamethoxam (Table.17).

Chlorantraniliprole

ADI of chlorantraniliprole was 2 mg kg^{-1}. The mean residue of chlorantraniliprole in cowpea fruits from 0th to 5th day after spraying followed as 0.21, 0.19, 0.18 and 0.16 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 110000 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 5^{th} day after spraying were 18.9, 17.1, 16.2 and 14.4 μg kg^{-1} bw d^{-1} respectively which were lower than the MPI of chlorantraniliprole.

4.3.3 Thiamethoxam 12.6 % + Lamda cyhalothrin 9.5 % ZC

Thiamethoxam

ADI of thiamethoxam was 0.08 mg kg^{-1}. The mean residue of thiamethoxam in cowpea fruits from 0^{th} to 3^{rd} day after spraying followed as 00.43, 0.19 and 0.11 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 4400 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 3^{rd} day after spraying were 38.7, 17.1 and 9.9 μg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiamethoxam (Table.18)

Table 17. Risk assessment of lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC in cowpea pods

ADI (mg kg^{-1} bw d^{-1})		Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})		Average residue (µg g^{-1})		TMRC (µg person $^{-1}$ day^{-1})	
Lambda cyhalothrin	Chlorantraniliprole				Lambda cyhalothrin	Chlorantraniliprole	Lamda cyhalothrin	Chlorantraniliprole	Lambda cyhalothrin	Chlorantraniliprole
0.02	2	55	0	90	1100	110000	0.12	0.21	10.8	18.9
0.02	2	55	1	90	1100	110000	0.09	0.19	8.1	17.1
0.02	2	55	3	90	1100	110000	0.08	0.18	7.2	16.2
0.02	2	55	5	90	-	110000	BDL	0.16	-	14.4
0.02	2	55	7	90	-	-	BDL	BDL	-	-

* MPI= ADI × Average body weight × 1000

Table 18. Risk assessment of thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC in cowpea pods

ADI (mg kg^{-1} bw d^{-1})		Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})		Average residue (µg g^{-1})		TMRC (µg person $^{-1}$ day^{-1})	
Thiamethoxam	Lambda cyhalothrin				Thiamethoxam	Lambda cyhalothrin	Thiamethoxam	Lambda cyhalothrin	Thiamethoxam	Lambda cyhalothrin
0.08	0.02	55	0	90	4400	1100	0.43	0.23	38.7	20.7
0.08	0.02	55	1	90	4400	1100	0.19	0.13	17.1	11.7
0.08	0.02	55	3	90	4400	1100	0.11	0.06	9.9	5.4
0.08	0.02	55	5	90	-	-	BDL	BDL	-	-

* MPI= ADI × Average body weight × 1000

Table 19. Risk assessment of beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC in cowpea pods

ADI (mg kg^{-1} bw d^{-1})		Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})		Average residue (µg g^{-1})		TMRC (µg person $^{-1}$ day^{-1})	
Beta cyfluthrin	Imidacloprid				Beta cyfluthrin	Imidacloprid	Beta cyfluthrin	Imidacloprid	Beta cyfluthrin	Imidacloprid
0.04	0.06	55	0	90	2200	3300	0.08	0.07	7.2	6.3
0.04	0.06	55	1	90	-	-	BDL	BDL	-	-

* MPI= ADI × Average body weight × 1000

Lamda cyhalothrin

ADI of lambda cyhalothrin was 0.08 mg kg^{-1}. The mean residue of lambda cyhalothrin in cowpea fruits from 0^{th} to 3^{rd} day after spraying followed as 0.23, 0.13 and 0.06 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 1100 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 3^{rd} day after spraying were 20.7, 11.7 and 5.4 μg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiamethoxam.

4.3.4 Beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC

Beta cyfluthrin

ADI of beta cyfluthrin was 0.08 mg kg^{-1}. The mean residue of beta cyfluthrin in cowpea fruits from 0^{th} (two hours) day after spraying followed as 0.08 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 2200 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC value after spraying was 7.2 μg kg^{-1} bw d^{-1} which was lower than the MPI of beta cyfluthrin (Table.19).

Imidacloprid

ADI of Imidacloprid was 0.08 mg kg^{-1}. The mean residue of imidacloprid in cowpea fruits from 0th (two hours) day after spraying followed as 0.07 mg Kg^{-1} respectively. Maximum permissible intake (MPI) was 3300 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC value after spraying was 6.3 μg kg^{-1} bw d^{-1} which was lower than the MPI of imidacloprid.

4.3.5 Flubendiamide 19.92 % + Thiacloprid 19.92 % SC

Flubendiamide

ADI of flubendiamide is 2 mg kg^{-1}. The mean residue of flubendiamide in cowpea fruits from 0^{th} to 7^{th} day after spraying followed as 1.18, 0.84, 0.73, 0.23

and 0.06 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 1100 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0th to 7th day after spraying were 106.2, 75.6, 65.7, 20.7 and 5.4 µg kg^{-1} bw d^{-1} respectively which were lower than the MPI of flubendiamide (Table. 20)

Thiacloprid

ADI of thiacloprid is 0.01 mg Kg^{-1}. The mean residue of thiacloprid in cowpea fruits from 0th to 3rd day after spraying were 0.35, 0.29 and 0.26 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 550 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0th to 3rd day after spraying were 31.5, 26.1 and 23.4 µg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiacloprid. Thus, the application of thiacloprid in cowpea at the recommended dose was not to cause adverse health impact on the consumers.

4.3.6 Hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG

Chlorantraniliprole

ADI of chlorantraniliprole is 2 mg kg^{-1}. The mean residue of chlorantraniliprole in cowpea fruits from 0th to 5th day after spraying followed as 0.60, 0.56, 0.27 and 0.17 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 110000 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0th to 7th day after spraying were 54, 50.4, 24.3 and 15.3 µg kg^{-1} bw d^{-1} respectively which were lower than the MPI of chlorantraniliprole (Table. 21).

Thiamethoxam

ADI of thiamethoxam is 0.08 mg kg^{-1}. The mean residue of thiamethoxam in cowpea fruits from 0th to 5th day after spraying followed as 0.81, 0.61, 0.25 and 0.13 mg kg-1 respectively. Maximum permissible intake (MPI) was 4400 mg kg^{-1}

Table 20. Risk assessment of flubendiamide 19.92 % + thiacloprid 19.92 % SC in cowpea pods

ADI (mg kg^{-1} bw d^{-1})		Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})		Average residue (µg g^{-1})		TMRC (µg person $^{-1}$ day^{-1})	
Flubendiamide	Thiacloprid				Flubendiamide	Thiacloprid	Flubendiamide	Thiacloprid	Flubendiamide	Thiacloprid
0.02	0.01	55	0	90	1100	550	1.18	0.35	106.2	31.5
0.02	0.01	55	1	90	1100	550	0.73	0.29	65.7	26.1
0.02	0.01	55	3	90	1100	550	0.84	0.26	75.6	23.4
0.02	0.01	55	5	90	1100	-	0.23	BDL	20.7	-
0.02	0.01	55	7	90		-	0.06	BDL	5.4	-
0.02	0.01	55	10	90	-	-	BDL	BDL	-	-

* MPI= ADI × Average body weight × 1000

Table 21. Risk assessment hand mixed product of chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (1:1) in cowpea pods

ADI (mg kg^{-1} bw d^{-1})		Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})		Average residue (µg g^{-1})		TMRC (µg person $^{-1}$ day^{-1})	
Chlorantraniliprole	Thiamethoxam				Chlorantraniliprole	Thiamethoxam	Chlorantraniliprole	Thiamethoxam	Chlorantraniliprole	Thiamethoxam
2	0.08	55	0	90	110000	4400	0.60	0.81	54	72.9
2	0.08	55	1	90	110000	4400	0.56	0.61	50.4	54.9
2	0.08	55	3	90	110000	4400	0.27	0.25	24.3	22.5
2	0.08	55	5	90	110000	4400	0.17	0.13	15.3	11.7
2	0.08	55	7	90	-	-	BDL	BDL	-	-

* MPI= ADI × Average body weight × 1000

bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 7^{th} day after spraying were 72.9, 54.9, 22.5 and 11.7 µg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiamethoxam.

4.3.7 Chlorantraniliprole (Sprayed as Single insecticide)

ADI of chlorantraniliprole is 2 mg kg^{-1}. The mean residue of chlorantraniliprole in cowpea fruits from 0^{th} to 5^{th} day after spraying followed as 0.42, 0.29, 0.09 and 0.06 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 110000 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0^{th} to 7^{th} day after spraying were 37.8, 26.1, 8.1 and 5.4 µg kg^{-1} bw d^{-1} respectively which were lower than the MPI of chlorantraniliprole (Table. 22).

4.3.8 Thiamethoxam (Sprayed as Single insecticide)

ADI of thiamethoxam is 0.08 mg kg^{-1}. The mean residue of thiamethoxam in cowpea fruits from 0th to 3^{rd} day after spraying followed as 0.53, 0.30 and 0.12 mg kg^{-1} respectively. Maximum permissible intake (MPI) was 4400 mg kg^{-1} bw d^{-1}, by taking 90g as daily consumption of cowpea fruits TMRC values were calculated. TMRC values from 0th to 3^{rd} day after spraying were 47.7, 27.00 and 10.8µg kg^{-1} bw d^{-1} respectively which were lower than the MPI of thiamethoxam (Table. 23).

Table 22. Risk assessment of chlorantraniliprole 18.5 % SC in cowpea pods (Sprayed as single insecticide)

ADI (mg kg^{-1} bw d^{-1})	Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})	Average residue (µg g^{-1})	TMRC (µg person $^{-1}$ day^{-1})
2	55	0	90	110000	0.42	37.8
2	55	1	90	110000	0.29	26.1
2	55	3	90	110000	0.09	8.1
2	55	5	90	110000	0.06	5.4
2	55	7	90	-	BDL	-

* MPI= ADI × Average body weight × 1000

Table 23. Risk assessment of thiamethoxam 25 % WG in cowpea pods (Sprayed as single insecticide)

ADI (mg kg^{-1} bw d^{-1})	Average body weight (kg)	Interval (days)	Daily consumption rate (g day^{-1})	MPI * (µg person $^{-1}$ day^{-1})	Average residue (µg g^{-1})	TMRC (µg person $^{-1}$ day^{-1})
0.08	55	0	90	4400	0.53	47.7
0.08	55	1	90	4400	0.30	27
0.08	55	3	90	4400	0.12	10.5
0.08	55	5	90	-	BDL	-

* MPI= ADI × Average body weight × 1000

Discussion

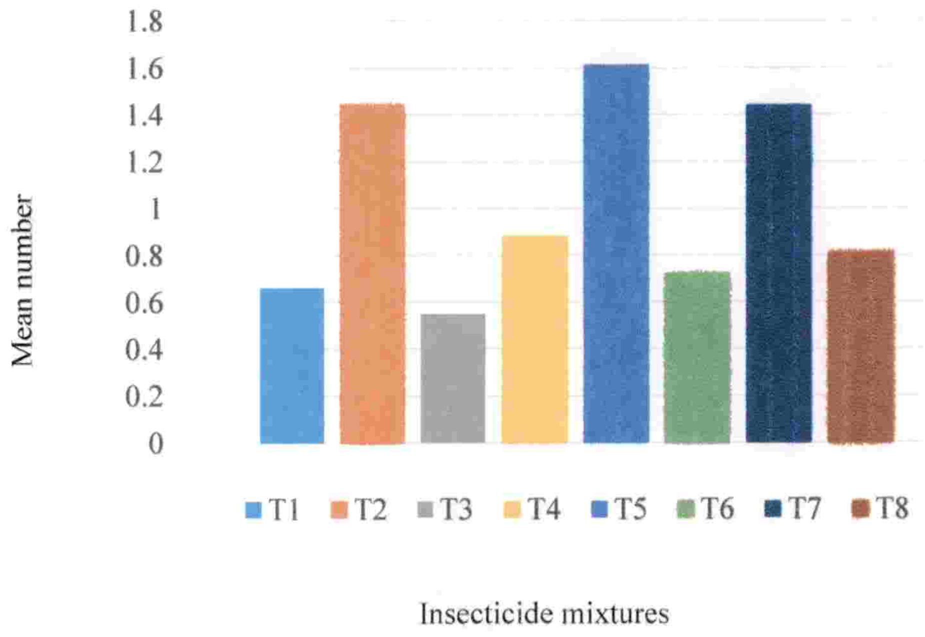
5. DISCUSSION

5.1 EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES AGAINST THE PEST COMPLEX IN COWPEA

Over the years, chemical pesticides had made a great contribution to the battle against pests and diseases. However, widespread and long-term use of single insecticide resulted in insecticide resistance and deposition of huge pesticide load in the crop as well as the environment, high mortality of beneficial arthropod fauna and high cost of cultivation. Invention of pesticide mixture with two or more single insecticides having different mode of action paved the way to solve the above problem. The primary benefits of insecticide mixtures are delay in development of insecticide resistance, less number of applications, less labour cost, chemical cost, less dosage when compared to single insecticides and control of pests in a broad range (Cabello and Canero, 1994).

Cowpea is one of the most important legume crops belongs to family Leguminaceae. It is used as green legume, fodder, vegetable as well as green manure crop. As many as 21 insect pests of different groups are recorded in cowpea crop from germination to maturity. The important pests infesting cowpea are aphid, *A. craccivora*, pod bug, *R. pedestris*, spotted pod borer, *M. vitrata* and leaf eating caterpillar, *S. litura* etc. Frequent application of same insecticides causes resistance, secondary pest outbreaks and pest resurgence problems along with destruction of natural enemies and environmental pollution. Currently there is an urgent need to identify the effective new chemistry insecticides which are relatively safe to the environment, less persistence, more specific and safe to natural enemies.

As compared to other vegetables crops, cowpea is infested with an array of pests *viz.*, sucking pest, borers, leaf feeders simultaneously especially at pod bearing stage. For controlling the pest complex, farmers used to apply a minimum of 5-6 sprays mainly by using conventional synthetic molecules. Moreover, applications of different groups of insecticides with short spells between two



T1- Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC

T2- Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC

T3- Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC

T4- Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC

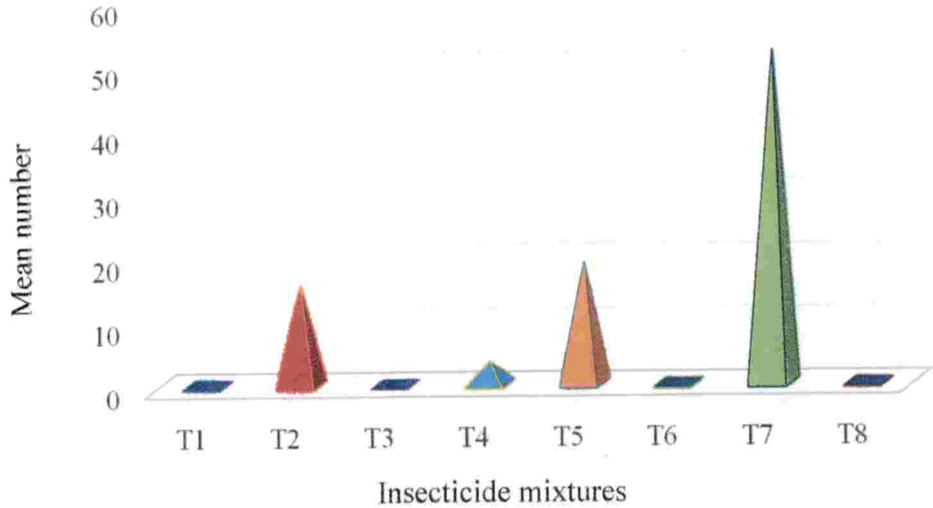
T5- Flubendiamide19.92 % +thiacloprid 19.92 % SC

T6- Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)

T7- Chlorantraniliprole18.5 % SC (check)

T8- Thiamethoxam 25 % WG (check)

Figure 1. Effect of insecticide mixtures on the population of pod bug, *Riptortus pedestris*



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T6- Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)

T7- Chlorantraniliprole18.5 % SC (check)

T8- Thiamethoxam 25 % WG (check)

Figure 2. Effect of insecticide mixtures on the population of cowpea aphid, *Aphis craccivora*

consecutive sprays lead to deposition of pesticides. The present study on the evaluation of insecticide mixtures against pests of cowpea revealed that the combination insecticides chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} and thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} were proved better in managing the sucking pests cowpea aphid, *A.craccivora* and pod bug, *R.pedestris* along with hand mixed insecticide mixture (Figure. 1 and 2).

The studies on the bio efficacy of combi products against cowpea pests are so meagre. However, several research works on efficacy of pesticide mixture against pests of cotton, tea, rice etc. are available. Studies conducted by insecticide mixture, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} against sucking pests was found to be effective against jassids and whiteflies in soybean (Birla, 2014) and sucking pests of tea (Samanta *et al.*, 2017).

Granular formulation chlorantraniliprole 5% + thiamethoxam 10 % WG was effective in managing sucking pests of rice (Baskaran *et al.*, 2013). These findings are in agreement with the present study. Roy *et al.*, (2017) reported that chlorantraniliprole 10 % + thiamethoxam 20 % SC was highly effective against aphid infesting cowpea. Various research works has been conducted by using single insecticide thiamethoxam against aphid. Thiamethoxam 25 WG @ 25 g a.i ha^{-1} was found to be effective in decreasing aphids in green gram (Sasmal and Kumar, 2013), brinjal (Arya, 2015), blackgram (Justin *et al.*, 2015), cowpea and salad cucumber (Thamilarasi, 2016), cowpea (Choudhary *et al.*, 2017) and in urd bean (Rajawat *et al.*, 2017).

In the present study, bioefficacy of insecticide mixtures against pod borer, *M.vitrata* revealed that lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} found to be effective for the management of *M.vitrata*. In 2017, Roy *et al.*, reported similar results in managing pod borer, *M.vitrata* in cowpea by spraying chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 180 ml ha^{-1} (Figure. 3 and 4).

However, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 35 g a.i ha^{-1} was found to be the best in reducing the infestation of borer pests in different crops *viz.*, pigeon pea (Patel and Patel, 2013), soy bean (Birla, 2014), cotton (Bajya *et al.*, 2015), cowpea (Grigolli *et al.*, 2015), brinjal (Sen *et al.*, 2017) and pigeon pea (Swami *et al.*, 2017)

In Kerala, Kartikeyan *et al.*, 2012 reported that flubendiamide + buprofezin @ 875 mL ha^{-1} was the best insecticide mixture against borer and sucking pests of rice. Sreelakshmi *et al.*, 2016 revealed that indoxacarb 14.5 %+ acetamiprid 7.7% SC @ 100 g a.i ha^{-1} was found to be effective in managing the resistant population of *M.vitrata*.

Several studies has been conducted using chlorantraniliprole and lambda cyhalothrin as single insecticides against *M.vitrata*. Chlorantraniliprole @ 0.15 mL L^{-1} was found to be superior in reducing larval population of *M.vitrata* in cowpea (Kumar *et al.*, 2014;Yadav and Singh, 2014), red gram (Kumar *et al.*, 2015), pigeon pea (Jakhar *et al.*, 2016). Toxicity of insecticides against pod borers in pigeon pea showed that lambda cyhalothrin 5 EC @ 25 g a.i. ha^{-1} was highly effective in reducing pod borer infestation in pigeon pea (Mohapatra and Srivastava, 2002; Kaushik and Pal, 2006; Dhaka *et al.*, 2011; Priyadarshini *et al.*, 2013), Indian bean (Viroja, 2003), green gram (Rani and Eswari, 2008) and in black gram (Sonune *et al.*, 2010).

The results of the present study on the evaluation of insecticide mixtures against leaf eating caterpillar showed that lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 0.50 mL L^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 0.30 mL L^{-1} and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 0.30 mL L^{-1} were found to be effective in the management of leaf eating caterpillar, *S.litura* (Figure. 5 and 6).

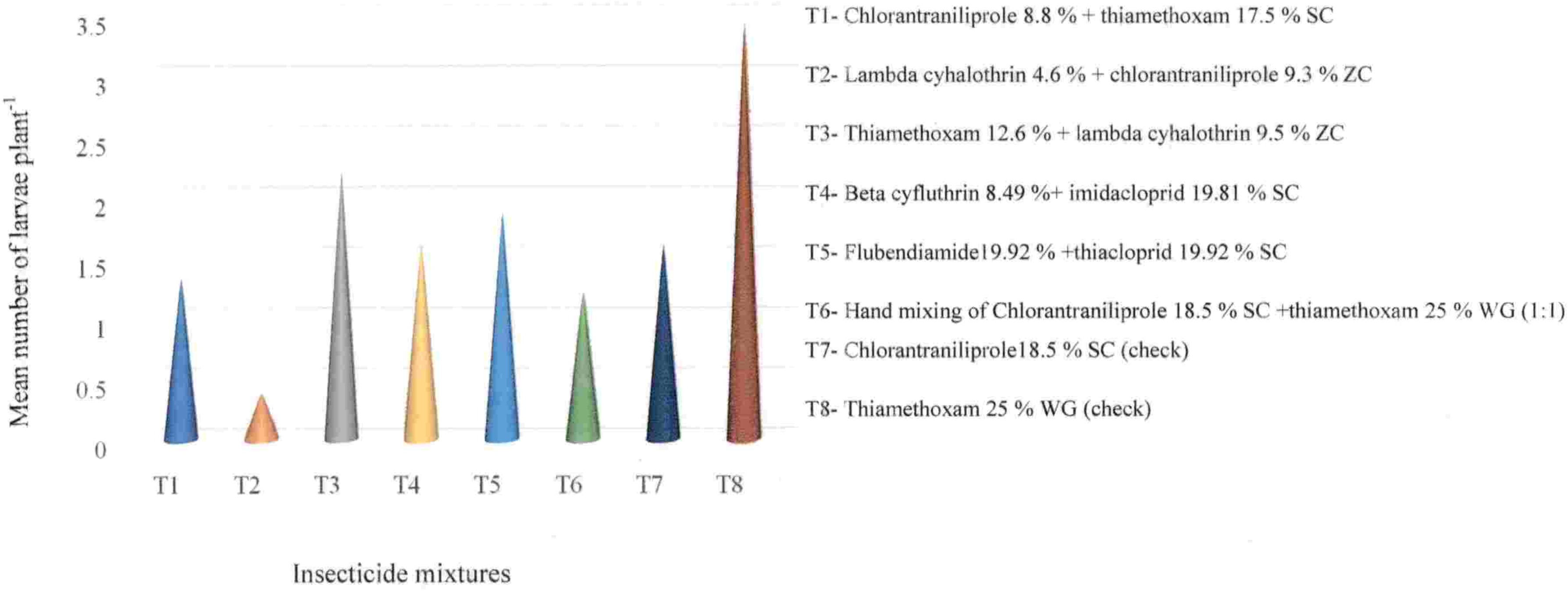
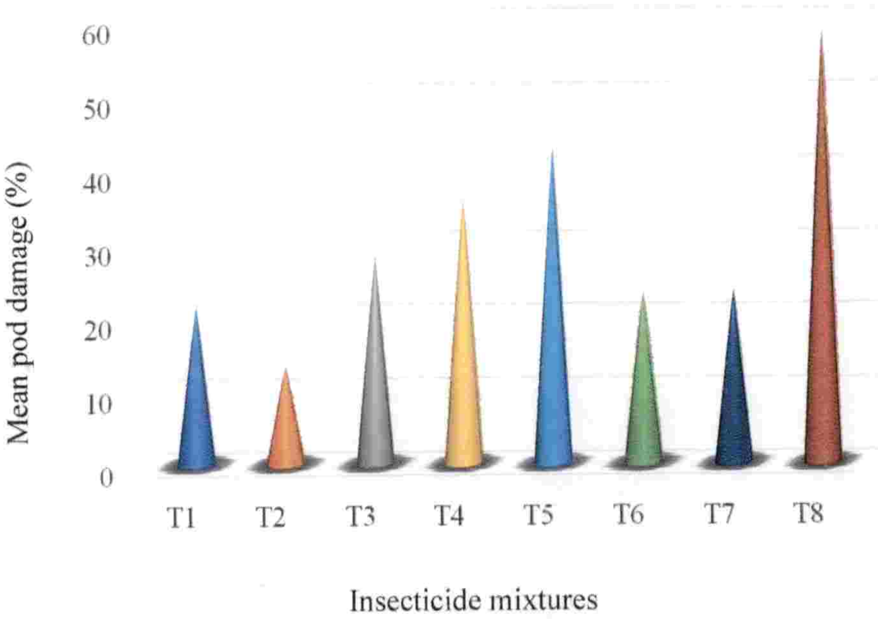


Figure 3. Effect of insecticide mixtures on the population of spotted pod borer, *Maruca vitrata*



T1- Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC

T2- Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC

T3- Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC

T4- Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC

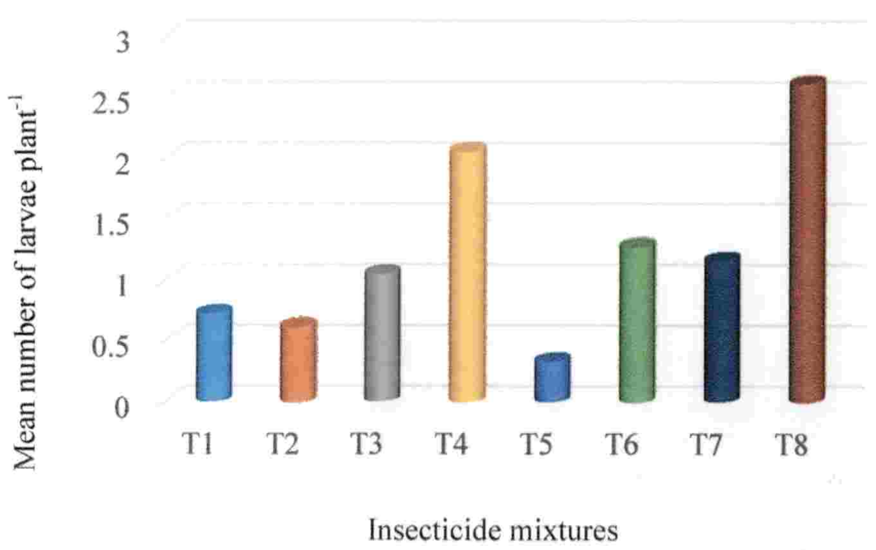
T5- Flubendiamide19.92 % +thiacloprid 19.92 % SC

T6- Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)

T7-Chlorantraniliprole18.5 % SC (check)

T8- Thiamethoxam 25 % WG (check)

Figure 4. Effect of insecticide mixtures on the pod damage by spotted pod borer, *Maruca vitrata*



T1- Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC

T2- Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC

T3- Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC

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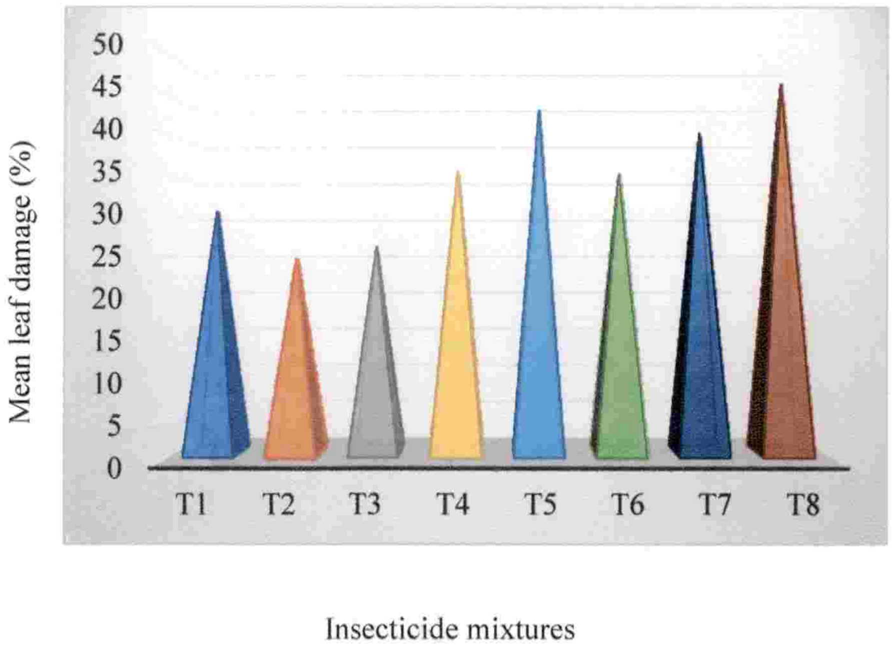
T7- Chlorantraniliprole18.5 % SC (check)

T8- Thiamethoxam 25 % WG (check)

Figure 5. Effect of insecticide mixtures on the population of leaf eating caterpillar, *Spodoptera litura*



T1- Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC

T2- Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC

T3- Thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC

T4- Beta cyfluthrin 8.49 %+ imidacloprid 19.81 % SC

T5- Flubendiamide19.92 % +thiacloprid 19.92 % SC

T6- Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1)

T7- Chlorantraniliprole18.5 % SC (check)

T8- Thiamethoxam 25 % WG (check)

Figure 6. Effect of insecticide mixtures on leaf damage by *Spodoptera litura*

Kousika *et al.*, (2015) reported that chlorantraniliprole 4.3% + abamectin 1.7% SC @ 60 g a.i. ha^{-1} was superior in reducing cent percent population of *S.litura*. However, many works have been conducted with single insecticides *viz.*, chlorantraniliprole, flubendiamide etc. Chlorantraniliprole @ 0.006% was the effective treatment against *S.litura* in different crops *viz.*, chilli (Hosamani *et al.*, 2008), castor (Narayanamma and Reddy, 2014), groundnut (Kumar *et al.*, 2015a). Efficacy of different insecticides against leaf eating caterpillar, *S. litura* in various crops showed that flubendiamide 480 SC @ 200 mL ha^{-1} was the best insecticide in rice (Mallikarjunappa *et al.*, 2008), chilli (Tatagar *et al.*, 2009; Reddy *et al.*, 2014a) and in soybean (Manu *et al.*, 2014; Patil *et al.*, 2015b).The results of laboratory studies against *S. litura* with different new generation insecticides revealed that chlorantraniliprole 18.5% SC @ 1-4 ppm was found to be superior (Karuppaiah *et al.*,2017 and Rajasekar and Sridevi, 2017). Similarly, evaluation of insecticides against *S.litura* under polyhouse condition in capsicum showed that chlorantraniliprole 18.5 % SC @ 0.1 mL L^{-1} was highly potent insecticide in controlling larval population and fruit damage (Maruthi *et al.*, 2017). In Kerala, studies conducted by Sreelakshmi (2017) reported that chlorantraniliprole @ 30 g a.i ha^{-1} and flubendiamide @ 48 g a.i ha^{-1} were effective in controlling resistant population of *S. litura*.

Along with ready-mix combi products, Hand mixing of Chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (1:1) @ 0.3 mL L^{-1} was found to be equally effective in reducing the infestation of all pests under present study. Farmers are usually adopting this practice for controlling more than one pest together. However, this practice is not scientific and dose may be higher than prescribed dose. Hence, we cannot advice this practice for the farmers.

The rate of resistance development in an arthropod pest population is approximately proportional to the frequency of pesticide applications, especially when using those with similar modes of action (Forgash, 1984; Tabashnik, 1989). Major resistance mechanisms associated with arthropod pests are metabolic detoxification and target site insensitivity (Roush, 1993; Jensen, 2000). When the pesticide enters the body, enzymes attack and detoxify or convert the active ingredient into a non-toxic form. In general, target site insensitivity involves interactions between the pesticide and the designated target site, which is similar to a key or active ingredient fitting into a lock or target site. A decrease in binding associated with the target site insensitivity is similar to the lock having been changed so that the key no longer fits, and thus the pesticide is no longer effective (Mallet, 1989).

In the present study, most of the mixtures used are the combinations of new generation insecticide groups *viz.,* diamides+ neonicotinoids, diamide + synthetic pyrethroid, neonicotinoid + synthetic pyrethroid and diamide + neonicotinoid. Diamides and neo nicotinoids are highly selective molecules. Diamides act on specific Ryanodine Receptors (RyRr) of insect muscle system. Hence, they are safe to mammals including humans. All molecules under diamide group come under the toxicity class 'green'. The main cause behind the action of these insecticide mixtures is the compatibility of single insecticides being mixed in formulation and their synergistic effect on the insects at a time and it is important to mix insecticides with different modes of action or those that affect different bio chemical processes in order to overcome the resistance in pest populations. Das (2014) explained the action of insecticide mixtures in detail and he reported that the action is in four ways. First, similar actions as two components in a mixture act independently but produce similar effects whether they are applied as a mixture. Second effect is additive effect in which combined effect of two chemicals is equal to the sum of the effect of each component given alone. Independent action in which two components are different and independent in action means no synergistic effect between them. Synergistic action in which the toxicity of the mixture is greater than the sum of effects of each component given alone. Finally, antagonistic action in which one component in the mixture reduces the activity of another insecticide in the mixture. Synergism may be the major action in mixtures and antagonism is the least discussed action in case of mixtures.

Arthropods present in the population resistant to one or more pesticides would likely succumb to the other pesticide in the mixture as long as pesticides with different modes of action are mixed together. Synergism may occur when one pesticide interferes with the metabolic detoxification of another pesticide. Certain organophosphates insecticides bind to the active site on esterase enzymes responsible for detoxification of pyrethroid insecticides and so organophosphate insecticides can be useful as synergists for pyrethroids. This is one of the primary reasons why many manufacturing companies formulate organophosphate and pyrethroid based insecticide mixtures to manage pest populations and counteract resistance (Ahmed, 2004).

Chlorantraniliprole belongs to ryanodine receptor modulators which activate muscle ryanodine receptors, leading to contraction and paralysis. Ryanodine receptors mediate calcium release into the cytoplasm from intracellular stores. Thiamethoxam belongs to nicotinic acetylcholine receptorcompetitive modulators which binds to the acetylcholine site on nAChRs, causing a range of symptoms from hyper-excitation to lethargy and paralysis and acetylcholine is the major excitatory neurotransmitter in the insect central nervous system (IRAC, 2018).

The effect of pesticide mixtures is unpredictable because the differences in the mode of action do not necessarily guarantee a lack of common resistance mechanisms and may only reflect the specificity associated with enzymes responsible for detoxification. Moreover, the effects of pesticide mixtures may vary depending on the arthropod pest population as a result of differences associated with the species, strain, and even biotype. However, continued use of these pesticide mixtures may result in the resistance to both modes of activity by pest populations, especially those that have the capacity of developing multiple resistance (Ahmad *et al.*, 2008). As in the case of single insecticide, care should be taken to avoid the continuous use of insecticide mixtures against same pest.

5.2 PERSISTENCE AND DISSIPATION OF INSECTICIDE RESIDUES IN COWPEA

A wide range of pesticides are being used indiscriminately for managing pests and diseases with least concern for their residual toxicities under field conditions. Dissipation rate of insecticides is one of the most important parameters in assessing their potential hazards on the environment. However, specific studies on the dissipation and persistence of insecticide mixtures in cowpea are so meagre.

In the present study, dissipation of effective mixtures like chlorantraniliprole and thiamethoxam dissipated below its LOQ in 10 days after spraying. However, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC dissipated within 5days. The studies on dissipation of chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC are so scanty. Whereas, Barik *et al.,* (2010) studied the dissipation of thiamethoxam+ lambda cyhalothrin and they reported that the residues of thiamethoxam persisted more than 15days and lambda cyhalothrin persisted up to 5 days in paddy.

The persistence of chlorantraniliprole and thiamethoxam in cowpea as single insecticide was studied in the present study. The result revealed that chlorantraniliprole and thiamethoxam as single insecticide dissipated within 7 and 5 days respectively. Contradictory to the present study, Vijayasree, (2013) reported that chlorantraniliprole persisted up to 10 days in cowpea. Chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC when applied as mixture, their residues persisted longer than when applied as single insecticides.

However, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC when sprayed as mixture, their residues persisted only up to 5 days. When sprayed as single insecticide, thiamethoxam persisted up to 5 days and lambda cyhalothrin persisted up to 15 days in okra. (Singh *et al.,*2007). These observations concluded that variation in the rate of dissipation is mainly due to the meteorological parameters existed in the experimental area, chemistry of insecticides, concentration of formulation etc. Bhattacharya *et al.*, 2017 reported that dissipation of any compound depends on various factors including plant matrix, chemical formulation, agroclimatic conditions, physical phenomenon, application method and chemical degradation in which sunlight place an important role.

The promising insecticide mixture against *M. vitrata* and *S. litura* in the present study is lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC which dissipated in 5 and 7 days respectively. Except present investigation, no study has been conducted on the dissipation of lambda cyhalothrin + chlorantraniliprole in any crop. However, several studies on dissipation of lambda cyhalothrin as single insecticides has been conducted in various crops Lambda cyhalothrin dissipated within15 days in okra (Singh *et al.*, 2007), 28 days in cardamom (George *et al.*, 2013). Studies on dissipation of chlorantraniliprole revealed 45 days in soils of sugarcane (Ramanasubramanian *et al.*, 2012), 21 days in cowpea (Vijayasree *et al.*, 2013), and 5 days in cauliflower curds (Kar *et al.*, 2013).

Risk assessment is the course to identify the potential menaces and the associated risks to life and health resulting from human exposure to chemicals present in food over a specific period (WHO, 2009). Consumer risk assessment is a crucial component in the regulatory approval of pesticides for use on food crops (Damalas and Eleftherohorinos, 2011; Huan *et al.*, 2015). The theortical maximum residual concentration (TMRC) of all pesticide mixtures were found to be well below the MPI on cowpea pods even at 2 hrs after spraying.

The overall experimental results concluded that spraying of chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} were effective in the management of pest complex in cowpea. Risk assessment studies revealed the safety of all pesticide mixtures and they do not impart any human health risk. Multilocational studies are necessary to give more accurate conclusion. In pest management strategy, insecticide mixtures play a major role by delaying the development of resistance, broad spectrum of activity, synergistic joint action and economic pest control. Additional research efforts are required to develop multi pesticide formulation and to develop safer green labelled mixtures for the future.

Summary

6. SUMMARY

Cowpea is known for its versatility and better adaptability to warm and dry conditions because of proven drought tolerance and thereby could prove more appropriate crop in current environmental changing scenario of global warming. Inspite of all improvement brought in cultivation of cowpea, its productivity is still very low due to pest attack. Moreover, the infestation of different groups of pests *viz.*, sucking pests, borer, leaf feeders etc. occurred at the same time especially from flowering stage to till harvesting of pods. Either knowingly or unknowingly, farmers are spraying toxic insecticides at short intervals having same mode of action. This frequent usage of insecticides resulted in the resistance problem and biomagnification. Therefore, it is important to have a critical look to manage pest complex with newer insecticide mixtures having different mode of action at a particular stage. Present study was undertaken to evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of cowpea and determine the persistence and dissipation rate insecticide mixtures in cowpea. The results obtained are summarized here under.

- Sucking pests *viz.*, cowpea aphid, *A.craccivora*; pod bug, *R.pedestris*; leaf feeders *viz.*, *S.litura*, pod borer *viz.*, *M.vitrata*; were recorded from the experimental plot.
- The studies on the efficacy of insecticide mixtures against pod bug, *R. pedestris* revealed that chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} was found effective in managing the population of pod bug followed by thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} and beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}. Less incidence of bug was found in effective treatments after 7 days of spraying.
- Management of cowpea aphid, *A. craccivora* using insecticide mixtures revealed that less number of aphid was observed in the plants treated with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} and

thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, against 211.67 aphids $plant^{-1}$ in control after 15 days of spraying.

- Studies on the efficacy of insecticide mixtures against leaf caterpillar, *S. litura* revealed a significant reduction in leaf damage by *S. litura* treated with lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (25.03) which was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (26.46) and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (30.20) after 10 days of spraying.

- In the management of cowpea pod borer, *M. vitrata*, less number of larvae was found in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} treated plants after 5 days of spraying against 6.67 larvae in control.

- Satisfactory results were obtained while validating the QuEChERS method for the pesticide residue analysis of cowpea with good recovery which ranged from 74.00 to 120.00 per cent.

- The residues of effective insecticide mixtures against sucking pests of cowpea *viz.*, chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} in which both the single insecticides were dissipated to BQL on 10^{th} day only with half-lives of 5.34 and 3.01 days respectively and thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} in which both the insecticides were reached BQL within 5 days with half-lives of 1.58 and 1.53 days respectively.

- The residues of effective insecticides against borer and leaf feeders of cowpea *viz.*, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} in which lambda cyhalothrin and chlorantraniliprole were reached to BQL on 5^{th} and 7^{th} day with half-lives of 5.48 and 13.67 days respectively. The residues of beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1} in which both the insecticides were reached to BDL on first day after application of insecticide. The residues of flubendiamide19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} in which both insecticides dissipated to BQL on 10^{th} and 5^{th} day with half-lives of 1.67 and 8.79 days respectively.

- The risk assessment studies have been done for all insecticide mixtures by using TMRC, ADI and MPI values. All the studies proved that insecticide mixtures do not cause any injurious effect on end users.

- The study could be concluded that spraying of chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} were effective in the management of pest complex in cowpea.

References

7. REFERENCES

Ahmad, M. 2004. Potentiation/antagonism of deltamethrin and cypermethrins with organophosphate insecticides in the cotton bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Pesti. Biochem. Physiol.* 80: 31-42.

Ahmad, M., Saleem, A. M., and Sayyed, A. H. 2008. Efficacy of insecticide mixtures against pyrethroid and organophosphate resistant populations of *Spodoptera litura* (Lepidoptera: Noctuidae). *Crop protec.* 28: 264-268.

Anastassiades, M., Lehotay, S. J., Stajnbaher, D., and Schenck, F. J. 2003. Fast and easy multiresidue method employing acetonitrile extraction / partitioning and "dispersive solid-phase extraction" for the determination of pesticide residues in produce. *J. AOAC Int.* 86(2): 412-431.

Arya, V. C. 2015. Management of sucking pests of brinjal. M.Sc (Ag.,) thesis, Kerala Agricultural University, Thrissur, 149 p.

Bairwa, B. and Singh, P. S. 2015. Evaluation of certain insecticides against spotted pod borer, *Maruca vitrata* (Geyer) on Mung bean. *Bioscan.*10(3): 1037-1039.

Bajya, D. R., Baheti, H. S., and Raza, S. K. 2015. Field efficacy of newer insecticide formulation Ampligo 150 ZC against bollworm complex in cotton. *J. Cotton. Res. Dev.* 29 (1): 94-98.

Banks, C. J. 1954. A method of estimating populations and counting large numbers of *Aphis fabae* Scop. *Bull. Entomol. Res.* 45: 751-756.

Barik, S. R., Ganguly, P., Kunda, S. K., Kole, R. K. and Bhattacharyya, A. 2010. Persistence behaviour of Thiamethoxam and Lambda cyhalothrin in transplanted paddy. *Bull. Environ. Contam. Toxicol.* 85:419-422.

Baskaran, R. K. M., Thangavel, K. and Sasikumar, G. 2013. Field efficacy of Virtako 40 WG (Chlorantraniliprole 20% + Thiamethoxam 20%) against major pests of rice. *Pestic. Res. J.* 25 (2): 140-145.

Bhamare, V. K. and Wadnerkar, D. W. 2018. Potency of insecticidal combinations against bollworm complex of cotton. *J. Pharmacogn. Phytochem.* SP (1):1164-1168.

Bhattacharyya, A., Majumder, S., Ghosh, B., and Roy, S. 2017. Dissipation Kinetics and Safety Evaluation of Mixed Formulation of Emamectin Benzoate 1.5 % + Fipronil 3.5 % w / v EC on Chilli. *Pestic Res J.* 29(2): 169-176.

Birla, D. 2014. Comparative field efficacy of combination insecticide against insect pests of soybean, *Glycine max* (L.) Merr. M. Sc (Ag.,) thesis, Rajamata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Indore, 93.p.

Borude, B. S., Bhalkare, S. K., Undirwade, D. B., and Rathod, P. K. 2018. Ready mix insecticides for cotton bollworm complex. *Int. J. Curr. Microbiol. Appl. Sci.* SI (6): 1974-1984.

Cabello, T. and Canero, R. 1994. Pesticide mixtures used on garden crops in greenhouses in southeast Spain: cost analysis. *Boletin Sanidad Vegetal.* 20: 429-436.

Choudhary, A. L., Hussain, A., and Choudhary, M. D. 2017. Bio-efficacy of newer insecticides against aphid, *Aphis craccivora* Koch on cowpea. *J. Pharmacogn. Phytochem.* 6(4): 1788-1792.

CIBRC [Central Insecticides Board and Registration Committee] 2018. CIBRC home page [online]. Available: http://www.cibrc.nic.in-online.org

Damalas., C. A, and Eleftherohorinos., I. G. 2011. Pesticide exposure, safety issues and risk assessment indicators. *Int. J. Enviro. Res. Public. Health.* 8: 1402-1419.

Das, S. K. 2014. Scope and relevance of using pesticide mixtures in crop protection: A critical review. *Int. J. Environ. Sci Toxic.* 2(5): 119-123.

Dhaka, S. S., Singh, G., Yadav, A., Rai, M., and Kumar, A. 2011. Efficacy of novel insecticides against pod borer, *Helicoverpa armigera* (Hubner) in Pigeon pea. *Prog. Hortic.* 47(1):98-102.

Dharumarajan., S, Dikshit., A. K. and Singh, S. B. 2009. Persistence of combination-mix (β-cyfluthrin + imidacloprid) on tomato (*Lycopersicon esculentum*). *Pestic. Res. J.* 21(2): 83-85

Dhere. A. D., Wadnerkar, D. W., More, D. G., and Jadhav, Y. T. 2014. Field efficacy of combination insecticides on sucking pests of Bt cotton. *Indian J. Entomol.*76 (1): 12-18.

Forgash, A. J. 1984. History, evolution and consequences of insecticide resistance. *Pesticide. biochem. Physiology*.22: 178-186.

George, T., Beevi, S. N., Xavier, G., and Kumar, N. P. 2013. Dissipation kinetics and assessment of processing factor for chlorpyrifos and lambda-cyhalothrin in cardamom. *Environ. Monit. Assess.*185: 5277-5284.

Ghule, D. D., and Bagde, A. S. 2016. Efficacy of different insecticides against mustard aphid, *Liphaphis erysimi* infesting mustard crop. *J. Glob. Biosci.* 5(5): 4109-4113.

Gowtham, V., Sundar, N. D., Balaji, K., and Karthikeyan, S. 2016. Study on the effectiveness of pesticides against cowpea aphid, *Aphis craccivora* (Koch).in cowpea. *Int. J. Plant. Prot.*9 (1): 146-149.

Grigolli, J. F. J., Luis, A., Lourencao, F., and Avila, C. J. 2015. Field Efficacy of Chemical Pesticides against *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) Infesting Soybean in Brazil. *American. J. Plant. Sci.* 6: 537-544.

Hosamani, A. C., Bheemanna, M., Sreenivas, A. G., Suresh, B. K., and Patil, B. V. 2008. Bioe-fficacy of chlorantraniliprole against chilli fruit borer complex in irrigated chilli ecosystem. *Pestic. Res. J.* 20 (2): 240-242.

Hoy, M. A. 1998. Myths, models and mitigation of resistance to pesticides. *Phil. Trans. Royal Soc. London Biol. Sci.* 353: 1787-1795.

Huan, Z., Xu, Z., Luo, J and Xie, D. 2016. Monitoring and exposure assessment of pesticide residues in cowpea from five provinces of southern China. *Reg.Toxicol.Pharmacol.* 81: 260-267.

Huan., Z, Luo., J, Xu., Z and Xie., D. 2015. Residues, dissipation and risk assessment of spinosad in cowpea under open field conditions. *Enivorn. Monit. Assess*. 187: 706.

IRAC [Insecticide Resistance Action committee] 2018. IRAC home page [online]. Available: http://www.irac-online.org

Jakhar, B. L., Kumar, S., and Ravindrababu, Y. 2016. Efficacy of different newer insecticides against legume pod borer, *Maruca vitrata* (Geyer) on pigeon pea. *Res. Crops.* 17(1): 134-136.

Jensen, S. E. 2000. Insecticide resistance in the western flower thrips, *Franklieniella occidentalis*. J. *Integrated. Pest. Manag. Rev.* 5: 131-146.

Justin, C. G. L., Anandhi, P., and Jawahar, D. 2015. Management of major insect pests of black gram under dryland conditions. *J. Entomol. Zool. Stud.* 3(1): 115-121.

Kamble, P. P., Kulkarni, S. R. and Patil, S. K. 2014. Efficacy of newer combination insecticides against shoot and fruit borer, *Earias vittella* (F.) on okra. *Pest manag. Hortic. Ecol. syst.* 20 (2): 242-244.

Kar, A., Mandal, K., and Singh, B. 2013. Environmental fate of chlorantraniliprole residues on cauliflower using QuEChERS technique. *Environ. Monit. Assess.* 185: 12551263.

Kartikeyan, K., Purushothaman, S. M., Smitha, S. G., and Ajish, P. G. 2012. Efficacy of a new insecticide combination against major pests of paddy. *Indian. J. Plant Prot.* 40 (4): 276-279.

Karuppaiah, V., Srivastava, C., and Subramanian, S. 2017. Toxicity and effectiveness of newer insecticides, conventional insecticides mixtures to field populations of *Spodoptera litura* (Noctuidae: Lepidoptera). *J. Entomol. Zool. Stud.* 5(6): 1893-1897.

Kattula, S. Y., Pandya, H. V, Kumar, S. S., and Kumar, S. G. 2017. Efficacy of different combination of insecticides against cowpea pod borer in cowpea [*Vigna ungiculata* (L.) Walp]. *Int. J. Curr. Microbiol. Appl. Sci.* 6 (6): 2030-2037.

KAU (Kerala Agricultural University) 2016. *Package of Practices Recommendations: Crops* 15th edition. Kerala Agricultural University, Thrissur, 392p.

Kaushik, A. K., Yadav, S. K., and Srivastava, P. 2016. Field efficacy of insecticides and mixture against spotted pod borer, *Maruca vitrata* (Fab.) on Cowpea. *Ann. Pl. Protec. Sci.* 24(1): 89-92.

Kaushik, D., and Pal, D. P. B 2006. Bio-efficacy of different insecticides against pod borer complex in pigeon pea. *Environ. Ecol.* 24: 184-186.

Kooner, R., Sahoo, S. K., Singh, B. and Battu, R.S. 2010. Dissipation kinetics of flubendiamide and thiacloprid on tomato (*Lycopersicon esculentum* Mill) and soil. *Qual. Assurance. Saf. Crops. Food.* 75:36-40

Kousika, J., Krishnamoorthy, S. V., and Raghumoorthi, K. N. 2015. Efficacy of insecticide mixture Chlorantraniliprole 4.3% + Abamectin 1.7 % SC against tomato pest complex. *Indian J. Entomol.* 77 (1): 56-65

Kulkarni, A. P., and Hodgson, E. 1980. Metabolism of insecticides by mixed function oxidase systems. *Pharmacol. Therapy*. 8: 379-475.

Kumar, N. N., Srinivasulu, D. V, and Sudarshan, P. 2015a. Bio-efficacy of Modern Insecticides against *Spodoptera litura* (Fab.) on Groundnut. *Int. J. Agric. Innov. Res.* 4 (3): 2319-2323

Kumar, S., Durairaj, C., Ganapathy, N., and Kumar, M. S. 2015b. Field evaluation of newer insecticide molecules and botanicals against pod borers of Red gram. *Legume. Res.* 38 (2): 260-267.

Kumar, S., Durairaj, C., Ganapathy, N., and Mohankumar, S. 2014a. Field efficacy of newer insecticides against legume pod borer, *Maruca vitrata* in Green gram. *Indian J. Plant. Prot.* 42(1): 1-5.

Kumar, S., Pal, S., Lal, G., Singh, D. K., and Umrao, R. S. 2014b. Bio-efficacy of insecticides and bio-pesticides against pod borer and jassids on Cowpea, *Vigna uniguiculata* (L.) *Ann. Pl. Protec. Sci.* 22(2): 264-267.

Mallapur, C. P., Chouraddi, M., Nayaka, P., Dhanalakshmi, D. N., and Balikai, R. A. 2012. Evaluation of insecticides against insect pest complex of okra. *Bioinfolet*. 9(3): 360-367.

Mallet, J. 1989. The evolution of insecticide resistance: have the insects won. *Tree.* 4: 336-340.

Mallikarjunappa, S., Kendappa, G. N. and Ganesh Bhat, U., 2008, Flubendiamide 20% WG- a novel insecticide for the control of rice stemborer, *Scirphophaga incertulas* and leaf folder *Cnaphalocrosis medinalis*. In Coleman memorial

National Symp. on Plant prot. 4-6, December, Univ. Agric. Sci., GKVK, Bangalore.

Mandal, K., Chahil, G. S., Sahoo, S. K., Battu, R. S. and Singh, B. 2010. Dissipation Kinetics of Beta cyfluthrin and Imidacloprid in Brinjal and Soil Under Subtropical Conditions of Punjab, India. *Bull Environ Contam Toxicol.* 84:225-229.

Mani, G.S. 1985. Evolution of resistance in the presence of two insecticides. Genetics. 109:761-783.

Manu, N., Patil, R. H., and Balikai, R. A. 2014. Efficacy of newer insecticides, biopesticides and poison baits against leaf eating caterpillars of soybean. *Karnataka J. Agric. Sci.* 27(2): 139-144.

Maruthi, M. S., Hanumanthaswamy, B. C., Sharanabsappa, and Adivappar, N. 2017. Evaluation of safer insecticides against *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae) on capsicum under naturally ventilated polyhouse condition. *J. Entomol. Zool. Stud.* 5(6): 268-271.

Mohapatra, S. D., and Srivastava, C. P. 2002. Bio-efficacy of chemical and biorational insecticide es against incidence of legume pod borer, *Maruca vitrata* (Geyer) in short duration pigeon pea. *Indian J. Plant Prot.* 30 (1): 22-25.

Narayanamma, V. L., and Reddy, K. D. 2014. Evaluation of newer insecticide molecules against lepidopteran pests in castor. *Indian J. Entomol.* 76(4): 273-278.

Owolabi, A. O., Ndidi, U. S., James, B. D., and Amune, F. A. 2012. Proximate, antinutrient, and mineral composition of five varieties of cowpea, Vigna unguiculate, commonly consumed in Samaru community, Zaria-Nigeria. *Asian. J. food. Sci. Tech.* 4(2): 70-72.

Oyewale, R. O., and Bamaiyi, L. J. 2013. Management of cowpea insect pests. *Sch. Acad. J. Biosci.* 1(5): 217-226.

Panse, V. G. and Sukhatme, P. V. 1967. *Statistical Method for Agricultural Workers.* Second edition. Indian Council of Agricultural Research. New Delhi, 381p.

Parmar, K. D., Singh, S., Shah, P. G., Joshi, M. N., Panchal, R. R. and Patel, A. R. 2012. Persistence of Flubendiamide and Thiacloprid in / on Chilli under Middle Gujarat Condition. *Pestic. Res. J.* 24 (1): 51-54.

Parmar, R. V., Chawla, S., Patel, G., Parmar, K. D., Patel, A. R., Patel, J. and Shah, P. G. 2016. Residues of Combination Product of Flubendiamide 24%+ Thiacloprid (24%) (480 SC) in Immature (green) and Mature pods of Red Gram and its Risk Assessment. *Pestic. Res J.* 28(1): 68-75.

Patel, D. J., Singh, S., Vaghela, K. M., Diwan, K. D. And Shah, P. G. 2012. Dissipation of Beta cyfluthrin and Imidacloprid on Okra Fruits under Middle Gujarat Conditions. *Pestic. Res. J.* 24(2): 183-187.

Patel, P. S., Patel, I. S., Panickar, B., Ravindrababu, Y., Gujarat, S., and Kharif, S. 2012. Management of Spotted Pod borer, *Maruca vitrata* in Cowpea through newer insecticides field experiment. *Trends Biosci.* 5(2): 149–151.

Patel, S. A. and Patel, R. K. 2013. Bio-efficacy of newer insecticides against pod borer complex of pigeon pea [*Cajanus cajan* (L.) millspaugh]. AGRES – An International e-Journal. 2 (3): 398-404.

Patil, P. P., Mohite, P. B., and Chormule, A. J. 2015a. Bio-efficacy of Some Newer Insecticides against Leaf Eating Caterpillar (*Spodoptera litura* Fab.) infesting soybean. *Pestic. Res. J.* 27(2): 271-276.

Patil, P. P., Mohite, P. B., and Chormule, A. J. 2015b. Bio-efficacy of insecticides as seed dressers against leaf eating caterpillar, *Spodoptera litura* (Fab.) infesting soybean. *Ann. Pl. Protec. Sci.* 23(1): 9-11.

Patil, S., Sridevi, D., Babu, T. R., and Pushpavathi, B. 2017. Relative efficacy of selected insecticides on cowpea aphid, *Aphis craccivora* (Koch) *J. Entomol Zool. Stud.* 5(5): 1603-1607.

Priyadarshini, G., Reddy, C. N., and Reddy, D. J. 2013. Bio-efficacy of selective insecticides against lepidopteran pod borers in pigeon pea. *Indian. J. Plant Prot.* 41(1): 6-10.

Rajasekar, B. and Sridevi, G. 2017. Biology and efficacy of insecticides against tobacco caterpillar, *Spodoptera litura* (Fabricius) on castor leaves. *Bull. Eniron. Pharmacol. Life Sci.* 6(8): 24-27.

Rajawat, I. S., Alam, M. A., Kumar, A., Tiwari, R. K., and Jaiswal, S. K. 2017. Efficacy of new molecules of insecticides against white fly *Bemisia tabaci* (Gennadius) and aphid *Aphis craccivora* (Koch) in Urdbean (*Vigna mungo* L.) *Indian. J. Agric. Res.* 51(5): 502-505.

Ramasubramanian, T., Paramasivam, M., Salin, K. P., and Jayanthi, R. 2012. Dissipation kinetics of chlorantraniliprole in soils of sugarcane ecosystem. *Bull. Environ. Contam. Toxicol.* 89: 1268-1271.

Randhawa, H. S., and Saini, M. K. 2015. Efficacy of different insecticides against pod borer, *Maruca vitrata* (Geyer) in pigeon pea, *Legume Res.* 38(5): 687-690.

Rani, C. S. and Eswari, K. B. 2008. Evaluation of some newer insecticides against maruga on green gram. *Asian J. Biosci.* 3(2): 346-347.

Rani, O.P.R. 2001. Production and evaluation of the fungus *Fusarium pollidoroseum* (Cooke) Sacc. as a biopesticide against pea aphid *Aphis craccivora* Koch. Ph. D. thesis. Kerala Agricultural University. 140 p

Reddy, A. V., Srihari, G., and Kumar, A. K. 2014a. Newer insecticides against pod borer *Spodoptera litura* and thrips *Scirtothrips dorsalis* in chilli (Capsicum annuum L.). *Pestic. Res. J.* 26(1): 74-77.

Reddy, D. S., Latha, M. P., Chowdary, R. L., and Kumar, R. L. 2014b. Efficacy of chemical and botanical against cowpea aphid [*Aphis craccivora* (Koch)]. *Bioinfolet.* 11(3B): 853-854.

Reghupathy, A. and Satyaseelan, V. 2011. Bio-efficacy of Ampligo 150 ZC (Chlorantraniliprole+Lambda-cyhalothrin) against Cotton Bollworm *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) [abstract]. In: Abstracts, World Cotton Research Conference on Technologies for Prosperity. 7-11 November, 2011, Renaissance Convention Centre, Mumbai, p.133. Abstract No. Poster no-70.

Roush, R. T. 1993. Occurrence, genetics and management of insecticide resistance. *Parasitology Today* 9: 174-179.

Roy, D., Chakraborty, G., and Sarkar, P. K. 2017. Comparative efficacy, non-target toxicity and economics of seven novel premixed formulations against *Maruca testulalis* G. and *Aphis craccivora* K. infesting cowpea. *J. Environ. Biol.* 38: 603-609.

Samanta, A., Alam, S. K. F., Patra, S., Sarkar, S., and Dey, P. K. 2017. Efficacy of Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5 % ZC against est Complex of tea in west bengal. *Pestic. Res. J.* 29 (2): 230-235.

Sasmal, A., and Kumar, S. 2016. Effect of insecticides against major sucking pests of Green gram in Coastal Odisha, *Ann. Pl. Protec. Sci.* 24(2): 276–282.

Sen, K., Samanta, A., Alam, S. K. F., and Dhar, P. P. 2017. Field evaluation of a New Ready-Mix Formulation Lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC) against Shoot and Fruit Borer (*Leucinodes* *orbonalis* Guen.) infestation in Brinjal. *J. Pharmacogn. Phytochem.* 6(5): 1674-1678.

Singh, S. P., Lal, K. M., and Kiran. 2007. Residues of lambda cyhalothrin in Okra and the effect of processing. *Pestic. Res J.* 19 (1): 98-100.

Singh, S., Shah, P. G., Patel, A. R., Patel, D. J. and Saiyad, M. S. 2009. Dissipation studies of β-cyfluthrin and imidacloprid as combination product in Brinjal (*Solanum melongena* L.) *Pestic. Res. J.* 21(2): 155-158.

Skylakakis, G. 1981. Effects of alternating and mixing pesticides on the build-up of fungal resistance. *Phytopathol.* 71: 1119-1121.

Sonune, V. R., Bharodia, R. K., Jethva, D. M., Rathod, R. T., and Deshmukh, S. G. 2010. Field efficacy of chemical insecticides against spotted pod borer, *Maruca vitrata* (F.) infesting black gram. *Legume Res.* 33(4): 287-290.

Soratur, M., Rani, D. D., Naik, S. M., and Jagadeesh, K. S. 2017. Efficacy of selected insecticides against aphids and Leaf hoppers in Cowpea (*Vigna unguiculata* (L.) Walp.) *J. Entomol. Zool. Stud.* 5(5): 281-284.

Sreelakshmi, P. 2017. Characterization and management of insecticide resistance in *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) Ph.D. thesis. Kerala Agricultural University.190 p.

Sreelakshmi, P., Paul, A., Beevi, N. S., Sheela, M. S., and Kumar, P. N. 2016. Management of resistant populations of legume pod borer, *Maruca vitrata* (Fab.) (Lepidoptera: Crambidae) using new generation insecticides. *Environ. Ecol.* 34(3): 917-921.

Sridhar, Y. and Sharma, A. N. 2013. Field Efficacy of Thiamethoxam and Lambda cyhalothrin Ready Mix Formulation, Alika 247 against Major Insect Pests of Soybean. *Indian J. Plant Prot.* 41(3): 202-205.

Srujana, Y. and Keval, R. 2014. Evaluation of insecticides against lepidopterous pod borers in pigeon pea. *Bioinfolet.* 119(2): 618-619.

Sujatha, B. and Bharpoda, T. M. 2017. Evaluation of insecticides against sucking pests grown during kharif. *Int. J. Curr. Microbiol. Appl. Sci.* 6(10): 1258-1268.

Sunda, N. R., Kumar, A., Bajpai, N. K., and Mandarwal, N. 2015. Investigations on the field bio-efficacy of some newer insecticides against insect pests of brinjal (*Solanum melongena* L.). *Ann. Agric. Res.* 36(4): 421-428.

Surpam, A. N., Neharkar, P. S., Shubhangi, P. B., Kamdi, S. R. and Kadam, B. S. 2015. Bioefficacy of new combi product against sucking pests of cotton. *Adv. Res. J. crop Improv.* 6(2): 170-177.

Swami., Hemant., Ameta, O. P., and Lekha. 2017. Bioefficacy of novel insecticides against pod borer, (*Helicoverpa armigera* Hubner) in pigeon pea. *Legume Res.*40(4): 756-761.

Tabashnik, B. E. 1989. Managing resistance with multiple pesticide tactics: theory, evidence, and recommendations. *J. Econ. Entomol.* 82: 1263-1269.

Tatagar, M. H., Mohankumar, H. D., Mesta, R. K., and Shivaprasad, M. 2014. Bio-efficacy of new molecule, Flubendiamide 24 % + Thiacloprid 24 % - 48 % SC against Chilli thrips, *Scirtothrips dorsalis*. *Karnataka J. Agric. Sci.* 27(1): 26-28.

Tatagar, M. H., Mohankumar, H. D., Shivaprasad, M., and Mesta, R. K. 2009. Bio-efficacy of flubendiamide 20 WG against chilli fruit borer, *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (F.) *Karnataka J. Agric. Sci.* 27(3): 579-581.

Thamilarasi, N. 2016. Management of pests of cowpea and salad cucumber in polyhouse. M. Sc.(Ag.,) thesis, Kerala Agricultural University, Thrissur, 156 p.

Vijayasree, V. 2013. Efficacy and Biosafety of new generation insecticides for the management of fruit borers of cowpea. Ph.D. thesis. Kerala Agricultural University. 220.p.

Vijayasree, V., Bai, H., Beevi, N.S., Mathew, T. B., Kumar, V., George, T., and Xavier, G. 2013. Persistence and Effects of Processing on Reduction of Chlorantraniliprole Residues on Cowpea Fruits. *Bull. Environ. Contam. Toxicol.* 90: 494-498.

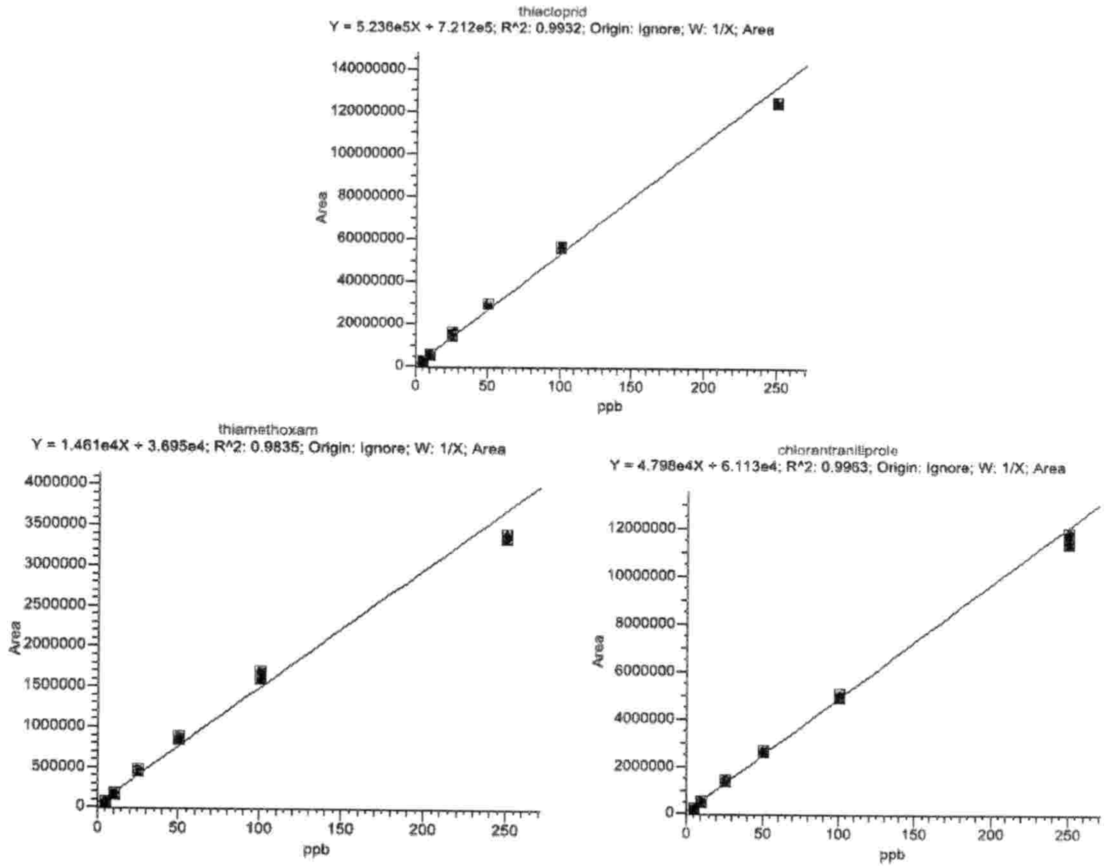
Viroja, K. J. 2003. Efficacy of conventional insecticides for management of Pod borers in Indian bean. M. Sc. (Ag.,) thesis, Junagadh Agricultural University, Junagadh, 159 p.

Wadaskar, R. M., Bhalkare, S. K., and Patil, A. N. 2013. Field efficacy of newer insecticides against pod borer complex of pigeon pea. *J. Food. Legumes.* 26 (1):62-66.

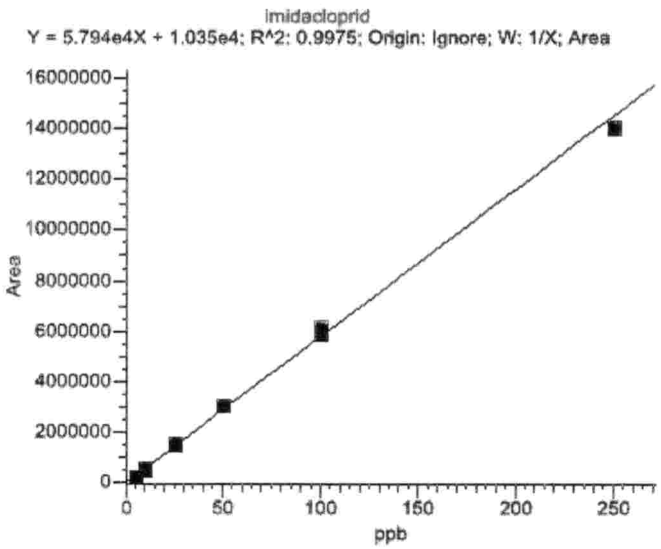
WHO [World Health Organisation]. 2009. Principles and methods for risk assessment of chemicals for food. Environmental Health Criteria, 240.World Health Organisation.

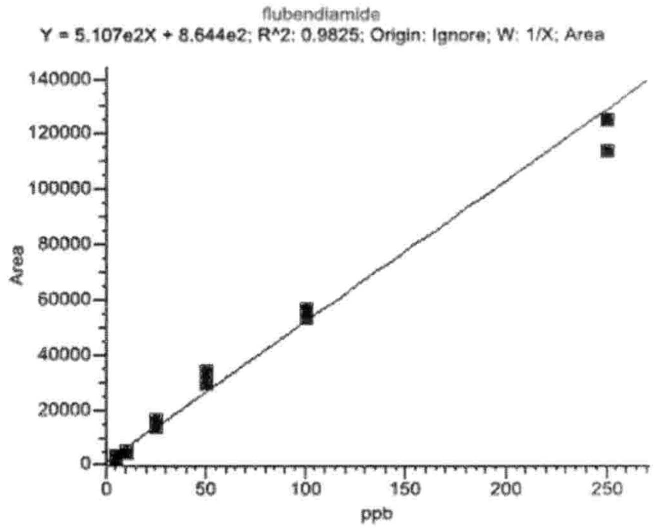
Yadav, N. K., and Singh, P. S. 2014. Bio-efficacy of chemical Insecticides against Spotted Pod Borer, *Maruca testulalis* (Geyer) on Cowpea. IJAEB: 7(1): 187-190.

Yadav, S. K., Agnihotri, M., and Bisht, R. S. 2015. Efficacy of insecticides and bio-pesticides against defoliators and spotted pod borer, *Maruca vitrata* in Black gram. *Ann. Pl. Protec. Sci.* 23 (1): 65-68.



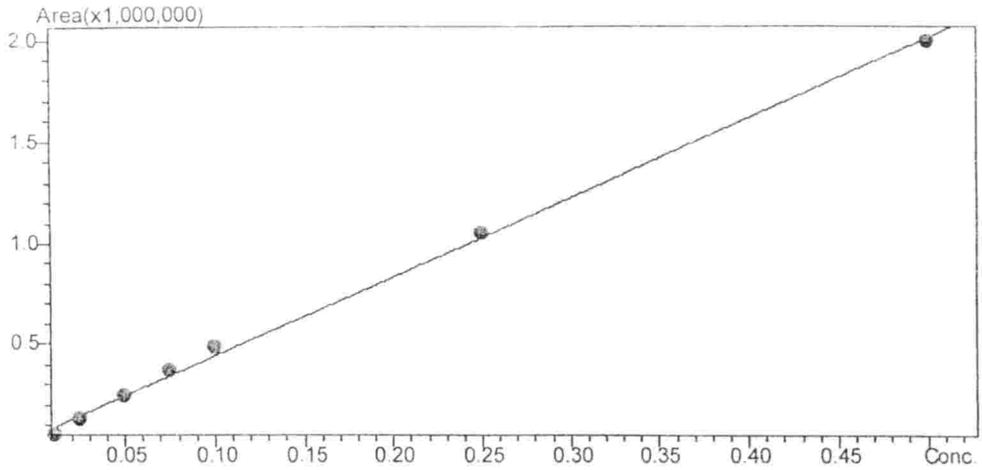
Appendix – I. Calibration curve of thiacloprid, thiamethoxam and chlorantraniliprole





Appendix – II. Calibration curve of imidacloprid and flubendiamide

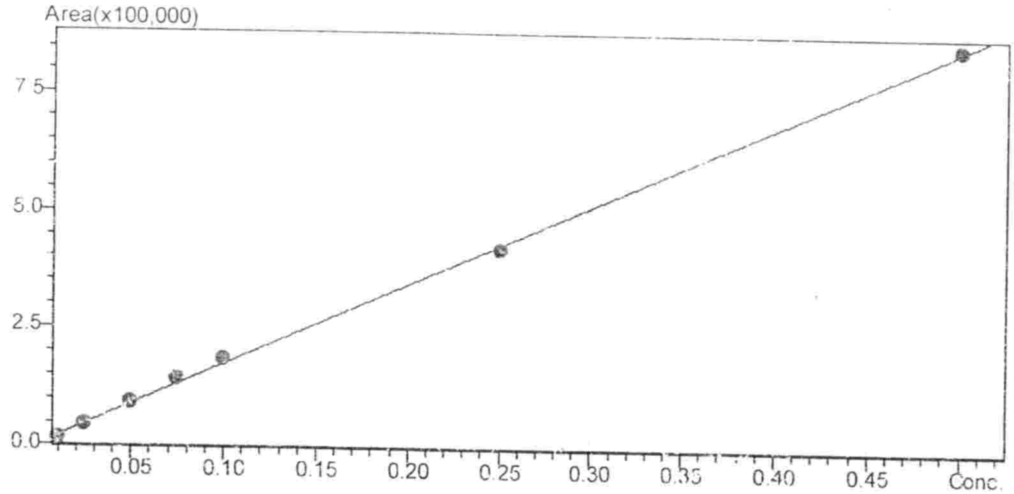
Appendix-III



Y = aX + b, a = 3908186, b = 51866.38, R^2 = 0.9982965, R = 0.9991479

Mean RF: 4706060, RF SD : 431378.8, RF %RSD : 9.166453

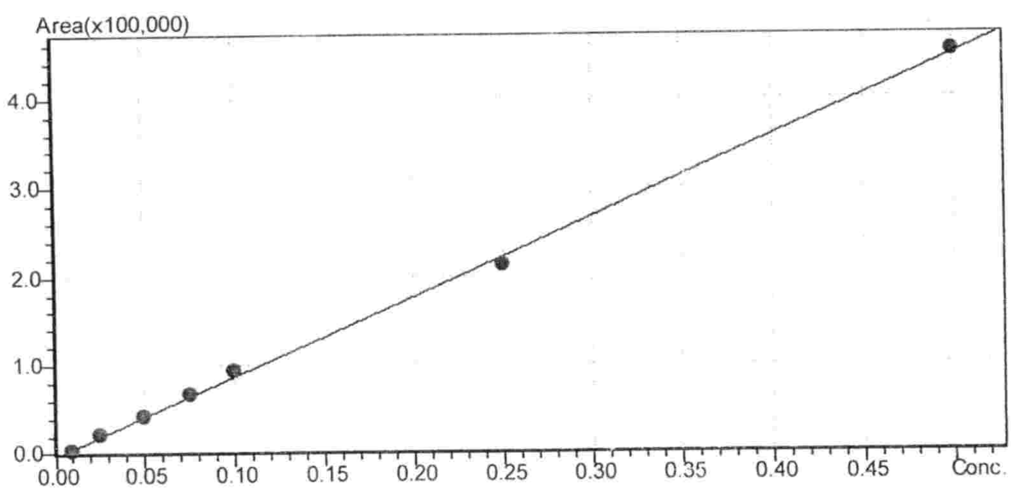
Calibration curve of Lamda cyhalothrin



Y = aX + b, a = 1698558, b = 4623.756, R^2 = 0.9993948, R = 0.9996973

Mean RF : 1724553, RF SD : 169509.3, RF %RSD : 9.829173

Calibration curve of Beta cyfluthrin-1

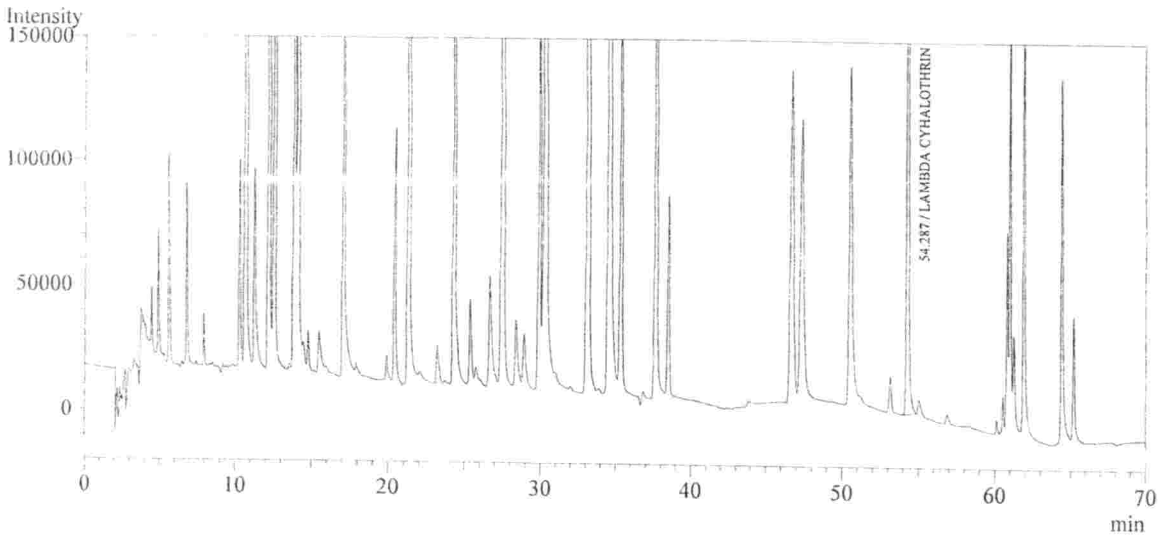


Y = aX + b, a = 901980.9, b = -2976.782, R^2 = 0.9991185, R = 0.9995592

Mean RF : 808221.3, RF SD : 160935.0, RF %RSD : 19.91224

Calibration curve of Beta cyfluthrin-2

Appendix –V

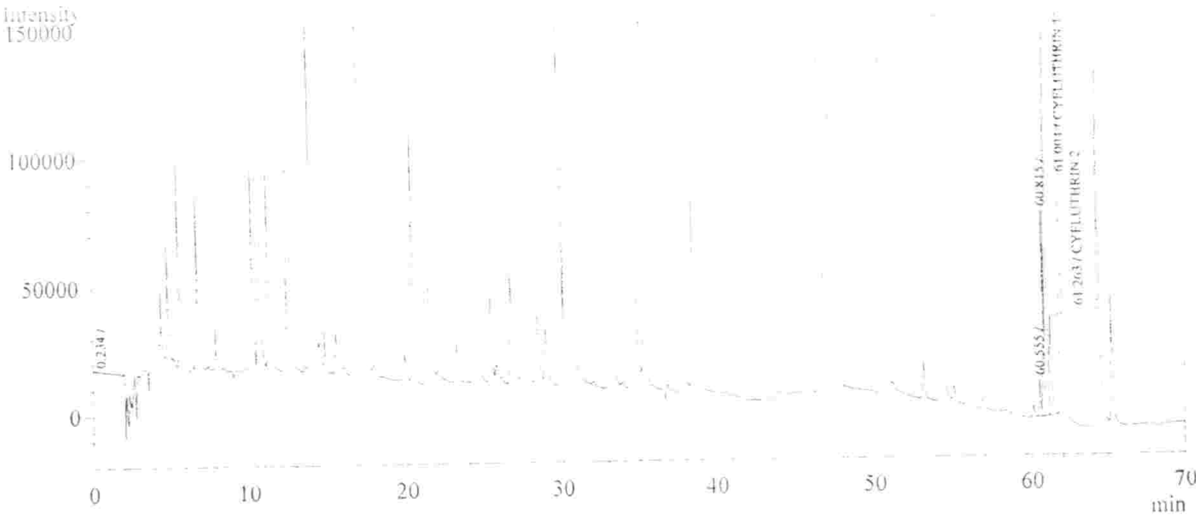


Peak Table - Channel 1

Peak#	Name	Ret.Time	Area	Conc.	Units
1	LAMBDA CYHALOTHRIN	54.287	2770576	0.667	ppm
Total			2770576		

GC-ECD chromatogram of lambda cyhalothrin

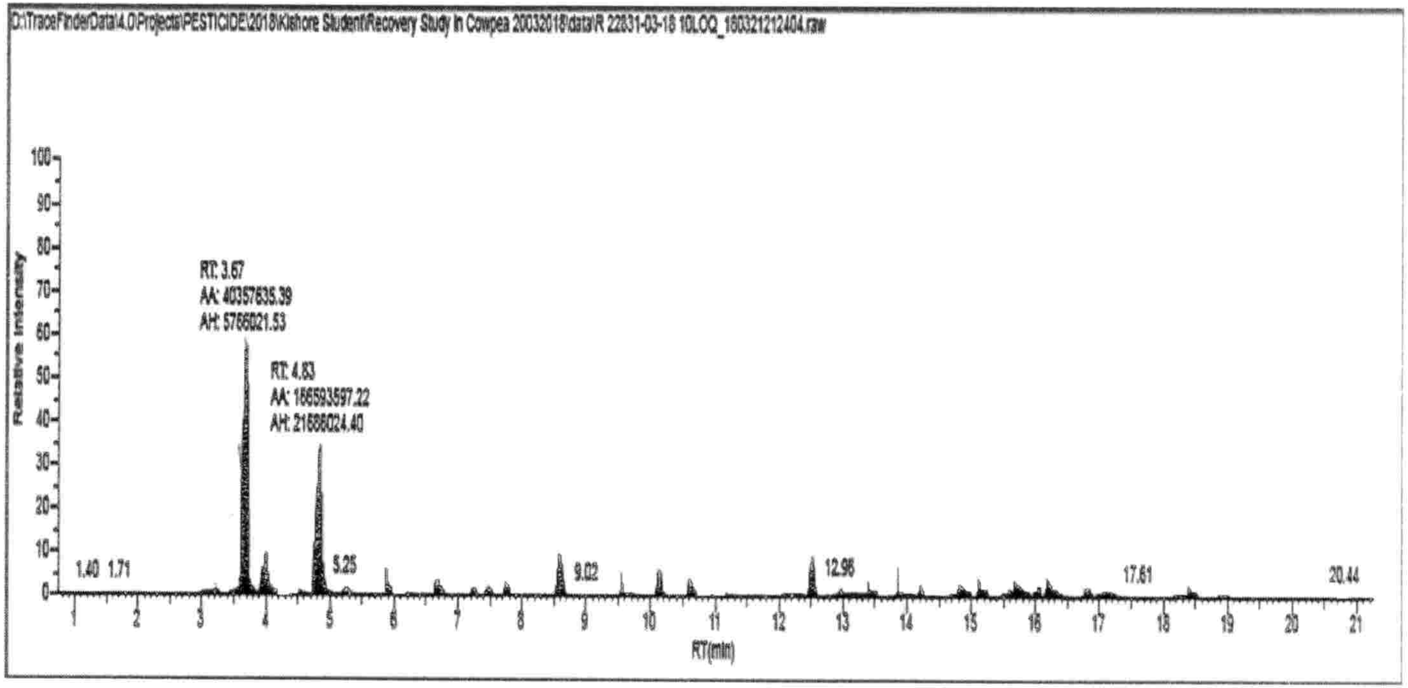
Appendix -VI



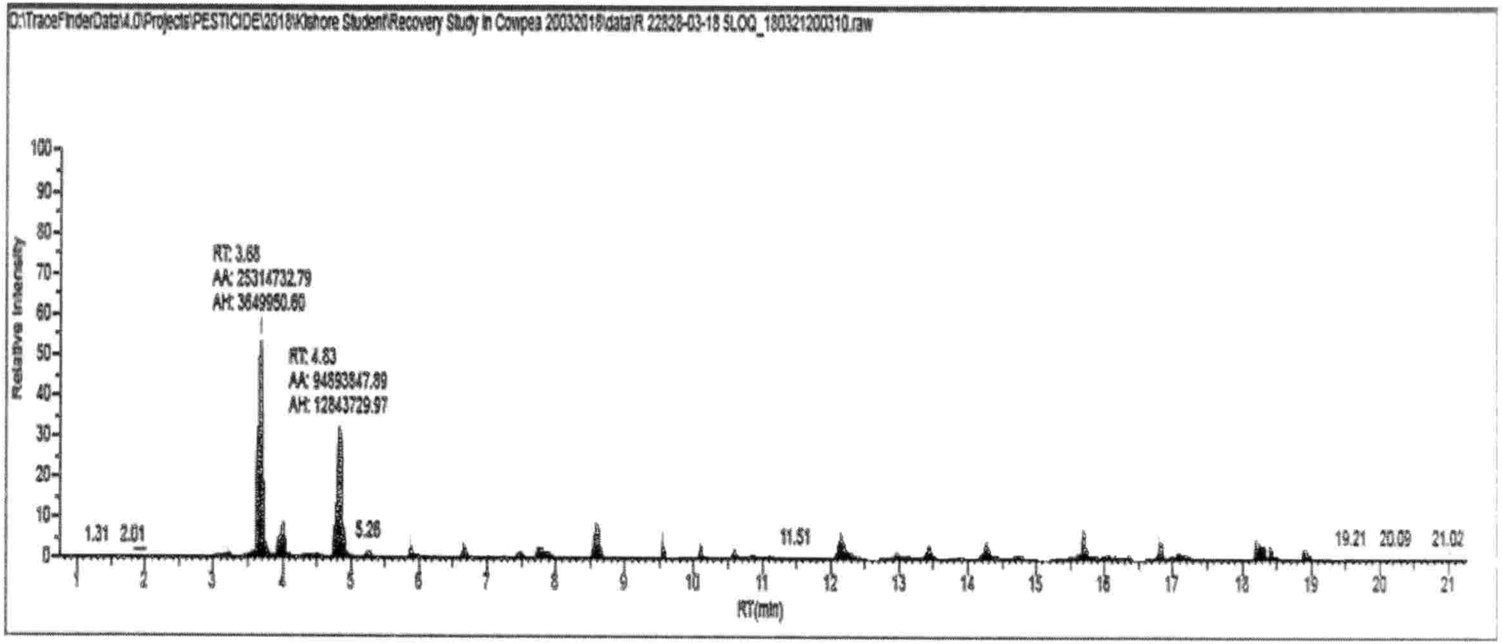
Peak Table - Channel 1

Peak#	Name	Ret.Time	Area	Conc.	Units
1		0.234	1098	0.000	
2		60.555	102682	0.000	
3		60.815	521774	0.000	
4	CYFLUTHRIN 1	61.004	1286097	0.709	ppm
5	CYFLUTHRIN 2	61.263	377908	0.406	ppm
Total			2289559		

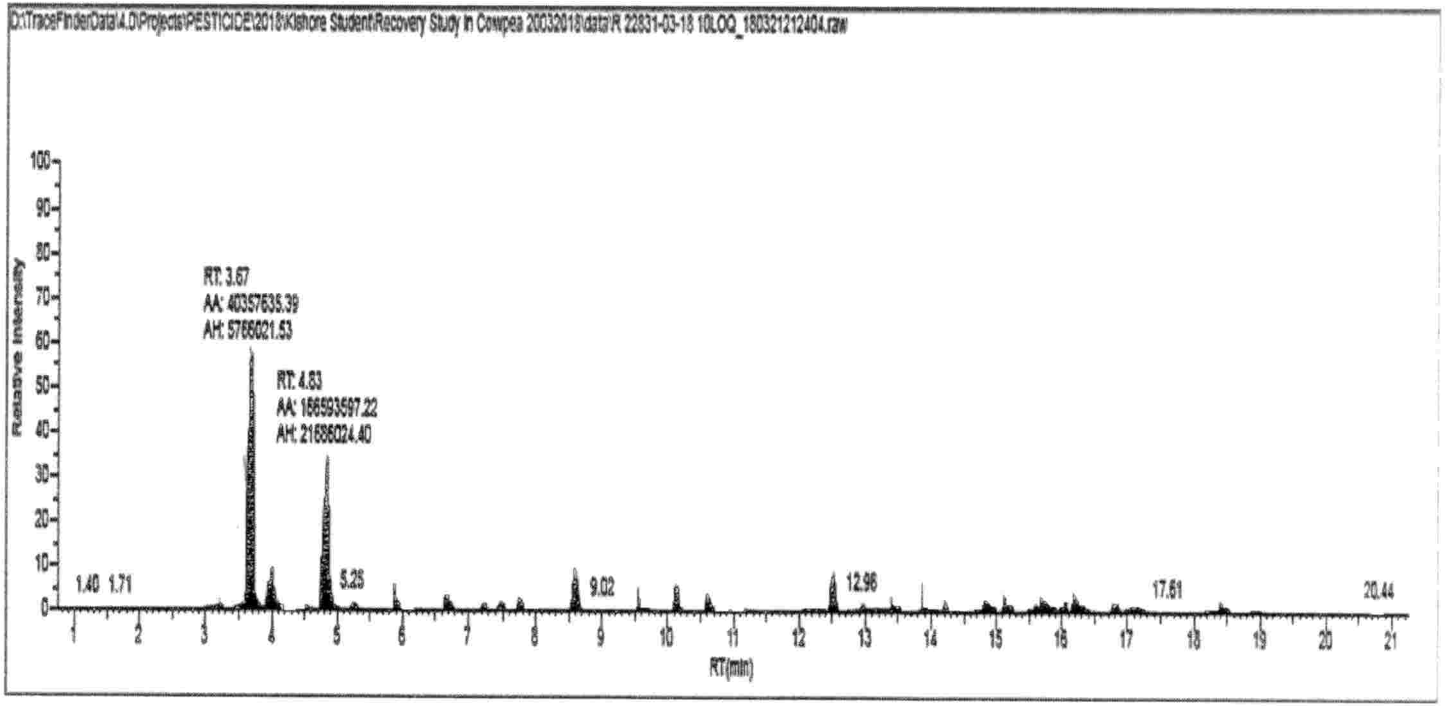
GC-ECD chromatogram of beta cyfluthrin



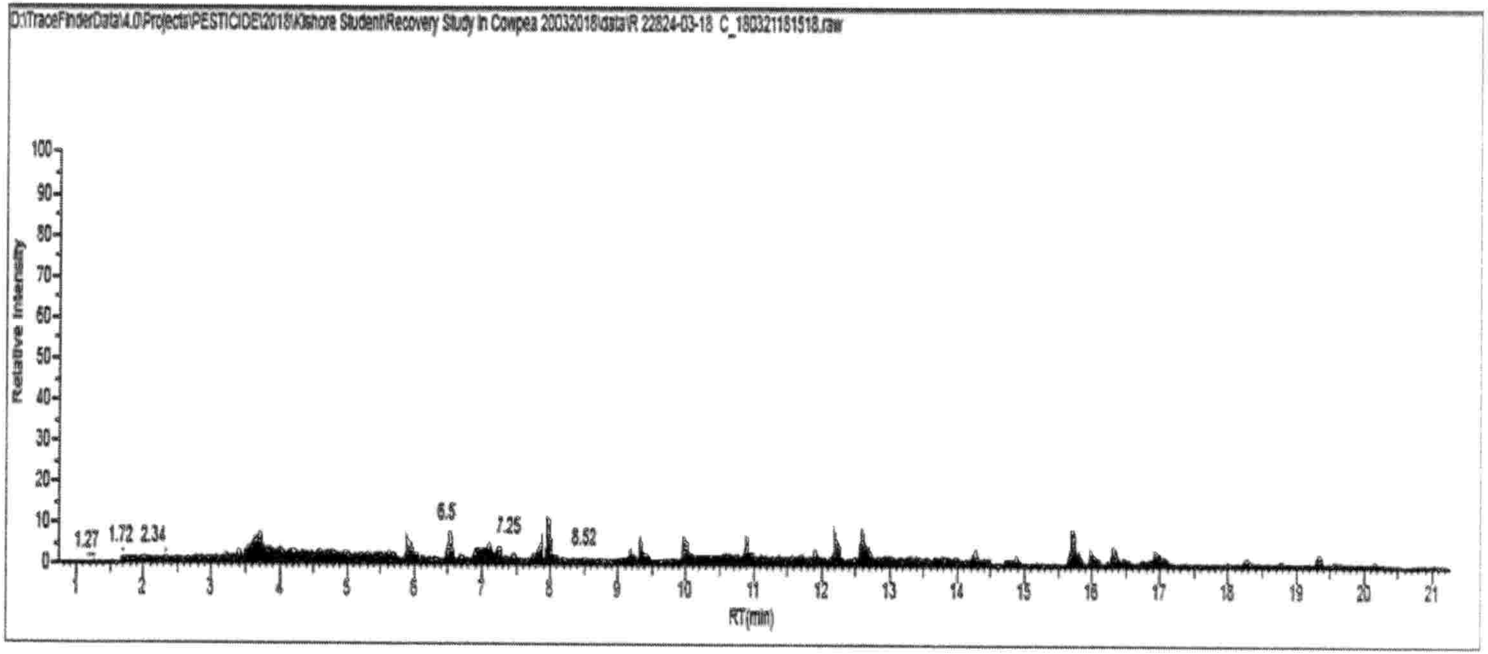
Appendix – VII. LC-MS/MS chromatogram of insecticides at LOQ



Appendix – VIII. LC-MS/MS chromatogram of insecticides at 5 LOQ



Appendix –IX. LC-MS/MS chromatogram of insecticides at 10 LOQ



Appendix – X. LC-MS/MS chromatogram of insecticides (Control)

INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN COWPEA

by

BANKA KANDA KISHORE REDDY

(2016-11-051)

ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

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ABSTRACT

A study on "Insecticide mixtures for the management of pest complex in cowpea" was undertaken in College of Agriculture, Vellayani and in the farmers field at Kalliyoor during 2016 to 2018. The main objectives were to evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of cowpea and to study the dissipation pattern of mixtures in cowpea pods. Major pests documented in the experimental field were sucking pests *viz*., pod bug, *Riptortus pedestris* Fabricius, cowpea aphid, *Aphis craccivora* Koch, spotted pod borer, *Maruca vitrata* Fabricius, and leaf eating caterpillar, *Spodoptera litura* Fabricius.

Experiment was laid out in RBD to study the efficacy of insecticide mixtures *viz.,* chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC 15.75+36.7 g a.i ha^{-1}, flubendiamide 19.92 % + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1}, chlorantraniliprole 18.5 % SC +thiamethoxam 25 % WG (hand mixed) @ 1:1 @ 0.30 mL L^{-1} along with standard checks chlorantraniliprole 18.5 % SC @ 30 g a.i ha^{-1} and thiamethoxam 25 % WG @ 0.30 g L^{-1} against cowpea pests (Cowpea variety- Vellayani Jyothika).

The results of the study revealed that chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} was found effective in managing the population of pod bug, *R. pedestris,* followed by thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} and beta cyfluthrin 8.49 % + imidacloprid 19.81 % SC @ 15.75+36.7 g a.i ha^{-1}. Less incidence of bug was found in effective treatments after 7 days of spraying. More or less similar result was obtained in the management of cowpea aphid, *A. craccivora.* Less number of aphid was observed in the plants treated with chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @

150 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1}, chlorantraniliprole 18.5 % SC + thiamethoxam 25 % WG (hand mixed) @ 1:1 @ 0.30 mL L^{-1} and thiamethoxam 25 % WG @ 30 g a.i ha^{-1} against 211.67 aphids $plant^{-1}$ in control after 15 days of spraying. Significantly higher reduction in leaf damage by *S. litura* was recorded in plants treated with lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} (25.03) which was on par with thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} (26.46) and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} (30.20) 10 days after spraying. Whereas, in the management of cowpea pod borer, *M. vitrata,* less incidence of larvae was found in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} and chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1} treated plants after 5 days of spraying against 6.67 larvae in control.

Dissipation of residues of these effective insecticide mixtures were studied by analysing the pods collected at 0, 1, 3, 5, 7, 10 and 15 days after treatment and the result showed that both the single insecticides in chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC were dissipated within ten days with half-lives of 5.34 and 3.01 respectively and in lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC, lambda cyhalothrin dissipated in five days and chlorantraniliprole dissipated in seven days with half-lives of 5.58 and 13.67 days respectively.

The infestation of sucking pests, borers and leaf feeders simultaneously occur in cowpea especially in pod bearing stage. The results of the study revealed that spraying chlorantraniliprole 8.8 % + thiamethoxam 17.5 % SC @ 150 g a.i ha^{-1}, thiamethoxam 12.6 % + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} and lambda cyhalothrin 4.6 % + chlorantraniliprole 9.3 % ZC @ 30 g a.i ha^{-1} could effectively manage pest complex in cowpea with minimal or no risk to the consumers.