INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN BRINJAL

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN BRINJAL"** 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.

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(Bista Jeba Bakthiyar)

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LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
a.i.	Active ingredient
BDL	Below detectable limit
BQL	Below quantification level
C.D.	Critical Difference
CIB &RC	Central Insecticide Board and Registration committee
DAS	Days after spraying
EC	Emulsifiable concentrate
et al	And others
g	Gram
GC-MS	Gass chromatography mass spectroscopy
ha^{-1}	per hectare
HPLC	High performance liquid chromatography
h	Hour
HAE	Hours after exposition
IRAC	Insecticide resistance action committee
IRM	Insecticide resistance management
kg	Kilogram
L	Litre
LC-MS	Liquid chromatography- Mass spectroscopy
LOQ	Limit of quantification
Mg	Milligram
mL	Millilitre
ppm	Parts per million
QuEChERSB	Quick, easy, cheap, effective, rugged and safe.

RBD	Randomized blocked design
SC	Suspension concentrate
SL	Soluble Liquid
SP	Soluble Powder
sp	Species
viz.,	Namely
WG	Wettable granules
ZC	Zeon capsules

Introduction

1. INTRODUCTION

Brinjal (*Solanum melongena* L.) is an economically important vegetable crop, popularly known as egg plant. It is native of Indian sub-continent, with India as the centre of origin (Gleddie *et al.,* 1986). In India the area under brinjal cultivation is estimated as 680 thousand ha with a production of 12706 MT. Whereas, in Kerala the area under brinjal cultivation is estimated as 1.57 thousand ha with 20.30 MT of production (GOI, 2018).

The major constraint in the cultivation of brinjal is pests and diseases. More than 150 insect pests were reported right from nursery stage to till harvesting, if left unchecked, often result 100 per cent crop loss. Among the insect pests infesting brinjal, the major ones are shoot and fruit borer, *Leucinodes orbonalis* (Guen.), epilachna beetle, *Epilachna vigintioctopunctata* (Fab.), whitefly, *Bemisia tabaci* (Genn.), leaf hopper, *Amrasca biguttula biguttula* (Ishida.) and mealy bug, *Coccidohystrix insolita* (Green.) (Tewari, 1986). Dhankar *et al.* (1997) reported 63 per cent yield loss due to shoot and fruit borer alone. Infestation by leaf hopper, whitefly and shoot and fruit borer results in about 70-92 per cent loss in yield of brinjal (Rosaiah, 2001). The brinjal mealy bug, *C. insolita* once a minor pest has assumed status of serious pest in brinjal (Saminathan *et al.,* 2010). Depending on the intensity of infestation the loss carried by sucking pests varies from 10-15 per cent (Munde *et al.,* 2011).

A wide range of insecticides have been proven to be effective in reducing the pest population. To contain these pests, farmers are applying various insecticides simultaneously at unreliable doses and resulted in development of pest resistance, resurgence, outbreak of secondary pest and destruction of natural enemies along with pollution of environment. Recently, different pesticide firms have formulated various insecticide mixtures which are the best alternatives to solve the above problems.

These insecticide mixtures can pay attention of sap sucking pests as well as leaf feeders/ chewing pests by different mode of action. Insecticide mixtures may offer benefits for Insecticide Resistance Management (IRM) when appropriately incorporated into rotation strategies with additional mode of action, but generally a single mixture should not be relied upon alone. According to Central Insecticide Board and Registration Committee, there are 67 insecticide mixtures registered in India till date (CIBRC, 2019). Insecticides mixtures provide technical advantage for controlling the 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.

Studies have established that insecticide mixtures increases the efficacy against insect pests such as aphids, thrips and jassids in okra (Mallapur *et al.,* 2012), thrips in chilli (Tatagar *et al.,* 2014) whiteflies, jassids and borers in brinjal (Sunda *et al.,* 2015), thrips and aphids in cotton (Surpam *et al.,* 2015), compared with individual application of insecticide. However, no studies have been carried out in Kerala on the bio efficacy of insecticide mixtures against pests of brinjal, hence present investigation is proposed. Moreover, studies on pesticide residue in brinjal fruits based on the harvest time residue would ensure the safety of the products to the consumers.

Keeping this in view, the study entitled "Insecticide mixtures for the management of pest complex in brinjal" was undertaken with the following objectives,

- To evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of brinjal.
- To find out the harvest time residues in fruits.

Review of literature

2. REVIEW OF LITERATURE

Brinjal, is one of the most commonly grown solanaceous vegetable and economically important vegetable in South Asia. Brinjal is infested with a complex of pests which leads to significant loss in yield. Information on the management of pest complex in brinjal using insecticide mixtures is meagre. The available literature related to the present study has been reviewed here.

2.1. PESTS OF BRINJAL

2.1.1. Shoot and Fruit Borer (*Leucinodes orbonalis*)

Brinjal fruit and shoot borer is a destructive and first ranked insect pest in almost all brinjal growing areas of the world. This insect has gained the potential status of pest owing to unique nature of feeding on monophagous diet aided by homing and tunneling behavior, ultimately enabled the insect to face the challenges of chemical pesticides (Hanur *et al.*, 2014).

Females lay eggs on foliage or fruit, on an average of 80 -250. The eggs hatched into larva within 3 to 4 days. Soon after hatching, young caterpillars bore into tender shoots near the growing point, into flower buds, or into the fruits. Caterpillars prefer fruits than other plant parts. Larvae go through five instars, larval period ranges from 7-13 days. The pupal period ranges from 7 to 11 days. (Atwal, 1976 ; Sethi *et al.*, 2016).

In early stage of the crop growth, shoot and fruit borer larva bores in to the shoots resulting in drooping, withering and drying of the affected shoots. During the reproductive stage, larva bores into the flower buds and fruits. The infested bore holes were invariably plugged with excreta. The infested fruits became unfit for consumption due to loss of quality and lose their market value due to secondary infection. The yield loss due to the pest is to the level of 70 to 92 per cent (Reddy and Srinivas, 2004).

2.1.2. Epilachna Beetle (*Epilachna vigintioctopunctata*)

The twenty eight spotted epilachna beetle, *E. vigintioctapunctata* is a notorious polyphagous pest established all over India infesting brinjal and other economically important crops belonging to solanaceae and cucurbitaceae (Rahaman *et. al.,* 2008).

The females lay eggs mostly on the lower leaf surfaces. Each female lays about 120 to 180 eggs. The egg is spindle-shaped and yellowish in colour. Eggs are laid in clusters of 10 to 40. The egg period varies from 2 to 4 days. The grub is creamy white or yellowish in color with black spiny hairs on the body. The grub period is 10 to 35 days. Grubs pupate on the leaves or stem. The pupa resembles the grub but it is mostly darker in color. The pupa bears spiny hairs on the posterior part of the body. The pupal period is one to two weeks. Adults are brownish or orange colored, hemispherical beetles (David and Ramamurthy, 2011).

The grubs and adults have chewing mouth parts and they scrape the chlorophyll from the epidermal layers of the leaves. The feeding resulted in a typical ladder-like window. The windows dry and drop off, leaving holes on the leaves. In severe infestations, several windows coalesce together and lead to skeletonization and formation of a papery structure on the leaf. The attack of epilachna beetle thus significantly hinders the growth and development of the crop accompained by striking yield reduction (Maurice *et. al.,* 2013).

Extensive feeding of epilachna beetle resulted leaf damage up to 80 per cent and reduction in fruit yield up to 60 per cent (Rajagopal and Trivedi 1989; Mall *et. al.,* 1992).

2.1.3. Whitefly (*Bemisia tabaci*)

Das and Islam (2014) reported that whiteflies are important sucking pest of brinjal which are widely distributed in tropical, sub-tropical and temperate regions and cause considerable damage to brinjal plants.

The females lay eggs near the veins on the underside of leaves. Each female lay about 300 eggs. Egg period is 3 to 5 days during summer and 5 to 33 days in winter. Upon hatching, the first instar larva moves on the leaf surface to locate a suitable feeding site and then insert its piercing and sucking mouthpart and begins sucking the plant sap from the phloem. Nymphal period is 9 to 14 days during summer and 17 to 73 days in winter. Adults emerge from puparia through a T-shaped slit, leaving behind empty pupal cases. The whitefly adult is a soft-bodied, moth-like fly. The wings are covered with powdery wax and the body is light yellow in color. Adults live from one to three weeks (David , 2001; Srinivasan, 2009).

Through their piercing and sucking mouth parts both nymphs and adults suck the sap from the leaves and excrete honeydew which cause sooty mold. The damaged leaves showed yellowing, followed by crinkling, curling, bronzing and drying of leaves. In case of severe damage, crop growth and yield are significantly reduced (Kumar *et. al.,* 2017).

Mane and Kulkarni (2011) studied the population dynamics of whitefly in brinjal. With increase in temperature and humidity, there was an increase in the population of whiteflies and vice-versa. Number of rainy days exhibited highest positive direct effect and evening relative humidity showed highest negative direct effect on the population of whiteflies.

2.1.4. Leaf Hopper (*Amrasca biguttula biguttula*)

Dhawan *et al.,* (1988) reported that *A. biguttula biguttula,* is a highly polyphagous pest causing damage to brinjal, cotton, okra, tomato, potato, peppers, cucurbits and other field crops (Shrinivasan and Babu, 2001).

Srinivasan (2009) reported that adult females lay eggs along the midrib and lateral veins of the leaves. The egg period is 4 to 11 days. The nymphs resemble the adults, but lack wings. They are pale green in color. They tend to move side ways when disturbed. The nymphal period varies from one to four weeks depending on the temperature. The adults are wedge-shaped, pale green insects. They have fully developed wings with a prominent black spot on each forewing. The adults live for one to two months.

These leaf hoppers impose direct damage by feeding and indirect damage by vectoring the disease. Both nymphs and adults suck sap from the under leaf surfaces and disrupt transportation in conducting vessels and results in photosynthesis reduction. In case of severe condition all leaves in the plants showed crinkling, hopper burn and cupping symptoms and finally yield reduction. (Ananad *et. al.,* 2013; Das and Islam, 2014).

2.1.5. Brinjal Mealy Bug (*Coccidohystrix insolita*)

Mealy bugs infest the under surfaces of leaves. The adult female have very small dorsal wax and secretes a white, waxy ovisac up to six times as long as the body of the female. The immature instars do not secrete a thick layer of mealy wax, the body being shiny yellow-green with sub median grey spots on two abdominal and one thoracic segments. Adults and nymphs cause damage by sucking the cell sap from the leaves (Moore *et.al.,* 2014).

Now the papaya mealy bug is causing damage to brinjal plants from the early stage to harvesting stage of the crop . Both nymphs and adults suck the sap from the lower leaf surfaces causes withering and yellowing of leaves (Janaki *et. al.,* 2012).

2.2. EFFICACY OF INSECTICIDES AGAINST PESTS OF BRINJAL

Sharma and Lal (2002) studied efficacy of thiamethoxam @ 25 g a.i. ha^{-1} in comparison with beta-cyfluthrin @ 18.75 g a.i. ha^{-1}, deltamethrin @ 20 g a.i. ha^{-1}, profenofos @ 500 g a.i. ha^{-1} and endosulfan @ 700 g a.i. ha^{-1} against *B. tabaci* and *A. biguttula biguttula* in brinjal and the percentage reduction of whitefly population was 94.80, 93.74, 88.38, 86.25 and 80.70 respectively, while the leaf hopper population was reduced by 94.06, 92.61, 82.50, 82.65 and 77.39 per cent, respectively.

Mhaske and Mote (2005) conducted a field experiment to evaluate the efficacy of new insecticides against sucking pests and shoot and fruit borer infesting brinjal. The insecticides for sucking pests consisted of imidacloprid 17.8 SL @ 13.5, 18.0 and 22.5 g a.i. ha^{-1}, thiamethoxam 25 WG @ 12.5, 25.0 and 50.0 g a.i. ha^{-1}, azadirachtin 1% EC @ 10.0, 12.5 and 15.0 g a.i. ha^{-1}, profenofos 50 EC @ 50 g a.i. ha^{-1}, triazophos 40 EC @ 800 g a.i. ha^{-1}. The insecticides for shoot and fruit borers consisted of profenofos 50 EC @ 500, 750 and 1000 g a.i. ha^{-1}, azadirachtin 1% EC @ 10.0, 12.5 and 15.0 g a.i. ha^{-1}, alpha-endosulfan 35 EC @ 280 g a.i. ha^{-1}, monocrotophos 36 EC @ 145 g a.i. ha^{-1}, endosulfan 35 EC @ 280 g a.i. ha^{-1}, deltamethrin 2.8 EC @ 11 g a.i. ha^{-1}, cypermethrin 10 EC @ 60 g a.i. ha^{-1}, and untreated control. The results revealed that higher doses of imidacloprid (18 and 22.5 g a.i. ha^{-1}) and thiamethoxam (25 and 50 g a.i. ha^{-1}) were found effective against leaf hoppers up to the 14th day and against thrips and whiteflies up to the 10 days after spray. Whereas profenofos 1000 g a.i. ha^{-1} and endosulfan 280 g a.i. ha^{-1} recorded least fruit infestation and gave significantly higher yield of fruits.

Field experiment conducted by Sharma *et al.* (2009) showed that fipronil at 50 g a.i. ha^{-1} was found effective against *L. orbanalis* and reduced per cent fruit damage to the tune of 8.26 compared with 18.89 in untreated control in brinjal. Jagginavar *et al.* (2009) evaluated the bio-efficacy of flubendiamide 480 SC at 3 concentrations *viz.,* @ 60, 72 and 90 g a.i ha^{-1} against *L. orbonalis* on brinjal and found that at 90 and 72 g a.i ha^{-1} recorded the lowest levels of shoot damage (11.43 and 16.21 %, respectively) at 7 days after the first spray and resulted in the lowest percentages of fruit damage (0.78 and 1.04 respectively). Similar trend was also observed on 7 DAS of second spray.

Anil and Sharma (2010) conducted field trails to evaluate the efficacy of bifenthrin at 25 and 50 g a.i ha^{-1}, fipronil at 50 g a.i ha^{-1}, carbosulfan at 187.5 g a.i ha^{-1}, cartap hydrochloride at 500 g a.i ha^{-1} and endosulfan at 700 g a.i ha^{-1} against leaf hopper and shoot and fruit borer infesting brinjal. They found that all the insecticides were effective in controlling the jassid population and also per cent fruit damage. The per cent damage by *L. orbonalis* in various treatments varied from 4.06 (cartap hydrochloride) to 8.26 (fipronil) while it was 18.89 in the untreated control.

Dattatray *et al.* (2012) found that lowest brinjal fruit damage by *L. orbonalis* (8.8 per cent) was recorded in the plots sprayed with chlorantraniliprole 18.5 % SC with high yield (528.5 q ha^{-1}) followed by flubendiamide 39.35 % SC where fruit damage of 10.9 per cent with yield of 451.2 q ha^{-1}. Control plots showed fruit infestation of 22.5 - 43.1 per cent with yield of 244.5 q ha^{-1}.

Shah *et al.* (2012) concluded that emamectin benzoate at 0.0025%, flubendiamide @ 0.01%, rynaxypyr @ 0.006%, lufenuron @ 0.005% and novaluron @ 0.01% recorded reduction of shoot and fruit damage (89.56%, 83.70%, 81.04%, 74.62%, 67.46% respectively) and gave significantly higher fruit yield and were found promising insecticides for the management of brinjal shoot and fruit borer.

Ghosal and Chatterjee (2013) conducted a field experiment to evaluate the efficacy of chloro-neonicotinoid as foliar application against brinjal whitefly, and they reported that imidacloprid 17.8 SL @ 50 g a.i ha^{-1}, was found superior against whiteflies and recorded the lowest number of whitefly population (1.55 /plant) and offered maximum reduction of whiteflies (83.15%) as well as highest marketable fruit yield (146.50 q ha^{-1}).

An experiment was conducted by Shaikh *et al.* (2014) to study the bio-efficacy of different insecticides against sucking pests *viz.*, whitefly and jassids infesting brinjal. They found that the insecticides spiromesifen 0.024 % (1.60, 1.98 /leaf) diafenthiuron 0.05 % (1.69, 1.87 /leaf) and triazophos 0.08% (1.82, 2.79 /leaf) emerged as the most effective insecticides against the whitefly and jassids followed by imidacloprid 0.002 % (1.98,2.29 /leaf), profenophos 0.05% (2.13, 2.11 /leaf) and cartap hydrochloride 0.05% (2.28, 2.23 /leaf). According to Chandra *et al.* (2014), better control of jassids and epilachna beetles on brinjal was obtained with cypermethrin 0.25D at 25 kg ha^{-1}.

Arya (2015) conducted a field experiment to study the bio-efficacy of different insecticides against sucking pests *viz.*, whitefly and jassids infesting brinjal. Results revealed that new generation insecticides *viz.,* spiromesifen 96 g a. i ha^{-1} and thiamethoxam 50 g a.i ha^{-1} were found effective against whiteflies and leaf hoppers on brinjal.

Anwar *et al.* (2015) studied the bioefficacy of different insecticides *viz.,* spinosad, emamectin benzoate, chlorpyrifos, profenofos, fenvalerate and cypermethrin against brinjal fruit borer and were compared with a control and they reported that emamectin benzoate was most effective against brinjal fruit borer which recorded lowest infestation (40.1%) followed by cypermethrin (40.43%), whereas fenvalerate offered moderate control (41.31%) of borers.

Kumar *et al.* (2017) evaluated the efficacy of different newer insecticides *viz.,* thiamethoxam 25 WG, imidacloprid 17.8 SL, acephate 20 SP, fipronil 5 SC, thiacloprid 240 SC and dimethoate 30 EC, the results revealed that thiamethoxam 25 WG @ 100 g ha^{-1} was found most effective insecticide in reducing the population of brinjal whitefly (0.33/ plant) followed by imidacloprid 17.8 SL @ 100 ml ha^{-1} (0.67/ plant).

Kolhe *et al.* (2017) conducted field experiments to determine field efficacy of certain chemicals and neem products against brinjal shoot and fruit borer and the results revealed that carbosulfan 25 EC @ 0.05% was found most effective and showed 6.50 per cent shoot infestation, 8.70 per cent fruit infestation followed by quinalphos 20 EC @ 0.05% (7.96% and 9.75%), cypermethrin 25 EC @ 0.05 (8.02% and 10.29), chlorpyriphos20EC @ 0.05% (8.07% and 11.42%), neem oil @ 2% (8.61% and 11.62%), NSKE @ 5% (10.94% and 12.58%) and neem leaf extract @ 5% (12.11% and 16.45%) .

Patel *et al.* (2018) evaluated the efficacy of novel insecticides like imidacloprid 17.8 SL @ 1.0 ml L^{-1}, indoxacarb 14.5 SC @ 1.0 ml L^{-1}, profenofos 50 EC @ 2.0 ml L^{-1}, spinosad 45 SC @ 0.4 ml L^{-1}, thiamethoxam 25 WG @ 0.1 g L^{-1} and acephate 75 SP @ 0.7 g L^{-1} against brinjal fruit borer. Results revealed that imidacloprid 17.8 SL was found most effective in reducing the mean shoot infestation (43.17 %) and fruit infestation (70.56 %) followed by indoxacarb 14.5 SC (40.57% and 66.98%), profenofos 50 EC (35.15% and 62.87%), spinosad 45 SC (33.94% and 61.27%), thiamethoxam 25% WG (33.31% and 59.48%) and acephate 75 SP (23.40 and 57.09%).

.2.3. INSECTICIDE MIXTURES

There are a number of single insecticides used for management of pest complex in brinjal, but development of resistance is a serious problem. Resistance management with insecticides has conventionally been approached by use of sequences of active substances with different modes of action and rotations. The insecticide mixtures of two unrelated compounds could enhance the toxicity of insecticides in resistant insect pests, thus forms a possible resistance management tool (Ahmed *et. al.*, 2011).

Combination of two chemicals with different mode of action in a single spray solution expose individuals to each insecticide simultaneously (Tabashnik, 1989; Hoy, 1998). The primary advantages of insecticide mixtures were controlling the pests in a broad range of settings, typically by increasing the level of controlling target pest and/or broadening the range of pests controlled (IRAC, 2018).

The insecticide co-formulated mixtures mostly appear advantageous in terms of delaying development of resistance to single compound (Skylakakis, 1981; Mani, 1985; Mallet, 1989). Other advantages of mixtures are synergistic effects, flexibility of application, less dosage, decreases labour costs, control pests in a broad range, target more than one life stage of the pest, more efficacy and more specific to pest. Insecticide co-formulated 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 incompatability of insecticides. Pre-mix formulations (Ready mix formulations) 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 (Cabello and Canero, 1994).

Das (2014) explained the action of insecticide mixtures in four ways *viz.,* similar effect, additive effect, synergism and antagonism. When the response is as expected, it is termed as additivity, when the response exceed expectations, it is synergism and when the response is less than expectation it is antagonism.

Synergism is the major action taking place in majority of insecticide co-formulations. Synergism may occur when one insecticide interfere with the metabolic detoxification of another insecticide in a combination mixture. Certain organophosphate insecticides binds to the active site related with esterase enzymes responsible for detoxification of pyrethroid-based insecticides and so organophosphate insecticides may be considered helpful synergists for pyrethroids (Kulkarni and Hodgson, 1980). This is one of the foremost reasons why manufacturing companies formulate organophosphate and pyrethroid-based insecticide mixtures to manage arthropod pest complexes and contract resistance. When synthetic pyrethroids were applied alone, these were detoxified by esterase enzymes present in the insect. But, when applied in mixture with organophsphates, those esterase enzymes were detoxified by organophosphates and then synthetic pyrethroids will act upon the nervous system which leading to hyper excitation of nerve membrane resulting in the death of the insect (Ahmad, 2004).

IRAC (2018) has given guiding principles for using combination products 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 compounds having the different mode of action should be recommended, not to use component molecules which are having cross resistance.

2.4. EFFICACY OF INSECTICIDE MIXTURES AGAINST PESTS OF BRINJAL

Samanta *et al.* (1999) conducted field trails and reported that quinalphos AF at 500, 750 and 1000 g a.i. ha^{-1} and its mixture with monocrotophos @ 500 + 360 g a.i. ha^{-1} gave excellent management of *L. orbonalis* and *H. vigintioctopunctata* on brinjal along with a significantly higher crop yield.

Biradar *et al.* (2001) reported that mixture of cypermethrin 3 EC + quinalphos 20 EC @ 0.25ml L^{-1} at an interval of 15 days found superior in reducing the shoot and fruit borer damage (48.5%) compared to untreated control (84.0%).

Ghangale *et. al.* (2002) tested the bioefficacy of some new ready mix insecticides against brinjal shoot and fruit borer. They reported that Nurelle D

505 (chlorpyriphos 500 g + cypermethrin 50 g @ 550 g a.i. ha^{-1}) was found most effective in reducing shoot (4.67%) and fruit infestation (20.81%).

Abrol and Singh (2003) conducted a field experiment to determine the efficacy of insecticide mixtures against brinjal shoot and fruit borer and they reported that mixture of endosulfan + deltamethrin (0.07%, 0.0025%) and endosulfan + fenvalerate (0.07% + 0.005%) were found highly effective against fruit borer that recorded only 13.3 per cent damage compared to control (69.8%).

Panda *et al.* (2005) evaluated the bioefficacy of some new groups of insecticides against the shoot and fruit borer and epilachna beetle infesting egg plant. The treatments were thiodicarb @ 375 g, 625 g and 1.0 kg ha^{-1}, alternate spraying of cartap hydrochloride @ 0.5 kg a.i. ha^{-1} and diflubenzuron @ 100 g a.i. ha^{-1}, carbofuran 3G @ 1.0 kg a.i. ha^{-1} + triazophos @ 400 g a.i. ha^{-1} + cartap hydrochloride @ 0.5 kg a.i. ha^{-1}, fipronil 0.4G @ 100 g a.i. ha^{-1} + triazophos @ 400 g a.i. ha^{-1} + cartap hydrochloride @ 0.5 g a.i. ha^{-1} and fipronil 5% SC @ 50 g a.i. ha^{-1}. They found that application of fipronil + triazophos + cartap hydrochloride showed the lowest shoot borer (% shoot infestation) and beetle damage (% leaf infestation) of 11.89 and 3.05 per cent respectively.

Field experiment conducted by Nath and Sinha (2011) to evaluate the efficacy of two doses of insecticides *viz.*, triazophos at 350 and 700 g a.i. ha^{-1} and deltamethrin at 10 and 20 g a.i. ha^{-1} and their registered mixture 'Spark' at 360 and 720 g a.i. ha^{-1} against insect pests of brinjal. Study revealed that triazophos @ 350 and 700 g a.i. ha^{-1}, deltamethrin @ 20 g a.i. ha^{-1} and mixture, triazophos + deltamethrin were found successful in managing the pests like *B. tabaci, A. biguttula bigutula* and *L. orbonalis.*

Field experiment was conducted by Kumar *et al.* (2012) to evaluate the potential of two botanicals *viz.*, ozoneem and neem seed kernel extract (NSKE) and three chemical insecticides *viz.*, imidacloprid, alphamathrin and chlorpyriphos 50% EC + cypermethrin 5% EC against shoot and fruit borer. The results revealed that three sprays of chlorpyriphos + cypermethrin @ 0.01% active substance (a.s.) in 15 days intervals was found the most economical and resulting in minimum shoot (2.15%) and fruit (12.95%) infestation, followed by alphamathrin @ 0.01% a.s. with a highest marketable yield of 87.77 q ha^{-1}. Maximum marketable yield was recorded from the treatment with alphamathrin, but due to high costs drawn in the use of this chemical, it took second place.

Wale and Chandele (2013) conducted field experiment to study the bioefficacy of evolved doses of Solomon (beta-cyfluthrin 9% + imidacloprid 21%) 300 OD, betacyfluthrin 2.5 SC, imidacloprid 200 SL, lamda cyhalothrin 5% + thiamethoxam 25 WG, monocrotophos 36 SL, triazophos 40 EC and endosulfan 35 EC. All the insecticide treatments were found effective for the control of aphids and fruit and shoot borer. The treatment Solomon (beta-cyfluthrin 9% + imidacloprid 21%) 300 OD @ 15.75 + 36.75 and 18 + 42 g a.i. ha^{-1} was found most superior for the control of aphids as well as fruit and shoot borer and also in obtaining good yield of brinjal. Application of Solomon (beta-cyfluthrin 9% + imidacloprid 21%) 300 OD did not produce any type of phytotoxicity on brinjal crop.

Sunda *et al.* (2015) reported that mixture of spirotetramat 120 + imidacloprid 120-240 SC @ 75 + 75 g a.i. ha^{-1} was found effective in reducing the population of jassids (85.11%) and whiteflies (79.00%) in brinjal.

Sharma *et al.* (2016) reported that mixture of triazophos + deltamethrin @ 360 g a.i. ha^{-1}, profenophos + cypermethrin @ 440 g a.i. ha^{-1} and chlorpyriphos+ cypermethrin @ 550 g a.i. ha^{-1} were found effective against leaf hopper, whitefly and shoot and fruit borer in brinjal. However, mixture of profenophos + cypermethrin exhibited low effectiveness against whitefly. Per cent infestation due to fruit and shoot borer on weight basis in various treatments ranged from 18.0 - 28.1 per cent as compared to 38.2 per cent in untreated control.

Sen *et al.* (2017a) conducted a field trail on new ready mix formulation, Ampligo 150 ZC (chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC) against brinjal shoot and fruit borer and they reported that chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC @ 35 g a.i. ha^{-1} recorded lowest shoot (1.26%) and fruit (2.49%) infestation followed by chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC @ 28 g a.i. ha^{-1} (1.59% shoot and 2.97% fruit infestation) and chlorantraniliprole 18.5% SC @ 30 g a.i. ha^{-1} (3.76% shoot and 3.32% fruit infestation).

Sen *et al.* (2017b) conducted field study to evaluate the bio efficacy of ready mix formulation, spirotetramat 120 + imidacloprid 120 - 240 SC against sucking pest complex in brinjal and results revealed that spirotetramat 120 + imidacloprid 120 - 240 SC @ 75 + 75 g a.i. ha^{-1} was found more effective in the reducing the population of leaf hopper (99.21%), whitefly (99.04%) and red spider mites (91.31%). The significant highest marketable yield was recorded in the treatment with spirotetramat 120 + imidacloprid 120 - 240 SC @ 75 + 75 g a.i. ha^{-1} (72.7 q ha^{-1}).

Sangamitra *et al.* (2018) conducted field experiment to evaluate bio efficacy of flubendiamide 24% w/v + thiacloprid 24% SC w/v against sucking pests in brinjal and they reported that the flubendiamide 24% + thiacloprid 24% SC w/v @ 84 + 84 g a.i ha^{-1} was highly effective in reducing aphids, jassids and thrips population (95.60, 95.33 and 91.88 %, respectively) in brinjal, followed by flubendiamide 24% w/v + thiacloprid 24% SC w/v @ 72+72 (87.79, 87.72 and 84.45 %, respectively) .

Negi and Srivastava (2018) conducted laboratory experiment to study the contact toxicity of three combination insecticides against 10 day old grubs (mean wt. 0.02 g/grub) of *H. vigintioctopunctata* by atomization method under *in vitro* conditions (Temp. 28°C, R.H. 78%). At 48 HAE, deltamethrin + triazophos and profenofos + cypermethrin were found equitoxic (LC_{50} = 0.0003%) showing 1.5

times lesser toxicity than chlorpyriphos + cypermethrin (LC_{50} = 0.0002%) and at 72 HAE, all the three were equitoxic (LC_{50} = 0.0002%).

Negi and Srivastava (2018) conducted another experiment to determine the contact and stomach toxicity of six insecticide mixtures against adults (mean wt. 0.021 g/adult) of *H. vigintioctopunctata* by leaf dip bioassay method under laboratory conditions (Temp. 28°C, R.H. 78%). At 24 HAE, beta-cyfluthrin + imidacloprid (LC_{50} = 0.0001%) recorded 130 and 9 times higher toxicity than ethion + cypermethrin (LC_{50} = 0.0139) and chlorpyriphos + cypermethrin (LC_{50}= 0.0009%) respectively at 48 HAE, the order of toxicity was beta-cyfluthrin + imidacloprid (LC_{50} = 0.00004%) >chlorpyriphos + cypermethrin (LC_{50} = 0.0005%) >deltamethrin + triazophos (LC_{50} = 0.0009%) >ethion + cypermethrin (LC_{50}= 0.0024%) >profenofos + cypermethrin (LC_{50} = 0.0026%) >cypermethrin + indoxacarb (LC_{50}= 0.0065%); at 72 HAE, profenofos + cypermethrin and cypermethrin + indoxacarb proved equitoxic (LC_{50} = 0.0013%) recorded 65, 2.60 and 1.62 times less toxic than beta-cyfluthrin + imidacloprid (LC_{50} = 0.00002%), deltamethrin + triazophos (LC_{50} = 0.0005) and ethion + cypermethrin (LC50 = 0.0008%) respectively.

2.5. PERSISTENCE AND DISSIPATON OF INSECTICIDE RESIDUES IN BRINJAL

Mandal *et al.* (2010) studied the dissipation of beta-cyfluthrin and imidacloprid in the insecticide mixture of Solomon 300 OD (β-cyfluthrin 9% + imidacloprid 21%) @ 60 and 120 g a.i. ha^{-1} at 7 days interval in brinjal. Half-life periods for β-cyfluthrin were found to be 1.74 and 1.39 days and for imidacloprid these values were observed to be 2.31 and 2.18 days respectively at single and double the application rate. β-cyfluthrin residues dissipated below the limit of quantification (LOQ) of 0.01 mg kg^{-1} after 5 and 7 days respectively at single and double application dosages, whereas imidacloprid residues took 10 days for reaching (LOQ) in both the dosages.

Kaur *et al.* (2011) estimated the residues of cypermethrin and decamethrin in brinjal fruits on following single application of Cymbush 25 EC @ 43.75 and 87.50 g a.i. ha^{-1} and of Decis 2.8 EC @ 11.20 and 22.40 g a.i. ha^{-1}. The average initial deposits of cypermethrin was 0.600 and 1.095 mg kg^{-1} and of decamethrin was 0.430 and 0.900 mg kg^{-1} for single and double dose, respectively. Residues reached below maximum residue limit (MRL) value of 0.2 and 0.05 mg kg^{-1} on third and seventh day for cypermethrin and decamethrin respectively. The half-life values (t(1/2)) were worked out as 1.16, 1.18 days for cypermethrin and 1.33, 1.42 days for decamethrin at single and double dose, respectively.

Rahman *et al.* (2014) conducted a study to determine the persistence of cypermethrin residues in brinjal fruit and in the soil. Different concentrations of cypermethrin (1 ml L^{-1} and 2 ml L^{-1}) were applied in the brinjal field. The residues were analyzed and results showed that cypermethrin residues determined from fruit and soil samples sprayed at the rate of 1 ml L^{-1} in the field were above maximum residue limits (MRL) up to three days after application (0.762 ppm) in fruit samples and up to five days after spraying in soil (0.608 ppm). In case of spraying 2 ml L^{-1} of cypermethrin, fruit samples had residues above MRL up to five days after spraying (0.753 ppm) and soil samples had up to seven days after spraying (0.768 ppm).

Chandra *et al.* (2014) conducted study to investigate persistence pattern of chlorpyrifos, cypermethrin and monocrotophos pesticide on brinjal. The pesticides were applied at dose of 100, 200, 300 g a.i. h^{-1} on brinjal. Samples of brinjal fruits were collected on 0, 1, 3, 5, 7, 9, 11, 13, 15 and 17 days after spraying. The average initial residue deposits were in the range of 0.362-0.876, 0.340-0.858 and 0.388-0.891 mg kg^{1} of chlorpyrifos, cypermethrin and monocrotophos respectively. The residues of pesticides fell below detection level in 13-17, 11-15 and 13-17 days in chlorpyrifos, cypermethrin and monocrotophos respectively.

Mutkule *et al.* (2015) studied the persistence behavior of quinalphos and fipronil at recommended doses and two times that of the recommended dose in brinjal fruits. The average initial deposits of quinalphos were 1.20 and 2.98 mg kg^{-1} on brinjal fruits which dissipated to below detectable limit on 7^{th} and 10^{th} day respectively. In case of fipronil, the average initial deposits were 0.46 and 1.13 mg kg^{-1} which dissipated 76.49 and 92.04% on 7^{th} and 10^{th} day respectively. The half life for quinalphos was 1.32 and 1.55 days respectively while that for fipronil was 2.55 and 2.62 days. Waiting period was 1.07-2.99 and 3.0-5.83 days for quinalphos and fipronil respectively.

Patil *et al.* (2018) conducted field trial to study the dissipation pattern of triazophos in/on brinjal by following two foliar applications at recommended (@ 500 g a.i. ha^{-1}) and double the recommended dose (@ 1000 g a.i. ha^{-1}) at fruiting stage. The brinjal crop was sprayed twice at 10 days interval. Average initial residues of triazophos in brinjal fruits were recorded as 0.90 and 1.85 mg kg^{-1} with the half life of 2.10 and 2.04 days at recommended and double recommended dose respectively. The residues of triazophos reached below quantification limit (BQL) after 7 and 10 days after spraying in both the doses.

Materials and methods

3. MATERIALS AND METHODS

The research project entitled "Insecticide mixtures for the management of pest complex in brinjal" aims to evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of brinjal and to find out the harvest time residues in fruits. Preliminary experiment was conducted under laboratory in Department of Agricultural Entomology and Field experiment was conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during summer 2018-19.

The materials utilized and methods followed for conducting the investigation is described in this chapter.

3.1. REARING AND MAINTENANCE OF INSECTS

3.1.1. Mealy Bug

Brinjal mealy bug, *C. insolita* was reared by using brinjal plants grown in pots under laboratory condition. Healthy adult mealy bugs collected from the brinjal plants grown in organic farm were inoculated on healthy brinjal plant for mass multiplication and maintained under natural day light conditions. The mealy bug crawlers emerging out from the under surface of leaves of the brinjal plant in a weeks' time and in a period of one month the colonies had spread over the brinjal plant. The third instar mealy bug nymphs were collected from the colonies for the bioassay studies to evaluate the efficacy of different insecticide mixtures against *C. insolita* under laboratory condition (Plate.1).

3.1.2. Epilachna Beetle

The epilachna beetle grubs and adults of *E. vigintioctopunctata* were reared in laboratory using fresh brinjal leaves collected from unsprayed plants. The adult beetles were collected from the brinjal plants grown in organic farm, brought to

1st instar nymph

2nd instar nymph

3rd instar nymph

Adult mealy bug

Plate 1. Life stages of *Coccidohystrix insolita*

laboratory and transferred into the trays lined with filter paper, provided with fresh and healthy brinjal leaves and cotton honey swab every day as food. Trays were covered by a muslin cloth and kept back in a rearing cage at room temperature at 26 ± 2°C. After egg laying, adult beetles were removed for uninterrupted hatching of eggs. After hatching, the grubs were transferred into separate trays. Grubs and adults obtained from the mass culture was used for the bio-assay studies in the laboratory condition (Plate. 2).

3.2. *IN VITRO* EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES

The seven insecticide mixtures along with control (Table. 1) were tested for the efficacy against nymphs of brinjal mealy bug, *C. insolita* and adults and grubs of epilachna beetle, *E. vigintioctopunctata*.

Design : CRD

Replications : 3

Treatments : 8

3.2.1. Against Brinjal Mealy Bug *C. insolita.*

Healthy, fresh leaves of brinjal grown in pots without any insecticidal sprays were collected and washed and cleaned. Leaf discs of 60 mm diameter were prepared and kept on filter paper. The leaf discs were sprayed with the insecticides solution by potter's tower spray method. After spraying, leaf discs were allowed to air dry for 5-10 minutes and placed in 100 mm glass petri dishes lined with a layer of filter paper to avoid the excess insecticide solution on the leaf disc. Twenty five third instar nymphs of mealy bug were released on each leaf disc. Three replicates were maintained for each treatment. Mortality of mealy bugs was assessed at 24, 48, 72, 96 and 120 h after treatment (Plate 3). A leaf disc sprayed with water served as control. The mealy bugs which did not respond for the fine prick made by the camel

A. Egg clusters

B. Grubs

1 st instar

2nd instar

3rd instar

4th instar

C. Pupa

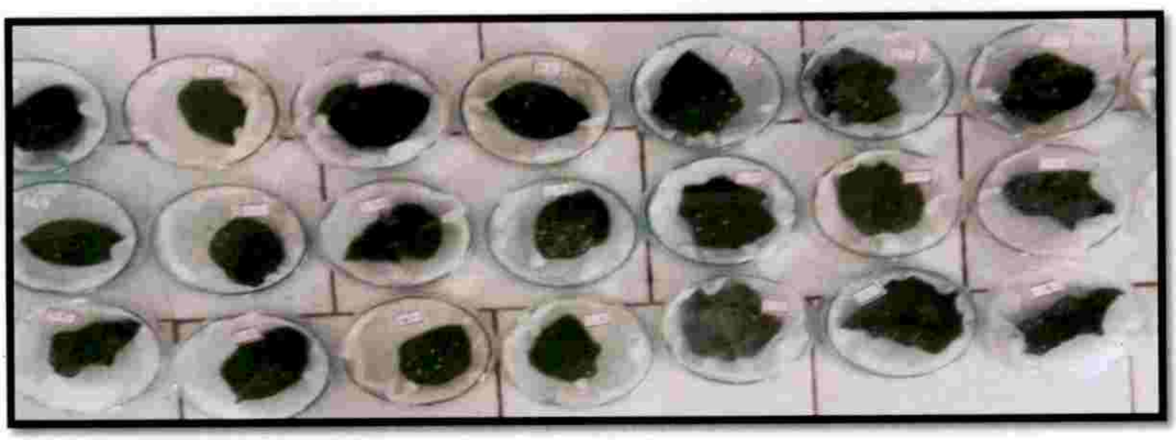
D. Adult

Plate 2. Life stages of *Epilachna vigintioctapunctata*

Table 1. Details of insecticide mixtures

Chemical name	Trade name	Chemical group	Mode of action as per IRAC, 2018	Field dose (mL or g L^{-1})
Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1}	Sinovid	Pyriproxyfen + Synthetic pyrithroid	Juvenile hormone mimics + Sodium channel modulators	1 ml L^{-1}
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	Fipromida	Phenyl pyrazoles + Neonicotinoid	GABA-gated chloride channel blockers + Nicotinic Acetylcholine receptor (nAChR) competitive modulators	0.50 g L^{-1}
Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC@ 27.5 g a.i ha^{-1}	Alika	Neonicotinoid + Synthetic pyrethroid	Nicotinic Acetylcholine receptor (nAChR) competitive modulators + Sodium channel modulators	0.50 ml L^{-1}
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	Solomon	Synthetic pyrethroid + Neonicotinoid	Sodium channel modulators + Nicotinic Acetylcholine receptor (nAChR) competitive modulators	0.40 ml L^{-1}
Flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1}	Belt Expert	Diamide + Neonicotinoid	Ryanodine receptor modulators and Nicotinic Acetylcholine receptor (nAChR) competitive modulators	0.40 ml L^{-1}
Cypermethrin 3% + quinalphos 20% EC@30+200 g a.i ha^{-1}	Alert	Synthetic pyrithroid + Organophosphates	Sodium channel modulators + Acetylcholinesterase (AChE) inhibitors	1.42 ml L^{-1}
Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1}	Deltron	Synthetic pyrithroid + Organophosphates	Sodium channel modulators + Acetylcholinesterase (AChE) inhibitors	0.60 ml L^{-1}

A. Potters tower spray method



B. Mealy bugs treated with insecticide mixtures

under laboratory conditions

Plate 3. Bioassay of insecticide mixtures against mealy bugs under laboratory condition.

hair brush was considered as dead. Percentage mortality of mealy bugs was calculated by using Abbott's formula (Abbot, 1925).

3.2.2. Against Epilachna Beetles.

Fresh brinjal leaves without any insecticidal spray were collected and washed and cleaned. Different solutions of insecticide mixtures were treated to leaves by leaf dipping bioassay method. Petioles of the brinjal leaves were tied with wet cotton plug (to avoid early drying) and placed in round plastic tray (29 cm × 8 cm) lined with filter paper. Brinjal leaves treated with water were considered as control. In each treated leaf 10 pre-starved (2 h) adult beetles were introduced individually and covered with muslin cloth (Plate 4). Three replicates were maintained for all treatments and the number of dead beetles were recorded after 24, 48, 72, 96 and 120h after treatment. Percentage mortality was calculated and corrected by Abbott's formula (Abbot, 1925).

3.2.3. Against Epilachna Grubs.

Fresh brinjal leaves without any insecticidal spray were collected and washed and cleaned. Different insecticides solutions were treated to leaves by leaf dipping bioassay method. Petioles of the brinjal leaves were tied with wet cotton plug (to avoid early drying) and placed in round plastic tray (29 cm × 8 cm) lined with filter paper. Brinjal leaves treated with water were considered as control. In each treated leaf 10 pre-starved (2 h) grubs were introduced individually and covered with muslin cloth. Three replicates were maintained for all treatments and the number of dead grubs were recorded after 24, 48, 72, 96 and 120 h after treatment. Percentage mortality was calculated and corrected by Abbott's formula (Abbot, 1925).

$$\text{Corrected mortality (\%)} = \frac{\text{mortality in treatment (\%)} - \text{mortality in control (\%)}}{100 - \text{mortality in control(\%)}} \times 100$$

A. Leaf dipping method

B. Epilachna beetles treated with insecticide mixtures

Plate 4. Bioassay of insecticide mixtures against epilachna beetle under laboratory conditions.

3.3. FIELD EVALUATION OF INSECTICIDE MIXTURES

Three insecticide mixtures found effective in laboratory experiment (Table. 2) were further evaluated in field for their efficacy in controlling pests in brinjal.

Design : RBD

Replication : 5

Treatments : 3+1 (control)

Field experiment was conducted at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram.

3.3.1. Preparation of Spray Solution

From the commercial formulation, the quantity of insecticide was worked out by following formula.

$$V = \frac{C \times A}{a.i}$$

Where,

V= Volume/weight of commercial insecticide required

C = Concentration of commercial insecticide

A = Amount of spray required

a.i. = Per cent active ingredient

3.3.2. Application of Spray Solution

The insecticide solution was freshly prepared at the experiment site just before spraying. The required quantity of insecticide per plot was first thoroughly

Table 2. Details of insecticide mixtures selected for field study

Chemical name	Trade name	Chemical group	Mode of action as per IRAC, 2018	Field dose (mL or g L^{-1})
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	Fipromida	Phenyl pyrazoles + Neonicotinoid	GABA-gated chloride channel blockers + Nicotinic Acetylcholine receptor (nAChR) competitive modulators	0.50 g L^{-1}
Cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1}	Alert	Synthetic pyrethroid + Organophosphates	Sodium channel modulators + Acetylcholinesterase (AChE) inhibitors	1.42 ml L^{-1}
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	Solomon	Synthetic pyrithroid+ Neonicotinoid	Sodium channel modulators + Nicotinic Acetylcholine receptor (nAChR) competitive modulators	0.40 ml L^{-1}

mixed in a water mixed thoroughly before spraying and stirred frequently all through the time of spray. The spraying operations were performed in the evening hours.

All the treatments were applied to the plots by using knapsack sprayer. The first spray was undertaken based on the pre treatment count of whiteflies, leaf hopper, mealy bug and shoot and fruit borer. Post treatment count were recorded 3, 5, 7, 9, 11, 13 and 15 days after each spraying. Observations on shoot borer was recorded at 3, 7, 11, 15 and 30 days after spraying and fruit infestation observation recorded at 15 and 30 days after spraying.

3.3.3. Experimental Details

Variety	Local variety
Season	Summer
Experimental design	Randomized block design (RBD)
Plot size	2 x 2 m
Spacing	65 x 65 cm
No.of treatments	4
No.of replications	5

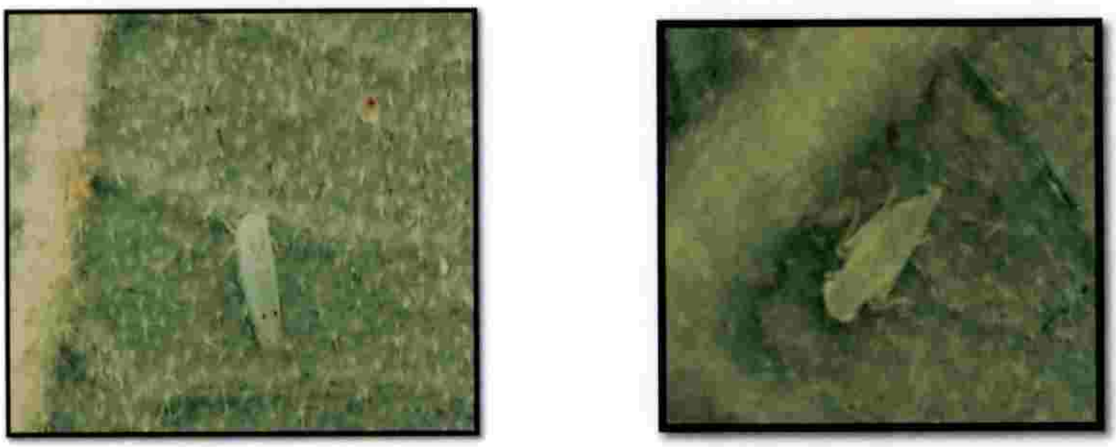
3.3.4. Sampling and Collection of Experimental Data

Five plants were selected randomly and tagged for recording the observations on infestation of sucking pests and shoot and fruit borer.

3.3.4.1. Population of Sucking Pest Complex

Population of leaf hopper and whitefly were recorded at 2 days intervals from three leaves selected from top, middle and bottom canopy of the plant beginning from pre treatment spray to fifteenth day after spraying (Plate 5 and 6) (Sen *et al.*, 2017b).

Plate 5. Brinjal whitefly, *Bemisia tabaci*



A. Adult **B. Nymph**

Plate 6. Brinjal leaf hopper, *Amrasca biguttula biguttula*

Population of mealy bug was recorded at 2 days interval on three leaves per 2 cm^2 leaf area selected from top, middle and bottom canopy of the plant (Saminathan *et al.*, 2010).

3.4.4.2. Infestation of Brinjal Shoot and Fruit Borer (BSFB)

Per cent shoot infestation

For recording shoot infestation, the number of infested and healthy shoots were recorded (Plate 7) from five randomly selected plants from each plot. Observations were recorded one day before spraying and infestation on new shoots were recorded at 3, 7, 11, 15 and 30 days after treatment. All the infested shoots from selected plants were marked using a rubber band tied around the shoot to avoid recounting during the next observation. Per cent shoot infestation was calculated by using the following formula (Sen *et al.*, 2017a).

$$\text{Per cent shoot infestation} = \frac{\text{No. of infested shoots}}{\text{Total no. of shoots}} \times 100$$

Per cent fruit infestation

Number of infested fruits and marketable fruits were counted one day before spraying and 15 and 30 days after spraying. Percentage infestation was calculated by using the following formula (Sen *et al.*, 2017a).

$$\text{Per cent fruit infestation (Number basis)} = \frac{\text{No. of infested fruit}}{\text{Total no. of fruits}} \times 100$$

3.3.4.3. Yield

The number and weight of fruits per plant was recorded after each harvest.

A. Shoot damage

B. Fruit damage

Plate 7. Brinjal shoot and fruit borer, *Leucinodes orbonalis*

3.4. STATISTICAL ANALYSIS

The obtained data on efficacy were statistically analyzed and subjected to the analysis of variance by adopting the appropriate methods (Panse and Sukhatme, 1976).

3.5. ESTIMATION OF RESIDUES OF INSECTICIDES IN BRINJAL FRUITS

Mature brinjal fruits were taken from experimental plots sprayed with insecticide mixtures *viz.,* betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} and cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} for estimation of harvest time residue in fruits. The determination of pesticide residues at the time of harvest was done in the Pesticide Residue Research and Analytical laboratory, AINP on Pesticide Residues, College of Agriculture, Vellayani.

3.5.1. Estimation of Persistence and Degradation of Residues of Insecticides

Fruit samples were collected at the time of harvesting. Brinjal fruits were chopped, homogenized, sub-sampled and extracted by following the QuEChERS (Quick, Easy, Cheap, Effective, Rugged, Safe) method. The estimation of residues of betacyfluthrin, cypermethrin and quinalphos was done using GC-ECD and the estimation of fipronil and imidacloprid was done using LC-MS/MS.

3.5.1.1. *Extraction and clean up*

Harvested fruits were well homogenized as such in a high-speed blender (BLIXER 6vv Robot Coupe) and a representative sample of 25 g was taken into a 250 ml centrifuge bottle. The analyte was extracted by addition of HPLC grade 50 ml acetonitrile and homogenized with a high speed tissue homogenizer (Heidolph Silent Crusher-M) at 14000 rpm for three minutes, to which 10 g of activated sodium chloride was added and vortexed for 2 min to attain separation of acetonitrile layer.

The homogenized samples were then centrifuged at 2500 rpm for five minutes. 12 ml of sample was transferred carefully to a 50 ml centrifuge tube containing 6 g pre activated sodium sulphate and vortexed for 2 minutes. The acetonitrile extracts were subjected to clean up by using dispersive solid phase extraction (DSPE). Transferred the 8 ml of supernatant to 15 ml centrifuge tube containing 0.20 g PSA and 1.20 g magnesium sulphate and then mixtures were shaken in vortex for two minutes and again centrifuged the vortexed mixture at 2500 rpm for 5 minutes. 5 ml of each supernatant liquids was transferred to turbo 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 and fipronil filtered through a 0.2 micron PVDF filter prior for the estimation in LC-MS/MS. 4 ml of the extract was evaporated in a turbovap and made up to 1 ml using n-hexane for cypermethrin, beta-cyfluthrin and quinalphos to GC-ECD & GC-FPD analysis.

3.5.1.2. ***Instrumentation***

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. A gradient system consisting 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 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 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.

GC-ECD

Estimation of residues of cypermethrin, beta-cyfluthrinand quinalphos 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 retention time of cypermethrin and betacyfluthrin under the above conditions was 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 were similar to that of GC.

The MS/MS conditions were optimized using direct infusion in to ESI source in positive mode to provide the 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.

3.5.1.3. ***Residue quantification***

Based on the peak area of the chromatogram obtained for various insecticides, the quantity of residue was determined by following formula.

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

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

Results

4. RESULTS

An experiment was conducted at College of Agriculture, Vellayani during summer season 2018-2019 to evaluate the efficacy of insecticide mixtures under laboratory and field condition to evolve an effective insecticide mixtures for the management of pest complex in brinjal. The data were analyzed statistically after appropriate transformation and experimental findings obtained from the present study are explained below.

4.1. EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES AGAINST THE PEST COMPLEX IN BRINJAL

4.1.1. Mortality of Nymphs of *C. insolita* treated with Insecticide Mixtures.

The per cent mortality of 3rd instar nymphs of *C. insolita*, treated with different insecticide mixtures are presented in Table 3. The highest mortality (93.86%) was observed in treatment cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} after 24 h of treatment and is statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (84.75 %). Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} recorded 58.97 per cent mortality and was found statistically on par with fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (55.85 %), pyriproxyfen 5% + fenpropathrin15% EC @ 25+75 g a.i ha^{-1} (53.97%), flubendiamide 19.92% + thiacloprid19.92% @ 48+48 g a.i ha^{-1} (53.10%) and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (53.03 %).

After 48 h of treatment cypermethrin 3% + quinalphos 20% EC@ 30 + 200 g a.i ha^{-1} recorded cent per cent mortality of the insects which was found statistically on par with the betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (96.67 %). Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} recorded 76.39 per cent mortality of insects and was found statistically on par with thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (70.48 %), fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (69.05%), flubendiamide 19.92% +thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (67.38 %) and pyriproxyfen 5%+fenpropathrin15% EC @ 25+75 g a.i ha^{-1} (62.06 %).

Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} recorded cent per cent mortality after 72 h of treatment. Fipronil 40% + imidacloprid 40% WG @175+175 g a.i ha^{-1} recorded 83.81 per cent mortality and was statistically on par with deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (81.24 %), thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (79.58 %), pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (78.01%) and flubendiamide 19.92% + thiacloprid19.92% SC @ 48+48 g a.i ha^{-1} (77.89 %).

After 96 h, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i. ha^{-1} recorded cent per cent mortality. Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} recorded 92.59 per cent mortality, which was statistically on par with the fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (88.89 %) followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (85.89 %). Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} showed 85.18 per cent mortality and was found statistically on par with the flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (77.77 %).

Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} treated insects recorded cent per cent mortality after 120 h of

Table 3. Percentage mortality of *Coccidohystrix insolita* treated with insecticide mixtures under laboratory conditions

Treatments	Corrected mortality (%) at different time intervals				
	24 h	48 h	72 h	96 h	120 h
Pyriproxyfen 5% + fenpropathrin 15% EC @ 25 + 75 g a.i ha^{-1}	53.97^{b} (47.34)	62.06^{c} (52.18)	78.01^{b} (62.47)	85.18b^{c} (67.45)	96.187^{ab} (80.58)
Fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1}	55.85^{b} (48.43)	69.05^{c} (57.14)	83.81^{b} (70.18)	88.89^{abc} (73.94)	100.00^{a} (89.42)
Thiamethoxam12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1}	58.97^{b} (52.15)	70.48^{c} (57.08)	79.58^{b} (63.14)	85.89^{bc} (67.64)	88.42^{bc} (73.54)
Betacyfluthrin 8.91% + imidacloprid19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}	84.75^{a} (67.09)	96.67^{ab} (77.51)	100.00^{a} (89.42)	100.00^{a} (89.42)	100.00^{a} (89.42)
Flubendiamide19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1}	53.10^{b} (46.79)	67.38^{c} (52.33)	77.88^{b} (63.16)	77.77^{c} (62.31)	86.42^{c} (68.33)
Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}	93.86^{a} (75.89)	100.00^{a} (89.42)	100.00^{a} (89.42)	100.00^{a} (89.42)	100.00^{a} (89.42)
Deltamethrin 1% + triazophos 35% EC @ 10 + 350 g a.i ha^{-1}	53.03^{b} (46.75)	76.39^{bc} (58.17)	81.24^{b} (65.92)	92.59^{ab} (76.83)	100.00^{a} (89.42)
CD (0.05)	(9.765)	(13.014)	(13.725)	(13.245)	(10.875)

*Values given in parenthesis are angular transformed value.

treatment which were found statistically on par with pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (96.18 %), thiamethoxam 12.6% + lambda cyhalothrin9.5% ZC @ 27.5 g a.i ha^{-1} (88.42%).

4.1.2. Mortality of Adults of *E. vigintioctopunctata* treated with Insecticide Mixtures.

The per cent mortality adults of epilachna treated with different insecticide mixtures are presented in Table 4. The highest mortality (53.33%) was observed in adult beetles treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 ga.i ha^{-1} after 24 h of treatment which was statistically on par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i. ha^{-1} (46.66 %), fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (40.00 %). Flubendiamide 19.92% + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} recorded 26.66 per cent mortality and was found statistically on par with deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (26.66 %), thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC@ 27.5 g a.i ha^{-1} (20.00 %) and pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (16.66 %).

After 48 h, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} recorded 80.00 per cent mortality and was found statistically on par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i. ha^{-1} (76.66 %) and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (70.00 %). Flubendiamide 19.92% + thiacloprid 19.92 % SC @ 48+48 g a.i ha^{-1} (56.66%) was found statistically on par with thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (50.00 %). Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} and pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} which recorded the lowest mortality of 36.66 per cent each.

Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} treated insects recorded cent per cent mortality after 72 h of treatment and was found statistically on par with the betacyfluthrin 8.91% + imidacloprid 19.81% SC @ 15.75+36.7 g a.i ha^{-1} (93.33%) and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (82.22%). Flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (74.81 %) was on par with deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (68.15 %) and thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (60.37%). Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} recorded mortality of 52.97 per cent.

After 96 h, treatment cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} treated insects recorded cent per cent mortality of beetles. Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (85.00%) was found statistically on par with flubendiamide 19.92 % + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (80.83%) and thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (80.09 %). Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} recorded a mortality of 70.00 per cent.

Cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} treated insects recorded cent per cent mortality after 120 h of treatment. Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} recorded 88.42 per cent mortality which was statistically on par with flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (84.26%) and thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (81.02 %). Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} recorded 72.68 per cent mortality.

Table 4. Percentage mortality of adults of *Epilachna vigintioctopunctata* treated with insecticide mixtures under laboratory conditions

Treatments	Corrected mortality (%) at different time intervals				
	24 h	48 h	72 h	96 h	120 h
Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1}	16.66^{c} (15.30)	36.66^{d} (37.14)	52.97^{e} (46.74)	70.00^{c} (57.43)	72.68^{c} (58.66)
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	40.00^{b} (30.99)	70.00^{ab} (56.99)	82.22^{abc} (65.28)	100.00^{a} (89.09)	100.00^{a} (89.09)
Thiamethoxam12.6%+ lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1}	20.00^{c} (23.85)	50.00^{cd} (45.00)	60.37^{de} (51.11)	80.09^{bc} (63.72)	81.02^{bc} (64.34)
Betacyfluthrin 8.91%+ imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	53.33^{a} (39.14)	80.00^{a} (63.92)	93.33^{ab} (80.54)	100.00^{a} (89.09)	100.00^{a} (89.09)
Flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1}	26.66^{c} (26.56)	56.66^{bc} (48.84)	74.81^{bcd} (60.01)	80.83^{bc} (62.24)	84.26^{b} (66.82)
Cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1}	46.66^{ab} (46.92)	76.66^{a} (61.21)	100.00^{a} (89.09)	100.00^{a} (89.09)	100.00^{a} (89.09)
Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1}	26.66^{c} (30.97)	36.66^{d} (37.22)	68.15^{cde} (55.79)	85^{b} (67.34)	88.42^{b} (73.42)
CD (0.05)	(7.875)	(11.008)	(14.461)	(8.478)	(10.787)

*Values given in parenthesis are angular transformed value

4.1.3. Mortality of Grubs of *E. vigintioctopunctata* treated with Insecticide Mixtures

The per cent mortality of epilachna grub treated with different insecticide mixtures are presented in Table 5. The highest mortality (73.33%) was observed in insects treated with fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} after 24 h of treatment and was found statistically on par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (70.00 %) and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (66.66%). Thiamethoxam 12.6% + lambda cyhalothrin 9.5 % ZC @ 27.5 g a.i ha^{-1} recorded 43.33 per cent mortality which was found statistically on par with the deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (36.66%) and flubendiamide 19.92 % +thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (23.33 %). Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} recorded 16.66 per cent mortality.

After 48 h, treatment betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} recorded 90.00 per cent mortality and was found statistically on par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (86.66 %), fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (76.66%) and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (73.33 %). Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} recorded 50.00 per cent mortality which was statistically on par with flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (43.33%) and pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (40.00 %).

Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} treated insects recorded cent per cent mortality after 72 h of treatment. Deltamethrin 1% + triazophos 35% EC@ 10+350 g a.i ha^{-1} recorded 85.92 per cent mortality. Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} showed 72.59 per cent mortality and was on par with the flubendiamide 19.92 % + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (69.26 %) and pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (60.84 %).

After 96 h, treatment betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} treated insects recorded cent per cent mortality and were found statistically on par with the deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} (88.89 %). Thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} showed 81.48 per cent mortality which was statistically on par with flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} (74.07%) and pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (71.95 %).

Treatments betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}, deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} treated insects recorded cent per cent mortality after 120 h of treatment. Flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1} recorded 87.83 per cent mortality which was found statistically on par with the thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1} (86.90%) and pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1} (78.30 %).

Based on the results of the laboratory experiments. Three insecticide mixtures *viz.,* cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} were selected for the field study to evaluate the efficacy of insecticide mixtures.

Table 5. Percentage mortality of grubs of *Epilachna vigintioctopunctata* treated with insecticide mixtures under laboratory conditions

Treatments	Corrected mortality (%) at different time intervals				
	24 h	48 h	72 h	96 h	120 h
Pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1}	16.66^{c} (23.85)	40.00^{b} (39.14)	60.84^{c} (51.35)	71.95^{b} (58.80)	78.30^{b} (62.42)
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	73.33^{a} (59.00)	76.66^{a} (61.21)	100.00^{a} (89.09)	100.00^{a} (89.09)	100.00^{a} (89.09)
Thiamethoxam12.6%+ lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1}	43.33^{b} (41.15)	50.00^{b} (45.00)	72.59^{c} (58.48)	81.48^{b} (68.56)	86.90^{b} (72.29)
Betacyfluthrin 8.91%+ imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	66.66^{a} (55.77)	90.00^{a} (74.69)	100.00^{a} (89.09)	100.00^{a} (89.09)	100.00^{a} (89.09)
Flubendiamide 19.92% + thiacloprid 19.92% SC@ 48+48 g a.i ha^{-1}	23.33^{bc} (24.44)	43.33^{b} (41.15)	69.26^{c} (56.47)	74.07^{b} (59.49)	87.83^{b} (72.91)
Cypermethrin 3% + quinalphos 20% EC@ 30 + 200 g a.i ha^{-1}	70.00^{a} (56.99)	86.66^{a} (68.21)	100.00^{a} (89.09)	100.00^{a} (89.09)	100.00^{a} (89.09)
Deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1}	36.66^{bc} (37.22)	73.33^{a} (59.00)	85.92^{b} (71.46)	88.89^{ab} (73.83)	100.00^{a} (89.09)
CD (0.05)	(17.765)	(13.372)	(11.520)	(17.063)	(14.158)

*Values given in parenthesis are angular transformed value.

4.1.4. Effect of Insecticide Mixtures on population of whitefly *Bemisia tabaci* under Field Conditions

The pre-treatment population of whitefly was uniform in all the experimental plots which ranged from 42 to 44 per plant, and the average population of whitefly was statistically non-significant (Table 6).

The relative efficacy of three insecticide mixtures on third day after treatment application indicated that all three insecticidal treatments were significantly superior over untreated control in reducing whitefly population. Among these treatments the lowest population of the pest was recorded in the plot sprayed with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (7.64 /plant) and was found statistically on par with, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (12.24 /plant) and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (14.96 /plant).

On 5 days after spraying (DAS), cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} was found statistically superior in reducing the pest population (3.96 /plant). Next effective treatments were betacyfluthrin 8.91% + imidacloprid 19.81% w/w @ 15.75+36.7 g a.i ha^{-1} (6.68 /plant) and fipronil 40%+ imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (9.48 /plant).

On 7 DAS, significant reduction in population of whitefly was recorded in plots treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (2.66 /plant). Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} treated plots showed 5.32 whiteflies/plant and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} treated plots recorded 7.72 whiteflies/plant.

On 9 DAS, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded the lowest number of whitefly population (2.28 /plant) which was statistically on par with, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (5.28 /plant) and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} recorded (7.04 /plant).

A significant reduction in the number of pest was seen in all treated plots on 11 DAS, compared to control plot. Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded the lowest number of whiteflies (1.12 /plant) and was found statistically on par with, fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (2.68 /plant) and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (2.78 /plant).

Observations recorded on 13 DAS, indicated that the population of whitefly was significantly reduced by all treatments compared to the control. Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded the lowest number of pests (0.92 /plant) and was statistically on par with the fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (2.96 /plant) and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (4.14 /plant).

Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} sprayed plots recorded the lowest whitefly population (0.72 /plant) after 15 DAS, which was statistically on par with fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (1.78 /plant) and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (1.92 /plant).

Table 6. Effect of insecticide mixtures on population of *Bemisia tabaci* under field conditions.

Treatments	Population of *Bemisia tabaci* (Number per plant)							
	Before spraying	3rd DAS	5th DAS	7th DAS	9th DAS	11th DAS	13th DAS	15th (DAS)
Fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i. ha^{-1}	43.40 (6.58)	14.96^{bc} (3.87)	9.48^{c} (3.07)	7.72^{c} (2.78)	7.04^{b} (2.66)	2.68^{a} (1.62)	2.96^{a} (1.70)	1.78^{a} (1.37)
Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}	43.40 (6.58)	7.64^{a} (2.76)	3.96^{b} (2.00)	2.66^{a} (1.62)	2.28^{a} (1.50)	1.12^{a} (1.02)	0.92^{a} (0.93)	0.72^{a} (0.83)
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}	43.52 (6.60)	12.24^{b} (3.50)	6.88^{a} (2.61)	5.32^{b} (2.34)	5.28^{b} (2.23)	2.78^{a} (1.65)	4.14^{a} (2.02)	1.92^{a} (1.38)
Control	42.28 (6.49)	45.32^{c} (6.72)	43.53^{d} (6.60)	36.04^{d} (6.00)	44.88^{c} (6.70)	44.49^{b} (6.67)	49.10^{b} (7.00)	50.82^{b} (7.12)
CD (0.05)	NS	(0.436)	(0.298)	(0.259)	(0.255)	(0.305)	(0.442)	(0.416)

*Values given in parenthesis are $\sqrt{x+1}$ transformed value.

*DAS- Days after spraying

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4.1.5. Effect of Insecticide Mixtures on Population of Leaf Hopper *Amrasca biguttula biguttula* under Field Conditions

The pre-treatment population of leaf hopper was uniform in all the experimental treatment plots which ranged from 37 to 40 per plant, and the average population of leaf hoppers were found statistically non-significant (Table 7).

The post treatment observations recorded on third day after treatment application clearly indicated that the lowest population of the leaf hopper were recorded in the plot sprayed with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (3.76 /plant) which was found statistically on par with the betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (5.00 /plant) and fipronil 40% + imidacloprid 40% WG @ 175+175g a.i ha^{-1} (10.50 /plant).

On 5 DAS, treatment cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} was found statistically superior in reducing the leaf hopper population (2.16 /plant). Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} recorded a population of 4.22 /plant and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} recorded a population of 5.84/plant.

On 7 DAS, significant reduction in population of leaf hopper was recorded in plots treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (1.44 /plant) and this was statistically on par with, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (2.68 /plant) followed by fipronil 40%+ imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (3.12 /plant).

On 9 DAS, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded lowest number of leaf hopper (1.08 /plant) which is statistically on par with the fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (2.80 /plant) and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (2.88 /plant).

A significant reduction in the number of leaf hopper were seen in all treated plots on 11 DAS as compared to control plot (45.76 /plant). Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded the lowest number of leaf hoppers (0.84 /plant) and was found statistically on par with the betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (1.68 /plant) and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (2.06 /plant).

Observations recorded on 13 DAS, indicated that the population of leaf hopper was significantly reduced by all treatments compared to the control (48.34 /plant). Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded the lowest number of leaf hopper population (0.64 /plant) and was found statistically on par with the betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (1.24 /plant) and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (1.68 / plant).

Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} sprayed plots recorded the lowest number of leaf hopper population (0.32 and 0.96 /plant respectively) on the fifteenth day after spraying and these were found on par with the betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (1.04 /plant).

4.1.6. Effect of Insecticide Mixtures on Population of Mealy Bug *Coccidohystrix insolita* under Field Conditions

The average pre-treatment population of mealy bug was uniform in all the experimental treatment plots.

The post treatment observations recorded on 3 DAS (Table 8) indicated that all the insecticidal treatments were significantly superior over untreated control in reducing the mealy bug population. Among these treatments, the plants treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded a population

Table 7. Effect of insecticide mixtures on population of *Amrasca biguttula biguttula* under field conditions

Treatments	Population of *Amrasca biguttula biguttula* (Number per plant)							
	Before spraying	3rd DAS	5th DAS	7th DAS	9th DAS	11th DAS	13th DAS	15th DAS
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	38.14 (6.18)	10.50^{c} (3.23)	5.84^{c} (2.40)	3.12^{b} (1.77)	2.80^{a} (1.67)	2.06^{a} (1.43)	1.68^{a} (1.29)	0.96^{a} (0.98)
Cypermethrin 3% + quinalphos 20% EC@ 30+200 g a.i ha^{-1}	39.22 (6.25)	3.76^{a} (1.93)	2.16^{a} (1.46)	1.44^{a} (1.19)	1.08^{a} (1.01)	0.84^{a} (0.89)	0.64^{a} (0.76)	0.32^{a} (0.54)
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	38.74 (6.22)	5.00^{b} (2.23)	4.22^{b} (2.04)	2.68^{ab} (1.62)	2.88^{a} (1.70)	1.68^{a} (1.28)	1.24^{a} (1.09)	1.04^{a} (0.99)
Control	37.16 (6.12)	38.36^{d} (6.19)	41.40^{d} (6.43)	39.14^{c} (6.25)	42.96^{b} (6.55)	45.76^{b} (6.75)	48.34^{b} (6.94)	51.02^{b} (7.13)
CD (0.05)	NS	(0.258)	(0.221)	(0.214)	(0.268)	(0.329)	(0.247)	(0.310)

*Values given in parenthesis are are$\sqrt{x+1}$ transformed value.

*DAS- Days after spray

of 18.94 /plant and was found statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (21.04 /plant). Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} recorded 26.44 mealy bugs/plant.

On 5 DAS, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} was found superior (15.98 mealy bugs/plant) in reducing the mealy bug population as compared to other insecticides. Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} recorded a population of 27.92 /plant and was found statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (28.74 /plant).

The observations recorded at 7 DAS, clearly indicated that mealy bug population was minimum in plots treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (13.08 /plant) as compared to other insecticides. Fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} recorded a population of 29.74 /plant which was statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (33.16 /plant).

On 9 DAS, the plants treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded the lowest mealy bug population (7.54 /plant) as compared to other insecticides. Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (21.16 / plant) was statistically on par with fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (21.74 /plant).

On 11 DAS, treatment cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} was found reducing the mealy bug population effectively (6.19 /plant) as compared to the other insecticides. Next effective treatment was betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (11.16 /plant). Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} recorded the population of 17.54 mealy bugs/plant.

Table 8. Effect of insecticide mixtures on population of *Coccidohystrix insolita* under field conditions

Treatments	Population of *Coccidohystrix insolita* Number per plant							
	Before spraying	3rd DAS	5th DAS	7th DAS	9th DAS	11th DAS	13th DAS	15th DAS
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	78.36 (8.84)	26.44^{b} (5.12)	27.92^{b} (5.24)	29.74^{b} (5.42)	21.74^{b} (4.63)	17.54^{c} (4.16)	13.54^{c} (3.60)	11.33^{c} (3.39)
Cypermethrin 3% + quinalphos 20% EC@ 30 + 200 g a.i ha^{-1}	75.38 (8.67)	18.94^{a} (4.33)	15.98^{a} (3.99)	13.08^{a} (3.61)	7.54^{a} (2.74)	6.19^{a} (2.48)	3.65^{a} (1.90)	1.71^{a} (1.29)
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	78.04 (8.81)	21.04^{ab} (4.57)	28.74^{b} (5.32)	33.16^{b} (5.73)	21.16^{b} (4.59)	11.16^{b} (3.29)	6.33^{ab} (2.50)	4.08^{ab} (1.99)
Control	74.96 (8.64)	87.88^{c} (9.36)	98.76^{c} (9.93)	102.52^{c} (10.11)	111.82^{b} (10.56)	108.46^{d} (10.40)	114.48^{d} (10.68)	117.72^{d} (10.84)
CD (0.05)	NS	(0.679)	(0.673)	(0.639)	(0.556)	(0.646)	(0.713)	(0.628)

*Values given in parenthesis are $\sqrt{x+1}$ transformed value

*DAS- Days after spray

On 13 DAS, the plants treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded lowest mealy bug population (3.65 /plant) and was found to statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD@ 15.75+36.7 g a.i ha^{-1}(6.33/ plant) and fipronil 40%+ imidacloprid 40% WG @ 175+175 g a.i ha^{-1}(13.54 /plant).

The observations recorded at 15 DAS, clearly indicated that treatment cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded lowest mealy bug population and was found most superior in reducing the population effectively (1.71 /plant) as compared to other treatments. The next best effective treatment was betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (4.08 /plant). Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} recorded a population of 11.33 /plant.

4.1.7. Effect of insecticide mixtures on shoot infestation by *L. orbonalis.*

The data on infestation of *L. orbonalis* on shoots was presented in Table 9.

The per cent shoot infestation in untreated plots showed an increasing trend from 2.04 to 9.28 during a span of 15 days. All the insecticides were found significantly superior over untreated control in minimizing the infestation of brinjal shoot borer.

The post treatment observations showed that there was no new infestation in treated plots on 3 DAS. Seven days after spraying plots treated with cypermethrin 3% + quinalphos 20% @ 30 + 200 g a.i ha^{-1} EC recorded lowest shoot damage (1.35%) and was found statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (1.42%) and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (2.19 %).

On 11 day after spraying, plots treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded 1.92 per cent shoot damage and was

Table 9. Effect of insecticide mixtures against the infestation of brinjal shoot borer *L. orbonalis*

Treatments	Shoot infestation (%)/ plant					
	Before spraying	3rd DAS	7th DAS	11th DAS	15th DAS	30 DAS
Fipronil 40%+ imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	11.75 (3.41)	0.00^{a} (0.70)	2.19^{a} (1.46)	2.39^{b} (1.53)	3.62^{b} (1.89)	1.93^{a} (1.39)
Cypermethrin 3% + quinalphos 20% EC@ 30+200 g a.i ha^{-1}	11.05 (3.30)	0.00^{a} (0.70)	1.35^{a} (1.15)	1.92^{a} (1.38)	2.44^{a} (1.54)	1.82^{a} (1.23)
Betacyfluthrin 8.91% + imidacloprid19.81% OD @ 15.75+36.7 g a.i ha^{-1}	10.51 (3.21)	0.00^{a} (0.70)	1.42^{a} (1.18)	2.04^{a} (1.42)	2.99^{a} (1.70)	1.74^{a} (1.09)
Control	9.90 (3.13)	2.04^{b} (1.58)	5.63^{b} (2.36)	7.08^{b} (2.65)	9.28^{b} (3.04)	14.06^{b} (5.09)
CD (0.05)	N.S	(0.162)	(0.242)	(0.239)	(0.348)	(0.532)

*Values given in parenthesis are $\sqrt{x} + 1$ transformed value.

*DAS- Days after spray

statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (2.04%) and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (2.39 %).

On 15 days after spraying, plots treated with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded 2.44 per cent shoot infestation and was found statistically on par with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (2.99 %) and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (3.62 %).

On 30 DAS, plots treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (1.74%) was the most superior treatment with lowest shoot damage and was found statistically on par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (1.82 %) and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (1.93 %).

4.1.8. Effect of Insecticide Mixtures on Fruit Infestation by *L. orbonalis.*

The results in respect of effect of different insecticide mixtures on infestation of *L. orbonalis* on brinjal fruits are presented in Table 10.

On 15 DAS, plots treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} recorded the lowest fruit damage (9.97%) and was statistically at par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded (11.94%). Fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} recorded 19.56 per cent fruit damage.

On 30 DAS, plots treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} recorded the lowest fruit damage (8.85 %) and was statistically on par with cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (10.34% /plant). Fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.iha^{-1} recorded 14.26 per cent fruit damage.

Table 10. Effect of insecticide mixtures against the infestation of brinjal fruit borer *L. orbonalis*

Treatments	fruit borer infestation (%) /plant		
	Before spraying	15 DAS	30 DAS
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	34.19 (5.83)	19.56^{b} (4.40)	14.26^{b} (3.76)
Cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1}	34.18 (5.78)	11.94^{a} (3.42)	10.34^{a} (3.20)
Betacyfluthrin 8.91% + imidacloprid 19.81% OD@ 15.75+36.7 g a.i ha^{-1}	36.48 (6.00)	9.97^{a} (3.14)	8.85^{a} (2.97)
Control	39.89 (6.33)	52.27^{c} (7.06)	50.14^{c} (7.07)
CD (0.05)	N.S	(0.641)	(0.299)

*Values given in parenthesis are $\sqrt{x+1}$ transformed value

*DAS- Days after spray

4.1.9. Effect of insecticide mixtures on leaf infestation caused by sucking pest complex

The data on infestation of leaves by sucking pest complex after treatment application is presented in Table 11. Before spraying the per cent leaf infestation caused by sucking pest complex was statistically non-significant.

The post treatment observations recorded on fifteen days after spraying indicated that betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} treated plots recorded the lowest damage of leaves (7.75%) and was found statistically on par with fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (7.79 /plant) and cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (9.44 %) leaf damage.

4.1.10. Effect of Insecticide Mixtures on Yield of Brinjal

Effect of insecticide mixtures on number and weight of fruits are given in Table 12.

Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} treated plots recorded the highest number of fruits (13.72/plant) and was found statistically on par with fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (12.95 /plant). Cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} recorded 11.70 fruits/plant.

Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} treated plots gave the highest yield of 1.72 kg /plant. In plot treated with fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1}, the yield was 1.64 kg /plant and cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} treated plot , it was 1.42 kg /plant.

Table 11. Brinjal leaves damaged by sucking pest complex

Treatments	Infestation of leaf (%) /plant	
	Before spraying	15DAS
Fipronil 40%+ imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	47.6	7.79[a]
Cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1}	46.34	9.44[a]
Betacyfluthrin 8.91% + imidacloprid19.81% OD @ 15.75+36.7 g a.i ha^{-1}	34.12	7.75[a]
Control	39.88	53.44[b]
CD 0.05	NS	2.984

*DAS - Days after spray

Table 12. Yield of brinjal treated with insecticide mixtures

Treatments	Yield / plant	
	Number of fruits /plant	Weight of fruit kg/ plant
Fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	12.95^{ab}	1.64^{b}
Cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1}	11.70^{b}	1.42^{c}
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	13.72^{a}	1.72^{a}
Control	5.84^{c}	0.62^{d}
CD (0.05)	1.279	0.099

4.1.11. Harvest Time Residue in Fruits treated with Insecticide Mixtures

Mature brinjal fruits were taken from experimental plots sprayed with fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} and cypermethrin 3% + quinalphos 20% EC @ 175+175 g a.i ha^{-1} for estimation of harvest time residue in fruits.

The harvest time residues of these effective insecticide mixtures were studied and results revealed that all three effective insecticide mixtures were below limit of quantification (LOQ) 0.05 mg kg^{-1} (Table 13).

Table 13. Harvest time residue in brinjal fruits treated with insecticide mixtures

Treatments		Mean residue (mg kg^{-1})
Fipronil 40%+ imidacloprid 40% WG @ 175+175 g a.i ha^{-1}	Fipronil	<LOQ
	Imidacloprid	<LOQ
Cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1}	Cypermethrin	< LOQ
	Quinalphos	<LOQ
Betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}	Betacyfluthrin	<LOQ
	Imidacloprid	<LOQ
Control		<LOQ

*LOQ – Limit of quantification (0.05 mg kg^{-1})

Discussion

5. DISCUSSION

Brinjal is an economically important vegetable crop grown throughout the country and is described as poor man's vegetable since it is popular among the small scale farmers and low income consumers. It is subjected to attack by many pests and diseases. The major insect pests are shoot and fruit borer, leaf hopper, whitefly , stem borer, hadda beetle and lace wing bug. Farmers are mainly depending on chemical pesticides for the management of the pests. The immediate and effective control of pests by insecticides influence the farmers easily as against the non-chemical methods of pest management. The knowledge about the most susceptible stage of the pest and actual impact of the pest populations on yield loss are the key factors for economic and successful pest management. The lack of awareness in these aspects led the farmers to use insecticides indiscriminately, which resulted in the development of resistance and resurgence in major agricultural pests, high mortality of natural enemies, deposition of huge pesticide load in the crop as well as the environment.

To prevent the resistance phenomenon, there is a need for development of insecticide mixtures having different compounds with different modes of action. Insecticide mixtures are usually applied in the field to enhance the spectrum of the control when multiple pests are attacking the crop simultaneously and also recommended to increase the efficacy of the control of a single pest to hinder the development of insecticide resistance or to battle current resistance in a pest species.

5.1 EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES UNDER LABORATORY CONDITION

A laboratory experiment was conducted to evaluate the efficacy of insecticide mixtures against third instar nymphs of mealy bug, *C.insolita* and third instar grubs and adults of epilachna, *E. vigintioctopunctata*. Insecticide mixtures *viz.,* pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1}, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, flubendiamide 19.92% + thiacloprid 19.92% SC @ 48 + 48 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1} and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} were tested. The results revealed that cent per cent mortality of epilachna grub and adult was observed in treatments betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} after 96 h treatment.

Treatments with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} recorded cent per cent mortality of mealy bug after 120 h of treatment.

The effective insecticide mixtures obtained from laboratory experiment in the present study were betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1}, and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1}. The effective treatments include compounds from new generation insecticide groups *viz.,* synthetic pyrethroids, neonicotinoids, organophosphates and phenyl pyrazoles. Synergism is the major action taking place in majority of insecticide co-formulations. Synergism may occur when one insecticide interfere with the metabolic detoxification of another insecticide in a combination mixture. Certain organophosphate insecticides binds to the active site related to esterase enzymes responsible for detoxification of pyrethroid-based insecticides and so organophosphate insecticides may be considered helpful synergists for pyrethroids (Kulkarni and Hodgson, 1980). This is one of the foremost reasons why manufacturing companies formulate organophosphate and pyrethroid-based insecticide mixtures to manage arthropod pest complexes and counteract resistance (Ahmad, 2004). Synthetic pyrethroids are sodium channel modulators which prolong the open time of voltage dependent sodium channels results in hyper exicitability, tremors, convulsions and eventually paralysis. Organophosphates are Acetyl choline esterase (AChE) inhibitors which acting as pseudosubstrate and forming a covalent bond with the active site of serine, results in accumulation of acetylcholine in the synapse and overstimulation of AChE receptors cause ultimately death by respiratory failure. Whereas, neonicotinoids are nicotinic acetylcholine receptor (nAChR) competitive modulators which bind to the acetylcholine site on nicotinic acetylcholine receptor leading to a range of symptoms such as hyper-excitation and paralysis. Phenyl-pyrazoles belongs to the group GABA- gated chloride channel blockers which affects chloride channel by inhibiting the GABA-receptors results in overstimulation of insect nervous system (IRAC, 2018).

The present results were in tune with the work of Negi and Srivastava (2018) who conducted laboratory experiment to study the contact toxicity of three combination insecticides against *H. vigintioctopunctata* and found that deltamethrin + triazophos and profenofos + cypermethrin were found equitoxic.

In the present study, superiority of quinalphos is in agreement with the results of the studies conducted by Samanta *et al.* (1999). They reported that quinalphos AF at 500, 750 and 1000 g a.i. ha^{-1} and mixture of quinalphos + monocrotophos @ 500+360 g a.i. ha^{-1} gave excellent management of the chewing pests *viz., H.vigintioctopunctata* and *L. orbonalis* on brinjal along with a significantly higher crop yield. Panda *et al.* (2005) reported that mixture of fipronil + triazophos + cartap hydrochloride @ 100 + 400 + 0.5 g a.i. ha^{-1} found effective against *H.vigintioctopunctata* and *L. orbonalis* in brinjal.

5.2. EVALUATION OF EFFICACY OF INSECTICIDE MIXTURES UNDER FIELD CONDITION.

Field experiment was laid out to evaluate the efficacy of the selected insecticide mixtures from laboratory studies *viz.* betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} , cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1}. During the experimental period major pests observed were whitefly, leaf hopper, mealy bug and shoot and fruit borer.

After spraying insecticide mixtures, the maximum reduction in population of sucking pests *viz.,* whitefly, leaf hopper and mealy bug were recorded from the treatment cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} (98.34%, 99.19% and 97.7%) (Fig 1). The present results are in confirmity with the results of Surpam *et al.* (2015) and where they reported that insecticide mixture, cypermethrin 10 % + indoxacarb 10 % SC 200 + 200 g a.i ha^{-1} was found effective against sucking pests *viz.* aphids and thrips in cotton. Study conducted by Sharma *et al.* (2016) showed that insecticide mixtures triazophos + deltamethrin @ 360 g a.i ha^{-1}, profenophos + cypermethrin @ 440 g a.i ha^{-1}, chlorpyriphos + cypermethrin @ 550 g a.i. ha^{-1} were found effective against sucking pests *viz.* whiteflies (*B. tabaci*) and leaf hopper (*A. biguttula biguttula)* and also were effective against chewing pest like shoot and fruit borer (*L. orbonalis*) in brinjal. Jha and Kumar (2017) conducted a field study and found that profenophos 40% + cypermethrin 4% EC @ 440 g a.i. ha^{-1} was effective against whiteflies (*B. tabaci*) in tomato.

In the present study other insecticide mixtures which reduce the population of whiteflies and leaf hopper were fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (95.89%, 97.47% respectively) and betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (95.58%, 97.31% /plant respectively). The present results were in tune with the work of Patil *et al.* (2009) they reported that

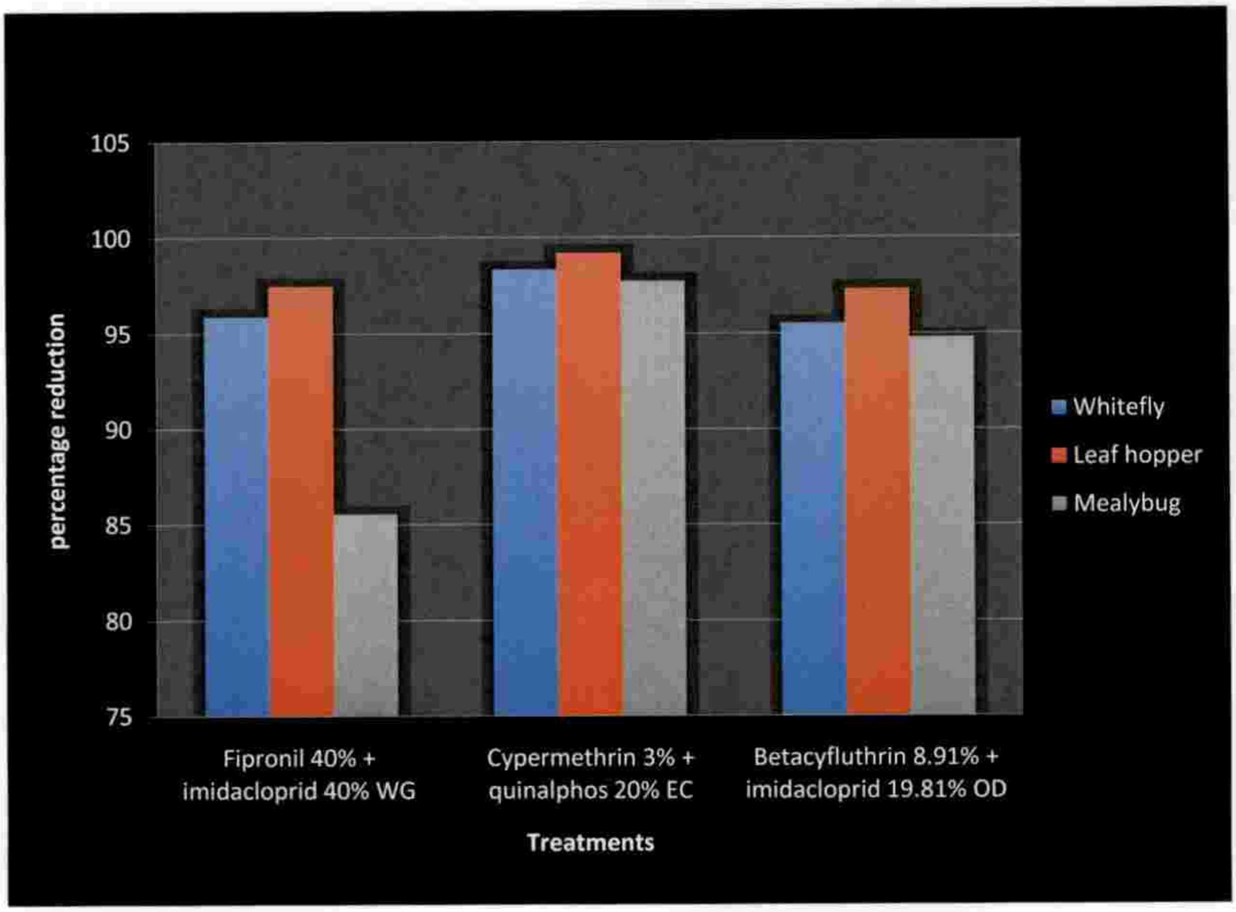

Fig. 1. Per cent reduction of sucking pest complex in brinjal treated with insecticide mixtures.

fipronil 40% + imidacloprid 80 WG 40% was effective in controlling jassids, aphids and thrips in cotton. Giraddi *et al.* (2017) found that combination of beta-cyfluthrin 90 + imidacloprid 210 OD @ 21.6 + 50.4 g a.i. ha^{-1} and @ 27.9 + 65 g a.i. ha^{-1} was found be the best in management of sucking pest *viz., S. dorsalis B. tabaci, P. latus and A. capparis* and also effective against *H. armigera* in chilli. Sen e*t al.* (2017) reported that spirotetramat 120 + imidacloprid 120 - 240 SC @ 75 + 75 g a.i. ha^{-1} was effective against *B. tabaci, A. biguttula biguttula and Tetranychus spp.* in brinjal. Viswanathan (2019) found that insecticide mixtures *viz.,* fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} and betacyfluthrin 8.91 % + imidacloprid 19.81 % OD @ 15.75 + 36.7 g a.i ha^{-1} was found effective against sucking pests *viz., S. dorsalis, B. tabaci, P. latus and A. gossipii* in chilli.

In the present study the lowest percentage of shoot borer damage was recorded in plants treated with betacyfluthrin 8.91 % + imidacloprid 19.81 % OD @ 15.75 + 36.7 g a.i ha^{-1} (1.74%) on 30 DAS and was found on par with cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (1.82 %) and fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (1.93%) (Table. 8). The lowest percentage of fruit borer damage was found in plants treated with cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (8.85%) on 30 DAS followed by betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (10.34%). Betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} treated plots recorded significantly higher yield (1.72 kg /plant) followed by fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (1.64 kg /plant) and cypermethrin 3 % + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (1.42 kg /plant) (Table. 9). The present findings were agreement with results of research work carried out by Biradar *et al.* (2001), they reported that mixture of quinalphos 3 EC + cypermethrin 10 EC at 0.25 ml L^{-1} found effective against shoot and fruit borer (*L. orbonalis*). Ghangale *et al.* (2002) conducted a study and reported that combination of chlorpyriphos 500 g + cypermethrin 50 g @ 550 g a.i. ha^{-1} was found effective against *L. orbonalis* in brinjal. Papal and Bharpoda (2009) revealed that cypermethrin 3 EC + quinalphos 20 EC 300 + 200 g a.i ha^{-1} was the best insecticide mixture against shoot and fruit borer (*E.vitella*) in okra. Pardeshi *et al.* (2010) conducted a field study and revealed that insecticide mixtures profenophos 40% + cypermethrin 4% EC @ 0.044% and chlorpyriphos 50% + cypermethrin % EC @ 0.055% were found effective against *E.vittella* in okra. Parmar *et al.* (2013) conducted a study and reported that ethion 40 % + cypermethrin 5% EC @ 0.045 % and triazophos 1% + deltamethrin 35% EC @ 0.036% were effective against shoot and fruit borer *E.vittella in* okra.

Insecticide resistance has become a major barrier to successful chemical control with conventional insecticides. The development of resistance to insecticides is governed by a complex of events and factors mainly, intense and frequent applications of insecticides which are often from the same chemical group or which pay the same mode of action.The target site insensitivity and metabolic resistance are the main mechanisms by which resistance is achieved in arthropod pests. Target site insensitivity involves alterations in the sequences of genes encoding for the insecticide target proteins, reducing the binding affinity of the toxic compound into a target site. When the pesticide enter into the insect body, enzymes attack and detoxify the active ingredient into non-toxic form (Mallet, 1989).

The main reason behind the action of these insecticide mixtures is the compatibility of single insecticides being mixed in formulation and their synergistic effect on the insects. It is important to mix insecticides with different modes of action or those that affects different bio chemical processes in order to overcome the resistance in pest population. When two compounds are mixed, they can be either potentiating or additive or antagonistic in an insect species. These effects can be varied on different insect species or strains depending upon their physiology and the mechanism of resistance developed. If a mixture is potentiating, it is a useful tool in enhancing control efficacy and combating insecticide resistance.

The effect of pesticide mixtures is changeable because the differences in the mode of action do not have necessity assurance for 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 upon 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 population, especially those that have the capacity of developing multiple resistance (Ahmad *et al.,* 2011). As in the case of single insecticide, care should be taken to avoid the regular use of insecticide mixtures against same pest.

5.3. ESTIMATION OF HARVEST TIME RESIDUES OF INSECTICIDE MIXTURES IN BRINJAL FRUITS.

A wide range of pesticides are being used erratically for managing pests and disease with minimum concern for their residual toxicities under field conditions. Persistence and dissipation rate of insecticides is one of the most important parameters in assesing their potential hazards on the environment. However, specific studies on the persistence and dissipation studies of selected insecticide mixtures in brinjal are so meagre.

In the present study, harvest time residues of effective insecticide mixtures *viz.,* betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} were estimated and were found below the limit of quantification (<LOQ). Earlier studies showed that betacyfluthrin + imidacloprid residues were reached below detectable limit (BDL) within 20 days after application in tomato (Dharumarajan *et al.*, 2009). Mandal *et al.* (2010) reported that betacyfluthrin reached BDL within 5 days whereas imidacloprid reached BDL

within 10 days in brinjal. Dissipation of betacyfluthrin + thiacloprid residues reached below detectable limit within 3 days in okra (Patel *et al.*, 2012).

Similar persistence pattern of cypermethrin and quinalphos were reported in earlier studies conducted in various crops. Kaur *et al.* (2011) reported that residues of cypermethrin reached below detectable limit within 7 days in brinjal, Rahman *et al.* (2014) reported that cypermethrin took 12 days to reach limit of quantification (LOQ) in brinjal. According to Chandra *et al.* (2014), cypermethrin took 11-15 days to reach limit of quantification (LOQ) in brinjal. Mutkule (2015) reported that residues of fipronil reached below detectable limit within 7-15 days and quinalphos took 7 days in brinjal.

The harvest time residues of fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} in brinjal were found below limit of quantification (<LOQ). Except present investigation, no study has been conducted on the dissipation of fipronil 40% + imidacloprid 40% WG in brinjal crop. However, several studies on dissipation of fipronil and imidacloprid were conducted in various crops as a single insecticides. Earlier studies on the degradation behavior of fipronil in okra (Gupta *et al.*, 2009) and cabbage (Bharadwaj *et al.*, 2012) reported that fipronil residues were not persisted beyond 15 days. Mutkule (2015) reported that residues of fipronil reached below detectable limit within 7-15 days in brinjal. Persistance and dissipitaion studies on imidacloprid as single insecticides has been conducted in various crops and residues of imidacloprid which persisted up to 5 days in brinjal (Singh, 2009), 7 days in okra (Patel *et al.*, 2012), 30-35 days in green chilli (Mathew *et al.*, 2012).

The overall experimental results concluded that spraying of betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} were effective for the management of pest complex in brinjal which also recorded the highest marketable fruit yield. Harvest time residues revealed the safety of all insecticide mixtures and they do not impart any human health risk. In insect- pest management strategy, insecticide mixtures play an important role by delaying the development of resistance and resurgence. Further research efforts are needed to develop multi pesticide formulations and development of safer green labelled co- formulated products for the future.

Summary

6. SUMMARY

Brinjal, (*S. melongena*) is an important crop in the plains of India that is practically available throughout the year. The production of egg plant is extremely constrained by many insect and non insect pests. To contain these pests, farmers are spraying toxic insecticides at short intervals regardless of various drawbacks. Therefore, it is important to have an alternative to manage the pest complex with newer insecticide mixtures having different mode of action. Present investigation was undertaken to evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of brinjal and to find out the harvest time residues in fruits. The salient findings of the investigations on the insecticide mixtures for the management of pest complex in brinjal are summarized below.

- Laboratory studies were carried out in CRD to evaluate the efficacy of insecticide mixtures *viz.* pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} against 3rd instar grubs and adults of epilachna, *Epilachna vigintioctopunctata*, and 3rd instar nymphs of brinjal mealy bug, *Coccidohystrix insolita*.
- The studies on the efficacy of insecticide mixtures against adults of epilachna *E. vigintioctopunctata,* revealed that cent per cent mortality of adults of epilachna beetle obtained from the treatment betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30+200 g a.i ha^{-1} and fipronil 40% + imidacloprid

40% WG @ 175+175 g a.i ha^{-1} after 96 h of treatment. Similar trends were obtained in the mortality of epilachna grub 72 h after treatment. Cent per cent mortality of mealy bug was observed when treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} , cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} after 120 h of treatment.

- Based on the laboratory results three effective insecticide mixtures were selected for field study *viz.,* betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1}.
- Field experiment was laid out in RBD at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during summer 2018-19. Major pests documented in experimental field were whitefly, leaf hopper, mealy bug and shoot and fruit borer.
- Less incidence of whiteflies was observed in cypermethrin 3 % + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (0.72 /plant) treated plants on fifteenth day after spraying followed by fipronil 40 % + imidacloprid 40 % WG @ 175 + 175 g a.i ha^{-1} (1.78 /plant) and betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (1.92 /plant). The lowest population of leaf hopper was observed in plants treated with cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (0.32 /plant) on fifteenth day after spraying followed by fipronil 40 % + imidacloprid 40 % WG @ 175+175 g a.i ha^{-1} (0.96 /plant) and betacyfluthrin 8.91% + imidacloprid 19.81 % OD @ 15.75+36.7g a.i ha^{-1} (1.04 /plant). Cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} was found to be superior over other treatments, in managing the population of mealy bug (1.71 /plant) on fifteen days after

treatment and was found on par with betacyfluthrin 8.91 % + imidacloprid 19.81 % OD @ 15.75+36.7 g a.i ha^{-1} (4.08 /plant).

- Low percentage of shoot borer damage was recorded in plants treated with betacyfluthrin 8.91 % + imidacloprid 19.81 % OD @ 15.75 + 36.7 g a.i ha^{-1} (1.74%) on 30 DAS and was found on par with cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (1.82 %) and fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (1.93%). Cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} treated plants showed the lowest fruit damage (8.85%) on 30 days after spraying followed by betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} (10.34%).
- Betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75 + 36.7 g a.i ha^{-1} treated plots recorded significantly higher yield (1.72 kg /plant) followed by fipronil 40% + imidacloprid 40% WG @ 175 + 175 g a.i ha^{-1} (1.64 kg /plant) and cypermethrin 3 % + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (1.42 kg /plant).
- The harvest time residues of these effective insecticide mixtures were studied and results revealed that all three effective insecticide mixtures were below limit of quantification (LOQ).
- The results of present study concluded that insecticide mixtures *viz.*, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} and fipronil 40 % + imidacloprid 40 % WG @ 175+175 g a.i ha^{-1} could effectively manage pest complex in brinjal.

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INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN BRINJAL

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ABSTRACT

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INSECTICIDE MIXTURES FOR THE MANAGEMENT OF PEST COMPLEX IN BRINJAL

An investigation on "Insecticide mixtures for the management of pest complex in brinjal" was carried out at College of Agriculture, Vellayani during 2018-2019. The objectives were to evaluate the efficacy of insecticide mixtures having component molecules of different mode of action against pests of brinjal and to find out the harvest time residues in fruits.

Preliminary experiment was carried out in CRD to evaluate the efficacy of insecticide mixtures against grubs and adults of epilachna beetle, *Epilachna vigintioctopunctata*, and nymphs of mealy bug, *Coccidohystrix insolita*. Insecticide mixtures *viz.* pyriproxyfen 5% + fenpropathrin 15% EC @ 25+75g a.i ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175g a.i ha^{-1}, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 27.5 g a.i ha^{-1}, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, flubendiamide 19.92% + thiacloprid 19.92% SC @ 48+48 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} , deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} were selected for the study. The recommended dose of these mixtures were prepared in aqueous solution and bioassay was done using 3rd instar grubs and adults of epilachna and 3rd instar nymphs of mealy bug.

Results of the laboratory experiment revealed, cent per cent mortality of epilachna adults which were treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} after 96 h of treatment. Similar results were obtained in the mortality of epilachna grub after 72 h of treatment. Cent per cent mortality of mealy bug was observed when treated with betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i

ha^{-1}, fipronil 40% + imidacloprid 40% WG @ 175+175g a.i ha^{-1} , cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and deltamethrin 1% + triazophos 35% EC @ 10+350 g a.i ha^{-1} after 120 h of treatment. Based on the laboratory results three insecticide mixtures were selected for field study *viz.,* betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3% + quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40% + imidacloprid 40% WG @ 175+175g a.i ha^{-1} .

Field experiment was laid out in RBD at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram during summer 2018-19. Major pests documented in experimental field were whitefly, leaf hopper, mealy bug and shoot and fruit borer. Less incidence of whiteflies was observed in cypermethrin 3 % + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (0.72 /plant) treated plants on fifteenth day after spraying followed by fipronil 40 % + imidacloprid 40 % WG @ 175+175 g a.i ha^{-1} (1.78 /plant) and betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (1.92 /plant). The Lowest population of leaf hopper was observed in plants treated with cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (0.32 /plant) on fifteenth day after spraying followed by fipronil 40 % + imidacloprid 40 % WG @ 175+175 g a.i ha^{-1} (0.96 /plant) and betacyfluthrin 8.91% + imidacloprid 19.81 % OD @ 15.75+36.7 g a.i ha^{-1} (1.04 /plant). Cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} was found to be superior over other treatments, in managing the population of mealy bug (1.71 /plant) on fifteen days after treatment and was found on par with betacyfluthrin 8.91 % + imidacloprid 19.81 % OD @ 15.75+36.7 g a.i ha^{-1} (4.08 /plant). Low percentage of shoot borer damage was recorded in plants treated with betacyfluthrin 8.91 % + imidacloprid 19.81 % OD@ 15.75+36.7 g a.i ha^{-1} (1.74%) on 30 DAS and was found on par with cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (1.82 %) and fipronil 40 % + imidacloprid 40% WG @ 175+175 g a.i ha^{-1} (1.93%). Cypermethrin 3% + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} treated plants showed the lowest fruit damage (8.85%) on 30 days after spraying followed by betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} (10.34%).

Betacyfluthrin 8.91 % + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1} treated plots recorded maximum yield (1.72 kg /plant) followed by fipronil 40% + imidacloprid 40% WG @ 175+175g a.i ha^{-1} (1.64 kg /plant) and cypermethrin 3 % + quinalphos 20 % EC @ 30 + 200 g a.i ha^{-1} (1.42 kg /plant).

The harvest time residues of these effective insecticide mixtures were studied and results revealed that all three effective insecticide mixtures were below limit of quantification (LOQ).

The results of present study revealed that insecticide mixtures *viz.*, betacyfluthrin 8.91% + imidacloprid 19.81% OD @ 15.75+36.7 g a.i ha^{-1}, cypermethrin 3%+ quinalphos 20% EC @ 30 + 200 g a.i ha^{-1} and fipronil 40 % + imidacloprid 40 % WG @ 175+175 g a.i ha^{-1} could effectively manage pest complex in brinjal.