MANAGEMENT OF PESTS AND PESTICIDE RESIDUES IN VEGETABLE AMARANTH (*Amaranthus tricolor* L.)

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KERALA, INDIA

2015

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by

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THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522
KERALA, INDIA

2015

DECLARATION

I, hereby declare that this thesis entitled **"MANAGEMENT OF PESTS AND PESTICIDE RESIDUES IN VEGETABLE AMARANTH (*Amaranthus tricolor* L.)"**is a *bona fide* 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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CERTIFICATE

Certified that this thesis entitled **"MANAGEMENT OF PESTS AND PESTICIDE RESIDUES IN VEGETABLE AMARANTH (*Amaranthus tricolor* L.)"** is a record of research work done independently by Mr. Pooru Muralikrishna under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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ACKNOWLEDGEMENTS

I am pleased to place my profound etiquette to ***Dr. Thomas Biju Mathew****, Professor, Department of Agricultural Entomology, College of Agriculture, Vellayani and honored Chairman of my Advisory Committee. I am indeed greatly indebted for the affectionate encouragement and cooperation he has imparted to me throughout my research work are invaluable and because of which I have been able to successfully complete the work assigned to me.*

I feel dearth of words to express my deep sense of gratitude, respect and sincere thanks to ***Dr. K, Sudharma,*** *Professor and Head, Department of Agricultural Entomology, College of Agriculture, Vellayani and member of my advisory committee for her worthy counsel, insightful and inspiring guidance, for critical perusal of manuscript and keen interest in planning and valuable suggestions during the course work.*

I wish to proper my genuine thanks to, ***Dr. Ambily Paul,*** *Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Vellayani, member of my advisory committee I am beholden beyond words to express my deep sense of gratitude for her brilliant counsel, transcendent suggestions, indefectible guidance, evincive criticism and inspiring encouragement to embellish the present study.*

Special thanks to ***Dr. M.S. Sheela****, Associate Director and Head, Department of Nematology, College of Agriculture, Vellayani for her timely co-operation and moral support which enabled me to accomplish this task.*

My heartfelt thanks to ***Dr. Celine V. A****, Professor and Head, Department of Agricultural Olericulture, College of Agriculture, Vellayani for her timely co-operation and moral support which enabled me to accomplish this task.*

I had a great privilege to work under the able and highly exceptional guidance of ***Dr. Naseema Beevi****, Professor and Principle Investigator, AINP on Pesticide Residue & Department of Agricultural Entomology, College of Agriculture, Vellayani..*

I acknowledge with sense of gratitude to ***Dr. Vijayaraghavan****, Department of Agricultural Statistics, College of Agriculture, Vellayani for his valuable advices in suggesting the statistical analysis of data.*

Special thanks to ***Dr. Thomas george.****,Associate Professor, Department of Soil Science, College of Agriculture, Vellayani for his valuable suggestions.*

I wish to thank my teachers, ***Dr. C Nandakumar, Dr. HebsyBai, Dr. Jiji, Dr. M.H. Faizal, Dr. N Anitha, Dr. K.D Prathapan, Dr. Devanesan, Dr. K.S. Premila, Dr. R. Krishnakumar, Dr. Reji Rani, Dr. Amritha****,* ***Dr. Narayana*** *and* ***Dr. M.S. Nisha*** *and non-teaching staff of Department of Agricultural Entomology for their timely help, constant encouragement and co-operation given during the course work.*

My special thanks to all my friends in Pesticide residue lab, ***Pratheeshchetan, Vishal chetan, Pradeepchetan, Reshmichechi, DeepaChechi, Surya Chechi, Prathibachechi, Mithrachechi, Priyachechi,***

Emily chechi, Renu, Binoychetan, Salmon chetan, George chetan, Rejithchetan, Sabari, Indira chechi, Anil chetan, Preethachechi, , Shaju and Vishnu who helped me at all stages of my research work.

My special thanks to Nithya and Lishma for their support at every time. No words are enough to express the affection to my classmates Aswathi, Divya, Akhila, Darshana, Milsha, Srinivas, Nagaraju, Akshayand my beloved seniors and juniorsLokesh sir, Aryachechi, Anichechi, Jaya chechi, Navi chechi, Malinichechi, Pallavichechi, Srinivas sir,Gangadhar sir,Kishore sir, Vidyamadam, Srilakshmi madam, Sai sir, Dheeraj, Shiva, Aruni, Jithin, Mrudhul, Gireesh, Satish, Eldosefor their help, constant encouragement and companionship in my personal and professional life and for their moral support during research work.

Diction is not at all enough to express my feelings towards my most beloved parents Sri P. Chandrudu and Smt. P. Sharadhawho constantly inspired, educated, guided and moulded me into the present position, without whom, I wouldn't have been here on this Elysium. Their boundless affection, meticulous care, admonishing remarks, consistent support and inimitable love acted as impetus on my fortitude during the whole course of my research.

With boundless affection, I would hearty acknowledge the constant encouragement and inspiration given to me by beloved brother Raghavendra.

I humbly thank the authorities of Kerala Agricultural University and Government of Kerala for the financial help in the form of stipend during my study period.

Above all, I thank the almighty GOD for his love and blessings without which I would not have been able to complete my studies and present this humble piece of work.

Pooru Muralikrishna

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LIST OF ABBREVATIONS

%	Per Cent
m^{-2}	Per square metre
@	At the rate of
a.i.	Active Ingredient
AINP (PR)	All India Network Project on Pesticide Residues
AR	Analytical Reagent
BDL	Below Detectable Limit
BtK	*Bacillus thuringiensis* kurstaki
CFU	Colony Forming Unit
CIBRC	Central Insecticide Board and Registration Committee
CRM	Certified Reference Material
C.D.	Critical Difference
Cm	Centimeter(s)
^0C	Degree Celsius
DAS	Days after spraying
EC	Emulsifiable Concentrate
EU	European Union
et al	And others
Fig.	Figure
FSSAI	Food Safety Standards Authority of India
g^{-1}	Per gram
GC	Gas Chromatography
h	Hour
HPLC	High Performance Liquid Chromatography
ha^{-1}	Per hectare
HAS	Hours After Spraying
ITCC	India Type Culture Colony

KAU	Kerala Agricultural University
Kg	Kilogram
L^{-1}	Per litre
LOD	Limit of Detection
LOQ	Limit of Quantification
M	Metre
Max.	Maximun
Min.	Minimum
ml	Milli litre
µl	Microlitre
Mm	Millimetre
m^{-2}	Per square metre
MRL	Maximum Residue Limit
OC	Organochlorines
OP	Organophosphates
Ppm	Parts per million
RSD	Relative Standard Deviation
SC	Suspension Concentrate
SD	Standard Deviation
SL	Soluble Liquid
sp.	Species
SP	Synthetic Prethroid
V. W	Veggie Wash
viz.	Namely
WG	Wettable Granule
WHO	World Health Organisation
WP	Wettable Powder

Introduction

1. INTRODUCTION

Vegetable amaranth is a common leafy vegetable in tropics and many warm temperate regions. It is cultivated in India, Malaysia, Myanmar, Taiwan, South Pacific Islands, tropical Africa, the Caribbean, Central and South America (Tindall, 1983). Amaranth plays an important role in nutrition among the leafy vegetables grown in India. In the leafy types, *Amaranthus tricolor* L. is a native of India and most commonly cultivated species in India. In Kerala, amaranth is raised round the year in the former paddy lowlands, garden lands and homesteads.

One of the major factors which hamper productivity and yield of amaranth, is infestation by insect pests. Leaf webbers, green grasshopper and tobacco caterpillar infest and devour the leaves of amaranth (Nair, 1975). Hitherto, plant protection measures against the pests especially in the market oriented cultivation of amaranth has largely been based on chemical pesticides. The major class of insecticides which were very popular in insect control in developing countries comprises organochlorines, organophosphates and synthetic pyrethroids. The package of practice of the Kerala Agricultural University (KAU, 2011) recommends the use of malathion 0.10 per cent or malathion 10 per cent dust in cases of severe infestation. These old generation insecticides are nerve poisons. Since, insects and other animals have similar tissue, reproductive, hormonal and nerve systems, these compounds have prospective effect on non target organisms including human beings (PPDB, 2014). Increased and non-judicious use of non-selective pesticides resulted in resistance development and resurgence of pests. Further, public concerns have grown considerably as a result of widespread environmental pollution, contamination of ground water and the presence of residues in food and water.

In the scenario of untenable dependence on chemical pesticides and public concerns, novel and more environmental friendly methods, tactics and schemes in the war against insect pests are called for. The novel insecticide chemistries are more tissue specific, highly branched long chain molecules that are activated in unique ways inside the target cells of insects resulting in less threat to other

organisms. These new generation insecticides, botanicals and bio insecticides are having selective toxicity to insects and safer to natural enemies.

The results of the Plan Scheme "Production and marketing of safe to eat (pesticide free) vegetables, fruits and food products for sale through government outlets" funded by Department of Agriculture, Government of Kerala, implemented by Kerala Agricultural University through the AINP on Pesticide Residues, College of Agriculture, Vellayani revealed that out of 37 red amaranth samples analyzed during the period of January – December 2013, seven samples were found as unsafe with high level of residues. In these detected insecticides most of residues belongs to organophosphate group. Frequent occurrence of chlorpyriphos, ethion, cypermethrin, fenvalerate, profenophos, methyl parathion and quinalphos residues were identified in these samples (PAMSTEV, 2014).

Food processing at domestic level would bid suitable revenue to tackle the current scenario of unsafe food (Kaushik *et al*., 2009). Hence, it is essential to explore strategies that address this situation affecting food safety especially for the developing countries where pesticide contamination is widespread due to indiscriminate usage. To ensure food safety for consumers, constant monitoring of pesticide residues in food commodities and standardization of simple, cost effective strategies to remove pesticides adoptable by consumers are necessary.

In this context, the present study was undertaken with the following objectives,

- To conduct a preliminary survey among amaranth growing farmers to collect information on pesticide use and pesticide residues on amaranth.
- To evaluate bio efficacy of new generation insecticides, botanicals and microbial insecticides for the management of amaranth pests.
- To standardize effective household method to decontaminate pesticide residues from amaranth.

Review of literature

2. REVIEW OF LITERATURE

Amaranth (*Amaranthus tricolor* L.) is widely known as "poorman's spinach", perhaps most nutritious leafy vegetable of the tropics. Amaranth is a good source of vitamins and minerals, being exceptionally rich in calcium, magnesium, iron, phosphorus, β-carotene and folic acid. Grain amaranth containing higher grain protein (13-19 %), with high lysine (6.09/100 g protein) and other sulphur containing amino acids (4.4 %) which are limiting factors in the conventional food grains (Martirosyan *et al.,* 2007). Amaranth is the most popular leafy vegetable consumed in Kerala. The crop is cultivated throughout the year. The productivity and yield of the crop is adversely affected by the infestation of pests and diseases. So farmers have been using chemical pesticides in wide range. However, their widespread use together with their unique physical, chemical and biological properties has raised serious concern among the public regarding their adverse effects on human health and environment. The literature related to pests of amaranth, pesticide residues, and different methods to removal of pesticide residues are reviewed here under.

2.1 PESTS OF AMARANTH

2.1.1 Leaf Webber

Amaranth leaf webber, *Hymenia recurvalis* (F) is also called as *Spoladia recurvalis* (F). In India the cultivated amaranth was infested by this pest during the warmer and early winter months (Lefroy, 1909). The occurrence of leaf webber *H. recurvalis* noticed on various species of amaranth in South India (Fletcher, 1914). Epenhuijsen (1974) and Grubben (1976) reported that in Africa the leaf caterpillar *H. recurvalis* is a major pest of *Amaranthus* spp. and beet. In India it is found on all the species of amaranth, but the cultivated species *A. cruentatus* L. and *A. dubius* Mart. are more seriously infested.

The moths were found in large numbers from July to October on various species of amaranth. As the severity of winter increased, their numbers gradually dwindled (Bhattacherjee and Menon, 1964). In January and February, they

became very scarce and by the advent of summer, their numbers again increased. The caterpillar feed on the epidermis and palisade tissues of the leaves which are webbed up with silvery threads. Sometimes the caterpillar webs together the leaves, feeds from within and skeletonise them completely (Bhattacherjee and Menon, 1964; Nair, 1975 and Nair, 1999). Yamad *et al.* (1979) worked out the biology of *H. recurvalis* on amaranth. The insect is found throughout the year but its most active season is from July to October. The caterpillars destroy the leaves by webbing them together and feeding from inside five to seven generations per year (Pande, 2009). *Trianthema portulacastrum* (desert horse purslane) was found as alternate host for *H. recurvalis*. The infestation of *H. recurvalis* was more in dry seasons than in wet seasons (Aderolu *et al.,* 2013).

Initial stages of *H. recurvalis* feed on the epidermis leaving a waxy layer by webbing the leaves together and later stages cause complete defoliation of weeds in cotton, pigeon pea, okra and black gram fields (Kedar and Kumaranag, 2013). Whereas, Lee *et al.,* (2013) reported that in beet webworm the development period of egg decreased with increase in temperature. The most voracious and damaging stage of *H. recurvalis* is the third instar larva which prefers tender leaf (Aderolu *et al.,* 2013).

Psara basalis F. is another leaf webber of amaranth (Ayyar, 1963). The occurrence of leaf webber *Psara pallidalis* on amaranth in West Africa was reported by Epenhuijsen (1974). The green caterpillar of the species *P. basalis* commonly occurs in Kerala. The larvae web together the leaves and feed from within (Nair, 1975; 1999).

2.1.2 Tobacco caterpillar

Nair (1975) and Nair (1999) reported that the larvae of the polyphagous pest *Spodoptera litura* (F.) fed on the leaves of amaranth occasionally. The tobacco caterpillar, *S. litura* is distributed worldwide and it is a member of the economically important polyphagous pest (>120 host plants) and causes serious crop losses (Singh and Jalali, 1997).

Butani (1977) and Reddy and Kumar (2004) reported that *S. litura* was present in the field throughout the year except during September to October. First instar exhibited no feeding preference, but the more mobile third instars showed a significant feeding preference for excised pigweed leaves (Showler, 2001).

2.1.3 Green grasshopper

Nair (1975) stated that *Atractomorpha crenulata* F. is a polyphagous grasshopper enjoying a countrywide distribution. The nymphs and adults of grasshopper *A. crenulata* feed on leaves of amaranth. He observed that the grasshopper was most active from July to September during which period, they caused the maximum damage and bred profusely. The activity decreased as the temperature fell and was the lowest during December and January.

2.1.4 Amaranth weevil

The occurrence of amaranth weevil *Hypolixus truncatulus* (F.) was reported by Nair (1975), Grubben (1976), Nayar *et al*. (1976) and David (2001).

Nair (1975) reported that an infested plant may contain 17 to 18 grubs causing it to rupture and break. Stunting and twisting of the plant, swelling of the branches and stems and suppression of shoot and leaf production are other symptoms of attack. David (2001) stated that the grubs bored into stems and caused gall like thickening, no serious damage was inflicted by the pest.

2.1.5 American serpentine leaf miner (ASLM)

In a survey conducted for assessing the incidence and severity of leaf miner, *Liriomyza trifolii* (Burgess) in Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, 70 plant species including vegetables were identified as host plants (Srinivasan *et al*., 1995). In Kerala, Reji (2002) revealed that *A. viridis* L. is a host plant of *L. trifolii* and the damage of this pest in cowpea was more severe during summer season in Kerala.

Jayakumar and Uthamasamy (2000) found that the incidence of *L. trifolii* was higher in summer than winter in cotton. Reddy and Kumar (2004) reported

that the peak infestation of leaf miner was noticed during March-April and the population declined during November-December.

2.1.6 Aphid

Nayar *et al*. (1976) reported that *Aphis craccivora* Koch was a pest of *A. viridis*.

2.1.7 Scale insects

The scale insects *Lecanium hesperidium* L. and *Pulvinaria durantae* T. infested the plants in South India (Nair, 1975; Nayar *et al*., 1976 and Nair, 1999).

2.1.8 Inflorescence thrips

The thrips *Euryaplothrips crassus* and *Haplothrips ceylonicus* Sch. infested the inflorescence of *Amaranthus* spp. (Nayar *et al*., 1976 and David, 2001).

2.1.9 Green semilooper

The green semilooper *Plusia eriosoma* D. feeds on leaves of amaranth (Nayar *et al*., 1976 and David, 2001). The occurrence of the semilooper *Plusia signata* F. in amaranth was reported by Nair (1999).

2.1.10 Tortoise beetle

The beetle *Cassida exilis* B. feeds on leaves of amaranth by scrapping the green tissue both in the grub and adult stages (Nair, 1975; 1999 and David, 2001).

2.1.11 Other pests

Coreid bugs *Cletus* spp. infests the amaranth crop in West Africa. The bugs cause damage to immature seeds by sucking on the inflorescence (Bohlen, 1973).

Leaf webber *P. bipunctalis* F. feed on leaves of amaranth in West Africa. The caterpillar spins a web causing the leaves to curl around them (Epenhuijsen, 1974).

African mole cricket *Gryllotalpa gryllotalpa* L. is an important pest on amaranth in Africa. The cricket cuts off young plants (Wyniger, 1962 and Grubben, 1976).

Nayar *et al*. (1976) reported the occurrence of leaf caterpillars such as *Junonia orithya* Linn., *Othreis fullonica* Linn., *Othreis materna* Linn. and *S. exigua* (Hb.) on amaranth.

2.2 BIO-EFFICACY OF INSECTICIDES AGAINST PESTS OF AMARANTH

2.2.1. Synthetic insecticides

2.2.1.1 Phenyl pyrazoles

Fipronil

Fipronil has proved its effectiveness in the control of *S. litura* as compared to that of emamectin (Sayyed and Wright, 2004). The bio efficacy of fipronil was determined at three concentrations 7.0 ppm (LC_{30}), 15 ppm (LC_{50}) and 126 ppm (LC_{90}) against seven days old *S. litura* and fipronil proved better than imidacloprid and indoxacarb in leaf dip method (Ramanagouda and Srivastava, 2009).

Fipronil 5 SC @ 1 ml L^{-1} treated plots gave additional yield of 4.98 t ha^{-1} than other insecticide treated plots against *H. recurvalis* (Majula and Kotikal, 2015a).

2.2.1.2 Spinosyns

Spinosad

Field experiments were conducted on chilli crop to assess the bioefficacy of spinosad 45 SC against pod borer *S. litura* at Regional Agricultural Research station, Guntur. Spinosad 45 SC tested at 100, 125, 162.5 and 200 ml ha^{-1} was effective against pod borer. Ovicidal toxicity of conventional and new insecticides

against eggs of *S. litura* were evaluated under laboratory condition by Khalid *et al.* (2001). It was found that spinosad 48 SC @ 0.015 % was effective with mortality of 73.33 per cent. Dey and Somchoudhury (2001) noticed that spinosad 48 SC @ 15-25 g a.i ha^{-1} gave effective control of *S. litura.* Also Ahmed (2004) reported that the spinosad was the most effective compound against the newly hatched larvae of both pink and spiny bollworms after 12 days for laboratory and field strain, respectively. Mallareddy *et al*. (2004) reported that spinosad 48 SC @ 0.015 % recorded 62.20 per cent reduction in *S. litura* larval population on cabbage crop. Similar studies conducted by Soujanya *et al*. (2004) and reported that spinosad 45 SC @ 0.015 % reduced the larval population of *S. litura* by 59.00 per cent in cabbage crop. Spinosad proved as second best effective after emamectin benzoate in the management of *S. litura* (Ahmed *et al.,* 2005).

In the plant pest notice published by Central Science Laboratary UK, it was recommended that spinosad was effective against *Spodoptera* spp on ornamentals and cucumbers. (Collins *et al.,* 2006). Spinosad 45 SC a new A: D ratio (Spinosyn A 50 % Min + Spinosyn D 50 % Max) at the rate of 75 g a.i ha^{-1} was found to be effective and optimum to combat cotton thrips and bollworms (Bheemanna *et al*., 2009). The LC_{50} of spinosad, was 22.179 ppm after 72 hours of treatment against 2^{nd} instar larvae of cotton leaf worm, *S. littoralis* (Boisd.) (Abdel-Hafez and Abdel-Aziz, 2010).

2.2.1.3 Indoxacarb

Indoxacarb 15 EC @ 0.024 % gave 86.66 per cent mortality of *S. litura* eggs when sprayed (Khalid *et al.,* 2001). The LC_{50} of indoxacarb was inferior to emamectin benzoate and fenvalerate but superior to cypermethrin, spinosad and quinalphos (Gupta *et al.,* 2004). Indoxacarb was proved to be the second most effective insecticide after emamectin benzoate for the management of *S. litura* (Ahmed *et al.,* 2005). Indoxacarb 14.5 SC @ 0.0145 % and thiodicarb 75 WP @ 0.075 % gave higher reduction in larval population of *S. litura* (Rao *et al.,* 2006). The LC_{50} (at 48 hours) and LT_{50} of indoxacarb on *S. litura* were 42.6 µg ml^{-1} and

38.2 hours and indoxacarb was found to be most effective against *S. litura* among fipronil, imidacloprid and methomyl (Ramanagouda and Srivastava, 2009). The recorded LC_{50} of *S. litura* in indoxacarb treated leaves was 16.9 mg L^{-1} and it was inferior to chlorantraniliprole and emamectin benzoate (Karuppaiah and Srivastava. 2013)

In indoxacarb treated amaranth plots, damage percentage of *H. recurvalis* decreased from eight to three and four at first day and fourth day after treatment, respectively (Majula and Kotikal, 2015b).

2.2.1.4 Avermectin

Avermectins act as agonists for gamma-amino butyric acid (GABA) gated chloride cannels. They bind with high affinity to site in the head and muscle neuronal membranes of various insect species (Gour and Sridevi, 2012).

Emamectin benzoate

Stanley *et al*. (2006) reported high toxicity of emamectin benzoate 5 SG with LC_{50} value 0.0015% in contradiction of *S. litura*. Toxicity of emamectin benzoate 5 SG and indoxacarb 15.8 EC to *S. litura* was evaluated by Dhawan *et al*. (2007). Prasad *et al*. (2007) conducted a comparative study of insecticides on relative toxicity of emamectin benzoate 5 SG, novaluron 10 EC and indoxacarb 14.50 EC and found that emamectin benzoate 5 SG was superior over the other two insecticides. Based on LC_{50} values in bioassay on *S. litura* larvae, emamectin benzoate 5 SG and indoxacarb 14.5 SC were comparatively superior over abamectin 1.90 EC at four, seven and ten days old larvae (Suby *et al*., 2008). Khalid and Prasad (2009) conducted a field experiment on chilli and reported that emamectin benzoate 5 SG @10 g a.i ha^{-1} was more effective against *S. litura*. Good fruit yield was observed when emamectin benzoate 5 SG @ 11 g a.i. ha^{-1} was sprayed against *S. litura* on chilli fruits (Tatagar *et al.,* 2009).

Ahmed *et al.* (2005) reported that emamectin benzoate as best control against *S. litura*, considering the lesser time and concentration required for effective management. Rehan *et al*. (2011) have recorded the LC_{50} data for emamectin benzoate, spinosad, imidacloprid and profenofos against field population of *S. litura*. Emamectin benzoate (1.59 ppm) was found to be the most toxic on the basis of LC_{50} value followed by spinosad (7.77 ppm), imidacloprid (258.75 ppm) and profenofos (689.5 ppm). Emamectin benzoate was found as effective against *S. litura* and its relative toxicity was 101 (Karuppaiah and Srivastava, 2013). Shaila *et al.* (2013) reported the LC_{50} value of emamectin benzoate against 3rd instar larvae of *S. litura* as 102.12 ppm by topical application method using micropipette. Highest yield of cabbage heads recorded in emamectin benzoate 5 SG @ 188 g ha^{-1} (37.52 t ha^{-1}) which was on a par with emamectin benzoate 5 SG @ 175 g ha^{-1} (37.35 t ha^{-1}), 150 g ha^{-1} (36.98 t ha^{-1}) and 125 g ha^{-1} (36.62 t ha^{-1}), followed by emamectin 5 SG @ 200 (35.83 t ha^{-1}) and 150 g ha^{-1} (35.28 t ha^{-1}) (Prathiban *et al.,* 2014).

Significant difference in yield of amaranth plots sprayed with emamectin benzoate 5 SG against *H. recurvalis* over other treatments (Majula and Kotikal, 2015b).

2.2.1.5 Chitin synthesis Inhibitors

Chitin synthesis Inhibitors consists of various compounds, acting on insects of different orders by inhibiting chitin formation, thereby causing abnormal endocuticular deposition and abortive moulting (Gour and Sridevi, 2012).

Buprofezin

Buprofezin did affect larval growth in silkworms where the older instars moulted and survived longer in both Petri dishes and cages. But even older instars did not survive at the higher concentrations after seven days of exposure (Vassarmidaki *et al.,* 2000). Buprofezin treated susceptible pests may remain alive

on the plant for three to seven days, but feeding damage during this time is typically very low (Ellsworth and Martinez-Carrillo, 2001). Insect growth regulators like buprofezin shows more effect on immature stages than to adults in a number of insect species (Schneide *et al.*, 2003). The mortality of *S. litura* was 43.33 per cent, whereas, in combination with spinosad enhanced to 83.3 per cent mortality (Ragaei and Sabry, 2011). The treatment of *S. littoralis* larvae with buprofezin and pyriproxyfen enhanced lipid peroxidation and insect antioxidant system for scavenging relative oxygen species (Fahmy, 2012). The significant level of mortality and weight reduction was observed at three DAT but the maximum mortality and weight reduction was found at seven DAT. Cuticular abnormalities were found when larvae were treated with higher concentrations of buprofezin in comparison with water-treated control (Das and Islam, 2014).

Buprofezin was found to be effective against *Tetranychus* mites and this effectiveness was comparable with diafenthiuron, fenpyroximate, abamectin and fenazaquin (Dharmishthabahen and Shukla, 2014)

2.2.1.6 Diamide

Diamide insecticides were recently introduced to the market, and are represented by two commercial compounds: flubendiamide and chlorantraniliprole (Hirooka *et al*., 2007).

Chlorantraniliprole

Median lethal concentration obtained by leaf dip method revealed that chlorantraniliprole (0.0001%) was effective against *S. litura* (Karuppaiah and Srivastava, 2013). Application of rynaxypyr (Coragen 20 %) led to significant reduction in carbohydrates content due to inhibition of digestive hydrolyzing enzymes activities and modulaiotn of chitin synthesis (Rashwan, 2013). A good yield of cabbage heads noticed in chlorantraniliprole 18.50 SC @ 50 mL ha^{-1} (34.98 t ha^{-1}) treated plots against *S. litura* (Prathiban *et al.*, 2014).

Flubendiamide

Masanori *et al*. (2005) reported that flubendiamide is highly effective against lepidopteron insects. In chilli field when flubendiamide was evaluated @ 60 g a.i. ha^{-1} and 40 g a.i. ha^{-1} against *S. litura,* higher yield of chilli fruits observed in 60 g a.i. ha^{-1} treated plots (Tatagar *et al.,* 2009). Meena *et al*. (2013) reported the efficacy of flubendiamide 39.35 SC at two concentrations 60 and 48 g. a.i. ha^{-1}, against the chilli defoliator *S. litura*. Maximum reduction in mean larvae per plant as well as lowest foliage damage was recorded in flubendiamide 39.35 SC @ 60 g.a.i. ha^{-1} followed by its next lower dosage@ 40 g.a.i/ha. Emamectin and flubendamide were more toxic with less LC_{50} values than pyrethroids (Bhatti *et al.,* 2013). Flubendiamide 480 SC @ 0.2 ml L^{-1} was found significantly superior in reducing the leaf eating caterpillar population and recorded highest seed yield (23.95 q ha^{-1}) followed by indoxacarb 14.5 SC (22.99 q ha^{-1}) and lambda cyhalothrin 5 EC (22.87 q ha^{-1}) as compared to other treatments including untreated check in amaranth (Manu *et al.,* 2014). The order of toxicity was emamectin benzoate > indoxacarb > novaluron > spinosad > flubendiamide > alphamethrin > endosulphan (Sharma and Pathania, 2014). Good mortality results were obtained when flubendiamide 39.35 SC was sprayed on *S. litura* population collected from chilli, castor, groundnut, sunflower, cabbage and onion (Tukaram *et al.,* 2014).

2.2.1.7 Benzoylureas

These compounds neither readily inhibit chitin synthesis in cell free systems, nor they block the chitin biosynthetic pathway in intact larvae (Oberlander and Silhacek 1998).

Novaluron

The mortality of *S. litura* larvae in the tested concentrations ranged between 23.3 to 80 per cent when data were recorded after 72 hours of treatment. The LC50 value was 33.86 x 10-3 per cent (Talikoti *et al.,* 2012). Novaluron was found to be inferior to emamectin benzoate and lufenuron in its effect to bring 100

per cent mortality of *S. litura* larvae (Shaila *et al.,* 2013). The toxicity ratio of novaluron on *S. litura* was 1.11 whereas, for emamectin benzoate it was 17.14 (Sharma and Pathania, 2014).

2.2.1.8 Keto enase group

Sipromesifen

In a field trial conducted at Chandra Krishi Vishwavidyalaya, West Bengal, spiromesifen (Oberon 240 SC) 624 ml ha^{-1} gave excellent control of red spider mite of brinjal along with significant increase in yield (Sekh *et al*., 2007). Studies on the bioefficacy of spiromesifen 240 SC conducted at instructional farm, RCA, MPUAT, Udaipur during summer and Kharif, 2009 revealed that two sprays of spiromesifen 240 SC at 625 ml ha^{-1} at 28 days interval was found most effective against mite and whitefly in tomato (Ameta *et al*., 2010).

Nauen and konanz (2005) found that the fecundity of two-spotted spider mite females directly treated on bean leaves was strongly reduced 48h after treatment with spiromesifen concentrations ranging between 0.064 and 40 mg L^{-1}: The lowest concentration halved the number of eggs laid, while the highest brought fecundity almost nil. Sublethal effects of spiromesifen were more pronounced than those of spirodiclofen, whose lowest concentration causing significant sublethal effect was 16 times lower than the recommended (Marcic, 2007). Spiromesifen had significant effect on fecundity, fertility and population growth of *Tetranychus* spp mites (Marcic *et al.,* 2009). Spiromesifen, a tetronic acid derivative acts as inhibitor of acetyl-CoA-carboxylase, a key enzyme in fatty acid biosynthesis. It is highly toxic to eggs and immature stages of spider mites, while it acts more slowly against adult females, causing reduction in fertility and fecundity (Marcic *et al*., 2011). Spiromesifen was the most promising acaricide for managing red spider mite *Tetranychus urticae* Koch (Sato *et al.,* 2011). Up to 95 per cent of mortality recorded in spiromesifen treated *Tetranychus* mites, within one day after treatment (Reddy and Latha, 2013).

2.2.1.9 Diafenthiuron

Diafenthiuron is a propesticide with lethal action in insects and mites that depends on the carbodiimide metabolite. This metabolite functions as a neurotoxicant, possibly by interfering with a biogenic amine (octopamine) mediated mechanism (Khadir and Knowles, 1991). Similar results were also reported by Patil (2005) who found that use of diafenthiuron resulted in more than 96 per cent mortality of adult mites. The ovicidal activity of diafenthiuron was identified by Patil and Nandihalli (2007), who reported that diafenthiuron caused more than 98 per cent egg mortality, based on their bioassay studies on *T. macfarlanei* infesting brinjal. The insecto-acaricide diafenthiuron, is a novel thiourea compound that disrupts oxidative phosphorylation by inhibition of the mitochondrial ATP synthase enzyme. It has been reported as effective against active stages of spider mites (Marcic *et al*., 2011). Similar studies were conducted by Krishna and Bhaskar, (2013) and revealed that fenazaquin 10 EC (25 micro L/10 ml) and diafenthiuron 50 WP (16 mg/10 ml) exhibited 100 per cent adult mortality within 24 hours of treatment application.

2.2.1.10 Fenpyroximate

The inhibition of mitochondrial NADH-CoQ reductase by fenpyroximate seems to induce a decrease in ATP contents and morphological changes in mitochondria. Ultimately, this would contribute to the acaricidal and knockdown activities against *T. urticae* by this compound (Motoba *et al.,* 1992). Fenpyroximate 5 SC @ 1 ml L^{-1} is one of the effective chemical to manage the *Tetranychus* spp mite in grapes (Kulakarni *et al.,* 2008). Babu *et al.,* (2009) studies revealed that 100 per cent mortality of *Tetranychus spp.* nymph and adults after 24 hours and no hatching of eggs in all the tested dosages of fenpyroximate.

2.2.1.11 Organophosphates

The organphosphorus compounds act by phosphorylating cholinesterase, an enzyme that plays a vital role in hydrolyzing acetylcholine. The OPs form complexes that are either irreversible or prevent readily release of the enzymes (Gour and Sridevi, 2012).

Malathion

Kumar *et al.* (2010) reported that phosalone, endosulfan, monocrotophos and malathion were highly toxic against the chilli pod borer, *S. litura.* In *H. recurvalis* infested amaranth plots when sprayed with malathion 50 EC comparatively lesser yield obtained over emamectin benzoate 5 SG (0.2 g L^{-1}), indoxacarb 15.8 SC (0.25 ml L^{-1}), fipronil 5 SC (1 ml L^{-1}) treated plots (Majula and Kotikal, 2015b).

Ethion

Gangopadhyay and Sarkar (2000) reported the overall performance of ethion (0.04 %, 0.06 %, and 0.08 %) and dicofol (0.03 %, 0.05 %, and 0.07 %) in reducing chilli mite than other treatments *viz.*, monocrotophos (0.03 %, 0.05 %, and 0.07 %) and endosulfan (0.03 %, 0.05 %, and 0.07 %). Ethion 50 EC proved to be superior in controlling the leaf curl disease of chilli with 6.41 per cent incidence through suppression of chilli thrips and mite and recorded the highest yield of green chilli (Mishra, 2003). Ethion 50 EC recorded 13.53 mites/leaf and 2.41 leaf curl index (LCI) which were at par with dicofol 18.5 EC (13.79 mites/ leaf and 2.14 LCI) which differ significantly from spiromesifen (Nagaraj *et al.*, 2007).

2.2.2 Microbial insecticides

2.2.2.1 Bacillus thuringiensis

The LD_{50} of *B. thuringiensis* against second instar larvae of *H. recurvalis* was found to be 2.51 x 10^9 spores per 100 ml (Thomas, 1964). Two proprietary products of *B. thuringiensis* were found to be effective against *H. recurvalis* (Gangawar *et al.*, 1980). The mortality of *H. recurvalis* in *B. thuringiensis* treatment increased gradually and on eight days after the second spray, even in lower doses (Leena *et al.*, 2005). Similar works conducted by Aswal and Bisht (2012) revealed that *B. thuringiensis* (1000 g. a.i. ha^{-1}) was an effective treatment,

where the percentage larval mortality of *H. recurvalis* , percentage leaf damage and grain yield of amaranth was observed to be 85.28, 32.08 and 13.59 q ha^{-1}, respectively. The mean population levels recorded in *B. thuringiensis* treated plots were 7.67, 10.67, 21.67, and 23.33 respectively at 1^{st}, 3^{rd}, 5^{th}, 7^{th} day after treatment (Majula and Kotikal, 2015b).

Chanpaisaeng *et al*. (2001) found high effectiveness of *B. thuringiensis* named JC590 (*B. thuringiensis* subsp. kurstaki) in killing Diamondback. Thappan *et al.* (2008) revealed the potentiality of *B. thuringiensis* kurstaki as as bioinsecticide against *S. litura, S. exigua* and *P. xylostella.* A detailed study on effect of 9 toxins of *B. thuringiensis* on *Spodoptera* by Martinez *et al.* (2008) revealed that the toxicity profile obtained differed from that observed in mortality assays. Cry1Aa, Cry1Ab, Cry1Ac, Cry1Ca, Cry1Da, and Cry1Fa toxins produced a similar larval growth inhibition. Cry2Aa had a lower but clear effect on larval growth inhibition, whereas Cry1Ba and Cry2Ab did not have any effect. Exposure to 500 μg ml^{-1} of Cry1Ac and Cry1Ca greatly reduced 50.0 and 46.80 per cent, and 58.70 and 57.30 per cent spermatophore acceptance by *H. armigera* and *S. exigua* females, respectively (Zhang *et al.,* 2013).

2.2.2.2 Entomopathogenic fungi

Beauveria bassiana

Beauveria bassiana kills arthopods by as a result of the insect coming into contact with the conidia (fungal spores). It takes three to five days for an infected insect to die. The dead insect may serve as a source of spores for secondary spread of the fungus. An infected adult male will also transmit the fungus during mating (Long *et al*., 2000).

Under glass house conditions in groundnut the entomopathogenic fungi *B. bassiana* @ 1 x 10^7 spores ml^{-1} was found to be not effective against *S. litura* (Jayanthi and Padmavathamma, 2001). When *S. litura* larvae were treated with *B.*

bassiana @ 2.4 × 10^7 and 2.4 ×10^4 spores ml^{-1} larvae failed to pupate (Malarvannan *et al.,* 2010). Similar studies conducted by Rajanikanth, *et al.* (2010) to evaluate pathogenicity of three isolates of *B. bassiana viz.*, Bb-13, Bb-11 and Bb-5A and one commercial isolate coded as Bb-N and two local isolates, Bb-L-1 and Bb-L-2 against third instar larvae of *S. litura.* Among these isolates strain Bb-5A was superior with significantly higher spore viability and pathogenicity. In field conditions when *B. bassiana* treated @ 2 g l^{-1} the population decreased to 1.17, 1.10, 1.17 at first, second and third day after spray respectively from 1.27 before the spray (Majula and Kotikal, 2015b).

2.2.3 Botanicals

Neem Azal @ 2.1 ml and 2.5 ml L^{-1} induced 71 and 75 per cent mortality of *S. litura* when sprayed on third instar larvae (Leena *et al.*, 2005). NSKE @ 5 per cent exhibited higher larval reduction 62.97, 84.81per cent of *S. litura* after first and second spray respectively, on soyabean (Patil *et al.* 2009). The aqueous solution and ethanol extracts of *Azadirachta indica* A. Juss. and *Melia* sp were also found to be effective against *S. litura* larvae (Anurag *et al.*, 2009). Similar studies were conducted by Singh *et al*. (2012) with rhizome extracts of different plants *viz.*, *Curcuma caesia* Roxb., *C. aromatic* Salisb., *C. longa* L., *Zingiber officinale* Roscoe cv. Nadia, *Z. officinale* cv. Adi Local, *Z. officinale* cv. Kekir and *Acorus calamus* L. Hexane and chloroform extracts of *A. calamus* were found highly effective with mortality ranging from 84 to 100 per cent respectively. In this study *Curcuma* spp. gave superior performance than the *Zingiber* spp. in similar solvent extracts. Among neem oil (NO), neem seed kernel extract (NSKE), neem cake extract (NCE) and neem leaf extract (NLE) lowest consumption index was noticed in NSKE (Razak *et al.*, 2014).

The neem extract 0.25 g w/v was an effective eco-friendly protectant against *H. recurvalis* in amaranth (Aderolu *et al.*, 2013). The mean populations of *H. recurvalis* in NSKE treated plots were 2.73, 0.93, 2.33 and 2.60 at first, third, fifth and seventh day after spraying, whereas in azadirachtin (1500 ppm) treated

plants the mean populations were 2.67, 0.90, 1.37 and 1.63 respectively (Majula and Kotikal, 2015b).

2.2 MANAGENET OF PESTICIDE RESIDUES IN AMARANTH

In Kerala amaranth crop was cultivated throughout the year. The productivity and yield of the crop adversely affected by the infestation of pests and diseases. So farmers used chemical pesticides in wide range. This tendency leads to high residues on amaranth crop. The tendency of farmers to apply pesticides in order to improve yield and quality by managing insect pests leads to contamination of vegetables with pesticide residues (Kumari *et al.,* 2002; 2003 and kumari, 2008). Food processing techniques have been found to significantly reduce the pesticide residues in fruits and vegetables in several studies (Chavarri *et al*., 2005; Dejonckheere *et al*., 1996; Elkins, 1989; Krol *et al*., 2000; Schattenberg *et al*., 1996).

To tide over the present consequence of unsafe food the food processing at domestic level would be the best solution (Kaushik *et al.,* 2009). The main exposure to pesticides in humans is via foods (especially by fruit and vegetables), contributing five times more than other routes, such as air and drinking water (Claeys *et al*., 2011). Nair *et al.* (2013b) revealed through a detailed survey that vegetables like capsicum, okra and curry leaves contained two, two and ten pesticides respectively in level above ADI. Department of Agriculture, Government of Kerala and Kerala Agricultural University through the Plan Scheme "Production and marketing of safe to eat (pesticide free) vegetables, fruits and food products for sale through government outlets" revealed that out of 141 vegetable samples analyzed during the period of July to September 2014, 12 samples were found to be contain detectable level of residues. Among these analyzed vegetables red amaranth was classified as one of the high risk group (PAMSTEV, 2014). However, their widespread use together with their unique physical, chemical and biological properties has raised serious concern among the public regarding their adverse effects on human health and environment.

A study was conducted to reduce the amount of pesticide residues from amaranth by following different household decontamination methods. The earlier works done in connection with the above topic are reviewed here.

Table 1a: Studies across the world on effects of washing on removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Tomato	Washing in water	Captan	60.00-80.00	Krol *et al.*, 2000
			Chlorothalonil		
			Endosulfan		
			Permethrin		
2	Potato	Washing with water	Chlorpropham	33.00 – 47.00	Lentza-Rizos and Balokas, 2001
3	Potato	Dipping in tap water for 10 minutes	Pirimphos-methyl	12.90	Zohair, 2001
			Malathion	11.60	
			Profenophos	13.50	
4	Asparagus	Washing with water	Chlorpyriphos	24.00	Chavari *et al.*, 2005
			Cypermethrin	32.00	
			Ethylene bisdithio carbamate	52.00	
5	Hot pepper (Capsicum)	Dipping for 1 minute in tap water	Profenophos	81.06	Radwan *et al.*, 2005
6	Sweet pepper (Capsicum)	Dipping for 1 minute in tap water	Profenophos	85.16	Radwan *et al.*, 2005

Table 1a continued

7	Eggplant	Dipping for 1 minute in tap water	Profenophos	99.26	Radwan *et al.,* 2005
8	Cucumber	Washing plus rubbing in running tap water	Diazinon	22.30	Cengiz *et al.,* 2006
9	Grapes	Washing with water	Azoxystrobin	50.00	Lentza-Rizos *et al.,* 2006
10	Tomato	Washing in water for 15 s and rubbing under running water	Procymidone	68.00	Cengiz *et al.* 2007
11	Spinach	Washed with tap water	Chlorpyriphos	20.00	Randhawa *et al.,* 2007
12	Cauliflower	Washed with tap water	Chlorpyriphos	27.00	Randhawa *et al.,* 2007
13	Potato	Washed with tap water	Chlorpyriphos	24.00	Randhawa *et al.,* 2007
14	Eggplant	Washed with tap water	Chlorpyriphos	18.00	Randhawa *et al.,* 2007
15	Tomato	Washed with tap water	Chlorpyriphos	25.00	Randhawa *et al.,* 2007
16	Okra	Washed with tap water	Chlorpyriphos	20.00	Randhawa *et al.,* 2007
17	Cabbage	Washing under tap water for 5 minutes	Chlorpyriphos	10.08	Zhang *et al.,* 2007
			p,p- DDT	15.38	
			Cypermethrin	12.21	
			Chlorothalonil	12.50	
18	Apple	Washing by hand rubbing	Captan	50.00	Rawn *et al.,* 2008

Table 1a continued

19	Pepper	Washing with water	Dichlofluanid	27.00 – 90.00	Lee and Jung 2009
			Flusilazole		
			Folpet		
			Iprodione		
			λ-cyhalothrin		
			Lufenuron		
20	Cabbage	Washing with tap water	Chlorpyriphos	0.23	Ling *et al.*, 2011
21	Garlic sprouts	Washing with tap water	Chlorpyriphos	3.65	Ling *et al.*, 2011
22	Tomato	Washing with tap water	Chlorpyriphos	46.60	Ling *et al.*, 2011
23	Cucumber	Washing with tap water	Chlorpyriphos	10.60	Ling *et al.*, 2011
24	Eggplant	Washing with tap water	Chlorpyriphos	36.30	Ling *et al.*, 2011
25	Carrot	Washing in water for 5 min	Boscalid	78.00	Bonnechere *et al.*, 2012
			Difenconazole	89.00	
			Tebuconazole	68.00	
			Chlorpyriphos	60.00	

Table 1a continued

26	Apple	Washing with water	Chlorpyriphos	17.00-21.00	Kong *et al* ., 2012
			Cypermethrin	6.70-7.10	
			Acetamiprid	13.00-32.00	
			Tebuconazole	42.00-67.00	
			Carbendazim	47.00-50.00	
27	Okra	Washing with water	Imidacloprid	27.69	Sheikh *et al.,* 2012
			Emamectin benzoate	24.00	
28	Bitter gourd	Washing with water	Bifenthrin	46.34	Mirani *et al.,* 2013
29	Bell peppers (Capsicum)	Washing with water	Imidacloprid	71.20	Al-Taher *et al.,* 2014
			Chlorpyriphos	43.14	
30	Red Delicious apples	Washing with water	Thiabendazole	50.97	Al-Taher *et al.,* 2014
			Diphenylamine	88.80	
31	Fuji apples	Washing with water	Pyrimethanil	40.36	Al-Taher *et al.,* 2014
			Thiabendazole	49.04	
			Diphenylamine	46.90	
32	Peaches	Washing with water	Fludioxonil	71.63	Al-Taher *et al.,* 2014
33	Oranges	Washing with water	Imazalil	64.71	Al-Taher *et al.,* 2014
			Thiabendazole	78.05	
34	Lemons	Washing with water	Imazalil	41.68	Al-Taher *et al.,* 2014

Table 1b: Studies in India on effects of washing on removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Bell pepper (Capsicum)	Washing with running tap water	Malathion	67.00-78.00	Bhagirathi *et al.*, 2001
2	Soya bean	Washing with water	Cypermethrin	37.00-49.00	Dikshit, 2001
	Tomato			5.00 – 14.00	
	Okra				
	Bottle gourd				
	Ridge gourd				
3	Okra	Washing with water	Beta cyfluthrin	35.70 - 42.00	Dikshit *et al.*, 2002
4	Tomato	Washing with water	Metalaxyl	25.3 – 28.9	Hanumantharaju and Awasthi, 2003
			Mancozeb	40.3 – 60.4	
			Ethylenethiourea	16.4 – 48.3	
5	Tomato	Washing with water	Lambda cyhalothrin	35.00 - 42.00	Jayakrishnan *et al* ., 2005
6	Brinjal	Washing with water	Quinalphos	21.1 – 51.8	Samanta *et al.*, 2006
			Methomyl	28.7 – 60.1	
			Alphacypermethrin	25.6 – 54.8	

Table 1b continued

7	Brinjal	Washing for 1 minutes under tap water	HCH	44.00	Kumari, 2008
			DDT	37.00	
			Endosulphan	27.00	
			SP	26.00	
			OP	77.00	
			Carbamates	21.00	
	Cauliflower		HCH	36.00	
			DDT	34.00	
			Endosulphan	34.00	
			SP	29.00	
			OP	74.00	
	Okra		HCH	38.00	
			DDT	20.00	
			Endosulphan	36.00	
			SP	31.00	
			OP	50.00	
8	Cabbage	Washing with water	Quinalphos	27.72-32.48	Aktar *et al.,* 2010
9	Okra	Washing with water	Fenazaquin	31.00 – 32.00	Duhan *et al.* 2010

Table 1b continued

10	Tomato	Washing with water	Endosulphan	67.93	Kapoor, 2010
			Carbaryl	65.10	
11	Brinjal	Washing with water	Cypermethrin	25.47	Walia *et al.*, 2010
12	Brinjal	Washing with water	Cypermethrin	28.00 – 35.00	Kaur *et al.*, 2011
			Decamethrin	22.22 – 27.90	
13	Okra	Washing with water	Chlorpyriphos	13.00 – 35.00	Samriti and Kumari, 2011
14	Eggplant	Washing one minute under tap water	Parathion	23.00	Satpathy, 2012
			Methyl parathion	22.00	
			Malathion	45.00	
			Fenitrothion	37.00	
			Formothion	20.00	
			Chlorpyriphos	37.00	
15	Okra	Washing one minute under tap water	Parathion	29.00	Satpathy, 2012
			Methyl parathion	29.00	
			Malathion	39.00	
			Fenitrothion	35.00	
			Formothion	20.00	
			Chlorpyriphos	31.00	

Table 1b continued

16	Tomato	Washing one minute under tap water	Parathion	37.00	Satpathy, 2012
			Methyl parathion	32.00	
			Malathion	41.00	
			Fenitrothion	34.00	
			Formothion	27.00	
			Chlorpyriphos	39.00	
17	Beans	Washing one minute under tap water	Parathion	33.00	Satpathy, 2012
			Methyl parathion	35.00	
			Malathion	43.00	
			Fenitrothion	39.00	
			Formothion	27.00	
			Chlorpyriphos	31.00	
18	Cauliflower	Washing one minute under tap water	Parathion	32.00	Satpathy, 2012
			Methyl parathion	34.00	
			Malathion	39.00	
			Fenitrothion	36.00	
			Formothion	29.00	
			Chlorpyriphos	35.00	

Table 1b continued

19	Capsicum	Washing one minute under tap water	Parathion	37.00	Satpathy, 2012
			Methyl parathion	36.00	
			Malathion	40.00	
			Fenitrothion	34.00	
			Formothion	27.00	
			Chlorpyriphos	31.00	
20	Tomato	Washing with water	Bifenthrin	16.66 - 19.04	Chauhan *et al.,* 2012
21	Cabbage	Washing under tap water for 2-3 minutes	Chlorantraniliprole	100.00	Kar *et al.,* 2012
22	Cauliflower	Washing under tap water for 2-3 minutes	Chlorantraniliprole	100.00	Kar *et al.,* 2012
23	Okra	Washing with normal water for 10 minutes	Deltamethrin	42.06	Parmar *et al.,* 2012
			Alphamethrin	26.32	
			Triazophos	41.75	
			Ethion	50.28	
			Cypermethrin	26.32	
			Profenophos	93.72	

Table 1b continued

24	Tomato	Washing under running tap water	Dimethoate	48.00	Vemuri *et al.,* 2014
			Methylparathion	50.00	
			Quinalphos	52.00	
			Endosulphan	53.00	
			Profenophos	47.07	
25	Brinjal	Washing under running tap water	Dimethoate	48.00	Vemuri *et al.,* 2015
			Methylparathion	50.00	
			Quinalphos	52.00	
			Endosulphan	53.00	
			Profenophos	47.07	

Table 1c: Studies in Kerala on effects of washing on removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Cardamom	Washing in water	Mancozeb	62.00	Mathew *et al*., 1999
2	Chilli	Washing in plain water for 20 minutes	Spiromesifen	58.86	Varghese, 2011
			Acetamiprid	95.89	
			Propargite	27.00	
			Ethion	27.38	
3	Rice	Washing four times for 5 min	Malathion	95.00	Nair *et al*., 2012
			Methyl parathion		
			Chlorpyriphos		
			Quinalphos		
			Fenvalerate		
			Cypermethrin		
4	Wheat	Washing four times for 5 min	Malathion	95.00	Nair *et al*., 2013a
			Methyl parathion		
			Chlorpyriphos		
			Quinalphos		
			Fenvalerate		
			Cyperemthrin		
5	Cow pea	Washing with water	Chlorantraniliprole	57.81	Vijayasree *et al.*, 2013
6	Okra	Dipping in water for 15 minutes	Malathion	37.67	Nair *et al.*, 2014
			Chlorpyriphos	9.48	
			Quinalphos	33.24	
			Profenophos	23.64	
			Cypermethrin	6.70	

Table 1c continued

7	Curry leaf	Dipping in water for 15 minutes	Malathion	25.88	Nair *et al.*, 2014
			Chlorpyriphos	10.80	
			Quinalphos	18.59	
			Profenophos	21.66	
			Cypermethrin	8.19	
8	Cow pea	Washing with water	Emamectin benzoate	100.00	Vijayasree *et al.*, 2014
			Spinosad	57.48	
9	Brinjal	Washing with water for 10 minutes	Chlorantraniliprole	86.38 – 88.78	Vijayasree *et al.*, 2015
10	Okra	Washing with water for 10 minutes	Chlorantraniliprole	56.35 - 66.74	Vijayasree *et al.*, 2015

Table 2a: Studies across the World on effects of cooking in removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Medicinal plants	Boiling in water	Lindane	100.00	Abou-Arab and Abou-Donia, 2001
			Profenophos		
			DDT		
			Endrin		
2	Potato	Cooking at 100 ^{o}C	Organo chlorines	30.10 – 35.30	Soliman, 2001
			Organo phosphates	49.00 – 53.00	
3	Beans	By using microwave for 15 to 45 minutes	Trifluralin	92 .00– 99.00	Castro *et al.* 2002
			Chlorpyriphos		
			Decamethrin		
			Cypermethrin		
			Dichlorovos		
4	Beans	Cooking	Malathion	56.70	Lalah and Wandiga, 2002
5	Maize	Cooking	Malathion	64.20	Lalah and Wandiga, 2002
6	Tomato	Cooking at 100 ^{0} C for 15	Maneb	74.00	Kontou *et al.,* 2004
7	Hot Pepper (Capsicum)	Frying	Profenophos	98.48	Radwan *et al,* 2005
8	Sweet pepper(Capsicum)	Blanching	Profenophos	98.06	Radwan *et al,* 2005
		Frying		100.00	

Table 2a continued

9	Eggplant	Blanching	Profenophos	100.00	Radwan *et al*, 2005
		Frying		100.00	
10	Plum fruit	Cooking	Trichlorfon	27.00	Fernandez-Cruz *et al.*, 2006
			Captan	100.00	
11	Cabbage	Stir – frying for 5 minutes	Chlorpyriphos	86.60	Zhang *et al.*, 2007
			p,p-DDT	67.50	
			Cypermethrin	84.70	
			Chlorothalonil	84.80	
12	Spinach	Cooking	Chlorpyriphos	38.00	Zhang *et al.*, 2007
13	Cauliflower	Cooking	Chlorpyriphos	29.00	Zhang *et al.*, 2007
14	Okra	Cooking	Chlorpyriphos	25.00	Zhang *et al.*, 2007
15	Hot pepper (Capsicum)	Cooking	Dichlofluanid	35-100	Lee and Jung, 2009
			Flusilazole		
			Folpet		
			Iprodione		
			λ-cyhalothrin		
			Lufenuron		
16	Cabbage	Boiling	Chlorpyriphos	55.50	Ling *et al.*, 2011
		Frying		93.30	
		Cooking under micro wave		60.30	
17	Garlic sprouts	Boiling	Chlorpyriphos	7.87	Ling *et al.*, 2011
		Frying		7.54	
		Cooking under micro wave		65.40	
18	Tomato	Boiling	Chlorpyriphos	75.90	Ling *et al.*, 2011
		Frying		10.30	
		Cooking under micro wave		67.20	

Table 2a continued

19	Cucumber	Boiling	Chlorpyriphos	20.0	Ling *et al.*, 2011
		Frying		5.13	
		Cooking under micro wave		5.88	
20	Eggplant	Boiling	Chlorpyriphos	56.0	Ling *et al.*, 2011
		Frying		63.2	
		Cooking under micro wave		39.8	
21	Okra	Boiling	Emamectin benzoate	35.0	Sheikh *et al.*, 2012

Table 2b: Studies across the India on effects of cooking in removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Soya bean	Steaming	Cypermethrin	63 – 74	Dikshit, 2001
2	Chick pea	Cooking	Deltamethrin	15.69	Lal amd Dikshit, 2001
3	Brinjal	Steaming	Organo phosphate	100.00	Kumari, 2008
4	Cauliflower	Steaming	Organo phosphate	92.00	Kumari, 2008
5	Okra	Steaming	Organo phosphate	75.00	Kumari, 2008
6	Rice	Cooking in pressure cooker	Lambda cyhalothrin	10.60	Rahula and Shah, 2008
			Deltamethrin	11.30	
		Cooking in micro wave oven	Lambda cyhalothrin	27.35	
			Deltamethrin	54.40	
		Cooking in open vessel	Lambda cyhalothrin	49.20	
			Deltamethrin	71.50	
7	Cabbage	Cooking	Quinalphos	41.30 – 45.20	Aktar *et al.*, 2010
8	Okra	Boiling	Fenazaquin	38.00 – 40.00	Duhan *et al.* 2010
9	Brinjal	Cooking in oil	Cypermethrin	45.20	Walia *et al.*, 2010
		Cooking in water		41.10	
10	Cabbage	Boiling for 5 minutes in water	Chlorantraniliprole	100.00	Kar *et al.*, 2012
11	Cauliflower	Boiling for 5 minutes in water	Chlorantraniliprole	100.00	Kar *et al.*, 2012
12	Okra	Cooking	Deltamethrin	76.64	Parmar *et al.*, 2012
			Alphamethrin	46.62	
			Triazophos	66.34	
			Ethion	61.88	
			Cypermethrin	60.53	
			Profenophos	95.10	
13	Eggplant	Boiling	Organo phosphate	64 - 86	Satpathy, 2012
14	Okra	Boiling	Organo phosphate	40 - 84	Satpathy, 2012

Table 2b continued

15	Tomato	Boiling	Organo phosphate	64 - 84	Satpathy, 2012
16	Beans	Boiling	Organo phosphate	58 - 84	Satpathy, 2012
17	Cauliflower	Boiling	Organo phosphate	64 - 86	Satpathy, 2012
18	Capsicum	Boiling	Organo phosphate	61 - 84	Satpathy, 2012
19	Tomato	Direct cooking	Dimethoate	56.41	Vemuri *et al.*, 2014
			Methylparathion	58.00	
			Quinalphos	58.20	
			Endosulphan	61.00	
			Profenophos	59.00	
20	Brinjal	Direct cooking	Dimethoate	56.41	Vemuri *et al.*, 2015
			Methylparathion	58.00	
			Quinalphos	58.20	
			Endosulphan	61.00	
			Profenophos	59.00	

Table 2c: Studies in Kerala on effects cooking in removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Capsicum	Cooking in open pan for 10	Fipronil	65.68	Xavier *et al.*, 2014

Table 3a: Studies across the World on effects of washing plus cooking in removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Cabbage	Washing in 8% brine solution followed by boiling in water for 20 min	Diazinon	80-90	Kang and Lee, 2005
			Dichlorovos		
2	Spinach	- Do -	Dichlorovos	72.00	Kang and Lee, 2005
3	Spinach	Washing for 5 seconds followed by cooking for 10-12 minutes	Chlorpyriphos	48.10	Randhawa *et al.*, 2007
4	Cauliflower	- Do-	Chlorpyriphos	12.00	Randhawa *et al.*, 2007
5	Potato	- Do -	Chlorpyriphos	59.56	Randhawa *et al.*, 2007
6	Eggplant	- Do -	Chlorpyriphos	28.00	Randhawa *et al.*, 2007
7	Tomato	- Do -	Chlorpyriphos	22.00	Randhawa *et al.*, 2007
8	Okra	- Do -	Chlorpyriphos	23.00	Randhawa *et al.*, 2007
9	Fruits	Washing with 2% tamarind solution followed by steam cooking	Monocrotophos	41.00	Gardenmo. net, 2011
			Fenitrothion	51.00	
			Fenvalerate	100.00	
10	Cabbage	Washing for 2-3 minutes followed by boiling for 5 minutes	Chlorantraniliprole	100.00	Kar *et al.*, 2012
11	Cauliflower	- Do -	Chlorantraniliprole	100.00	Kar *et al.*, 2012
12	Green chilli	Washing followed by cooking	Trifloxystrobin	100.00	Yang *et al.*, 2012
13	Spinach	Washing followed by cooking	Azoxystrobin	100.00	Yang *et al.*, 2012
14	Perilla leaf	Washing followed by cooking	Azoxystrobin	100.00	Yang *et al.*, 2012
15	Bitter gourd	Plain washed dehydrated fried	Profenophos	89.47	Mirani *et al.* 2013
		Detergent washed dehydrated fried		90.35	

Table 3b: Studies across the India on effects of washing plus cooking in removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Brinjal	Washing plus cooking	Alphamethrin	25.00 – 33.00	Kanta *et al.*, 2001
2	Tomato	Washing plus cooking	Alphamethrin	11.00 – 30.00	Kanta *et al.*, 2001
3	Chickpea	Washing followed by steaming	Deltamethrin	40.00 – 60.00	Lal and Dikshit , 2001
4	Brinjal	Washing followed by steam cooking	Triazophos	64.00 – 88.00	Reddy *et al.* 2001
			Lindane	42.00 – 56.00	
5	Tomato	Washing followed by cooking	Metalaxyl	78.30 – 78.60	Hanumantharaju and Awasthi, 2003
			Mancozeb	74.60 – 78.40	
			Ethylenethiourea	44.50– 48.30	
6	Tomato	Washing plus steaming	Lambda cyhalothrin	60.00 – 69.00	Jayakrishnan *et al.*, 2005
7	Brinjal	Washing and cooking	Quinalphos	28.20 – 69.00	Samanta *et al.*, 2006
			Methomyl	44.40 - 76.10	
			Alphacypermethrin	40.00 – 70.20	
8	Cabbage	Washing plus cooking	Quinalphos	66.45 – 68.19	Aktar *et al.*, 2010
9	Okra	Washing plus boiling	Fenazaquin	60.00 – 61.00	Duhan *et al.* 2010
10	Okra	Washing + cooking	Chlorpyriphos	64.00 – 77.00	Samriti and kumari, 2011
11	Brinjal	Washing followed by cooking	Cypermethrin	31.00 – 42.00	Kaur *et al.*, 2011
			Deltamethrin	26 .00– 37.00	
12	Tomato	Washing + cooking	Bifenthrin	42.10 – 45.23	Chauhan *et al.*, 2012
13	Cabbage	Washing for 2-3 minutes followed by boiling for five minutes	Chlorantraniliprole	100.00	Kar *et al.*, 2012

Table 3b continued

14	Cauliflower	- Do -	Chlorantraniliprole	100.00	Kar *et al.*, 2012
15	Tomato	Washing with 2 % salt solution plus cooking	Dimethoate	99.00	Vemuri *et al.*, 2014
			Methylparathion	100.00	
			Quinalphos	98.02	
			Endosulphan	99.03	
			Profenophos	99.70	
16	Brinjal	Washing with 2 % salt solution plus cooking	Dimethoate	99.00	Vemuri *et al.*, 2015
			Methylparathion	100.00	
			Quinalphos	98.02	
			Endosulphan	99.01	
			Profenophos	99.70	

Table 4a: Studies across the World on effects of different solutions on removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Apple	Dipping in chlorine	Mancozeb	56.00 – 99.00	Hwang *et al.* 2001
		Dipping in chlorine dioxide		36.00 – 87.00	
2	Potato	Acetic acid solution	Organo chlorine	18.20 – 65.30	Soliman, 2001
		NaCl solution		18.20 – 15.60	
3	Potato	Citric acid	Pirimophos methyl	100.00	Zohair,2001
			Malathion	94.70 – 96.90	
			Profenophos	100.00	
		Ascorbic acid	Pirimophos methyl	100.00	
			Malathion	87.90 – 92.70	
			Profenophos	100.00	
		Acetic acid	Pirimophos methyl	100.00	
			Malathion	100.00	
			Profenophos	100.00	
		Hydrogen peroxide	Pirimophos methyl	100.00	
			Malathion	89.90 – 93.00	
			Profenophos	100.00	
		Sodium chloride	Pirimophos methyl	100.0	
			Malathion	100.00	
			Profenophos	100.00	
		Sodium carbonate	Pirimophos methyl	100.00	
			Malathion	100.00	
			Profenophos	100.00	
4	Beans	NaCl	Malathion	59.00	Lalah and Wandiga, 2002

Table 4a continued

5	Maize	NaCl	Malathion	71.20	Lalah and Wandiga, 2002
6	Maize	NaCl solution	Organo chlorine	28.00 – 93.00	Wheeler, 2002
7	Hot pepper (Capsicum)	Acetic acid 2%	Profenophos	60.61	Radwan *et al*, 2005
		Potassium permanganate		95.75	
		Sodium hydroxide 0.1%		65.15	
		Sodium chloride 1%		79.85	
8	Sweet pepper (Capsicum)	Acetic acid 2%	Profenophos	85.48	Radwan *et al*, 2005
		Potassium permanganate		83.22	
		Sodium hydroxide 0.1%		79.35	
		Sodium chloride 1%		74.84	
9	Eggplant	Acetic acid 2%	Profenophos	100.00	Radwan *et al*, 2005
		Potassium permanganate		90.74	
		Sodium hydroxide 0.1%		92.22	
		Sodium chloride 1%		97.41	
10	Egg plant	Pickled with rice bran solution	Chlorothalonil	95.00	Adachi and Okano, 2006
			Tetradifon	80.00	

Table 4a continued

11	Cabbage	2 % NaCl solution for 5 minutes	Chlorpyriphos	15.96	Zhang *et al.*, 2007
			p,p- DDT	23.07	
			Cypermethrin	10.68	
			Chlorothalonil	16.96	
		6 % NaCl solution for 5 minutes	Chlorpyriphos	29.41	
			p,p- DDT	40.17	
			Cypermethrin	32.82	
			Chlorothalonil	46.42	
		10 % NaCl solution for 5 minutes	Chlorpyriphos	60.50	
			p,p- DDT	58.97	
			Cypermethrin	64.12	
			Chlorothalonil	66.96	
		2 % Acetic acid solution for 5 minutes	Chlorpyriphos	21.84	
			p,p- DDT	28.20	
			Cypermethrin	17.56	
			Chlorothalonil	19.64	
		6 % Acetic acid solution for 5 minutes	Chlorpyriphos	50.42	
			p,p- DDT	50.42	
			Cypermethrin	34.35	
			Chlorothalonil	49.10	
		10 % Acetic acid solution for 5 minutes	Chlorpyriphos	70.59	
			p,p- DDT	60.68	
			Cypermethrin	69.47	
			Chlorothalonil	67.86	
10	Cabbage	Sodium hypo chloride solution	Chlorpyriphos	56.60	Ling *et al.*, 2011
12	Garlic sprouts	Sodium hypo chloride solution	Chlorpyriphos	25.60	Ling *et al.*, 2011
13	Tomato	Sodium hypo chloride solution	Chlorpyriphos	37.20	Ling *et al.*, 2011
14	Cucumber	Sodium hypo chloride solution	Chlorpyriphos	2.04	Ling *et al.*, 2011
15	Eggplant	Sodium hypo chloride solution	Chlorpyriphos	32.10	Ling *et al.*, 2011

Table 4b: Studies across in India on effects of different solutions on removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Green chillies	Dipping in 2% salt solution for 10 minutes	Triazophos	32.50 - 84.21	Kumar *et al.*, 2000
			Acephate	78.95	
2	Grapes	Dipping in 2% common salt for 10 minutes	Quinalphos	50.00 – 51.77	Reddy and Rao, 2002
			Chlorpyriphos	65.00 – 67.52	
3	Tomato	Citrus solution	Lambda cyhalothrin	26.00 – 43.00	Jayakrishnan *et al.*, 2005
		Saline solution		30.00 – 46.00	
4	Eggplant	0.001% KMnO4	Organo phosphates	36.50 – 92.60	Satpathy, 2012
5	Tomato	0.1% Ascorbic acid	Organo phosphates	54.00 – 76.00	Satpathy, 2012
6	Okra	0.1% Acetic acid	Organo phosphates	45.00 – 91.00	Satpathy, 2012
7	Beans	0.1% Malic acid	Organo phosphates	47.00 – 82.00	Satpathy, 2012
8	Cauliflower	0.1% Oxalic acid	Organo phosphates	43.00 – 67.00	Satpathy, 2012
9	Capsicum	0.1% NaHCO3	Organo phosphates	49.00 – 95.00	Satpathy, 2012
10	Okra	Washing with 2% brine solution for 10 minutes	Deltamethrin	50.47	Parmar *et al.*, 2012
			Alphamethrin	31.58	
			Triazophos	54.69	
			Ethion	56.35	
			Cypermethrin	50.00	
			Profenophos	94.67	
11	Tomato	Washing with 2 % salt sloution	Dimethoate	78.00	Vemuri *et al.*, 2014
			Methylparathion	82.00	
			Quinalphos	91.30	
			Endosulphan	89.00	
			Profenophos	88.20	
12	Brinjal	Washing with 2 % salt sloution	Dimethoate	78.00	Vemuri *et al.*, 2015
			Methylparathion	82.00	
			Quinalphos	91.30	
			Endosulphan	89.00	
			Profenophos	88.20	

Table 4c: Studies in Kerala on effects of different solutions on removal of pesticide residues from different agricultural commodities

Sl. No	Commodity	Type of treatment	Pesticides	Removal (%)	Reference
1	Bitter gourd	Dipping in 2% salt water for one hour	Monocrotophos	90.00	Kumar, 1997
			Phosphamidon		
2	Capsicum	Dipping in 2% tamarind for 15 minutes	Organo phosphates	24.84 – 34.42	Nair, 2013
			Synthetic pyrethroids	37.73 – 39.35	
		Dipping in 2% vinegar for 15 minutes	Organo phosphates	31.18 – 48.46	
			Synthetic pyrethroids	57.70 – 74.88	
		Dipping in 1% turmeric for 15 minutes	Organo phosphates	17.07 – 22.71	
			Synthetic pyrethroids	16.52 – 21.64	
		Dipping in 2% common salt for 15 minutes	Organo phosphates	33.09 – 48.00	
			Synthetic pyrethroids	53.26 – 54.74	
		Dipping in 2% butter milk for 15 minutes	Organo phosphates	21.44 – 26.38	
			Synthetic pyrethroids	22.02 – 33.28	
		Dipping in luke warm water for 15 minutes	Organo phosphates	11.89 – 19.16	
			Synthetic pyrethroids	16.93 – 17.23	
3	Cow pea	Dipping in 2% common salt for 20 minutes	Chlorantraniliprole	52.01 – 76.64	Vijayasree *et al.* 2013
		Dipping in 2% tamarind for 20 minutes		47.82 – 67.96	
		Dipping in 2% vinegar for 20 minutes		70.48 – 87.47	
		Dipping in 2% slaked lime for 20 minutes		90.90 - 91.25	
		Dipping in 2% baking soda for 20 minutes		45.56 – 47.19	
		Dipping in 1% turmeric for 20 minutes		79.81 – 91.70	

Table 4c continued

4	Okra	Dipping in 2% tamarind for 15 minutes	Organo phosphorous	24.84 – 33.46	Nair *et al.,* 2014
		Dipping in 2% vinegar for 15 minutes		38.67 – 63.76	
		Dipping in 1% turmeric for 15 minutes		32.14 – 52.88	
		Dipping in 2% common salt for 15 minutes		54.38 – 68.24	
		Dipping in 2% butter milk for 15 minutes		13.90 – 67.75	
		Dipping in luke warm water for 15 minutes		18.68 – 39.67	
5	Curry leaf	Dipping in 2% tamarind for 15 minutes	Organo phosphorous	57.10 – 65.65	Nair *et al.,* 2014
		Dipping in 2% vinegar for 15 minutes		41.77 – 52.77	
		Dipping in 1% turmeric for 15 minutes		8.90 – 63.89	
		Dipping in 2% common salt for 15 minutes		54.38 – 68.24	
		Dipping in 2% butter milk for 15 minutes		11.44 – 66.70	
		Dipping in luke warm water for 15 minutes		17.84 – 32.53	

Table 4c continued

6	Cow pea	Dipping in 2% common	Emamectin	85.56 –	Vijayasree *et al.*, 2014
			Spinosad	56.36 -	
		Dipping in 2% tamarind	Emamectin	100.00	
			Spinosad	66.19 –	
		Dipping in 2% vinegar	Emamectin	33.82 –	
			Spinosad	50.79 –	
		Dipping in 2% slaked	Emamectin	100.00	
			Spinosad	68.08 –	
		Dipping in 2% baking	Emamectin	57.49 –	
			Spinosad	38.71 –	
		Dipping in 1% turmeric	Emamectin	82.44 –	
			Spinosad	38.05 –	
7	Chilli	Dipping in	Fipronil	96.10 –	Xavier *et al.*, 2014
		Dipping in		93.61 –	
		Dipping in		91.60 –	
		Dipping in		95.06 –	
8	Brinjal	Dipping in 2% common	Chlorantraniliprole	82.45 – 90.66	Vijayasree *et al.*, 2015
		Dipping in 2% tamarind		77.47 – 79.96	
		Dipping in 2% vinegar		76.32 – 100	
		Dipping in 2% slaked		93.07 – 94.70	
		Dipping in 2% baking		82.95 – 100	
		Dipping in 1% turmeric		86.52 – 88.79	
9	Okra	Dipping in 2% common	Chlorantraniliprole	50.94 – 77.04	Vijayasree *et al.*, 2015
		Dipping in 2% tamarind		47.78 – 64.86	
		Dipping in 2% vinegar		69.04 – 86.10	
		Dipping in 2% slaked		85.91 – 86.48	
		Dipping in 2% baking		41.77 – 48.09	
		Dipping in 1% turmeric		75.66 – 84.33	

Table 4c continued

Materials and Methods

3. MATERIALS AND METHODS

The present study "Management of pests and pesticide residues in vegetable amaranth" aims to assess the bio-efficacy of new generation insecticides for the management of leaf feeding insects and mite pests of amaranth and to standardize methods to remove pesticide residues in vegetable amaranth. Survey in connection with the present study was conducted among the farmers in Kalliyoor and Pappanchani locations in Thiruvananthapuram. Laboratory experiments were conducted at the Department of Agricultural Entomology, College of Agriculture, Vellayani and the field experiments on evaluation of bio efficacy of chemicals were carried out in Instructional Farm, College of Agriculture, Vellayani and in farmer's field at Kalliyoor panchayat.

3.1 SURVEY TO DOCUMENT PEST INCIDENCE, PESTICIDE USAGE, AND PESTICIDE RESIDUES IN AMARANTH

A detailed survey was conducted to document the pest incidence, pesticide usage and pesticide residues in amaranth in Kalliyoor (8.414132, 76.986987) and Pappanchani (8.435633, 76.978064) of Thiruvananthapuram district during March 2014 – June 2014. Ten farmers each from two locations engaged in commercial cultivation of red amaranth were selected randomly for the survey. The weather data during the survey presented in Appendix-I

3.1.1 Documentation of Pest Occurrence

Occurrence of pests in amaranth grown in Kalliyoor and Pappanchani was monitored. The pest incidence and symptoms of damage were recorded. Adult and immature stages of pests were collected from these fields and brought to the laboratory for photography.

3.1.2. Documentation of Pesticide Usage

The pesticide use pattern in amaranth in two locations of Thiruvananthapuram district were recorded using a questionnaire (Appendix-II). The type, dosage and frequency of application of pesticides were recorded. The source of pesticides and information on pesticide usage, dose etc., were also collected.

3.1.3. Documentation of Pesticide Residues in Farm-Gate Samples

Amaranth samples were collected from different amaranth growing farmers in two different locations to monitor the presence of residues in amaranth. The samples were brought to Pesticide Residue Research and Analytical Laboratory, College of Agriculture, Vellayani for the analysis of pesticide residues.

3.2 LABORATORY EVALUATION OF BIO-EFFICACY OF INSECTICIDES, MICROBIAL INSECTICIDES AND BOTANICALS AGAINST LEAF WEBBER, LEAF EATING CATERPILLAR AND MITE

The experiments were laid out in completely randomized block design with 15 treatments, three replications and an untreated check. The treatments are detailed in Table-5.

3.2.1 Evaluation Against *H. recurvalis* and *S. litura* by using Leaf Disc Method

H. recurvalis and *S. litura* were reared in laboratory conditions (Average temperature max = 29 ± 2^0 C, min = 21 ±2^0 C, R.H = 80 ± 15 %, sunshine hours 7 ±1). The nucleus cultures were obtained by collecting larvae from the infested leaves of amaranth from untreated field. Different instar larvae were collected from instructional farm, College of Agriculture, Vellayani. Larvae of *H. recurvalis* and *S. litura* were reared in laboratory in separate troughs up to adult stage. These adults were released in a cage of size 1.6X1.0X1.18 m^3 with two

windows at each side to release adults and one door at two sides to introduce fresh plants. The entire cage was covered with iron mesh for easy observation (Plate 1). Four amaranth plants at the age of 20-25 days were kept along with pots inside the cage to create natural climate for adult growth and fed with five per cent diluted honey solution (Shirai, 2006). The adult was fed by immersing cotton buds in five per cent honey solution and were hanged from the roof of cage @ 10 per cage. The progeny culture obtained from this nucleus culture was reared up to second instar on amaranth plants kept in the cage. These second instar larvae were taken out for evaluation of treatments.

The treatments are given in Table. 5 were sprayed on bulk crop kept separately for each treatment using hand sprayer (one L capacity). Leaves with uniform size were collected randomly from this bulk crop. These leaves were placed in Petri plates at the rate of one leaf per Petri plate.

Second instar larvae of *H.recurvalis* and *S. litura* collected from cage were released into Petri plates containing treated leaves with three replications. Larvae were released @ ten larvae of *H. recurvalis* and *S. litura* separately in each Petri plate (Tukaram *et al.,* 2014). Observations were taken at six hours interval. Larvae were considered as dead when there was no movement of the insects when disturbed with Camel zero brush. Dead larvae were counted and discarded after every observation. In the case of microbial insecticides *viz., Beauveria bassiana* two per cent WP and *Beauveria bassiana* (ITCC 6063) CFU - $10^8 g^{-1}$ the movement of larvae were observed. The percentage mortality was calculated by using Abbot's formula (Abbot, 1925).

3.2.2 Evaluation against mites using leaf disc method

Amaranth plants were raised in grow bags to culture red spider mite (*Tetranychus* spp). Mites were collected from field and released into the plants of 20 days age. Plants were given one per cent extra dose of nitrogen in the form of Urea sprayed at 15 days after sowing and were kept under partially shaded condition.

The treatments (Table 6) were applied on bulk crop and treated leaves transferred to Petri plates as described in 3.2.1. Adult mites were collected from laboratory grown plants and were released into petri plates by using fine, smooth brush. Ten mites were transferred into each Petri plate containing treated leaves (Abhilash, 2001). Observations were recorded at 6 hours interval. The percentage mortality of mite was recorded using Abbot's formula (Abbot, 1925).

Table 5: List of the chemicals, microbial insecticides and botanicals evaluated for their bio-efficacy against *H. recurvalis* and *S. litura*.

No	Common Name	Trade Name	Dosage
1	Chlorantraniliprole 18.5 SC	Coragen	0.006%
2	Novaluron 10 EC	Rimon	0.015%
3	Buprofezin 25 SC	Applaud	0.03%
4	Flubendiamide 39.35 SC	Fame 480 SC	0.0096%
5	Spinosad 45 SC	Tracer	0.015%
6	Emamectin benzoate 5 SG	Proclaim	0.002%
7	Indoxacarb 14.5 SC	Avaunt	0.015%
8	Thiacloprid 21.7 SC	Alanto	0.036%
9	Fipronil 5 SC	Regent	0.01%
10	*Bacillus thuringiensis* kurstaki	Abtek- BT	5 ml L^{-1}
11	*Beauveria bassiana* WP	KAU	2 %
12	*Beauveria bassiana*	ITCC 6063	CFU-10^{8} g^{-1}
13	Oxuron	Oxuron	5 ml L^{-1}
14	Malathion 50 EC	Celthion	0.1%
15	Neem Seed Kernel Extract	------	5 %

Plate 1: Cage used for rearing of *Hymenia recurvalis* and *Spodoptera litura* adults

Table 6: List of the insecticides evaluated for bio-efficacy against mite pests of amaranth.

No	Common Name	Trade Name	Dosage (%)
1	Buprofezin 25 SC	Applaud	0.03
2	Diafenthiuron 50 WP	Pegasus	0.06
3	Emamectin benzoate 5 SG	Proclaim	0.002
4	Spiromesifen 22.9 SC	Oberon	0.0192
5	Fenpyroximate 5 EC	Mitigate	0.003
6	Ethion 50 EC	Fosmite	0.15

3.3 FIELD EVALUATION OF INSECTICIDES AGAINST PESTS OF AMARANTH

Five insecticides found as effective in laboratory were tested in field conditions along with insecticides check and an untreated check against *S. litura* in farmer's field in a location in Nedinjal village (8.4189170, 76.980203), against *H. recurvalis* and *S. litura* in Instructional Farm, College of Agriculture, Vellayani. The two insecticide cum acaricides which were found as effective against mite in laboratory were evaluated in field in Instructional farm, College of Agriculture, Vellayani. The experiments were laid out in randomized block design (RBD) with four replications.

3.3.1 Raising of Amaranth

Plots of 2 x 2 m were prepared with 30 cm ridges between plots. Seeds of amaranth variety Arun procured from Department of Olericulture, Vellayani, Thrissur were broadcasted in each plot. The number plants were around 90 plants per plot. The crop irrigated by using hose pipe. The excess seedlings were thinned two weeks after germination. The crop was raised during the period from August 2014 to September 2014 in farmers field (Nedinjal) and from October 2014 to November 2014 in Instructional Farm, College of Agriculture, Vellayani (Appendix-III). All the management practise except the plant protection against

insect pest in amaranth were followed as per the recommended package of practices of Kerala Agricultural University (KAU, 2011).

3.3.2 Evaluation of Treatments

Four sprayings were done at seven days interval. First spraying was done at seventh day after sowing. Observations were taken at first, third, fifth day after every spraying as post treatment count and one pre-treatment count before every spray. Observations were taken for number of infested leaves out of total leaves per plant in five plants, number of larvae before and after the treatment in five plants, number of natural enemies before and after the treatment and yield.

3.3.3 Yield of Amaranth in Plots Treated with Different Insecticides

The amaranth plants were harvested at 33 to 35 days age after sowing. The weight of harvested amaranth plants were recorded and expressed as g/plant. From plot weight of twenty single plants measured and mean was calculated.

3.4 STANDARDISATION OF DOMESTIC PRACTICES FOR DECONTAMINATION OF INSECTICIDE RESIDUES FROM AMARANTH

The pesticides detected in survey samples from Kalliyoor and Pappanchani locations were used to standardise the domestic decontamination method for decontamination of insecticide residues from amaranth. Laboratory experiments were carried out for standardization of techniques to decontaminate them. The experiments were carried out at Pesticide Residue Research analytical (PRRAL) which is under the All India Network Project on Pesticide Residues, College of Agriculture, Vellayani during 2013 to 2015.

3.4.1 Raising of Test Plants

Amaranth seeds were procured from Department of Olericulture, College of Agriculture, Vellayani. These seeds sown in grow bags and plants were raised organically. Along with insecticides detected in survey samples two more organo phosphates were sprayed on different plants with one treatment as control

untreated with three replications in each treatment. The insecticides sprayed were mentioned in Table 7. The insecticide sprayed plants were kept in covered conditions for a day to protect from rain. The treated plants were harvested at one day after spraying.

3.4.2 Validation of Multi Residue Methods (MRM) for Pesticide Residue Analysis in Amaranth

The standard protocol was used for each substrate to validate Multi Residue Method (MRM). These validation experiments were conducted by Modified Standard Method "AOAC 18th edition 2007:2007.01". Validation parameters *viz*., Limit of Detection, Limit of Quantification, Linearity, Recovery and Repeatability (Zanella *et al*., 2000) were evaluated for pesticides under laboratory conditions at AINP on Pesticide Residue, College of Agriculture, Vellayani.

Table 7: Insecticides (100 ppm) sprayed to test residues and to standardise decontamination practices

Sl. No	**Insecticide**	**Concentration (100ppm of a.i) of formulation**	**Trade name**	**Manufacturing company**
1.	Dimethoate 30 EC	0.5 ml/L	Rogorin	Insecticides (India) company
2.	Malathion 50 EC	0.2 ml/L	Celthion	Excel pulverising company
3.	Chlorpyriphos 20 EC	0.4 ml/L	Radar 20 EC	ISAGRO ASIA
4.	Quinalphos 25 EC	0.3 ml/L	Ekalux 25 EC	Syngenta India
5.	Profenophos 50 EC	0.2 ml/L	Curacron 50 EC	- Do -

6.	Ethion 50 EC	2.0 ml/L	Fosmite	PI Industries
7.	Bifenthrin 10 EC	0.4 ml/L	Markar	Dhanuka
8.	Lamda cyhalothrin 5 EC	0.5 ml/L	Karate	Syngenta India
9.	Cypermethrin 25 EC	1.0 ml/L	Cymbush 25 EC	- Do -
10.	Fenvelerate 20 EC	0.2 ml/L	Fenval 20 Ec	ISAGRO ASIA

3.4.2.1 *Reagents, Chemicals and Glass Wares*

Certified Reference Materials (CRM) of different pesticides used in the present study having purity ranging from 95.10 to 99.99 per cent mentioned in Table 9 were purchased from M/s Sigma Aldrich and stored in a freezer at low temperature (-20^0 C), without exposure to light and moisture. The glassware, reagents and equipment used in this study were mentioned in Table 8.

All the glassware were first washed with clean tap water, then with 1 per cent laboline, again washed thoroughly with tap water, distilled water and then rinsed with distilled acetone. These washed glass wares were kept at room temperature for drying and then kept in a hot air oven for three hours at 50 ^{0}C temperature. Syringes were pre-rinsed thoroughly with acetone followed by n-hexane. All solvents were all glass distilled before use in this study. Acetone pre-washed sodium sulphate, sodium chloride and magnesium sulphate were dried at room temperature and then activated in hot air oven at 450 ^{0}C for five hours for this study.

Table 8: Reagent chemicals and glass wares used in laboratory for residue analysis study.

Laboratory glass ware	Chemical reagents	Equipments
Beaker 100, 250 and 500 ml	Acetic acid glacial	Blender

Centrifuge tube 15 ml and 50 ml	Acetone AR grade	Homogenizer
Class A pipette 0.5 ml, 1 ml, 2 ml, 5 ml and 10 ml	Acetonitrile HPLC grade	Hot air oven
Conical flask 250 ml	Florisil AR grade	Laboratory centrifuge
Graduated test tube 5 ml, 10 ml, 15 ml, 20 ml and 25 ml.	Magnesium Sulphate (hydrated) AR grade	Mechanical shaker
Micropipette 1ml and 5 ml	n-Hexane HPLC grade	Vortex shaker
Micro syringe 10 µL and 500 µl	Primary Secondary Amine (PSA)	Turbovap evaporator LV
Turbovap tube 20 ml and 30 ml	Sodium Chloride AR grade	Weighing balance
	Sodium Sulphate AR grade (anhydrous)	Gas Chromatograph – (Shimadzu GC 2010 A)

3.4.2.2 *Determination of Limit of Detection (LOD)*

3.4.2.2.1 *Preparation of standard pesticide mixture*

To obtain a stock solution of 1000 mg kg^{-1}, weighed amount of analytical grade material of each pesticide was dissolved in a minimum quantity of distilled acetone and diluted with n-hexane: toluene (1:1). From these stock solution intermediate standards of 100 mg kg^{-1} of individual pesticide was prepared. In a volumetric flask, aliquots of intermediate standards of individual pesticide group (six organophosphates and four synthetic pyrethroids) were drawn to get separate working standard mixtures of each group at a concentration level of 10 mg kg^{-1}. Final volume was made up with n- hexane. From this, a working standard mixture of one mg kg^{-1} containing 10 different pesticides belonging to two different pesticide groups (Table 9) was prepared and it was serially diluted to lower concentrations of 0.5, 0.25 and 0.05 mg kg^{-1}.

3.4.2.2.2 *Standardization of condition of Gas Chromatograph (GC)*

Gas Chromatograph with working parameters as shown in Table 10 was used for analysis. A column temperature programme was developed to get proper separation of all pesticides used in the analysis.

Two ml of each working standard (0.5, 0.25 and 0.05 mg kg^{-1}) was injected in the Gas Chromatograph under set standard GC conditions. A quantity of 0.5 mg kg^{-1} of individual standard injected in to GC to calculate retention time of each pesticides and Limit of Detection (LOD) of the instrument was calculated for each pesticide, based on the lowest concentration of pesticide that can be identified under standard GC conditions. LOD was estimated from the chromatogram corresponding to the lowest point used in the matrix-matched calibration. The Limit of Detection (LOD) for the pesticides is considered to be the concentration that produced a signal to noise ratio of more than 3.

3.4.2.3 Calibration and Linearity

Linearity of the 10 pesticides selected for the study was tested. Different concentration levels of analytes (0.5, 0.25 and 0.05) in three replicates were analysed to establish the calibration curves. The linearity response line (calibration curve) was plotted with concentration of pesticide at X-axis and peak area count at Y-axis. Simple linear regression analysis was performed to calculate the slope and the intercept. The least square regression method was used to test linearity of each analyte and the coefficient of determination (R^2) was calculated. Simple linear regression was performed to calculate the slope and the intercept.

Table 9: List of Certified Reference Material (CRM) used in the preparation of pesticide mixture.

Sl. No	Pesticide group	Certified Reference Material	Purity (%)
		Chlorpyriphos	99.9
		Ethion	97.8

1.	Organophosphates	Malathion	97.2
		Profenophos	98.2
		Quinalphos	99.2
		Dimethoate	98.2
2.	Synthetic pyrethroids	Bifenthrin	98.3
		Cypermethrin	95.1
		Fenvalerate	98.7
		Lambda cyhalothrin	97.4

3.4.2.4 Determination of Limit of Quantification (LOQ)

Limit of Quantification (LOQ) of the analytical methodology for the extraction of pesticide residues was also calculated. LOQ is the minimum concentration of contaminant in a food sample that can be determined quantitatively with an acceptable accuracy and consistency (mean recoveries for each representative commodity in the range 70 - 120 %, with a RSD <20 %). LOQ values were obtained from the LOD values calculated as described under 3.4.2.2.2 applying the following formula: LOQ=3.3 x LOD. (FSSAI, 2012)

3.4.2.5 Determination of Recovery and Repeatability

3.4.2.5.1 *Sample processing*

Twenty five gram of control samples (pesticide residues below detectable level) of blended amaranth were taken in 200 ml centrifuge tubes in three replicates each were spiked with six organophosphate and four synthetic pyrethroid pesticides (Table 7) at the required fortification levels i.e. LOQ, 5 x LOQ and 10 x LOQ, adding an appropriate volume of working standard of 10 mg L^{-1}. In order to attain proper homogeneity of pesticides in the samples, this mixture was then shaken thoroughly. If excess of solvent observed in tubes containing fortified samples, those tubes were left open for a while just to allow

the evaporation of excess solvent. To this mixture a volume of 50 ml acetonitrile was added and then homogenized in centrifuge at 14000 rpm for one minute for uniformity of sample. To this mixture, 10 g of sodium chloride was added and centrifuged at 2000-2500 rpm for 4 min. A quantity of 16 ml supernatant was collected from this and transferred to a 50 ml centrifuge tube containing 6.0 g sodium sulphate and vortexed. A total of 12 ml supernatant was then transferred to a 15 ml centrifuge tube containing 1.2 g magnesium sulphate and 0.2 g Primary Secondary Amine (PSA) and vortexed for 30 s and centrifuged at 2500 rpm for three min. From this 4.0 ml of upper layer was evaporated by using Turbovap at 50^0C. The dry residue was reconstituted to one ml using n-hexane and analyzed in a Gas Chromatograph.

3.4.2.5.2 *Estimation*

One µl of cleaned extracts of sample was injected into Gas Chromatograph. The cleaned extracts were analyzed in a Gas Chromatograph under working parameters as shown in Table 10.

Table 10: Details and operating parameters of Gas Chromatograph.

Gas Chromatography	Shimadzu GC-2010
Detector	^{63}Ni Electron Capture Detector (ECD)
Column	Dimethyl polysiloxane, 30m x 0.25mm i.d
Film thickness	0.25 µm
Carrier gas	Nitrogen (99.99 %)
Carrier gas flow	11.7 ml/min
Column oven temperature	170.0^0C
Injection temperature	250.0^0C
ECD temperature	300.0^0C
Split ratio	1:10
Column flow	0.79 ml/min

3.4.2.5.3 *Residue quantification and recovery calculation*

Pesticide residue in substrate (mg kg^{-1}) =

$$\frac{\text{Peak area of sample} \times \text{Concentration of standard injected} \times \text{Volume of sample injected} \times \text{DF}}{\text{Peak area of standard} \times \text{Volume of standard injected}}$$

Dilution Factor (DF) =

$$\frac{\text{Volume of solvent added} \times \text{Final volume of the extract}}{\text{Weight of sample (g)} \times \text{Volume of extract taken for concentration}}$$

Percentage recovery (%) =

$$\frac{\text{Concentration of pesticide residue obtained} \times 100}{\text{Concentration of pesticide residue added}}$$

3.4.3 Evaluation of effective domestic practices for decontamination of insecticide residues from amaranth

The red amaranth plants grown organically in premises of PRRAL, Vellayani were used for this study. An insecticide mixture emulsion was prepared by using pesticides detected during survey of farm – gated samples and two more organo phosphate insecticides. The insecticides used in insecticide mixture were described in Table 7. Hundred ppm of each insecticide was prepared separately and mixed in one litre water. The amaranth plants were sprayed with this insecticide mixture using a hand sprayer (1 L). Sprayed plants were kept under covered conditions to protect from rain. Treated plants were harvested at one day after spraying. Individual treated plants were subjected to different

decontamination practices and some plants were kept as un processed control for comparison.

The different treatments used in this experiment are mentioned below.

T1 – Dipping in water + cooking (closed pan)

T2 - Dipping in 2 % tamarind solution (20 g of tamarind paste dissolved in one liter water) + washing

T3 - Dipping in 2 % common salt solution (20 g of common salt dissolved in one liter water) + washing

T4 - Dipping in 1 % turmeric powder (10 g of turmeric powder dissolved in one liter water) + washing

T5 - Dipping in 2 % vinegar (20 ml of vinegar dissolved in one liter water) + washing

T6 - Dipping in 1 % KAU Veggie wash (10 ml of Veggie wash dissolved in one liter water) + washing

T7 - Dipping in 1 % KAU Veggie wash (10 ml of Veggie wash dissolved in one liter water) + cooking

T8 - Dipping in 1 % KAU Veggie wash (10 ml of Veggie wash dissolved in one liter water) + washing

T9 - Dipping in 1 % KAU Veggie wash (10 ml of Veggie wash dissolved in one liter water) + cooking

T10 - Dipping in water (control)

Plant samples were subjected to these treatments individually for ten minutes. In case of washing + cooking (T1) treatment, plants were subjected dipping in water for 10 minutes followed by three washings under tap water and cooking in closed pan for 10 minutes. Plants were dipped in treatment solution for

10 minutes followed by three normal washings under tap water in T2 – T6. In T8 and T9 treatments the plants were dipped in one per cent KAU veggie wash for 20 minutes followed by three normal washings. In T7 and T9 the plants were cooked in closed pan for ten minutes after dipping in Veggie wash (1 %) followed by three normal washings in water.

The processed samples were homogenised after chopping into small pieces and the representative sample (25 g) in three replications was used for residue estimation. The analytical procedure for estimation of residues of 10 insecticides was followed as detailed under section 3.4.2.5.

The residues present in unprocessed and processed samples were estimated and the percentage of residue removal was calculated. The formula used for estimation of residues in processed and un-processed samples was mentioned under 3.4.2.5.2. The percentage of residue removal was calculated by using the following formula.

Percentage of residues removal =

$$\frac{\text{Amount of residues in unprocessed sample - Amount of residues in processed sample}}{\text{Amount of residues in unprocessed sample}} \times 100$$

3.5 DATA ANALYSIS

Data relating to each aspect were analysed statistically. Appropriate transformations were made wherever necessary. Significant results were compared on the basis of critical difference.

The overall efficacy of insecticides against leaf webbers, leaf eating caterpillars and mites of amaranth was worked out for which the insecticides were ranked based on their performance in each parameter (pest control, compatibility with natural enemies and yield). The efficiency of household method to

decontaminate pesticide residues from amaranth samples were ranked based on their percentage of removal of residues (Gomez and Gomez, 1984).

Results

4. **RESULT**

4.1 SURVEY TO DOCUMENT THE PEST INCIDENCE, PESTICIDE USAGE AND PESTICIDE RESIDUES IN AMARANTH

The data on pest incidence, pesticide usage and the residues of pesticides found in survey samples are presented in Tables 11 to 13.

4.1.1 Documentation of Pest Occurence

Details of pests observed in amaranth of fields in Kalliyoor and Pappanchani locations are presented in Table 11.

In Kalliyoor, *H. recurvalis* was the major pest causing 50 per cent pest incidence followed by *S. litura.* The lowest percentage incidence was noticed in amaranth due to the infestation of *Tetranychus* spp. (10 %).

S. litura was the major pest causing 50 per cent pest incidence followed by *H. recurvalis* (45 %) in Pappanchani. The lowest percentage of incidence (5 %) was recorded in amaranth due to infestation of *Tetranychus* spp.

Table 11: Incidence of pests in amaranth in Kalliyoor and Pappanchani, Thiruvananthapuram district (March 2014 to May 2014).

Location	Pests observed	Percentage of incidence (%)
Kalliyoor	*Hymenia recurvalis* *Spodoptera litura* *Tetranychus* spp	50.00 40.00 10.00
Pappanchani	*Hymenia recurvalis* *Spodoptera litura* *Tetranychus* spp	45.00 50.00 5.00

4.1.2 Documentation of Pesticide Usage

Details of pesticide usage in surveyed areas are presented in Table 12. Among the farmers in Kalliyoor and Pappanchani, 60 per cent of the respondents used pesticides mainly to manage leaf webbers only. However, 30 per cent and 10 per cent farmers reported that pesticide usage was mainly to manage *S. litura* and mites respectively.

Quinalphos was the major insecticide used by 40 per cent of the farmers to contain pests of amaranth, followed by lambda-cyhalothrin (30%). Chlorpyriphos, dimethoate and malathion were used by 10 per cent of farmers each. All farmers surveyed reported that for the selection of pesticides they have depended on pesticide shop only. Regarding the source of technical information 40 per cent of famers depend on pesticide shops, 30 per cent of farmers had their own decision, while 20 per cent of farmers gathered information from other progressive farmers. Only 10 per cent responded that they had collected information from Agricultural Officers.

The survey revealed that 40 per cent farmers collected information on pesticides dose from pesticide shop. Whereas 35 per cent farmers had own decision on dose of pesticide application. Fifteen per cent of farmers gathered information on pesticide dose from progressive farmers. Only 10 per cent farmers were applying pesticides on dose recommended by Agricultural Officers.

According to survey application of pesticides was at different intervals. Forty per cent of farmers used to spray insecticides at four day intervals. Twenty five per cent of farmers sprayed at three days and five days intervals each. However 10 per cent used to spray at six day interval only. The survey revealed that 80 per cent of farmers were not paying any attention towards

Table 12: Pesticide use among amaranth farmers in Kalliyoor and Pappanchani, Thiruvananthapuram district (March 2014 to May 2014).

Particulars		Farmers (%)
Pesticides used against	a) Leaf webber	60.00
	b) Spodoptera	30.00
	c) Mites	10.00
Major pesticides used	a) Malathion	10.00
	b) Chlorpyriphos	10.00
	c) Quinalphos	40.00
	d) Dimethoate	10.00
	e) Lambda-cyhalothrin	30.00
Source of insecticides	a) Pesticide shop	100.00
	b) Directly from company	00.00
Source of technical information on pesticides	a) Agricultural officers	10.00
	b) Pesticide company	00.00
	c) Other progressive farmers	20.00
	d) Own decisions	30.00
	e) Media	00.00
	f) From pesticide shops	40.00
Source of information on dose of pesticides	a) Agricultural officers	10.00
	b) Pesticide shops	40.00
	c) Other progressive farmers	15.00
	d) Own decisions	35.00
	e) Media	00.00
Frequency of insecticide application	a) Three day interval	25.00
	b) Four day interval	40.00
	c) Five day interval	25.00

	d) Six day interval	10.00
Attention towards labels on pesticide bottles before use	a) Yes	20.00
	b) No	80.00
Awareness regarding pesticide residues	a) Aware	20.00
	b) Unaware	80.00
Dosage of pesticide application in comparison with dosage recommended by CIBRC for vegetables	a) Less than recommended dose	00.00
	b) Recommended dose	30.00
	c) Double to the recommended dose	65.00
	d) Higher than double dose	5.00

leaflet attached with pesticide bottles before application of pesticides, whereas only 20 per cent of farmers were showing attention to labels. Eighty per cent of farmers were unaware of pesticide residues, only 20 per cent had awareness about pesticide residues.

Among the surveyed farmers, 65 per cent were applying insecticides at double the dose recommended by Central Insecticide Board and Registration Committee for vegetables, 30 per cent were applying at the recommended dose itself. Five per cent of farmers surveyed were applying more than double the recommended dose, while no farmer was applying insecticide at less than the recommended dose.

4.1.3 Documentation of Pesticide Residues in Farm-Gate Samples

The extent of pesticide residues detected in surveyed samples is presented in Table 13. Among twenty surveyed samples, 13 samples had residues of quinalphos (0.04-1.20 ppm) and 4 samples exceeded the EU-MRL (0.05 ppm). Chlorpyriphos was found in three samples and the levels detected in all the three were above EU-MRL level. Profenofos, bifenthrin, ethion and fenvalerate were

found in one sample each as above EU-MRL. Among surveyed samples, lambda-cyhalothrin and cypermethrin were found in one sample each and they were below EU-MRL.

Table 13: Extent of pesticide residues in farm-gate samples collected from selected farmers.

Pesticides detected	Amount of Residues found (conc. in ppm)	Samples with pesticide residues (out of 20 samples)	EU –MRL (ppm)	Below / above MRL
Chlorpyriphos	1.009-1.14	3	0.05	Above
Quinalphos	0.04-1.20	13	0.05	Below & above
Profenophos	0.02	1	0.01	Above
Bifenthrin	0.09	1	0.05	Above
Ethion	0.03	1	0.01	Above
Cypermethrin	0.19	1	0.70	Below
Lambda-Cyhalothrin	0.025	1	1.00	Below
Fenvalerate	0.08	1	0.02	Above

ppm - parts per million, EU- European Union, MRL- Maximum Residue Limit

4.2 LABORATORY EVALUATION OF BIO-EFFICACY OF INSECTICIDES, MICROBIAL INSECTICIDES AND BOTANICALS AGAINST LEAF WEBBER, LEAF EATING CATERPILLAR AND MITE

The results on the laboratory evaluation of chemical, microbial and botanical insecticides against *H. recurvalis, S. litura* and *Tetranychus* spp when evaluated by the leaf disc method are presented in Table 14 to 18.

4.2.1 Evaluation Against *H.recurvalis* and *S. litura* by Using Leaf Disc Method

4.2.1.1 H. recurvalis

The results of the study on bio-efficacy of chemical, microbial and botanical insecticides against *H. recurvalis* are presented in Table 14 and 15.

The treatments varied significantly on their toxicity to *H. recurvalis* after six hours of treatment. Among the insecticides evaluated, fipronil 0.01 % recorded 100 per cent mortality against *H. recurvalis*. This was followed by indoxacarb 0.015 %, thiacloprid 0.036 % and emamectin benzoate 0.002 % with per cent mortality of 94.44, 88.89 and 83.33 respectively, all the above treatments were statistically on par with each other. Whereas the mortality noticed in *B. thuringiensis* 5 ml L^{-1} was 66.67 per cent. This was followed by malathion 0.1 % (55.30 %) and novaluron 0.015 % (33.33 %). However, the mortality recorded in buprofezin 0.03 %, oxuron 5 ml L^{-1}, spinosad 0.015 %, chlorantraniliprole 0.006 %, flubendiamide 0.0096 % and NSKE 5 ml L^{-1} were 27.78, 16.67, 11.11, 5.57, 5.57 and 5.57 per cent respectively.

Mortality of larvae recorded after 12 hours of treatment revealed the superiority of indoxacarb 0.01 %, thiacloprid 0.036 % along with fipronil 0.01 % with cent per cent mortality (Table 14). These treatments were followed by emamectin benzoate 0.002 per cent (94.44 %) and *B. thuringiensis* 5 ml L^{-1} (88.89 %) and all the above five treatments were found statistically on par. Whereas malathion 0.10 % (66.66 %), novaluron 0.015 % (50.00 %), flubendiamide 0.0096 % (33.33 %), spinosad 0.015 % (27.78 %), buprofezin 0.03 % (27.78 %) and oxuron 5 ml L^{-1} (27.78 %) were the succeeding better treatments. Larval mortality was less in NSKE 5ml L^{-1} (16.67 %) and chlorantraniliprole 0.006 % (11.11 %). However, all the above treatments showed significant difference with the untreated check.

Similarly the treatments have shown significant differences with respect to their toxicity observed on *H. recurvalis* larvae after 18 hours of treatment. Cent per cent mortality was obtained in larvae treated with emamectin benzoate 0.002 % and *B. thuringiensis* 5 ml L^{-1} along with fipronil 0.01 %, indoxacarb 0.015 % and thiacloprid 0.036 %. Significantly higher levels of mortality were recorded in larvae treated with malathion 0.10 % (88.89 %) and novaluron 0.015 % (77.78 %), both the treatments were on par with the each other. No significant difference was observed among the treatments spinosad 0.015 % (50.00 %), flubendiamide 0.0096 % (44.44 %) and oxuron 5 ml L^{-1} (44.44 %).

Table 14: Effect of new generation insecticides, botanicals and microbial insecticides on the mortality of *H. recurvalis* under laboratory conditions

TREATMENTS	Mean percentage mortality of *Hymenia recurvalis* when observed at					
	6 HAS	12 HAS	18 HAS	24 HAS	30 HAS	36 HAS
T1-Chlorantraniliprole 18.5 SC - 0.006%	5.57^{e} (8.81)	11.11^{g} (16.45)	11.11^{e} (16.45)	50.00^{bc} (45.00)	88.89^{bc} (62.18)	100.00^{a} (88.83)
T2- Novaluron 10 EC - 0.015%	33.33^{d} (34.78)	50.00^{cd} (45.00)	77.78^{b} (62.18)	88.89^{a} (62.18)	100.00^{a} (88.83)	100.00^{a} (88.83)
T3- Buprofezin 25 SC - 0.03%	27.78^{d} (31.54)	27.78^{ef} (37.54)	38.89^{cd} (38.51)	61.11^{b} (51.49)	83.33^{bc} (62.18)	55.55^{c} (48.24)
T4-Flubendiamide 39.35 SC - 0.0096%	5.57^{e} (8.81)	33.33^{de} (35.26)	44.44^{cd} (41.74)	61.11^{b} (51.49)	94.44^{ab} (81.19)	100.00^{a} (88.83)
T5-Spinosad 45 SC - 0.015%	11.11^{de} (16.45)	27.78^{ef} (37.54)	50.00^{c} (45.00)	66.67^{b} (55.21)	77.78^{cd} (62.18)	100.00^{a} (88.83)
T6- Emamectin benzoate 1 WG - 0.002%	83.33^{abc} (69.74)	94.44^{a} (81.19)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)
T7- Indoxacarb 14.5 SC - 0.015%	94.44^{ab} (81.10)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)
T8- Thiacloprid 21.7 SC - 0.036%	88.89^{abc} (73.54)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)
T9- Fipronil 5 SC - 0.01%	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)
T10- *Bacillus thuringiensis* kurstaki - 5 ml L^{-1}	66.67^{c} (54.73)	88.89^{ab} (62.18)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)
T11-Oxuron - 5 ml L^{-1}	16.67^{de} (16.45)	27.78^{ef} (37.54)	44.44^{cd} (41.74)	55.56^{b} (48.24)	72.22^{d} (58.45)	83.33^{b} (9.18)
T12 -Neem Seed Kernel Extract - 5 %	5.57^{e} (8.81)	16.67^{fg} (24.09)	27.78^{d} (37.54)	33.33^{c} (35.26)	38.89^{e} (38.51)	55.56^{c} (62.18)
T13- Malathion 50 EC – 0.1 %	55.30^{d} (34.78)	66.66^{bc} (54.73)	88.89^{b} (62.18)	100.00^{a} (88.83)	100.00^{a} (88.83)	100.00^{a} (88.83)
T14– Untreated	0.00^{e} (1.17)	0.00^{h} (1.17)	5.57^{e} (8.81)	5.57^{d} (8.81)	11.11^{f} (16.45)	16.67^{d} (24.09)
CD (0.05)	(18.927)	(12.159)	(11.853)	(11.387)	(11.671)	(5.791)

HAS= Hours After Spraying

Values shown in parentheses are Arc sin transformed values

Whereas the mortality noticed in buprofezin 0.03 %, NSKE 5 ml L^{-1} and chlorantraniliprole 0.006 % were 38.89, 27.78 and 11.11 per cent respectively.

More or less similar results were obtained in the mortality of *H. recurvalis* at 24 hours after treatment. In addition to fipronil 0.01 %, indoxacarb 0.015 %, thiacloprid 0.036 %, emamectin benzoate 0.002 % and *B. thuringiensis* 5 ml L^{-1}, cent per cent mortality was recorded in malathion 0.10 % treatment also. These were followed by novaluron 0.015 % (88.89 %) which was statistically on par with the above treatments. However, the efficacy of spinosad 0.015 % (66.67 %), flubendiamide 0.0096 % (61.11 %) and buprofezin 0.03 % (61.11 %) were statistically on par with each other. The per cent mortality expressed in larvae sprayed with oxuron 5 ml L^{-1}, chlorantraniliprole 0.006 % and NSKE 5 ml L^{-1} were 55.56, 50.00 and 33.33 respectively, whereas all the above treatments showed significant differences from the untreated check (5.56 %).

At 30 hours after release, novaluron 0.015 % recorded 100 per cent mortality in addition to fipronil 0.01per cent, indoxacarb 0.015 per cent, thiacloprid 0.036 %, emamectin benzoate 0.002 %, *B. thuringiensis* 5 ml L^{-1} and malathion 0.10 %. These treatments were followed by flubendiamide 0.0096 % (94.44 %), chlorantraniliprole 0.006 % (88.89 %) and buprofezin 0.03 % (83.33 %) and these were on par also. Whereas the percentage mortality noticed in spinosad 0.015 %, oxuron 5ml L^{-1} and NSKE 5ml L^{-1} treated larvae were 77.78, 72.22 and 38.89 per cent respectively.

Cent per cent mortality of *H. recurvalis* observed in all treated larvae except in buprofezin 0.03 %, oxuron 5ml L^{-1} and NSKE 5ml L^{-1} at 36 hours after release. Whereas in untreated leaves, the percentage mortality recorded was 16.67 only.

In case of bio agents, the results on mobility of larvae of *H. recurvalis* after treatment with *B. bassiana* @ 20 g L^{-1} and *B. bassiana* @ CFU-10^8 g^{-1} are presented in Table 15. At 12 hours, the arrested mobility of *B. bassiana* @ 20 g L^{-1} and *B. bassiana* @ CFU-10^8 g^{-1} in larvae were 11.11 and 16.67 per cent. The numbers of immobile larvae increased 24 hours after spraying, for *B. bassiana* @ 20 g L^{-1} and it was 22.22 per cent while for *B. bassiana* @ CFU-10^8 g^{-1} it was

27.78. The percentage of immobilized larvae in *B. bassiana* @ CFU-10^8 g^{-1} treatment was 50, whereas in *B. bassiana* @ 20 g L^{-1} treatment, 38.89 per cent larvae were immobilized 36 hours after spraying. However, 83.33 and 77.77 per cent larvae stopped movement 48 hours after treatment by *B. bassiana* @ 20 g L^{-1} and *B. bassiana* @ CFU-10^8 g^{-1} respectively. Cent per cent immobility was noticed in *B. bassiana* @ CFU-10^8 g^{-1} treated leaves while 94.44 per cent immobility was obtained in *B. bassiana* @ 20 g L^{-1} treated leaves, 60 hours after treatment. Cent per cent cessation of movement of *H. recurvalis* larvae was observed at 72 hours after treatment, in the case of *B. bassiana* when sprayed at both the doses 10 g and 20 g L^{-1}.

Table 15: Effect of movement of *H. recurvalis* larvae by bio agents

TREATMENTS	Mean number of larvae with arrested mobility					
	12 HAS	24 HAS	36 HAS	48 HAS	60 HAS	72 HAS
T 1- *Beauveria bassiana* - 2% WP	11.11 (3.13)	22.22 (4.75)	38.89 (6.29)	83.33 (9.15)	94.44 (9.76)	100.0 (10.05)
T2- *Beauveria bassiana* (ITCC 6063) CFU - 10^8 g^{-1}	16.67 (4.20)	27.78 (5.31)	50.00 (7.07)	77.77 (8.86)	100.0 (10.05)	100.0 (10.05)
Untreated	0.00 (1.00)	5.55 (2.06)	16.67 (4.20)	16.67 (4.20)	27.77 (5.31)	38.88 (6.28)
CD (0.05)	(1.693)	(2.098)	(1.323)	(0.977)	(0.988)	(0.678)

Values shown in parenthesis are √x+1 transformed values

4.1.1.2 S. litura

The data on the toxicity of different treatments on the second instar larvae of *S. litura* is presented in Table 16 and 17.

At six hours after exposure to the treated leaves a wide variation was observed in the data on mortality of *S. litura* larvae in leaves treated with different insecticides. Highest mortality (72.22 %) was recorded in emamectin benzoate

0.002 % treated leaves, was statistically superior over all other treatments and it was followed by malathion 0.10 % (44.44 %), novaluron 0.015 % (27.78 %), indoxacarb 0.015 % (27.78 %) and fipronil 0.01 % (11.11 %). Whereas the percentage mortality recorded in buprofezin 0.03 per cent and oxuron treatments were 5.57 per cent. No mortality was observed at 6 hours after exposure to chlorantraniliprole 0.006 %, flubendiamide 0.0096 %, spinosad 0.015 %, thiacloprid 0.036 %, *B. thuringiensis* 5 ml L^{-1} or NSKE 5 ml L^{-1} and also in untreated leaves.

At 12 hours after release of the test insect, emamectin benzoate 0.002 % recorded as the best treatment with cent per cent mortality and this was followed by malathion 0.10 % (61.11 %). Whereas, the next better treatments were fipronil 0.01 % (61.11 %) and indoxacarb 0.015 % (50.00 %) which were statistically on par (Table 16). The per cent mortality recorded in novaluron 0.015 %, flubendiamide 0.0096 %, chlorantraniliprole 0.006 % treated leaves were 33.33, 22.22 and 22.22 per cent respectively. Among the different treatments, less percentage mortality was obtained for *S. litura* in thiacloprid 0.036 % (16.67 %), buprofezin 0.03 % (16.67 %), spinosad 0.015 % (16.67 %) and oxuron 5 ml L^{-1} (11.11 %). However, no mortality was recorded in *B. thuringiensis* 5 ml L^{-1}, NSKE 5 ml L^{-1} and in untreated leaves.

More or less similar results were obtained after 18 hours of treatment also. The superior treatments were emamectin benzoate 0.002 % and indoxacarb 0.015 % with recorded percentage mortality of 100 and 83.33 per cent. No significant difference observed in malathion 0.10 % (72.22 %), novaluron 0.015 % (61.11 %) and fipronil 0.01 % (61.11 %). Whereas the percentage mortality recorded in flubendiamide 0.0096 %, spinosad 0.015 %, buprofezin 0.03 %, chlorantraniliprole 0.006 % and oxuron 5 ml L^{-1} were 44.44, 44.44, 27.78, 26.67 and 22.22 per cent respectively. Mortality percentage was less in thiacloprid 0.036 % (16.67 %), *B. thuringiensis* 5 ml L^{-1} and NSKE 5 ml L^{-1} (11.11 %). In untreated leaves there was no mortality recorded at 18 hours after spraying also.

Table 16: Effect of new generation insecticides, botanicals and microbial insecticides on the mortality of *S. litura* under laboratory condition

TREATMENTS	Mean percentage mortality of *Spodoptera litura*					
	6 HAS	12 HAS	18 HAS	24 HAS	30 HAS	36 HAS
T1-Chlorantraniliprole 18.5 SC - 0.006%	0.00^{d} (1.17)	22.22^{cd} (27.81)	24.44^{ef} (35.26)	26.67^{f} (38.51)	57.78^{cd} (50.21)	74.44^{b} (62.51)
T2- Novaluron 10 EC - 0.015%	27.78^{b} (31.54)	33.33^{c} (35.26)	61.11^{cd} (51.49)	61.11^{de} (51.49)	63.33^{cd} (51.49)	93.33^{a} (81.19)
T3- Buprofezin 25 SC - 0.03%	5.57^{cd} (8.81)	16.67^{de} (24.09)	27.78^{fg} (31.54)	44.44^{ef} (41.75)	46.67^{de} (41.75)	68.89^{b} (58.94)
T4-Flubendiamide 39.35 SC - 0.0096%	0.00^{d} (1.17)	22.22^{cd} (27.81)	44.44^{de} (41.75)	77.78^{cd} (62.18)	93.33^{a} (81.19)	100.0^{a} (88.83)
T5-Spinosad 45 SC - 0.015%	0.00^{d} (1.17)	16.67^{de} (24.09)	44.44^{de} (41.75)	44.44^{ef} (41.75)	40.00^{de} (41.75)	55.56^{bc} (51.49)
T6- Emamectin benzoate 1 WG - 0.002%	72.22^{a} (58.45)	100.0^{a} (88.83)	100.0^{a} (88.83)	100.0^{a} (88.83)	100.0^{a} (88.83)	100.0^{a} (88.83)
T7- Indoxacarb 14.5 SC - 0.015%	27.78^{b} (31.52)	$50\ .00^{b}$ (45.00)	83.33^{b} (65.90)	83.33^{bc} (65.90)	82.22^{b} (65.90)	93.33^{a} (81.19)
T8- Thiacloprid 21.7 SC - 0.036%	0.00^{d} (1.17)	16.67^{de} (24.09)	16.67^{gh} (24.09)	27.78^{fg} (31.54)	22.22^{ef} (31.54)	37.78^{cd} (41.75)
T9- Fipronil 5 SC - 0.01%	11.11^{c} (16.45)	61.11^{b} (51.49)	61.11^{cd} (51.49)	66.67^{cd} (55.21)	68.89^{bc} (58.94)	86.67^{a} (77.46)
T10- *Bacillus thuringiensis* kurstaki - 5 ml L^{-1}	0.00^{d} (1.17)	0.00^{f} (1.17)	16.67^{gh} (24.09)	16.67^{g} (24.09)	22.22^{ef} (31.54)	43.33^{bc} (45.00)
T11-Oxuron - 5 ml L^{-1}	5.57^{cd} (8.81)	11.11^{e} (16.45)	22.22^{fg} (24.81)	27.78^{fg} (31.54)	28.89^{ef} (35.26)	37.78^{cd} (41.75)
T12 -Neem Seed Kernel Extract - 5 %	0.00^{d} (1.17)	00.00^{f} (1.17)	11.11^{h} (61.45)	16.67^{g} (24.09)	17.78^{f} (27.81)	18.89^{d} (31.54)
T13- Malathion 50 EC – 0.1 %	44.44^{b} (41.75)	61.11^{b} (51.49)	72.22^{bc} (58.45)	88.89^{ab} (77.46)	100.0^{a} (88.83)	100.0^{a} (88.83)
T14– Untreated	0.00^{d} (1.17)	0.00^{f} (1.17)	0.00^{i} (1.17)	0.00^{h} (1.17)	5.56^{g} (1.17)	11.11^{e} (16.45)
CD (0.05)	(11.672)	(8.013)	(10.201)	(12.224)	(11.393)	(13.614)

HAS= Hours After Spraying

Values shown in parentheses are Arc sin transformed values

After 24 hours, the mortality observed in malathion 0.10 % treated leaves was 88.89 per cent and it was on par with emamectin benzoate 0.002 % (100 %). Malathion 0.10 % was followed by indoxacarb 0.015 % (83.33 %) and flubendiamide 0.0096 % (77.78 %). The next effective treatments were fipronil 0.01 % and novaluron 0.015 % with noticed mortality 66.67 and 61.11 per cent. Whereas the mortality recorded in spinosad 0.015 %, buprofezin 0.03 %, oxuron 5 ml L^{-1}, thiacloprid 0.036 % and chlorantraniliprole 0.006 % were 44.44, 44.44, 27.78, 27.78 and 26.67 per cent respectively. In the case of *B. thuringiensis* 5 ml L^{-1} and NSKE 5 ml L^{-1}, mortality observed was the least (16.67 %).

At the end of 30 hours after release, 100 per cent mortality was observed in malathion 0.10 % along with emamectin benzoate 0.002 %. The next better treatments were flubendiamide 0.0096 % and indoxacarb 0.015 % with 93.33 and 82.22 per cent mortality. All the above treatments were statistically on par with each other. The percentage mortality recorded in indoxacarb 0.015 % and fipronil 0.01 % were 82.22 and 68.8 and these two were statistically on par with each other. Novaluron 0.015 %, chlorantraniliprole 0.006 %, buprofezin 0.03 % and spinosad 0.015 % recorded 63.33, 57.78, 46.67 and 40.00 per cent mortality respectively, and were on par with each other. The per cent mortality recorded in oxuron 5 ml L^{-1}, thiacloprid 0.036 %, *B. thuringiensis* 5 ml L^{-1} and NSKE 5 ml L^{-1} were 28.89, 22.22, 22.22 and 17.78 respectively. However, in untreated leaves the mortality was 5.56 per cent only.

The cent per cent mortality was observed in flubendiamide 0.0096 %, emamectin benzoate 0.002 % and malathion 0.10 % treated larvae after 36 hours of release. It was followed by novaluron 0.015 %, indoxacarb 0.015 % and fipronil 0.01 % with recorded mortality of 93.33, 93.33 and 86.67 per cent respectively. All the above treatments were statistically not different among each other. However, 74.44, 68.89, 55.56, 43.33, 37.78 and 37.78 were the mortality percentages exhibited by the treatments chlorantraniliprole 0.006 %, buprofezin 0.03 %, spinosad 0.015 %, *B. thuringiensis* 5 ml L^{-1}, thiacloprid 0.036 % and oxuron 5 ml L^{-1} respectively on *S. litura* larvae. Whereas, among all treatments

the lowest mortality was recorded in NSKE 5 ml L^{-1} (18.89%) treated larvae. All the above treatments were superior to the untreated check (11.11 %).

The results on effect of microbial insecticides on mobility of larvae of *S. litura* are presented in Table 17. In *B. bassiana* CFU - 10^8 g^{-1} treatment, 5.56 per cent larvae were immobilized whereas no effect was noticed in *B. bassiana* 20 g L^{-1} treated larvae at 12 hours after treatment. After 24 hours of treatment, 22.22 and 16.67 per cent immobility were recorded in *B. bassiana* CFU - 10^8 g^{-1} and *B. bassiana* 20 g L^{-1} treated larvae respectively. However the percentages of immobile larvae increased after 36 hours of treatment. The percentage of immobile larvae in *B. bassiana* CFU - 10^8 g^{-1} and *B. bassiana* 20 g L^{-1} treated leaves were 31.11 and 17.18 per cent respectively. More or less similar results were obtained at 48 hours after treatment, the immobility percentages recorded were 66.66 and 61.11 in *B. bassiana* CFU - 10^8 g^{-1} and *B. bassiana* 20 g L^{-1} treated larvae respectively. The highest immobility was recorded in *B. bassiana* CFU - 10^8 g^{-1} (94.44 %), where as in *B. bassiana* 20 g L^{-1} 88.8 per cent larvae stopped their movement after 60 hours of treatment. Cent per cent immobility was noticed in both treatments after 60 hours, which were significantly different from untreated check.

Table 17: Effect on movement of *S. litura* larvae by bio agents

Treatments	Mean number of larvae with arrested mobility					
	12 HAS	24 HAS	36 HAS	48 HAS	60 HAS	72 HAS
T 1- *Beauveria bassiana*- 2% WP	0.00 (1.00)	16.67 (4.20)	17.78 (3.81)	61.11 (7.86)	88.87 (9.47)	100.0 (10.05)
T 2- *Beauveria bassiana* (ITCC 6063) CFU - $10^8 g^{-1}$	5.56 (2.07)	22.22 (4.75)	31.11 (5.61)	66.66 (8.22)	94.44 (9.76)	100.0 (10.05)
Untreated	0.00 (1.00)	0.00 (1.00)	11.11 (3.13)	27.77 (5.31)	33.33 (5.85)	38.88 (6.28)
CD (0.05)	NS	NS	1.107	1.047	0.648	0.678

Values shown in parenthesis are $\sqrt{x+1}$ transformed values

Based on the above study, the treatments which were found as effective against *H. recurvalis* and *S. litura* under laboratory conditions were further evaluated in field.

4.2.2 Evaluation Against Mites Using Leaf Disc Method

The result on contact toxicity of insecticides on mite, *Tetranychus* spp. are presented in Table 18.

Among the various treatments evaluated, buprofezin 0.03 % and emamectin benzoate 0.002 % recorded 80 per cent mortality of red spider mite and were superior to the other treatments at six hours after release. These treatments were followed by diafenthiuron 0.06 % (70.00 %). The above three treatments were statistically on par. Whereas the percentage mortality observed in spiromesifen 0.0192 % treated leaves were 63.33 per cent. The mortality of mites in fenpyroximate 0.003 % treated plots was 50 per cent. Whereas the lowest mortality exhibited by ethion 0.15 % was only 10 per cent.

At 12 hours after release of the mites, 100 per cent mortality was recorded in buprofezin 0.03 %, diafenthiuron 0.06 %, emamectin benzoate 0.002 % and spiromesifen 0.0192 % treated mites. However, fenpyroximate 0.003 % and ethion 0.15 % showed mortality of 86.67 and 30.00 per cent respectively.

All the treatments recorded cent per cent mortality except ethion 0.15 % after 18 hours of release. In ethion 0.15 % treated leaves, the mortality of red spider mite was recorded 33.33 per cent. After 24 hours and 30 hours of release 50.00 and 56.67 per cent mortality of mites were noticed, respectively into ethion 0.15 % treated leaf discs.

Table 18: Effect of insecticides on the mortality of *Tetranychus* spp under laboratory conditions

Treatments	Mean percentage mortality of *Tetranychus* spp.				
	6 HAS	12 HAS	18 HAS	24 HAS	30 HAS
T1-Buprofezin 25 SC – 0.03 %	80.00[a] (63.43)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)
T2- Diafenthiuron 50 WP – 0.06 %	70.00[b] (56.99)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)
T3-Emamectin benzoate 5 SG – 0.002%	80.00[a] (63.43)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)
T4-Spiromesifen 22.9 SC – 0.0192 %	63.33[b] (50.85)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)
T5-Fenpyroximate 5 EC – 0.003%	50.00[c] (45.00)	86.67[b] (66.15)	100.00[a] (89.09)	100.00[a] (89.09)	100.00[a] (89.09)
T6-Ethion 50 EC – 0.15%	10.00[d] (18.43)	30.00[c] (33.21)	33.33[b] (35.22)	50.00[b] (45.00)	56.67[b] (48.85)
T7- Untreated	0.00[e] (0.91)	0.00[d] (0.91)	0.00[c] (0.91)	3.33[c] (6.75)	3.33[c] (6.75)
CD (0.05)	(10.000)	(3.107)	(2.301)	(6.699)	(7.053)

H AS= Hours After Spraying

* Values shown in parentheses are Arc sin transformed values

4.3 FIELD EVALUATION OF INSECTICIDES AGAINST PESTS OF AMARANTH

The data on evaluation of effective treatments under field conditions is presented in Tables 19 to 28.

4.3.2 Evaluation of Treatments

4.3.2.1 Evaluation of insecticides in farmer's field

Since there was no population of leaf webbers and mites in farmer's field in Nedinjal location, field evaluation was carried only against *S. litura*. The results of this evaluation are presented in Table 19 and 20.

4.3.2.1.1 Evaluation of different treatments against population of S. litura.

The results on evaluation of different treatments on population of *S. litura* are presented in Table 19.

The first spray was given seven days after sowing.Significantly less population (0.42 caterpillars per plant) of *S. litura* was observed in emamectin benzoate 0.002 % treated plots after first day of spraying. In malathion 0.10 % treated plots the population was reduced to 0.70 larvae per plant and it was on par with emamectin benzoate 0.002 %. This was followed by indoxacarb 0.015 % and fipronil 0.01 % with 1.47 and 1.74 larvae per plant and these two were statistically on par. The next effective treatments were flubendiamide 0.0096 % and novaluron 0.015 % with 3.25 and 3.74 larvae per plant, respectively.

Significant reduction in population levels was observed on the third day after treatment. Complete reduction of population was observed in emamectin benzoate 0.002 per cent treated plots and this was followed by malathion 0.10 %, indoxacarb 0.015 % and flubendiamide 0.0096 % with 0.20, 0.39 and 0.48 larvae per plant and all these treatments were statistically on par. The next effective treatments were novaluron 0.015 % (0.52 larvae per plant) and fipronil 0.01 % (0.72 larvae per plant), which were on par. Population levels in untreated plots were high with 8.73 larvae per plant.

At five days after treatment slight increase in population was observed in all treated plots. Where as in malathion treated plots very low population (0.21) was observed and this treatment was followed by emamectin benzoate 0.002 %, fipronil 0.01 %, indoxacarb 0.015 %, novaluron 0.015 % and flubendiamide 0.0096 % with 0.83, 0.87, 0.93, 1.15 and 1.39 larvae per plant, respectively. All

Table19: Evaluation of new generation insecticides on *S. litura* population under field conditions

TREATMENTS	Mean Population of *Spodoptera litura* larvae*															
	FIRST SPRAY				SECOND SPRAY				THIRD SPRAY				FOURTH SPRAY			
	PTC	1DAT	3 DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT	PTC	1DAT	3 DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT
T1- Novaluron 10 EC – 0.015 %	4.22 (2.24)	3.74^{b} (2.12)	0.52^{b} (1.25)	1.15^{b} (1.46)	1.62^{b} (1.62)	0.56^{b} (1.25)	0.22^{b} (1.10)	0.65^{b} (1.29)	1.12^{bc} (1.46)	0.65^{b} (1.29)	0.22^{b} (1.10)	1.05^{b} (1.43)	1.23^{b} (1.49)	0.65^{b} (1.29)	0.46^{b} (1.21)	0.93^{b} (1.39)
T2- Flubendiamide 39.35 SC – 0.0096%	8.47 (3.08)	3.25^{b} (2.04)	0.48^{bc} (1.22)	1.39^{b} (1.54)	1.54^{b} (1.59)	0.87^{b} (1.37)	0.22^{b} (1.10)	1.05^{b} (1.43)	1.36^{b} (1.54)	0.32^{bc} (1.12)	0.22^{b} (1.10)	0.99^{b} (1.41)	1.30^{b} (1.52)	0.65^{b} (1.29)	0.22^{b} (1.10)	1.05^{b} (1.43)
T3- Emamectin benzoate 1 WG – 0.002 %	5.30 (2.53)	0.42^{d} (1.18)	0.00^{c} (1.00)	0.83^{b} (1.35)	0.83^{b} (1.35)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.22^{b} (1.10)	0.42^{bcd} (1.18)	0.00^{c} (1.00)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.00^{c} (1.00)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.22^{b} (1.10)
T4- Fipronil 5 SC – 0.01%	8.51 (3.12)	1.74^{c} (1.67)	0.72^{b} (1.28)	0.87^{b} (1.37)	1.72^{b} (1.65)	0.40^{b} (1.18)	0.40^{b} (1.18)	0.65^{b} (1.29)	1.61^{b} (1.62)	0.40^{bc} (1.18)	0.22^{b} (1.10)	0.22^{b} (1.10)	0.40^{bc} (1.18)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.40^{b} (1.18)
T5- Indoxacarb 14.5 SC – 0.015%	6.39 (1.99)	1.47^{c} (1.57)	0.39^{bc} (1.19)	0.93^{b} (1.40)	0.93^{b} (1.39)	0.22^{b} (1.10)	0.00^{b} (1.00)	0.65^{b} (1.29)	0.92^{d} (0.89)	0.22^{bc} (1.10)	0.00^{b} (1.00)	0.65^{b} (1.29)	0.65^{bc} (1.29)	0.22^{b} (1.10)	0.00^{b} (1.00)	0.87^{b} (1.37)
T6-Malathion 50 EC (check) – 0.1 %	8.73 (3.12)	0.70^{d} (1.21)	0.20^{bc} (1.10)	0.21^{b} (1.10)	0.22^{b} (1.10)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.11^{cd} (0.90)	0.00^{c} (1.00)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.00^{c} (1.00)	0.00^{b} (1.00)	0.00^{b} (1.00)	0.22^{b} (1.10)
T7- Untreated	8.70 (3.11)	8.70^{a} (3.11)	8.73^{a} (3.12)	8.73^{a} (3.12)	8.99^{a} (3.16)	8.99^{a} (3.16)	8.99^{a} (3.16)	10.83^{a} (3.42)	10.83^{a} (3.42)	10.83^{a} (3.42)	10.83^{a} (3.42)	11.80^{a} (3.20)	11.80^{a} (3.20)	11.80^{a} (3.20)	14.80^{a} (3.97)	14.80^{a} (3.97)
CD (0.05)	NS	(0.352)	(0.232)	(0.529)	(0.556)	(0.372)	(0.243)	(0.466)	(0.560)	(0.276)	(0.204)	(0.449)	(0.487)	(0.369)	(0.353)	(0.476)

*Mean number of larvae observed in 5 plants

PTC- Pre Treatment Count, DAT- Days After Treatment

Values shown in parentheses are √x+1 transformed values

these above treatments were on par and significantly different from untreated control (8.73 larvae per plant).

At 15 days after sowing, second spray was given. Before the second spray the population level ranged from 0.22 to 8.99 larvae per plant. On first day after treatment, no population of *S. litura* was observed in emamectin benzoate 0.002 % and malathion 0.10 % treated plots. These treatments were followed by indoxacarb 0.015 % (0.22 larvae per plant), fipronil 0.01 %, novaluron 0.015 % and flubendiamide 0.0096 % (0.87 larvae per plant). All treatments were on par and significantly different from untreated plots (8.99 larvae per plant).

The population level in indoxacarb 0.015 % treated plots reduced to zero at three day after treatment in addition to the emamectin benzoate 0.002 % and malathion 0.10 %. These treatments were followed by flubendiamide 0.0096 %, novaluron 0.015 % and fipronil 0.01 % with 0.22, 0.22 and 0.40 larvae per plant. All these treatments did not differ statistically.

At five days after treatment, population of *S. litura* increased in all plots except in malathion treated plots. There was no statistical variation in population among all treated plots when observed at five days after treatment. All these treatments significantly varied from control.

The third spray was given at 23rd day from sowing when the mean population of *S. litura* per plant ranged from 0.42 to 10.83 larvae per plant. Subsequent to the application of treatments, the population decreased to 0.00 in emamectin benzoate 0.002 % and malathion 0.10 % from 0.42 and 0.11 respectively on first day after the third spray. The population levels in indoxacarb 0.015 %, flubendiamide 0.0096 % and fipronil 0.01 % were brought down to 0.22, 0.32 and 0.40 larvae per plant, respectively. All the above treatments were on par with each other. These treatments were followed by novaluron 0.015 % with a population level of 0.65 larvae per plant.

Table 20: Effect of pesticides on the extent of infestation of leaves of amaranth plants by *S. litura* after different spray

TREATMENTS	Percentage of leaves infested after different sprays			
	First spray	Second spray	Third spray	Fourth spray
T1- Novaluron 10 EC – 0.015 %	16.74 (3.43)	7.43[a] (2.90)	6.67[b] (2.73)	5.06[b] (2.45)
T2- Flubendiamide 39.35 SC – 0.0096 %	9.60 (2.32)	1.67[c] (1.44)	3.17[bc] (1.96)	3.34[bc] (2.06)
T3- Emamectin benzoate 1 WG – 0.002 %	16.39 (3.41)	4.47[bc] (2.07)	3.92[bc] (2.11)	3.30[bc] (2.05)
T4- Fipronil 5 SC – 0.01%	15.91 (3.36)	5.44[ab] (2.40)	5.17[b] (2.46)	4.97[b] (2.44)
T5- Indoxacarb 14.5 SC – 0.015 %	23.75 (4.53)	5.71[ab] (2.45)	4.48[bc] (2.20)	4.51[b] (2.31)
T6-Malathion 50 EC (check) – 0.1 %	6.94 (2.09)	1.66[c] (1.44)	2.11[c] (1.64)	1.76[c] (1.55)
T7- Untreated	31.98 (5.16)	8.67[a] (3.08)	14.04[a] (3.82)	11.85[a] (3.54)
CD (0.05)	NS	(0.786)	(0.770)	(0.551)

Mean of five plants

Values shown in parentheses are √x+1 transformed values

At third day after treatment, the population levels in indoxacarb 0.015 % treated plots were reduced to 0.00 along with those in emamectin benzoate 0.002 % and malathion 0.10 % treatments. These were followed by flubendiamide 0.0096 %, novaluron 0.015 % and fipronil 0.01 % with a population level of 0.22 larvae per plant in these three treated plots.

Five days after treatment, the population levels of *S. litura* increased to 0.65, 0.99, 1.05 and 11.80 larvae per plant in indoxacarb 0.015 %, flubendiamide

0.0096 %, novaluron 0.015 % and untreated plots respectively. There was no change in the population levels in malathion 0.10 %, emamectin benzoate 0.002 % and fipronil 0.01 % treated plots. Except untreated plot, all the above treatments were on par with each other.

Fourth spray was given at 30 days after sowing. At first day after fourth spraying, all treatments were statistically on par with each other but significantly different from control (11.80 larvae per plant). Complete control was noticed in fipronil 0.01 % treated plots along with emamectin benzoate 0.002 % and malathion 0.10 % treated plots. Reduction in population levels was recorded in indoxacarb 0.015 % (0.22 larvae per plant), flubendiamide 0.0096 % (0.65 larvae per plant) and novaluron 0.015 % (0.65 larvae per plant).

On third day after treatment, not a single larva could be recorded in emamectin benzoate 0.0096 %, fipronil 0.01 %, indoxacard 0.015 % and malathion 0.10 % treated plots. Theses where followed by flubendiamide 0.0096 % and novaluron 0.015 % with 0.22 and 0.46 larvae per plant.

At five days after treatment, population levels of *S. litura* showed an increasing trend in all plots. Among the treated plots, lowest population was observed in emamectin benzoate 0.002 % and malathion 0.10 % treated plots *i.e*., 0.22 larvae per plant. These were followed by fipronil 0.01 %, indoxacarb 0.015 %, novaluron 0.015 % and flubendiamide 0.0096 % with 0.40, 0.87, 0.93 and 1.05 larvae per plant, respectively. All the above treatments did not show any statistical difference among each other.

4.3.2.1.1 Percentage Infestation by S. litura

The results on percentage infestation by *S. litura* in amaranth plants in treated plots with selected treatments are presented in Table 20.

The percentage of infestation by *S. litura* was the lowest (6.94) in malathion 0.10 % treated plots and it was followed by flubendiamide 0.0096 %

(9.60 %) after first spray. Whereas, in fipronil 0.01 %, emamectin benzoate 0.002 % and novaluron 0.015 % the percentage of infestations noticed were 15.91, 16.39 and 16.74 per cent respectively. Among all treated plots, highest percentage of infestation (23.75) was recorded in indoxacarb 0.015 % treated plots. In untreated plots the observed infestation was 31.98 per cent.

After second spray, the lowest percentage of infestation (1.66 %) was recorded in malathion 0.10 % treated plots. Whereas, in flubendiamide 0.0096 % the percentage infestation was 1.68. Next lowest infestation percentage was obtained in emamectin benzoate 0.002 % treated plots (4.47 %) followed by fipronil 0.01 per cent (5.44 %), indoxacarb 0.015 % (5.71 %) and novaluron 0.015 % (6.87 %). However, in untreated plots the infestation was 16.64 per cent.

More or less similar results were obtained after third spray in amaranth plots. Among all treated plots, low percentage of infestation was recorded in malathion 0.10 % (2.11). However, in flubendiamide 0.0096 % it was 3.17 per cent and it was followed by emamectin benzoate 0.002 % (3.92 %), indoxacarb 0.015 %, fipronil 0.01 % (5.17 %) and novaluron 0.015 % (6.68 %). Significantly high levels of infestation noticed in untreated plots (14.04 %).

Among all treated plots the superior treatment with respect to percentage of infestation by *S. litura* was malathion 0.10 % (1.76 %). This was followed by flubendiamide 0.0096 % and emamectin benzoate 0.002 % with percentage of infestation of 3.30 and 3.34 respectively. Whereas, in indoxacarb 0.015 %, fipronil 0.01 % and novaluron 0.015 % sprayed plots the infestation was 4.51, 4.97 and 5.06 per cent respectively. While in untreated plots the infestation was up to 16.16 per cent per plant.

4.3.2.2 Evaluation of Treatments in Instructional Farm, Vellayani

4.3.2.2.1 Evaluation of different treatments against H. recurvalis population

The observed results on bio-efficacy of selected treatments against *H. recurvalis* under field conditions are presented in Table 21 and the results on percentage of infestation are represented in Table 22 (Plate 2).

On seventh day after sowing the first spray was given. The pre-treatment count observed ranged from 9.49 to 12.24 larvae per plant.

At first day after treatment, higher extent of reduction in population of *H. recurvalis* was observed in fipronil 0.01 % treated plots (0.40 larvae per plant) which was followed by indoxacarb 0.015 % and emamectin benzoate 0.002 % with mean population of 0.93 and 1.23 larvae per plant, respectively. All the above treatments were on par. The next effective treatments were malathion 0.10 % and novaluron 0.015 % with mean population of 1.69 and 1.96 larvae per plant respectively, these two treatments being statistically on par with each other. These were followed by flubendiamide 0.0096 % with a mean population of 2.27 larvae per palnt. All the above treatments are significantly different from untreated plot (10.68 larvae per plant).

The population of *H. recurvalis* in fipronil 0.01 % treated plots completely reduced to zero at three days after treatment. This treatment was followed by indoxacarb 0.015 % (0.46 larvae per plant), emamectin benzoate 0.002 % (0.65 larvae per plant) and novaluron 0.015 % (0.72 larvae per plant). The mean population observed in flubendiamide 0.0096 % and malathion 0.10 % treated plots were 0.93 larvae per plant.

At five days after treatment there was no significant difference in population of *H. recurvalis* among all treated plots, but were significantly different from that of untreated plot.

The population level of *H. recurvalis* observed in fipronil 0.01 % treated plots remained zero after one day also. The population observed in emamectin benzoate 0.002 %, indoxacarb 0.015 %, flubendiamide 0.0096 % and novaluron

Plate 2a: Adult

Plate 2b: Larva

Plate 2c: Damage

Plate 2: *Hymenia recurvalis* larva, adult and damage

0.015 % were 0.22, 0.22, 0.46 and 0.46 larvae per plant. All these above treatments did not show any significant difference among each other.

At third day after treatment, the population levels increased in all treated and untreated control plots. Lowest population was observed in fipronil 0.01 % treated plots and this was followed by indoxacarb 0.015 % (0.46 larvae per plant) and novaluron 0.015 % (0.72 larvae per plant), all the above treatments were on par. These treatments were followed by flubendiamide 0.0096 % and malathion 0.1%. After five days in fipronil 0.01 % and indoxacarb 0.0015 % treated plots, lowest population (0.22 larvae per plant) was observed. These treatments were followed by novaluron 0.0015 %, flubendiamide 0.0096 %, malathion 0.10 % and emamectin benzoate 0.002 % with observed population levels 0.46, 0.46, 0.65 and 0.87 larvae per plant, respectively. All the above treatments were on par among each other.

The third spray was given at 23rd day after sowing. Before the third spray the population level of *H. recurvalis* caterpillars ranged from 0.32 to 12.38 larvae per plant.

One day after third spray no population was noted in fipronil 0.01 % treated plots. The next lowest population (0.22 larvae per plant)was observed in emamectin benzoate 0.002 % and indoxacarb 0.015 % treated plots. These treatments were followed by flubendiamide 0.0096 %, novaluron 0.015 % and malathion 0.10 % with population 0.46, 0.46 and 0.65 larvae per plant, respectively. All these treatments were on par with each other and significantly different from untreated control.

No population was noticed in fipronil 0.01 % and indoxacarb 0.015 % treated plants at three day after treatment. The population observed in all

Table 21: Evaluation of new generation insecticides on *H. recurvalis* population under field conditions

TREARMENTS	Mean Population Of *Hymenia recurvalis* larvae*															
	FIRST SPRAY				SECOND SPRAY				THIRD SPRAY				FOURTH SPRAY			
	PTC	1DAT	3 DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT	PTC	1DAT	3 DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT
T1- Novaluron 10 EC – 0.015 %	10.99 (3.46)	1.96^{bc} (1.72)	0.72^{bc} (1.31)	0.46^{b} (1.21)	0.72^{b} (1.31)	0.46^{b} (1.21)	0.72^{b} (1.31)	0.46^{b} (1.21)	0.72^{b} (1.31)	0.46^{b} (1.21)	0.22^{b} (1.10)	1.12^{bc} (1.45)	1.36^{bc} (1.54)	0.72^{b} (1.31)	0.46^{b} (1.21)	1.36^{b} (1.54)
T2- Flubendiamide 39.35 SC – 0.0096%	11.99 (3.60)	2.97^{b} (1.99)	0.93^{b} (1.39)	0.46^{b} (1.21)	0.46^{b} (1.21)	0.46^{b} (1.21)	0.93^{b} (1.39)	0.46^{b} (1.21)	0.46^{b} (1.21)	0.46^{b} (1.21)	0.22^{b} (1.10)	1.40^{b} (1.55)	1.69^{b} (1.64)	0.65^{b} (1.29)	0.46^{b} (1.21)	0.99^{b} (1.41)
T3- Emamectin benzoate 1 WG – 0.002 %	12.24 (3.64)	1.23^{cd} (1.49)	0.65^{bc} (1.29)	0.65^{b} (1.29)	0.65^{b} (1.29)	0.22^{b} (1.10)	0.65^{b} (1.29)	0.87^{b} (1.37)	0.65^{b} (1.29)	0.22^{b} (1.10)	0.22^{b} (1.10)	0.65^{bcd} (1.29)	0.93^{bc} (1.39)	0.22^{bc} (1.10)	0 .00^{c} (1.00)	0.65^{b} (1.29)
T4- Fipronil 5 SC – 0.01%	11.47 (3.53)	0.40^{d} (1.18)	0 .00^{c} (1.00)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0.22^{b} (1.10)	0.22^{b} (1.10)	0.32^{b} (1.12))	0.00^{b} (1.00)	0 .00^{b} (1.00)	0.22^{cd} (1.10)	0.46^{c} (1.21)	0 .00^{c} (1.00)	0 .00^{c} (1.00)	0.93^{b} (1.39)
T5- Indoxacarb 14.5 SC – 0.015%	11.93 (3.60)	0.93^{cd} (1.39)	0.46^{bc} (1.21)	0.22^{b} (1.10)	0.46^{b} (1.21)	0.22^{b} (1.10)	0.46^{b} (1.21)	0.22^{b} (1.10)	0.46^{b} (1.21)	0.22^{b} (1.10)	0 .00^{b} (1.00)	0 .00^{d} (1.00)	0.65^{c} (1.29)	0 .00^{c} (1.00)	0 .00^{c} (1.00)	0.65^{b} (1.29)
T6-Malathion 50 EC (check) – 0.1 %	11.77 (3.57)	1.69^{c} (1.64)	0.93^{b} (1.39)	0.65^{b} (1.29)	0.65^{b} (1.29)	0.65^{b} (1.29)	0.93^{b} (1.39)	0.65^{b} (1.29)	0.65^{b} (1.29)	0.65^{b} (1.29)	0.22^{b} (1.10)	0.46^{bcd} (1.21)	0.65^{c} (1.29)	0.22^{bc} (1.10)	0.22^{bc} (1.10)	0.46^{b} (1.21)
T7- Untreated	9.49 (3.24)	10.68^{a} (3.41)	11.60^{a} (3.55)	12.10^{a} (3.62)	12.38^{a} (3.66)	12.38^{a} (3.66)	11.60^{a} (3.55)	12.10^{a} (3.62)	12.38^{a} (3.66)	12.38^{a} (3.66)	12.38^{a} (3.66)	11.67^{a} (3.56)	14.37^{a} (3.92)	14.37^{a} (3.92)	14.94^{a} (4.00)	14.94^{a} (4.00)
CD (0.05)	NS	(0.344)	(0.361)	(0.372)	(0.324)	(0.317)	(0.361)	(0.372)	(0.324)	(0.317)	(0.245)	(0.369)	(0.343)	(0.258)	(0.204)	(0.447)

*Mean number of larvae observed in 5 plants, PTC- Pre Treatment Count, DAT- Days After Treatment

Values shown in parentheses are √x+1 transformed values

remaining treatments was 0.22 larvae per plant. All these treatments varied significantly with untreated check.

At five days after treatment the population levels increased in all treatments except in malathion 0.10 % where the population was zero. The population levels were higher in fipronil 0.01 %, malathion 0.10 % and emamectin benzoate 0.002 % treated plots with 0.22, 0.46 and 0.65 larvae per plant, respectively. All the above treatments were on par. These treatments were followed by novaluron 0.015 % (1.12 larvae per plant) and flubendiamide 0.0096 per cent (1.40 larvae per plant).

The recorded pre-treatment count before the fourth spray was ranged from 0.46 to 14.37 larvae per plant and the spray was given at 30 days after sowing.

In fipronil 0.01 % and indoxacarb 0.015 % treated plots no population was observed at first day after treatment. In both emamectin benzoate 0.002 % and malathion 0.10 % treated plots, the next lower population level of 0.22 larvae per plant was recoded. All these treatments came on par with each other and these treatments were followed by flubendiamide 0.0096 % and novaluron 0.015 %with 0.65 and 0.72 larvae per plant.

At three days after treatment, the population remained at zero level in emamectin benzoate 0.002 % along with fipronil 0.01 % and indoxacarb 0.015 %. These treatments were followed by malathion 0.10 % (0.22 larvae per plant). All the above treatments did not show significant difference among each other. The next lowest population level recorded in flubendiamide 0.0096 % and novaluron 0.015 % was 0.46 larvae per plant.

At five days after treatment, the lowest population of *H. recurvalis* was noticed in malathion 0.10 % (0.46 larvae per plant) and it was followed by indoxacarb 0.015 %, emamectin benzoate 0.002 %, fipronil 0.01 % and flubendiamide 0.0096 % with 0.65, 0.65, 0.93 and 0.99 larvae per plant respectively. All the above treatments were statistically on par with other and

these treatments were followed by novaluron 0.015 % (1.36 larvae per plant). All the treatments differed significantly from untreated control.

4.3.2.1.2 Percentage Infestation by H. recurvalis

The results of studies on infestation of *H. recurvalis* on amaranth plants treated with different selected insecticides are presented in Table 22 (Plate 2).

The percentage of infestation in amaranth plots treated with different insecticides ranged from 8.06 to 19.04 per cent leaves infested per plant. Lowest percentage of infestation was observed in indoxacarb 0.015 % treated plots, followed by fipronil 0.01 % (14.71), malathion 0.10 % (15.16), emamectin benzoate 0.002 % (15.28), flubendiamide 0.0096 % (15.62) and novaluron 0.015 % (16.14). Highest percentage of infestation (19.04) was observed in untreated plots.

After second spray the mean percentage of leaves infested per plant ranged from 3.25 to 23.16. The lowest percentage of infested leaves was recorded in flubendiamide 0.0096 per cent treated plots (3.25). Whereas 3.84, 5.75, 6.53, 7.22 and 9.51 percentage of infested leaves was observed in fipronil 0.01 %, indoxacarb 0.015 %, novaluron 0.015 %, malathion 0.10 % and emamectin benzoate 0.002 % sprayed plots. All the above treatments were statistically on par with each other. Among all plots, highest infestation percentage was observed in untreated plots.

A wide range of percentage infestation (4.01 to 15.35) was observed in amaranth plots after third spray. The lowest and the highest percentage infestation by *H. recurvalis* was observed in flubendiamide 0.0096 % treated and untreated plots. However the percentage of infestation noticed in fipronil 0.01 %, emamectin benzoate 0.002 %, malathion 0.10 %, indoxacarb 0.015 % and

Table 22: Effect of pesticides on the extent of infestation of amaranth plants by *H. recurvalis* after different sprays

TREATMENTS	Percentage of leaves infested after different sprays			
	First spray	Second spray	Third spray	Fourth spray
T1- Novaluron 10 EC – 0.015 %	16.14 (3.38)	6.53[b] (2.58)	7.48[b] (2.72)	6.19[b] (2.53)
T2- Flubendiamide 39.35 SC – 0.0096%	15.62 (3.34)	3.25[b] (1.87)	4.01[b] (2.12)	4.46[b] (2.17)
T3- Emamectin benzoate 1 WG – 0.002 %	14.70 (2.68)	9.51[b] (3.00)	5.26[b] (2.35)	4.83[b] (2.13)
T4- Fipronil 5 SC – 0.01%	15.28 (3.30)	3.84[b] (1.97)	4.22[b] (2.17)	4.18[b] (2.13)
T5- Indoxacarb 14.5 SC – 0.015%	8.06 (2.19)	5.75[b] (2.45)	7.09[b] (2.75)	5.82[b] (2.50)
T6-Malathion 50 EC (check) – 0.1 %	15.16 (3.30)	7.22[b] (2.67)	6.67[b] (2.55)	5.43[b] (2.32)
T7- Untreated	23.68 (4.52)	23.16[a] (4.89)	15.35[a] (4.03)	16.15[a] (3.73)
CD (0.05)	NS	(1.337)	(0.948)	(0.923)

Mean of five plants

Values shown in parentheses are √x+1 transformed values

novaluron 0.015 % sprayed plots were 4.22, 5.26, 6.67, 7.09 and 7.48 per cent.

More or less similar results were obtained after fourth spray application also. The percentage infestation among all plants ranged from 4.18 to 13.15. The mean percentage of infested leaves was lower in flubendiamide 0.0096 % and it was followed by fipronil 0.01 %, emamectin benzoate 0.002 %, malathion 0.10 %, indoxacarb 0.015 % and novaluron 0.015 % treated plots with infestation percentage of 4.46, 4.83, 5.43, 5.82 and 6.19 respectively. However, the recorded infestation in untreated plots was 13.15 per cent.

4.3.2.2.3 Evaluation of different treatments against S. litura population

The results on study of evaluation of treatments against *S. litura* population and percentage of infestation are represented in Table 23 and Table 24 (Plate 3).

The first spraying was done at seven days after sowing. The mean population of *S. litura* caterpillars before the spray ranged from 8.22 to 9.24.

At one day after the treatment, significantly low population was observed in all treated plots. Lowest population (0.40 larvae per plant) recorded in emamectin benzoate 0.002 % treated plots, followed by malathion 0.10 % (0.93 larvae per plant) and these two treatments were statistically on par. The next lowest population (1.47 larvae per plant) was recorded in indoxacarb 0.015 %, which was followed by fipronil 0.01 % and novaluron 0.015 % with population 2.63 and 2.74 larvae per plant, respectively, these two treatments being on par. These two treatments were followed by flubendiamide 0.0096 % with a population of 4.46 larvae per plant.

At three days after treatment, the population of *S. litura* declined at a greater extent. No population was detected in emamectin benzoate 0.002 % treated plots and this was followed by malathion 0.10 %, flubendiamide 0.0096 % and indoxacarb 0.015 % with population of 0.22, 0.46 and 0.46 larvae per plant,

Plate 3a: Adult

Plate 3b: Larva

Plate 3c: Damage

Plate 3: *Spodoptera litura* larva, adult and damage

respectively. All these four treatments were statistically on par with each other. The population level noticed in novaluron 0.015 % (0.72 larvae per plant) and fipronil 0.01 % (0.93 larvae per plant) treated plots were on par which were significantly superior over control.

Increase in population levels was noted in all plots except malathion 0.10 % treated plots at five days after treatment. In malathion 0.10 % the observed population was only 0.21 larvae per plant, it was superior over all other treatments which was followed by emamectin benzoate 0.002 %, indoxacarb 0.015 %, novaluron 0.015 % and flubendiamide 0.0096 % with mean population of 0.83, 0.93, 1.149 and 1.39 larvae per plant, respectively. All the above treatments were statistically on par. Among all treated plots, higher population of *S. litura* was recorded in fipronil 0.01 % treated plots (1.72 larvae per plant). All the above treatments were significantly superior over untreated check (8.73 larvae per plant). Second spraying was done at 15^{th} day after sowing. Before the second spray, the pre-treatment population level of *S. litura* ranged from 0.83 to 8.73 larvae per plant.

No population was observed in malathion 0.10 %, emamectin benzoate 0.002 % treated plants at the first day of treatment. Indoxacarb 0.015 % (0.22 larvae per plant), fipronil 0.01 % (0.40 larvae per plant), novaluron 0.015 % (0.56 larvae per plant) and flubendiamide 0.0096 % (0.87 larvae per plant) were the best treatments with respect to their bio-efficacy against S. *litura.* All the above treatments were on par with each other.

At third day after second spray, no population was recorded in indoxacarb 0.015 % treated plots along with malathion 0.10 % and emamectin benzoate 0.002 % treated plots. These treatments were followed by flubendiamide 0.0096 %, novaluron 0.015 % and fipronil 0.01 % with population levels of 0.22, 0.22 and 0.40 larvae per plant, respectively and all these treatments were statistically on par with each other.

Table 23: Evaluation of new generation insecticides on *S. litura* population under field conditions

TREARMENTS	Mean Population of *Spodoptera litura* larvae*															
	FIRST SPRAY				SECOND SPRAY				THIRD SPRAY				FOURTH SPRAY			
	PTC	1DAT	3 DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT	PTC	1DAT	3 DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT
T1- Novaluron 10 EC – 0.015 %	8.73 (3.12)	2.74^{c} (1.93)	0.72^{bc} (1.31)	1.15^{bc} (1.46)	1.62^{b} (1.62)	0.56^{b} (1.25)	0.22^{b} (1.10)	0.65^{b} (1.29)	1.12^{b} (1.46)	0.65^{b} (1.29)	0.22^{b} (1.10)	1.05^{b} (1.43)	1.23^{b} (1.49)	0.65^{b} (1.29)	0.46^{b} (1.21)	0.93^{b} (1.39)
T2- Flubendiamide 39.35 SC – 0.0096%	8.47 (3.08)	4.46^{b} (2.34)	0.46^{bcd} (1.21)	1.39^{bc} (1.54)	1.54^{b} (1.59)	0.87^{b} (1.37)	0.22^{b} (1.10)	1.05^{b} (1.43)	1.36^{b} (1.54)	0.65^{b} (1.29)	0.22^{b} (1.10)	0.99^{b} (1.41)	1.30^{b} (1.52)	0.65^{b} (1.29)	0.22^{b} (1.10)	1.05^{b} (1.43)
T3- Emamectin benzoate 1 WG – 0.002 %	7.36 (2.89)	0.40^{f} (1.18)	0 .00^{d} (1.00)	0.83^{bc} (1.35)	0.83^{b} (1.35)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0.22^{b} (1.10)	0.65^{b} (1.29)	0 .00^{c} (1.00)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0.22^{bc} (1.10)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0.65^{b} (1.29)
T4- Fipronil 5 SC – 0.01%	9.24 (3.20)	2.63^{cd} (1.90)	0.93^{b} (1.39)	1.72^{b} (1.65)	1.72^{b} (1.65)	0.40^{b} (1.18)	0.40^{b} (1.18)	0.65^{b} (1.29)	1.61^{b} (1.62)	0.56^{bc} (1.25)	0.22^{b} (1.10)	0.22^{b} (1.10)	0.40^{bc} (1.18)	0.22^{b} (1.10)	0.22^{b} (1.10)	0.40^{b} (1.18)
T5- Indoxacarb 14.5 SC – 0.015%	7.15 (2.85)	1.47^{de} (1.57)	0.46^{bcd} (1.21)	0.93^{bc} (1.40)	0.93^{b} (1.39)	0.22^{b} (1.10)	0 .00^{b} (1.00)	0.65^{b} (1.29)	1.60^{b} (1.61)	0.46^{bc} (1.21)	0 .00^{b} (1.00)	0.65^{b} (1.29)	0.65^{bc} (1.29)	0.22^{b} (1.10)	0 .00^{b} (1.00)	0.87^{b} (1.37)
T6-Malathion 50 EC (check) – 0.1 %	8.70 (3.11)	0.93^{cf} (1.39)	0.22^{cd} (1.10)	0.21^{c} (1.10)	0.22^{b} (1.10)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0.22^{b} (1.10)	0.22^{bc} (1.10)	0 .00^{b} (1.00)	0.00^{b} (1.00)	0 .00^{c} (1.00)	0 .00^{b} (1.00)	0 .00^{b} (1.00)	0.22^{b} (1.10)
T7- Untreated	8.22 (3.04)	8.22^{a} (3.04)	8.73^{a} (3.12)	8.73^{a} (3.12)	8.73^{a} (3.12)	8.99^{a} (3.16)	8.99^{a} (3.16)	11.83^{a} (3.58)	11.86^{a} (3.58)	11.90^{a} (3.59)	11.90^{a} (3.59)	14.80^{a} (3.97)	14.71^{a} (3.96)	15.02^{a} (4.00)	15.83^{a} (4.10)	17.93^{a} (4.35)
CD (0.05)	NS	(0.347)	(0.234)	(0.535)	(0.563)	(0.370)	(0.238)	(0.471)	(0.556)	(0.282)	(0.205)	(0.446)	(0.488)	(0.376)	(0.349)	(0.477)

*Mean number of larvae observed in 5 plants,

PTC- Pre Treatment Count, DAT- Days After Treatment

Values shown in parentheses are √x+1 transformed values

On the fifth day of second spraying, the population level increased slightly except in plots treated with malathion 0.10 %. This superior treatment was followed by emamectin benzoate 0.002 % (0.22 larvae per plant), indoxacarb 0.015 % (0.65 caterpillars per plant), novaluron 0.015 % (0.65 larvae per plant), fipronil 0.01 % (0.65 larvae per plant) and flubendiamide 0.0096 % (1.05 larvae per plant), all treatments being statistically on par with superior treatments.

The pre-treatment count of *S. litura* population before the third spray ranged from 0.22 to 11.86 larvae per plant and spraying was done at 23rd day after sowing.

More or less similar results were observed in the case of population at one day after spraying. No population of *S. litura* was noted in amaranth plots treated with emamectin benzoate 0.002 %. However the population levels observed in malathion 0.10 %, indoxacarb 0.015 % and fipronil 0.01 % treated plots were 0.22, 0.46 and 0.56 larvae per plant, respectively and all these treatments did not show any statistical difference among each other. These treatments were followed by flubendiamide 0.0096 % and novaluron 0.015 % with mean population level of 0.65 larvae per plant in both the treatments.

Similarly, at third day after spraying, no population of *S. litura* was noticed in emamectin benzoate 0.002 % treated plots along with indoxacarb 0.015 % and malathion 0.10 % treated plots and these superior treatments were followed by flubendiamide 0.0096 %, novaluron 0.015 % and fipronil 0.01 % with similar level of population (0.22 larvae per plant).

At fifth day after spraying also no population was recorded in emamectin benzoate 0.002 per cent and malathion 0.10 % treated plots. Next lowpopulation level was recorded in fipronil 0.01 % treated plots and this was followed by indoxacarb 0.015 % (0.65 larvae per plant), flubendiamide 0.0096 % (0.99 larvae per plant) and novaluron 0.015 % (1.05 larvae per plant). However, all these

treatments were statistically on par with each other and significantly different from untreated plots (14.80 larvae per plant).

The pre-treatment populations before fourth spray ranged from 0.22 to 14.71 larvae per plant. No population was observed in emamectin benzoate 0.002 per cent treated plots along with malathion 0.10 % sprayed plots on first day after spraying. However, the population perceived in indoxacarb 0.015 % and fipronil 0.01 % applied plots were 0.22 larvae per plant. These treatments were followed by flubendiamide 0.0096 % (0.65 larvae per plant) and novaluron 0.15 % (0.65 larvae per plant) treatments. All these treatments were statistically on par with each other.

Along with emamectin benzoate 0.002 % and malathion 0.10 % treated plots, zero population levels was also observed in indoxacarb 0.015 % sprayed plots. However, the population noticed in flubendiamide 0.0096 %, fipronil 0.01 % and novaluron 0.015 % treated plots were 0.22, 0.22 and 0.46 larvae per plant, respectively. All these treatments did not show any statistical difference among each other.

At five days after treatment, the population levels increased in all plots. Lowest population (0.22 larvae per plant) was observed in malathion 0.10 % treated plots. More or less similar levels of population were observed in fipronil 0.01 % (0.40 larvae per plant). However, the population levels recorded in emamectin benzoate 0.002 %, novaluron 0.015 % and flubendiamide 0.0096 % treated plots were 0.87, 0.93 and 1.05 larvae per plant. All the above treatments did not show any statistical difference among each other but having significant differences between untreated plots (17.93 larvae per plant).

4.3.2.2.4 Percentage Infestation by S. litura

The results of the study on evaluation of different insecticides on the percentage of infestation of *S. litura* are shown in Table 24.

Table 24: Effect of pesticides on the extent of infestation of amaranth plants by *S. litura* after different sprays

TREATMENTS	Percentage of leaves infested after different sprays			
	First spray	Second spray	Third spray	Fourth spray
T1- Novaluron 10 EC – 0.015 %	30.38^{ab} (5.00)	9.25^{b} (2.91)	7.72^{b} (2.88)	6.32^{b} (2.65)
T2- Flubendiamide 39.35 SC – 0.0096%	15.67^{bc} (3.34)	5.90^{bc} (2.26)	4.34^{bc} (2.17)	3.30^{bcd} (1.98)
T3- Emamectin benzoate 1 WG – 0.002 %	15.67^{bc} (3.34)	6.21^{bc} (2.31)	4.26^{bc} (2.16)	3.02^{cd} (1.89)
T4- Fipronil 5 SC – 0.01%	23.96^{b} (4.55)	7.83^{b} (2.78)	6.17^{b} (2.65)	4.14^{bcd} (2.22)
T5- Indoxacarb 14.5 SC – 0.015%	23.34^{b} (4.50)	6.35^{bc} (2.55)	7.18^{b} (2.79)	5.92^{bc} (2.54)
T6-Malathion 50 EC (check) – 0.1 %	7.81^{c} (2.17)	3.45^{c} (1.71)	2.38^{c} (1.70)	1.60^{d} (1.52)
T7- Untreated	48.68^{a} (6.78)	15.96^{a} (4.05)	17.36^{a}(4.20)	19.46^{a} (4.49)
CD (0.05)	(1.797)	(1.064)	(0.925)	(0.717)

Mean of five plants

Values shown in parentheses are √x+1 transformed values

Among all plots the *S. litura* infestation showed wide variation ranging from 7.81 to 48.68 per cent. After the first spray, the mean number of leaves infested was lowest in malathion 0.10 % treated plots. Whereas, the higher percentage infestation noticed in untreated plots. The percentage infestation

detected in flubendiamide 0.0096 %, emamectin benzoate 0.002 %, indoxacarb 0.015 %, fipronil 0.01 % and novaluron 0.015 % were 15.67, 15.67, 23.34, 23.96 and 30.38, respectively.

The mean infestation of *S. litura* recorded in treated plots was lowest in malathion 0.10 % (3.45) treated plots and it was followed by flubendiamide 0.0096 % (3.53), indoxacarb 0.015 % (6.35), fipronil 0.01 % (7.83) and novaluron 0.015 per cent (9.25). However, the highest infestation percentage was observed in untreated plots (13.71).

More or less similar results were obtained after third spray also. The percentage infestation varied very much with population levels ranging from 2.39 to 17.36. In malathion 0.10 % sprayed plots 2.39 per cent infestation was recorded. The per cent infestation in flubendiamide 0.0096 %, emamectin benzoate 0.002 %, fipronil 0.01 %, indoxacarb 0.015 % and novaluron 0.015 % treated plots were 3.43, 4.26, 6.17, 7.18 and 7.73 respectively, all the treated plots were statistically on par. However, the percentage of infestation in untreated plots was as high as 17.36.

Comparatively less percentage infestations was observed in treated plots after fourth spray. Among all treated plots 1.60 percentage infestation noticed in malathion 0.10 % treated plots where as the percentage infestation recorded in emamectin benzoate 0.002 %, flubendiamide 0.0096 %, fipronil 0.01 %, indoxacarb 0.015 % and novaluron 0.015 % treated plots were 3.02, 3.30, 4.14, 5.92 and 6.32. However, in untreated plots, infestation was up to 19.47.

4.3.2.2.5 Evaluation of different treatments against Tetranychus spp population

Population of Tetranychus mites was observed on the foliage of red amaranth at the age of 18 days after sowing (Plate 4). So only two sprayings were done in order to evaluate treatments against mites. The results of this study on mean population of red spider mite are shown in Table 25 and results on percentage of infestation are presented in Table 26.

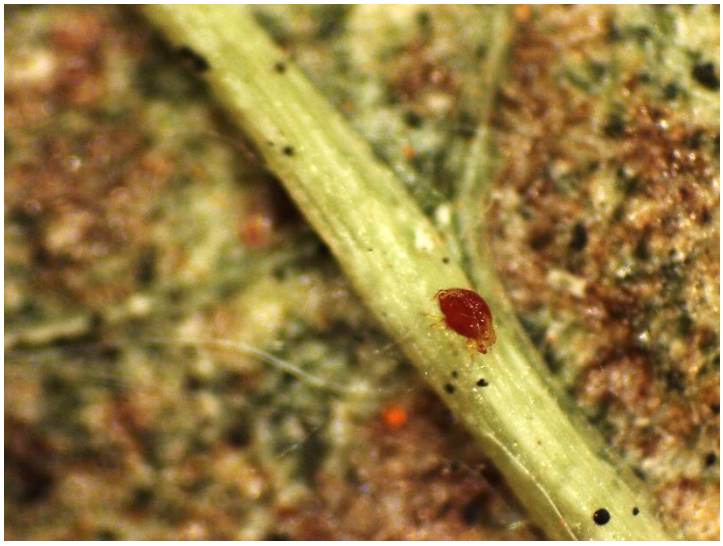


Plate 4a: Adult

Plate 4b: Mild damage symptom

Plate 4c: Severe damage symptom

Plate 4: *Tetranychus* spp mite adult, damage symptoms

More or less similar pre-treatment count was recorded before first spray. The mean population of mites ranged from 13.50 to 16.00, when the spraying was done at 23rd day of sowing.

At one day after spraying the mean population of red spider mites observed in buprofezin 0.03 % and spiromesifen 0.0192 % were 3.75 and 5.25 respectively. Whereas in ethion 0.15 %treated plots the observed population was 7.00 while in untreated plots, the populations remained as 14.75 mites per plant.

No population of mites was noticed in buprofezin 0.03 % sprayed plots on third day of spraying and it was followed by spiromesifen 0.0192 % (2.00). However in insecticide check ethion 0.15 % treated plots, mean number of mites per plant recorded was 5.25 and in untreated plots there was no change in population level.

On fifth day after spray, the population levels increased in all plots. Whereas lowest population (2.50 mites per plant) was observed in buprofezin 0.03 % treated plots and it was statistically on par with spiromesifen 0.0192 % (4.25 mites per plant) treated plots. In ethion 0.15 % sprayed plots, the population level increased to 7.25 mites per plant. All the above treatments were significantly different from untreated plots (20.00 mites per plant).

The mean population levels of mites found before the second spray (30th day of sowing) ranged from 2.50 to 20.00 number per plant. Decrease in population levels was recorded on first day after treatments in treated plots. Among

Table 25: Evaluation of new generation insecticides on population of *Tetranychus* spp under field conditions

TREATMENTS	Mean population of mites*							
	FIRST SPRAY				SECOND SPRAY			
	PTC	1 DAT	3DAT	5 DAT	PTC	1 DAT	3 DAT	5 DAT
T1-Buprofezin 25 SC – 0.03 %	12.50 (3.58)	3.75^{c} (1.94)	0.00^{d} (1.00)	2.50^{c} (1.71)	2.50^{c} (1.71)	0.00^{c} (1.00)	0.00^{c} (1.00)	1.75^{b} (1.53)
T2- Spiromesifen 22.9 SC – 0.0192 %	16.00 (4.09)	5.25^{bc} (2.48)	2.00^{c} (1.61)	4.25^{bc} (2.15)	4.25^{b} (2.15)	1.00^{c} (1.36)	1.00^{c} (1.36)	1.87^{b} (1.64)
T3- -Ethion 50 EC (Check) – 0.15 %	13.50 (3.80)	7.00^{b} (2.82)	5.25^{b} (2.49)	7.25^{b} (2.86)	8.25^{bc} (3.03)	4.25^{b} (2.28)	3.25^{b} (2.06)	2.75^{b} (1.86)
T4-Untreated	14.75 (3.95)	14.75^{a} (3.95)	14.75^{a} (3.95)	20.00^{a} (4.55)	20.00^{a} (4.55)	20.75^{a} (4.62)	22.50^{a} (4.83)	25.50^{a} (5.11)
CD (0.05)	NS	(0.820)	(0.553)	(0.920)	(0.905)	(0.515)	(0.424)	(0.798)

*Mean number of adult mites observed in 5 plants

PTC- Pre Treatment Count, DAT- Days After Treatment

Values shown in parentheses are √x+1 transformed values

all plots, lowest population level was observed in buprofezin 0.03 % (0.00). This treatment was followed by spiromesifen 0.0192 % (1.00 mites per plant) and it has not shown any significant difference with the best treatment. Whereas in insecticidal check ethion 0.15 % treated plots, the mean population was 4.25 mites per plant while in untreated plots the population level increased to 20.75 mites per plant.

More or less similar results were observed on mite population at third day after spray. No population was recorded in buprofezin 0.03 % treated plots and this was followed by spiromesifen 0.0192 % with next lowest population of 1.00 mites per plant. However, in ethion 0.15 % applied plots, the mean number of mites per plant was 3.25. Whereas, 22.50 mites per plant were recorded in untreated plots.

Increase in population levels were noticed in all plots except in ethion 0.15 % treated plots on fifth day of treatment. The superior treatment was buprofezin 0.03 % with observed mean number of mites per plant being 1.75. Next lowest population (1.87) recorded in spiromesifen 0.0192 % treated plots and it was statistically on par with buprofezin 0.03 %. In ethion 0.15 % sprayed plots, the mean population was 2.75 mites, whereas in untreated plots the mean population went up to 25.50 mites per plant. Treatments other than control were found to be effective in suppressing mite opulation.

4.3.2.2.6 Percentage Infestation by Tetranychus spp

The percentages of infestations by red spider mite are detailed in Table 26 (Plate 4).

Among all treated plots, lowest infestation percentage was noticed in buprofezin 0.03 % treated plots (14.58 %) and it was followed by spiromesifen 0.0192 % (15.30 %). In ethion 0.15 % (insecticidal check) sprayed plots, the infestation was 15.53 per cent. Whereas, in untreated plots the infestation was 16.35 per cent.

After second spary, the lowest per cent of infestation (9.76 %) by red spider mites was recorded in buprofezin 0.03 % and it was superior over other treatments. It was followed by spiromesifen 0.0192 % with a per cent onfestation of 11.85. However, in ethion 0.15 % (insecticidal check) the infestation was 16.21 per cent, while in untreated plots, the infestation pet cent was as high as 31.50 per cent.

Table 26: Infestation of amaranth plants by red spider mite when treated with selected insecticides

TREATMENTS	Mean number of infested plants observed at days after spray	
	First spray	Second spray
T1-Buprofezin 25 SC – 0.03 %	14.58 ± 0.26	9.76 ± 0.75
T2-Spiromesifen 22.9 SC – 0.0192 %	15.30 ± 0.60	11.85 ± 0.81
T3-Ethion 50 EC (Check) – 0.15 %	15.53 ± 0.59	16.21 ±0.92
T4-Untreated	16.35 ± 0.75	31.50 ± 3.11
CD (0.05)	3.370	6.832

Mean of five plants

4.3.2.2.7 Safety evaluation of insecticides on spiders in amaranth eco system

The results on the evaluation of insecticides on safety of spiders (natural enemies of pests) on amaranth are presented in Table 27. Build-up of spider population was noticed from 20 days after sowing onwards. As there was no expertse available for taxonomic identity, total population could only be monitored (Plate 5).

Before the third spray (23 DAS) spider was observed in emamectin benzoate 0.002 %, malathion 0.10 % and fipronil 0.01 % treated plots. Whereas, in other plots the mean population of spiders ranged from 0.46 to 1.23 per plant. Higher number of spiders (1.23) was noticed in flubendiamide 0.0096 % treated plots and it was followed by untreated plots with population level 1.00. However

Plate 5: Spiders observed in amaranthus field

in novaluron 0.015 % and indoxacarb 0.015 % treated plots lower population of 0.72 and 0.46 was recorded.

On first day after treatment, mean population (1.23) of spiders in untreated plots and flubendiamide 0.0096 % treated plots were equal. The population levels decreased in novaluron 0.015 % and indoxacarb 0.015 % sprayed plots to 0.46 and 0.22 respectively. Whereas, in malathion 0.10 % emamectin benzoate 0.002 per cent and fipronil 0.01 % applied plots no population of spiders could be observed.

Table 27: Effect of new generation insecticides on population of spiders in field conditions

TREATMENTS	Mean population of spiders after third spray*				Mean population of spiders after fourth spray*			
	PTC	1 DAT	3 DAT	5DAT	PTC	1 DAT	3 DAT	5DAT
T1- Novaluron 10 EC – 0.015 %	0.72^{bc}(1.31)	0.46^{b}(1.21)	0.22^{c}(1.10)	0.22^{bc}(1.10)	0.22^{c}(1.10)	0.22^{bc}(1.10)	0.22^{cd}(1.10)	0.65^{b} (1.29)
T2- Flubendiamide 39.35 SC – 0.0096%	1.23^{a} (1.50)	1.23^{a} (1.50)	1.23^{a} (1.50)	1.47^{a} (1.57)	1.47^{ab}(1.57)	1.47^{a} (1.57)	1.47^{b} (1.57)	2.19^{a} (1.78)
T3- Emamectin benzoate 1 WG – 0.002 %	0.00^{d} (1.0)	0.00^{c} (1.0)	0.00^{b} (1.0)	0.22^{bc}(1.10)	0.22^{c} (1.10)	0.00^{c} (1.0)	0.00^{d} (1.0)	0.46^{b} (1.21)
T4- Fipronil 5 SC – 0.01%	0.00^{d} (1.0)	0.00^{c} (1.0)	0.00^{b} (1.0)	0.46^{bc}(1.21)	0.46^{c} (1.21)	0.00^{c} (1.0)	0.00^{d} (1.0)	0.46^{b} (1.21)
T5- Indoxacarb 14.5 SC – 0.015%	0.46^{c} (1.21)	0.22^{bc}(1.10)	0.00^{b} (1.0)	0.72^{b} (1.31)	0.72^{bc}(1.31)	0.46^{b} (1.21)	0.46^{c} (1.21)	0.72^{b} (1.31)
T6-Malathion 50 EC (check) – 0.1 %	0.00^{d} (1.0)	0.00^{c} (1.0)	0.00^{b} (1.0)	0.00^{c} (1.0)	0.22^{c} (1.10)	0.00^{c} (1.0)	0.00^{d} (1.0)	0.72^{b} (1.31)
T7- Untreated	1.00^{ab}(1.41)	1.23^{a} (1.45)	1.23^{a} (1.50)	1.96^{a} (1.72)	1.96^{a} (1.72)	1.96^{a} (1.72)	2.48^{a} (1.86)	2.74^{a} (1.93)
CD (0.05)	(0.169)	(0.191)	(0.138)	(0.258)	(0.276)	(0.209)	(0.183)	(0.301)

*Mean number of spiders observed in 5 plants

PTC- Pre Treatment Count, DAT- Days After Treatment

Values shown in parentheses are √x+1 transformed values

No spider population was built-up in plots sprayed with malathion 0.10 %, emamectin benzoate 0.002 % and fipronil 0.01 %. Along with these plots in indoxacarb 0.015 % treated plots also spider population level came down to zero level at three days after spraying. In novaluron 0.015 % the population level decreased (0.22). Highest spider population (1.23) was noticed in flubendiamide 0.0096 % treated plots indicating safety of the product equal to that of untreated plots.

The number of spiders in treated plots were higher in all plots except in malathion 0.10 % treated plots, whereas the highest population (1.96) was recorded in untreated plot and it was followed by flubendiamide 0.0096 % (1.47), these two being statistically on par. The spider population observed in indoxacarb 0.015 %, fipronil 0.01 %, emamectin benzoate 0.002 % and novaluron 0.015 % treated plots were 0.72, 0.46, 0.22 and 0.22 respectively.

The pre-treatment count before fourth spray (30 DAS) on spider population was almost similar to the mean populations observed at fifth day of third spray application. The pre-treatment populations ranged from 0.22 to 1.96.

Among all plots, highest number of spiders (1.96) was noticed in untreated plots and it was followed by flubendiamide 0.0096 % with a mean spider population 1.47. Flubendiamide 0.0096 % did not show any statistical difference with untreated plots. However, the 0.46 and 0.22 mean populations were recorded in indoxacarb 0.015 % and novaluron 0.015 % treated plots, whereas no population could be observed in malathion 0.10 %, fipronil 0.01 per cent and emamectin benzoate 0.002 % sprayed plots.

More or less similar results recorded at three days after spraying. Same population levels were maintained in all other treatments except in untreated plots, where the population was increased to a level of 2.48.

At five days after treatment, along with untreated plots, mean populations of spiders in all plots increased. Highest population of spiders were observed in

untreated plots (2.74) and it was on par with flubendiamide 0.0096 % (2.19). The next higher population level (0.72) was observed in indoxacarb 0.015 % and malathion 0.10 % treated plots and these were followed by novaluron 0.015 % (0.65). However, the populations in emamectin benzoate 0.002 % and fipronil 0.01 % were 0.46 only and non-significant.

4.3.3 Yield of amaranth in plots treated with different insecticides

The results on the effect of different treatments on yield of amaranth are presented in Table 28. Among the treated plots highest yield was recorded in plot treated with flubendiamide 0.0096 % (75.30 g/plant) and it was statistically higher than other treatments. This was followed by emamectin benzoate 0.002 % treated plots (71.75). The recorded yield in malathion 0.10 %, fipronil 0.01 %, indoxacarb 0.015 % and novaluron 0.015 % treated plots were 70.35, 69.80, 63.15 and 59.00 g/plant respectively, whereas in untreated plots the yield was 43.76 g/ plant.

Table 28: Effect of different insecticides on the yield of amaranth

TREATMENT	Yield (g/plant)*
T1- Novaluron 10 EC – 0.015 %	59.00
T2- Flubendiamide 39.35 SC – 0.0096%	75.30
T3- Emamectin benzoate 1 WG – 0.002 %	71.75
T4- Fipronil 5 SC – 0.01%	69.80
T5- Indoxacarb 14.5 SC – 0.015%	63.12
T6-Malathion 50 EC (check) – 0.1 %	70.35
T7- Untreated	43.76
CD (0.05)	2.906

*Mean weight of 20 plants

4.4 STANDARDISATION OF DOMESTIC PRACTICES FOR DECONTAMINATION OF INSECTICIDE RESIDUES FROM AMARANTH

Development of a Multi Residue Method (MRM) satisfying the requirements of Limit of Detection, Limit of Quantification, Linearity, Recovery and Repeatability for the estimation of multiple residues in amaranth is essentially required for analysis of pesticide residues. The results of validation are mentioned below.

4.4.2 Validation of Multi Residue Methods (MRM) for Pesticide Residue Rnalysis inAmaranth

Results of the preliminary method validation of selected insecticides for residue analysis in amaranth are presented in Table 29 to 31.

4.4.2.2 Determination of Limit of Detection (LOD)

The concentration of each pesticide that produced a signal to noise ratio of more than three, was considered as Limit of Detection (LOD) of GC and it was estimated from the chromatogram corresponding to the lowest point used in the matrix-matched calibration. In the present study with ten pesticides, the LOD of GC was 0.01 mg kg^{-1} and at LOD, the S/N ratios for all the 10 pesticides were greater than three. The retention time of these pesticides under specified operating conditions of GC are given in Table 29.

4.4.2.3 Calibration and Linearity

A calibration curve was prepared by plotting concentrations (0.05, 0.1, 0.25 and 0.5 mg kg^{-1}) vs. peak area (Appendix IV). Good linearity was found within the range of 0.05-0.5 mg kg^{-1} which is evident from Coefficient of Determination (R^2) for each pesticide. The chromatograms of the standard mixture fortified at 0.05, 0.1, 0.25 and 0.5 mg kg^{-1} were kept as Appendix V.

4.4.2.4 Determination of Limit of Quantification (LOQ)

The Limit of Quantification (LOQ) of the proposed method was calculated by considering a value of 10 times more than that of background noise. The LOQs

Table 29. The retention time of organophosphate and synthetic pyrethroid insecticides under specified operating conditions of Gas Chromatograph* with electron capture detector (ECD).

Sl. No	Pesticide	Retention Time (min)
1	Dimethoate	11.133
2	Malathion	20.775
3	Chlorpyriphos	21.678
4	Quinalphos	25.824
5	Profenophos	30.412
6	Ethion	35.862
7	Bifenthrin	47.69
8	Lambda-cyhalothrin	54.819
9a	Cypermethrin -1	61.694
9b	Cypermethrin -2	62.092
9c	Cypermethrin- 3	62.332
9d	Cypermethrin- 4	62.494
10a	Fenvalerate – 1	64.883
10b	Fenvalerate – 2	65.704

*Operating conditions mentioned in Table 10

of all the ten pesticides in this method were calculated as 0.05 mg kg^{-1}. For the insecticides tested in this experiment the LOD of Gas Chromatograph recorded was 0.01 mg kg^{-1} while the LOQ noted was 0.05 mg kg^{-1}.

4.4.2.5 Determination of Recovery and Repeatability

The results on method validation for repeatability of six organo phosphates and four synthetic pyrethroid insecticides in amaranth are presented in Table 30 and 31 respectively. The repeatability in terms of recovery percentage of the method was determined at three levels 0.05mg kg^{-1} (LOQ), 0.25 mg kg^{-1} (5 x LOQ) and 0.5mg kg^{-1} (10 x LOQ).

In the case of organo phosphates at 0.05 ppm level of fortification the percentage recovery of six organo phosphates ranged from 81.22 to 99.52 (Table 30). At 0.05 mg kg^{-1} the mean recovery of dimethoate was 93.39 per cent with relative standard deviation of 6.19 per cent. Whereas the recovery percentages of malathion, chlorpyriphos, quinalphos, profenophos and ethion were 91.41, 92.07, 86.65, 91.81 and 93.51 with RSD of 9.66, 6.98, 0.88, 5.00 and 4.74 per cent respectively.

At 0.25 mg kg^{-1} level of fortification the recovery percentages obtained for six organo phosphate insecticides ranged from 91.81 to 98.28 per cent. A satisfactory recovery was obtained for all six insecticides, dimethoate (95.72 %), malathion (95.24 %), chlorpyriphos (97.86 %), quinalphos (94.52 %), profenophos (95.66 %) and ethion (95.31 %) with relative standard deviation 2.44, 2.35, 1.55, 2.55, 1.00 and 3.43 per cent respectively.

The percentage recovery of six insecticides at 0.5 mg kg^{-1} fortification level ranged from 70.28 to 98.09. The mean per cent recovery of six organo phosphates were dimethoate 87.86 (RSD 17.93 %), malathion 80.92 (RSD 10.78 %), chlorpyriphos 88.60 (RSD 13.11 %), quinalphos 87.88 (RSD 11.84 %), profenophos 92.26 (RSD 10.34 %) and ethion 92.00 (RSD 7.56 %).

A satisfactory recovery was obtained in the case of synthetic pyrethroids (Table 31). The recovery at 0.05 ppm level of fortification for four insecticides ranged from 72.16 to 96.28 per cent. The mean percentage recovery of bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate were 90.08, 89.84, 93.01 and 74.12 with relative standard deviation of 8.15, 3.19, 4.83 and 4.22 respectively.

Table 30: Recovery and repeatability of organo phosphate insecticides in amaranth at different fortification levels

S. No	Insecticides	Level of fortification					
		LOQ (0.05 mg kg $^{-1}$)		5 x LOQ (0.25 mg kg $^{-1}$)		10 x LOQ (0.5 mg kg $^{-1}$)	
		Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)
1	Dimethoate	93.39 ± 6.19	6.63	95.72 ± 2.33	2.44	87.86 ± 15.28	17.39
2	Malathion	91.41 ± 8.83	9.66	95.24 ± 2.23	2.35	80.92 ± 8.72	10.78
3	Chlorpyriphos	92.07 ± 6.43	6.98	97.86 ± 1.52	1.55	88.60 ± 11.61	13.11
4	Quinalphos	86.65 ± 0.77	0.88	94.52 ± 2.41	2.55	87.88 ± 10.41	11.84
5	Profenophos	91.81 ± 4.59	5.00	95.66 ± 0.96	1.00	92.26 ± 9.54	10.34
6	Ethion	93.51 ± 4.43	4.74	95.31 ± 3.27	3.43	92.00 ± 6.95	7.56

Number of replications at each level (n) = 3

SD = Standard Deviation

RSD = Relative Standard Deviation

Percentage recovery of four insecticides in amaranth ranged from 86.95 to 99.41at 0.25 mg kg^{-1} fortification level. The mean percentage recovery of four insecticides *viz.*, bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate were 94.67 (RSD of 2.04 %), 97.84 (RSD of 1.64 %), 96.56 (RSD of 0.89 %) and 90.68 per cent (RSD of 3.63 %) respectively.

Table 31: Recovery and repeatability of synthetic pyrethroid insecticides in amaranth at different fortification levels

S. No	Insecticides	Level of fortification					
		LOQ (0.05 mg kg $^{-1}$)		5 x LOQ (0.25 mg kg $^{-1}$)		10 x LOQ (0.5 mg kg $^{-1}$)	
		Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)	Mean recovery (%) ± SD	RSD (%)
1	Bifenthrin	90.80 ± 7.40	8.15	94.69 ± 1.94	2.05	92.72 ± 5.62	6.063608
2	Lambda cyhalothrin	89.85 ± 2.87	3.20	97.84 ± 1.61	1.64	94.58 ± 3.32	3.51238
3	Cypermethrin	93.01 ± 4.49	4.83	96.56 ± 0.86	0.89	92.46 ± 3.45	3.736445
4	Fenvalerate	74.12 ± 3.13	4.22	90.68 ± 3.29	3.63	92.54 ± 2.98	3.220281

Number of replications at each level (n) = 3

SD = Standard Deviation

RSD = Relative Standard Deviation

At 0.5 mg kg^{-1} fortification level, the recovery ranged between 86.33 and 97.29 per cent, whereas the mean of percentage recovery of four insecticides were 9.72 with RSD of 6.06 per cent, 94.57 with RSD of 3.51 per cent, 92.46 with RSD of 3.74 per cent and 94.30 with RSD of 3.22 per cent respectively for bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate.

4.4.3 Evaluation of Effective Domestic Practices for Decontamination of Insecticide Residues from Amaranth

The effect of different household decontamination practices in removing of different insecticide residues from amaranth was studied in this experiment and the results of this study are presented in Table 32 and 33.

4.4.3.1 Removal of organo phosphate insecticides

The results on extent of removal of six organo phosphate insecticides through different decontamination practices are presented in Table 32.

4.4.3.1.1 Dimethoate

The percentage removal of dimethoate residues in amaranth when subjected to different decontaminating treatments showed that all the treatments were significantly different from unprocessed samples in their effectiveness in removing dimethoate residues. Up to 86.27 per cent of residues could be removed from treated samples through dipping in one per cent KAU veggie wash for 20 minutes followed by cooking, while dipping in KAU veggie wash (1 %) alone for 20 minutes resulted in reduction of 85.63 per cent and these two treatments were statistically on par. These were followed by washing in water followed by cooking and dipping in two per cent solution of common salt with percentage of

removal 76.94 and 73.53. It has been found that dipping in tamarind (2 %) and dipping in vinegar (2 %) could remove residues up to 67.84 and 67.79 respectively. However, by dipping in turmeric (1 %) the residues could be removed only up to 57.92 per cent. Dipping in water for 10 minutes could remove only to a lesser extent (49.73 %).

4.4.3.1.2 Malathion

In the case of malathion, per cent removal in all the treatments showed statistical difference from unprocessed samples. Highest percentage of malathion residues was removed when amaranth plants were subjected to dipping in veggie wash (1 %) for 20 minutes followed by cooking (96.47 %). More or less similar percentage residue removal was noticed in the treatments of veggie wash (1%) for 10 minutes plus cooking, veggie wash (1 %) for 20 minutes and vinegar (2 %) for 10 minutes with 92.64, 90.67 and 90.34 percentage removal respectively. All these four treatments were statistically on par with each other. However, the percentage residue removal through washing + cooking, dipping in common salt (2 %), dipping in water, dipping in one per cent turmeric and dipping in one per cent tamarind were 84.86, 83.24, 80.57, 79.61 and 77.71 respectively, all these treatments being on par with each other.

4.4.3.1.3 Chlorpyriphos

Among all decontamination treatments, the superior treatment for removing chlorpyriphos was two per cent vinegar with 96.61 per cent of residue removal and it was followed by one per cent veggie wash (20 minutes) + cooking with 86.45 percentage of removal. These treatments were followed by dipping in one per cent KAU veggie wash for 20 minutes (61.20 %), washing + cooking (61.15 %), dipping in two per cent common salt (60.66 %) and dipping in water (56.18 %) in removing chlorpyriphos residues and all these treatments did not show significant difference among them. Extent of removal of chlorpyriphos residues from amaranth was only to a lower level when dipped in two per cent

Table 32: Extent of removal of organo phosphate insecticides residues from amaranth

TREATMENTS	Mean per cent removal of insecticides (%) ± SD						
	Dimethoate	Malathion	Chlorpyriphos	Quinalphos	Profenophos	Ethion	Mean
T1-Washing *+ Cooking	76.94±5.05^{b} (0.30)	84.86±2.73^{cdef} (0.08)	61.15±1.08^{d}(0.80)	72.29±8.10^{abc} (0.50)	77.33±3.01^{a} (0.68)	62.30±9.20^{cde}(0.96)	73.07
T2-2%Tamarind*	71.22±4.72^{bc} (0.38)	77.71±0.96^{g} (0.12)	51.05±2.88^{e}(1.00)	62.95±1.50^{cd} (0.52)	63.11±7.23^{c} (1.03)	69.04±0.95^{bc} (0.90)	65.96
T3- 2% Common salt*	73.53±5.50^{bc} (0.34)	83.24±8.91^{defg} (0.08)	60.66±2.28^{d} (0.81)	67.60±6.23^{bcd} (0.53)	79.50±5.93^{a} (0.57)	66.43±7.45^{cd} (0.95)	72.53
T4-1%Turmeric*	57.92±11.25^{ef} (0.53)	79.61±3.03^{fg} (0.10)	34.56±6.88^{f}(1.3)	48.89±8.34^{f} (0.83)	58.41±13.95^{cd} (1.14)	54.32±9.25^{e} (1.29)	56.23
T5-2% Vinegar*	67.79±8.72^{cd} (0.41)	90.34±9.88^{abcd}(0.05)	96.61±0.02^{a}(0.07)	60.47±12.30^{de} (0.72)	67.27±4.95^{bc} (0.92)	58.93±8.87^{de} (1.16)	74.67
T6-1% KAU Veggie wash*	61.08±8.38^{de} (0.52)	86.8±5.69^{bcde} (0.08)	29.75±15.21^{f}(0.89)	48.14±7.95^{f} (0.84)	53.31±11.75^{d} (1.16)	44.78±28.01^{f} (1.62	53.94
T7- 1% KAU Veggie wash* + cooking	73.93±9.23^{bc} (0.37)	92.64±1.56^{ab}(0.04)	69.63±7.39^{c}(0.49)	77.40±6.52^{ab} (0.40)	73.45±8.35^{ab} (0.67)	70.63±8.3^{abc} (0.87)	76.27
T8-1% KAU Veggie wash#	85.63±17.55^{a} (0.18)	90.67±1.00^{abc} (0.05)	61.20±1.25^{d}(0.80)	73.75±7.62^{ab} (0.46)	78.48±3.08^{a} (0.63)	77.93±0.89^{ab} (0.64)	78.39
T9- 1% KAU Veggie wash# + cooking	86.27±1.10^{a} (0.16)	96.47 ±0.68^{a} (0.01)	86.45 ±1.21^{b}(0.28)	81.02 ± 2.20^{a} (0.33)	76.73 ± 4.25^{ab}(0.62)	78.59±0.90^{a} (0.62)	83.33
T10- Water*	49.73±3.61^{f} (0.66)	80.56± 2.48^{efg} (0.105)	56.18±5.93^{d} (0.89)	51.29±5.14^{ef} (0.723)	51.78±6.21^{d} (1.36)	37.39±6.50^{f} (1.80)	54.48
Untreated	(1.32)	(0.55)	(2.06)	(1.37)	(2.87)	(2.917)	
CD (0.05)	8.330 (0.174)	7.171 (0.063)	5.049 (0.167)	10.296 (0.201)	9.641 (0.366)	9.435 (0.312)	

Values shown in parentheses are concentration of insecticide residues in mg kg $^{-1}$

* subjected to dipping in treatment solutions for 10 minutes followed by three normal washings

subjected to dipping in treatment solutions for 20 minutes followed by three normal washings

tamarind solution (51.05%), which was followed by dipping in one per cent turmeric (34.56 %).

4.4.3.1.4 Quinalphos

All the treatments were found effective in removing the insecticide load from amaranth plants (Table 19). Highest percentage of removal of quinalphos residues (81.02 %) was observed in dipping in one per cent KAU veggie wash (20 minutes) + cooking and it was followed by dipping in KAU veggie wash (1 %) for 10 minutes plus cooking (77.40 %), dipping in one per cent KAU veggie wash (20 minutes) without cooking (73.75 %) and dipping in water + cooking (72.29 %). All the above treatments were statistically on par. More or less similar percentage of residue removal was noticed in two per cent common salt (67.60 %), two per cent tamarind (62.99 %) and two per cent vinegar (60.47 %), these treatments were on par with each other. By subjecting plants to dipping in tap water 51.30 percentage of residues were removed. However, 48.89 percentage of removal was observed in one per cent turmeric.

4.4.3.1.5 Profenophos

In removal of profenophos residues in amaranth, all the decontaminating treatments were found as effective. Statistically superior treatment was two per cent common salt (79.5 %) and it was followed by dipping in KAU veggie wash for 20 minutes (1 %), dipping in KAU veggie wash for 20 minutes (1 %) + cooking and washing + cooking with 78.49, 78.26 and 77.34 percentage of residue elimination. All these treatments have not shown significant difference with each other. Dipping in vinegar (2 %), tamarind (2 %) and turmeric (1 %) could remove residues to the tune of 67.27, 63.11 and 58.41 per cent respectively. However, the percentage of removal by dipping in water was 51.78 only.

4.4.3.1.6 Ethion

The results on percentage removal of ethion by different treatments ranged from 37.39 to 78.59 per cent. Among all treatments highest removal (78.59 %) was observed in dipping in one per cent KAU veggie wash for 20 minutes + cooking, which was followed by dipping in one per cent KAU veggie wash for 20 minutes without cooking with 77.93 percentage of residue removal and these two treatments were statistically on par with each other. However, the percentage removal recorded for tamarind (2 %), common salt (2 %) and washing were 69.04, 66.43 and 62.30, all these treatments have not shown statistical difference with each other. More or less similar results were observed in dipping in two per cent vinegar (58.94 %) and one per cent turmeric (54.32 %). However, by dipping in water only 37.93 percentage residues were removed.

4.4.3.2 Removal of synthetic pyrethroid insecticides

The results on extent of removal of four synthetic pyrethroid insecticides through different decontamination practices are presented in Table 33.

4.4.3.2.1 Bifenthrin

Among all treatments for removal of bifenthrin residues from amaranth, highest removal was noticed in dipping in one per cent KAU veggie wash (20 minutes) + cooking (72.22 %) and it was followed by dipping in one per cent KAU veggie wash for 20 minutes (68.28 %), two per cent tamarind (65.33 %), dipping in KAU veggie wash (10 minutes) plus cooking (61.03 %) and two per cent common salt (60.15 %). All the above mentioned treatments were statistically on par with each other. However, the percentage of residue removal recorded in normal washing + coking, dipping in vinegar (2 %), dipping in water and dipping in one per cent turmeric were 58.83, 55.24, 54.59 and 52.61 respectively.

Table 33: Extent of removal of synthetic pyrethroid insecticides residues from amaranth

Treatments	Mean per cent removal of insecticides (%) ± SD				
	Bifenthrin	Lambda-cyhalothrin	Cypermethrin	Fenvalerate	Mean
T1-Washing* + Cooking	58.83 ± 8.24^{bc} (1.02)	63.13 ± 9.37^{c} (1.14)	60.12 ± 11.70^{bc} (1.13)	59.75 ± 5.87^{cde} (1.57)	60.47
T2-2%Tamarind*	65.33 ± 6.91^{abc} (0.86)	65.54 ± 6.44^{bc} (1.07)	71.17 ± 5.96^{ab} (0.83)	66.73 ± 7.30^{abcd} (1.28)	67.81
T3- 2% Common salt*	60.15 ± 6.90^{abc} (1.00)	58.64 ± 9.27^{c} (1.28)	65.87 ± 8.42^{ab} (0.97)	69.88 ± 19.52^{abc} (1.11)	64.80
T4-1%Turmeric*	52.61 ± 9.13^{cd} (1.17)	55.36 ± 9.55^{c} (1.38)	60.14 ± 9.38^{bc} (1.14)	60.45 ± 10.97^{bcd} (1.50)	58.65
T5-2% Vinegar*	55.24 ± 13.24^{c} (1.10)	58.25^{c} ± 4.64 (1.31)	61.89 ± 14.40^{abc} (1.06)	54.41 ± 11.50^{de} (1.74)	58.19
T6-1% KAU Veggie wash*	40.28 ± 8.88^{d} (1.49)	42.34 ± 10.65^{d} (1.45)	48.39 ± 9.99^{c} (1.53)	43.90 ± 9.93^{c} (2.12)	43.72
T7- 1% KAU Veggie wash *+ cooking	61.03 ± 9.76^{abc} (0.92)	66.05 ± 10.51^{bc} (1.10)	62.72 ± 14.41^{abc} (1.04)	65.07 ± 10.71^{abcd} (1.30)	63.71
T8-1% KAU Veggie wash#	68.28 ± 9.53^{ab} (0.78)	76.96 ± 2.28^{ab} (0.72)	75.36 ± 15.33^{ab} (0.67)	76.40 ± 9.76^{ab} (0.89)	76.24
T9- 1% KAU Veggie wash# + cooking	72.22 ± 1.08^{a} (0.76)	79.25 ± 4.34^{a} (0.71)	78.55 ±10.44^{a} (0.59)	79.19 ± 5.51^{a} (0.88)	77.30
T10- Water*	54.59 ± 11.60^{c} (1.12)	61.23 ± 16.40^{c} (1.16)	65.12 ± 10.01^{ab} (0.99)	63.06 ± 14.29^{abcd} (1.38)	61.11
Untreated	(2.54)	(3.17)	(2.95)	(3.96)	
CD (0.05)	(0.244) 12.841	(0.339) 12.559	(0.354) 16.707	(0.518) 16.342	

Values shown in parentheses are concentration of insecticide residues in mg kg $^{-1}$

* subjected to dipping in treatment solutions for 10 minutes followed by three normal washings

subjected to dipping in treatment solutions for 20 minutes followed by three normal washings

4.4.3.2.2 Lambda-cyhalothrin

The extent of removal of lambda-cyhalothrin residues in amaranth ranged from 42.34 to 79.25 percentages. Up to 79.25 percentage of residue removal observed in treatment one per cent KAU veggie wash for 20 minutes+ cooking and it was statistically not differed with treatment one per cent KAU veggie wash (20 minutes) without cooking (76.96 %). These were followed by one per cent KAU veggie was (10 mintes) plus cooking and two per cent tamarind with percentage of removal 66.05 and 65.54 respectively. However, more or less similar removal was observed in treatments washing + cooking (63.13 %), water (61. 23 %), two per cent common salt (58.64 %), two per cent vinegar (58.25 %), one per cent turmeric (55.36 %) and dipping in one per cent KAU veggie wash for 10 minutes (42.34 %).

4.4.3.2.3 Cypermethrin

All the treatments used in this study were more or less equally effective in removal of cypermethrin residues from amaranth. Among all treatments, highest removal was observed in treatment one per cent KAU veggie wash (20 minutes) followed by cooking (78.55 %), it was followed by one per cent KAU veggie wash (20 minutes) without cooking (75.36 %), two per cent tamarind (71.17 %), two per cent common salt (65.87 %), water (65.12 %) and one per cent KAU veggie wash (10 minutes) plus cooking (62.72 %). All the above treatments were statistically on par. Whereas in two per cent vinegar, one per cent turmeric, normal washing plus cooking and one per cent KAU veggie wash (10 minutes) treatments the percentage of removal observed were 61.89, 60.14, 60.12 and 48.39 respectively.

4.4.3.2.4 Fenvalerate

In removal of fenvalerate residues from amaranth, highest removal was recorded by treatment one per cent KAU veggie wash (20 minutes) + cooking (79.19 %), these was followed by dipping in one per cent KAU veggie wash for 20 minutes (76.40 %), two per cent common salt (69.88 %), two per cent tamarind (66.73 %), one per cent KAU veggie wash (10 minutes) plus cooking (65.07 %) and water (63.06 %). All the above treatments were statistically on par. However, 60.45, 59.75, 54.41 and 43.90 percentage of residues were removed when treated with one per cent turmeric, washing plus cooking, two per cent vinegar and one per cent KAU veggie wash (10 minutes).

Discussion

5. DISCUSSION

The leaf webbers and leaf eating caterpillars are serious pests in amaranth because of their destructiveness, abundance and distribution. Farmers rely mostly on chemical pesticides for their timely control there by mitigating the possible losses which indirectly results in pesticide residues on crop. The information gathered from present study on the major pests, pesticide usage and pesticide residues on amaranth and the efficacy of new generation insecticides, botanicals and microbial insecticides to contain these pests to suggest safer alternatives for management of pests and standardization of domestic practices to remove pesticide residues from amaranth are discussed under the following heads.

5.1 SURVEY TO DOCUMENT THE PEST INCIDENCE, PESTICIDE USAGE AND PESTICIDE RESIDUES IN AMARANTH

A preliminary survey was conducted among amaranth farmers at Kalliyoor and Pappanchani locations of Thiruvananthapuram district which represents the major amaranth growing zone, to correlate incidence of major pests, pesticide use pattern and pesticide residues on amaranth.

The results of survey revealed that *H. recurvalis* was noticed in Kalliyoor and Pappanchani locations in 50 and 45 per cent of amaranth fields respectively. Whereas the *S. litura* was recorded in 40 and 50 per cent of surveyed fields in Kalliyoor and Pappanchani locations respectively. These results agree with the findings of Ebert *et al.* (2011), who reported that *H. recurvalis* and *S. litura* were the major lepidopteran pests in amaranth.

The results of survey on pesticide usage by amaranth farmers revealed that 40 per cent of the farmers getting information on pesticides dosage mainly from pesticides shops who are not having any technical knowledge on label claim. Whereas only 10 per cent of survey reported farmers consulting agricultural officers for correct information on dose of pesticides. This may be the reason that 65 per cent farmers were reported to apply pesticides at double the dosage recommended for vegetables by CIB&RC. Most striking information gathered was that 40 per cent of farmers surveyed were applying pesticides at four day

intervals. Whereas, only 10 per cent of farmers kept an interval of six days between each spray. The frequency of application was one of the reasons for high amount of pesticide residues on agricultural commodities (Ambrus, 2000).

Pesticide application is recognised as important tool in sustainable food production, but their unjudicious use might cause potential health risks from both occupational and non-occupational exposures. For example, different pesticides have been implicated in chronic neurotoxicity, endocrine disruption, immune impacts, genotoxicity, mutagenicity and carcinogenesis through routes that include consumption of dietary residues (PPDB, 2014). Consequently monitoring of pesticide residues in agricultural commodity is needed for ensuring food safety to consumers. In this study, a survey was conducted to monitor the pesticide residues in amaranth by collecting farm gate samples in two locations, Kalliyoor and Pappanchani, Thiruvananthapuram district during March 2014 – June 2014. The results of this study (Table 13) are discussed here below.

Out of 20 samples analysed, 16 samples were detected with pesticide residues, whereas four samples were completely free from pesticide residues. This survey revealed the presence of eight pesticide molecules *viz.*, chlorpyriphos, quinalphos, profenophos and ethion belonging to organophosphates, bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate belonging to synthetic pyrethroids. Among the different pesticides, quinalphos (*O*,*O*-diethyl *O*-quinoxalin-2-yl phosphorothioate) was detected in 13 samples out of 20 samples analysed (Table 13). Because of its broad spectrum, contact and stomach action, quinalphos is preferred by farmers as effective against a variety of pests including insects and mites (Das and Mukherjee, 2000)

Chlorpyriphos (*O*,*O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate) has been the second frequently detected organophosphate (3 samples) insecticide, which is not registered for even one leafy vegetable crop in India (CIB&RC, 2014). The most likely explanation for widespread contamination of chlorpyriphos in agricultural commodity is due to its broad spectrum activity as

insecticide, acaricide and nematicide and its lesser price. Its high preference is also evident from its high production rate (3887 MT/year) (Arora *et al.,* 2011). This observation is in agreement with that of Marasinghe *et al.,* 2011 who reported that chlorpyriphos was detected in many food commodities and also in water sources in Sri Lanka.

Considering pesticide groups, it may be concluded that insecticides belonging to organophosphate group predominated over synthetic pyrethroid and organochlorine compounds. This trend is also supported by the consumption pattern of pesticides which also indicated greater use of organophosphates when compared with synthetic pyrethroids and organochlorines (Adityachaudhury *et al.*, 1997). Dietary contamination to organophosphate insecticides is of health concern due to potential cumulative effects of these pesticides that act through a common mechanism of toxicity, the inhibition of acetyl cholinesterase (Ecobichon, 1995).

Among the eight insecticides detected in this study, only three insecticides (chlorpyriphos, quinalphos and lambda cyhalothrin) were used by farmers as inferred from the survey. The residues detected in the present study were chlorpyriphos (1.009-1.14 mg kg $^{-1}$), quinalphos (0.04-1.20 mg kg $^{-1}$), profenophos (0.02 mg kg $^{-1}$), bifenthrin (0.09 mg kg $^{-1}$), ethion (0.03 mg kg $^{-1}$), cypermethrin (0.19 mg kg $^{-1}$), lambda-cyhalothrin (0.025 mg kg $^{-1}$) and fenvalerate (0.08 mg kg $^{-1}$) for which no FSSAI MRL exists which means none of the pesticides detected were registered for use in amaranth. Only EU MRL was available, which was taken for this study because of the absence of MRL by Codex and FSSAI. It was reported that residues of organophosphate insecticides *viz.*, chlorpyriphos (0.22 – 1.14 mg kg $^{-1}$), ethion (0.33 mg kg $^{-1}$), methyl parathion (0.02 mg kg $^{-1}$), profenophos (0.02 mg kg $^{-1}$) and quinalphos (0.17 – 1.20 mg kg $^{-1}$) and synthetic pyrethroids like cypermethrin (0.19 mg kg $^{-1}$) and fenvalerate (0.08 mg kg $^{-1}$) have been detected in amaranth samples collected from farm-gates and local markets in Kerala (PAMSTEV, 2014).

Some of the samples tested in the present study had multiple residues with some samples containing two to three pesticides. However, none of these detected pesticides were registered for use in India by CIB &RC in leafy vegetables.

Human beings are exposed to pesticide through the consumption of treated food that contain residues. So assessment of dietary exposure to pesticides which combines both food consumption data and data on the concentration of pesticides in food are essential. In this study, long term (chronic) and short term (acute) health risk to consumers by pesticide through intake of contaminated food were estimated in terms of Average Daily Intake (ADI) and ARfD values for each commodity using the highest detected pesticide residue levels, based on methods recommended by the WHO (WHO, 2003). WHO has recommended to compare highest detected level of pesticide with percentage of ARfD and percentage of ADI for assessing acute and chronic health risk. If pesticides detected resulted in an intake of >50 per cent and >4 per cent of percentage of ADI value, it can be considered to cause acute and chronic health risk (Dalvie and London, 2009).

The insecticides like chlorpyriphos, ethion and Lambda cyhalothrin exceeded the ARfD values (Table 34). However, none of the detected pesticides resulted in an intake of >50 per cent of ARfD value which gave an impression of having no acute health risk, as per the guidelines of WHO.

5.2 LABORATORY EVALUATION OF BIO-EFFICACY OF INSECTICIDES, MICROBIAL INSECTICIDES AND BOTANICALS AGAINST LEAF WEBBER, LEAF EATING CATERPILLAR AND RED SPIDER MITE

The efficacy of nine new generation insecticides *viz.*, chlorantraniliprole 18.5 SC - 0.006 %, novaluron 10 EC - 0.015 %, buprofezin 25 SC - 0.03 %, flubendiamide 39.35 SC - 0.0096 %, spinosad 45 SC - 0.015 %, emamectin benzoate 1 WG - 0.002 %, indoxacarb 14.5 SC - 0.015 %, thiacloprid 21.7 SC - 0.036% and fipronil 5 SC - 0.01 %, three microbial insecticides *viz., Bacillus thuringiensis* kurstaki - 5 ml L^{-1}, *Beauveria bassiana*- 2 % WP and *Beauveria bassiana* (ITCC 6063) CFU - 10^8 g^{-1} and two botanicals *viz.*, oxuron

Table 34: Risk assessment of pesticides detected in farm gate samples of amaranth, in terms of ADI and ARfD values.

*Amount consumed per day (g/day/person)	Pesticides detected (mg kg^{-1})	Highest residue level (mg kg^{-1})	Average daily intake (mg /kg bodyweight)	**ADI(mg/kg body weight)	% of ADI based on highest residue level	**ARfD (mg/kg body weight)
2	Chlorpyriphos	1.14	3.8×10^{-5}	0.01	11.4	0.1
	Quinalphos	1.20	4×10^{-5}	NA	NA	NA
	Profenophos	0.02	6.7×10^{-7}	0.03	0.07	1.0
	Ethion	0.09	2.9×10^{-6}	0.002	4.5	0.015
	Bifenthrin	0.03	9.9×10^{-7}	0.015	0.2	0.03
	Cypermethrin	0.19	6.3×10^{-6}	0.05	0.38	0.2
	Lambda-Cyhalothrin	0.025	8.2×10^{-7}	0.0025	1.0	0.005
	Fenvalerate	0.08	2.6×10^{-6}	0.02	0.4	NA

*Assuming a 60 kg person, total intake of each commodity is estimated from cluster diets compiled by the Global Environment Monitoring System– Food Contamination Monitoring and Assessment Programme (WHO/GEMS/FOODS) on http://www.who.int/foodsafety/chem/gems/en/index1.html.
** PPDB: Pesticide http://sitem.herts.ac.uk/aeru/footprint/en/index.html.

and neem seed kernel extract were assessed in comparison with malathion 50 % EC – 0.1 % as insecticide check against lepidopteran pests of amaranth. Five insecticide cum acaricides *viz*., buprofezin 25 SC – 0.03 %, diafenthiuron 50 % WP – 0.06 %, emamectin benzoate 5 SG – 0.002 %, spiromesifen 22.9 SC – 0.0192 % and fenpyroximate 5 EC – 0.003 % were evaluated against red spider mite.

Laboratory evaluation against *H. recurvalis* revealed that the insecticides at six hours after release cent per cent mortality recorded in fipronil 0.01 % treated larvae whereas 55.30 per cent mortality observed in malathion 0.1 % (insecticidal check) treated larvae (Table 14). These results are in agreement with the findings of Majula and Kotikal (2015a), who reported that fipronil was the most effective insecticide to bring quick mortality of *H. recurvalis* among the new generation insecticides tested. After 18 hours of release, cent per cent mortality was noticed in emamectin benzoate 0.002 %, indoxacarb 0.015 %, thiacloprid 0.036 %, fipronil 0.01 % and *B. thuringiensis* kurstaki - 5 ml L^{-1} and all these were on par with malathion 0.1%. Johnson (1968) reported that in the reduction in larval population of *H. recurvalis, B. thuringiensis* was superior to malathion (0.05%). *B. thuringiensis* recorded maximum mortality of *H. recurvalis* and it was on par with insecticidal check (Leena *et al.,* 2005). More or less similar results were published by Majula and Kotikal (2015b) that emamectin benzoate and indoxacarb were effective in management of *H. recurvalis* but indoxacarb was found as inferior than emamectin benzoate to bring faster mortality. At 36 hours interval cent per cent mortality was recorded in chlorantraniliprole 0.006 %, flubendiamide 0.0096 % and spinosad 0.015 % treated larvae also. Even though flubendiamide 0.0096 % and chlorantraniliprole 0.006 % treated larvae took 36 hours, to cause cent per cent mortality, all larvae in these treatments have stopped feeding on amaranth leaves within a period of six hours after exposure because of the specific mode of action of these diamides. Applications of diamide insecticides led to significant reduction in carbohydrate content, associated with

general disturbances in carbohydrates metabolism, as expressed by significant inhibition of digestive hydrolyzing enzymes activities (Rashwan, 2013).

In the case of bio-efficacy evaluation of treatments against leaf eating caterpillar *S. litura,* cent per cent mortality observed in emamectin benzoate 0.002 % treated larvae at 12 hours after treatment whereas 61.00 per cent mortality in malathion 0.1 % (insecticidal check) treated larvae (Table 16). In this study emamectin benzoate 0.002 % was found as most effective to bring quick cent per cent mortality than all treatments. This finding is in conformity to that of Prasad *et al.,* (2007) who reported that emamectin benzoate 0.002 % was the best treatment than novaluron and indoxacarb considering the relative toxicity to *S. litura.* To bring cent per cent mortality of *S. litura* it took 30 hours. The treatments on par with malathion 0.1 % after 30 hours of release were emamectin benzoate 0.002 % and flubendiamide 0.0096 %. At 36 hours after release novaluron 0.015 % (93.33 %), indoxacarb 0.015 % (93.33 %) and fipronil 0.01 % (86.67 %) also came on par with the insecticide check malathion 0.1 %. In other treatments the mortality percentage of *S. litura* were 74.44, 68.89, 55.56, 43.33, 37.78, 37.78 and 18.89 in chlorantraniliprole 0.006 %, buprofezin 0.03 %, spinosad 0.015 %, *B. thuringiensis* kurstaki - 5 ml L^{-1}, thiacloprid 0.036 %, oxuron 5 ml L^{-1} and NSKE 5 % respectively. These results were in agreement with the findings of Ramanagouda and Khalid *et al.* (2001), Ahmed *et al.* (2005), Patil *et al.* (2009), Srivastava (2009), Ragaei and Sabry (2011), Karuppaiah and Srivastava (2013) and Sharma and Pathania (2014).

Taking into account of the combined efficacy of treatments on both lepidopteran test insects *viz., H. recurvalis* and *S. litura,* the effective treatments were further evaluated under field conditions.

The results on evaluation of insecticide cum acaricides on *Tetranychus* spp, it was observed that at 12 hours after treatment in buprofezin 0.03 %, diafenthiuron 0.06 %, emamectin benzoate 0.002 % and spiromesifen 0.0192 % treated leaves, cent per cent mortality of the mites was observed. Whereas, in

acaricide check ethion 0.15 %, only 30.00 percentage mortality was recorded. These results were in agreement with those findings of Reddy and Latha (2013) who reported 95 per cent mortality in spiromesifen treated *Tetranychus* mites, within one day after treatment. Similar results were also obtained in the study conducted by Krishna and Bhaskar, (2013) which revealed that fenazaquin 10 EC (25 micro L / 10 ml) and diafenthiuron 50 WP (16 mg/10 ml) exhibited 100 per cent mortality of adult mites within 24 hours of treatment application. In ethion treated leaves even after 30 hours after treatment 56.67 per cent mortality of the mites could be recorded. By taking into consideration of effectiveness under laboratory consideration, two safer pesticides were selected for evaluation under field conditions with one acaricidal check, ethion.

5.3 FIELD EVALUATION OF INSECTICIDES AGAINST PESTS OF AMARANTH

A field experiment was laid out to evaluate the efficacy of the best five treatments *viz.,* novaluron 10 EC – 0.015 %, flubendiamide 39.35 SC – 0.0096 %, emamectin benzoate 1 WG – 0.002 %, fipronil 5 SC – 0.01 % and indoxacarb 14.5 SC – 0.015 % with insecticidal check malathion 50 EC- 0.1 % against both lepidoperan pests *viz., S. litura* and *H. recurvalis* and two insecticide cum acaricide *viz.,* buprofezin 25 SC – 0.03 % and spiromesifen 22.9 SC – 0.0192 % with acaricide check ethion 50 EC– 0.15 % against mite pest *Tetranychus* spp.

The results indicated that all treatments were effective in controlling *H. recurvalis* when compared with those of untreated control. At third day after treatment no population observed in all four fipronil 0.01 % treated plots (Table 21). Comparatively less reduction observed in flubendiamide 0.0096 % treated plots (0.93) and it comparable to the insecticidal check malathion (0.10 %). At five days after treatment there was no significant difference between the treated plots. All plots did not show any significant difference with untreated control after first spray. After second spray except flubendiamide 0.0096 % all the treatments were superior over insecticidal check and flubendiamide 0.0096 % was

statistically on par to insecticidal check malathion 0.1 % (Table 21). Among all treatments no treatment found as below than insecticidal check, malathion 0.1 % in effectiveness on mean population of *H. recurvalis.* While in percentage of infestation also there was no significant difference among the all treated plots (Table 22). The present findings on the effectiveness of indoxacarb, emamectin benzoate, fipronil, flubendiamide, novaluron and malathion were in agreement with the findings of Majula and Kotikal, (2015a) and Majula and Kotikal (2015b).

Field studies conducted on *S. litura* using the new generation insecticides, novaluron 0.015 %, flubendiamide 0.0096 %, emamectin benzoate 0.002 %, fipronil 0.01 % and indoxacarb 0.015 % with malathion 0.10 % as check, revealed that all the treatments were effective in controlling the population when compared to the untreated check. After first spray higher population reduction recorded in emamectin benzoate 0.002 % (0.00) and untreated check malathion 0.10 % (0.22). Karuppaiah and Srivastava (2013) evaluated the efficacy of new generation insecticides against *S. litura* and found that emamectin benzoate was superior over anthranilic diamide and indoxacarb insecticides. Among all treated plots the highest population was observed in fipronil 0.01 % treated plots. These results were not in agreement with the findings of Ramanagouda and Srivastava, (2009) who revealed that fipronil was effective than indoxacarb against *S. litura.* In the case of percentage of infestation flubendiamide 0.0096 % (15.67 %) and emamectin benzoate 0.002 % (15.67 %) showed on par results with insecticidal check (7.81 %). In flubendiamide 0.0096 % treated plots even though comparatively higher population observed than malathion 0.10 %, damage percentage was equal to malathion 0.10 %. More or less similar trends were observed after second, third and fourth spray also (Table 23 and 24).

The *Tetranychus* mite population was observed from 20 days after sowing. Hence only two sprayings were done at seven days interval. In field experiment both the treatments spiromesifen 0.0192 % and buprofezin 0.03 % were found to be equally effective in reducing mite population and percentage of infestation (Table 25 and 26) and superior over acaricidal check ethion 0.115 %.

In the case of toxicity of tested insecticides on spider population in amaranth eco system less toxicity observed in flubendiamide 0.0096 % treated plots (1.23-2.19) whereas as equal number of population observed with untreated control plots (1.23-2.74).

Among the all treated plots highest yield recorded in flubendiamide 0.0096 % treated plots (75.30 g/plant). The results of present study are supported by works of Mallikarjunappa *et al.* (2008). When compared to flubendiamide 480 SC @ 0.2 ml L^{-1} was found significantly superior in reducing the leaf eating caterpillar population and recorded highest seed yield (23.95 q ha^{-1}) followed by indoxacarb 14.5 SC (22.99 q ha^{-1}) and lambda cyhalothrin 5 EC (22.87 q ha^{-1}) as compared to other treatments including untreated check in amaranth (Manu *et al.*, 2014).

5.4 STANDARDISATION OF DOMESTIC PRACTICES FOR DECONTAMINATION OF INSECTICIDE RESIDUES FROM AMARANTH

The analytical method used for the analysis of pesticide residues in amaranth is Multi Residue Method (MRM). The analytical methods that are used to measure pesticide residue in food should be capable of measuring pesticide residues at very low levels (Taylor *et al*., 2002). In addition, these methods should be capable to identify and quantify the types of pesticides found in food products (Sannino *et al*., 2004). Moreover, these analytical methods should be simple, robust and fast. Multi residue methods are ideally suited to satisfy these requirements for pesticides, since they are typically simple, robust and rapid. In this study, Multi Residue Methods (MRM) for pesticide residue analysis of amaranth were validated by conducting recovery studies. This method has given satisfactory results on Limit of Detection, Limit of Quantification, Linearity, Recovery and Repeatability for the estimation of multiple pesticide residues. From the results it is clear that the method adopted for analysis of residue in amaranth had an agreeable analytical performance in terms of selectivity and linearity. Satisfactory linearity was found within the range of 0.05-0.5 mg kg^{-1} for

the six organo phosphates and four synthetic pyrethroid insecticides tested (Appendix IV). Even at the lowest level of fortification, satisfactory recoveries and relative standard deviations were achieved for most of the pesticides evaluated. For all the ten pesticides under study, the mean per cent recoveries were in the range of 72 - 98 per cent and the repeatability of the recovery results, as indicated by the RSD < 20 % confirmed that the method adopted was sufficiently reliable for pesticide residue analysis in amaranth (Table 29 - Table 31).

Based on the survey data (Table 13) six organophosphorous insecticides *viz.*, dimethoate, chlorpyriphos, quinalphos, malathion, ethion and profenophos and four synthetic pyrethroids *viz.*, bifenthrin, cypermethrin, fenvalerate and lambda cyhalothrin were selected for standardizing a practice by evaluating different household products and methods based on their effectiveness to decontaminate insecticide residues from amaranth. The different decontamination practises tested in this study were washing followed by cooking in closed pan (usual Kerala style cooking), dipping of plants in different solutions of tamarind (2%), common salt (2%), turmeric (1%), vinegar (2%), veggie wash (1%), veggie wash (1%) plus cooking and water (control) for 10 minutes. The sprayed plants dipped in solution were subjected to three normal washings with tap water. The efficiency of decontaminating practice was expressed in terms of percentage of removal of insecticide residues, concentration (ppm) of insecticide residues remained on the sample after washing and also in terms of processing factor. Processing factor is the concentration of pesticide residue in processed samples divided by the concentration of the residue in unprocessed sample. Insecticide wise and treatment wise comparison of processing factors and percenatage of removal are illustrated in Fig 1 and 2 and Fig 3 and 4.

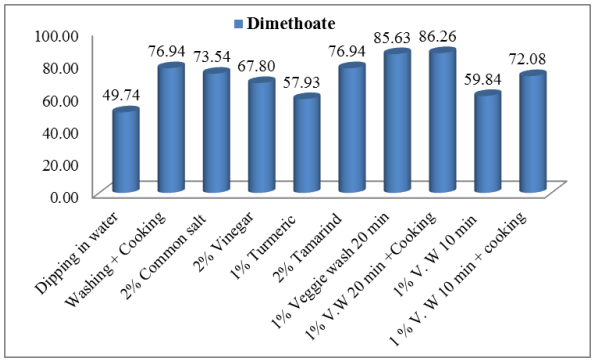
The effect of different practices on removal of organo phosphorous insecticide residues from amaranth at one day after spraying are presented in Table 32. Comparatively less percentage removal was observed in the case of synthetic pyrethroids than organophosphates when subjected to different

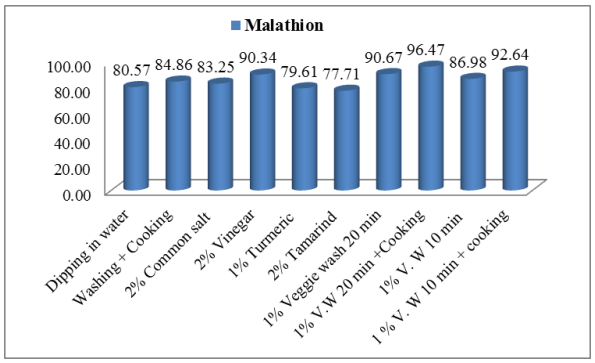
treatments. The organophosphorous pesticides were removed more effectively by acidic, neutral and alkaline solutions and the amount of residue removal depended on the concentration and kind of solutions (Zohair, 2001). The percentage removal of synthetic pyrethroids *viz.,* bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate are presented in Table 33 and the efficiency of different decontamination treatments in terms of processing factor is shown in Fig 1 and 2.

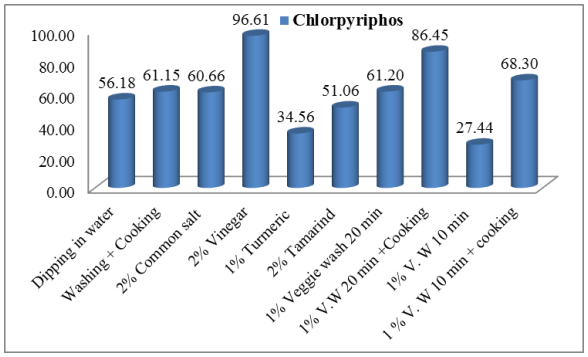
The results indicated that decontamination treatments including tamarind (2 %), vinegar (2 %), common salt (1 %) and KAU veggie wash (1%) and cooking process such as washing plus cooking and cooking after washing with KAU veggie wash (1%) showed significant effect in reducing both organophosphorous and synthetic pyrethroid insecticides from amaranth when compared to dipping in tap water alone. The extent of removal of insecticide residues through dipping in water depend upon the solubility of the insecticides in water and the type of insecticide formulation. The ten insecticides analysed in this study were emulsifiable concentrates (EC) and water miscibility of these formulations were low. After one day of spraying when plants were subjected to dipping in water for 10 minutes followed by three normal washing, a wide range of pesticide residues were removed. When compared to the amount of residues removed in washed samples to those in unprocessed sample, maximum reduction was recorded in the case of malathion (80.56 %), followed by cypermethrin (65.12 %), fenvalerate (63.06 %), lambda cyhalothrin (61.23 %), chlorpyriphos (56.18 %), bifenthrin (54.59 %), profenophos (51.78 %), quinalphos (51.29 %), dimethoate (49.73 %) and ethion (37.39 %). Among all the insecticides lowest per cent removal was observed in dimethoate followed by ethion. In the case of dimethoate, systemic nature of the insecticide might be the reason for lower extent of removal. The effectiveness of washing on removal of residues depended upon the location of the pesticide present whereas the surface residues are responsive to washing, systemic residues present in tissue will be less amenable (Holland *et al.*, 1994).

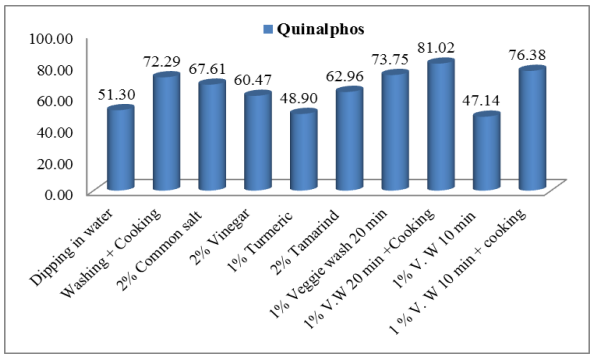
Fig 4: Effect of different treatments on the extent of removal of insecticides residues in amaranth expressed as percentage of removal-treatment wise

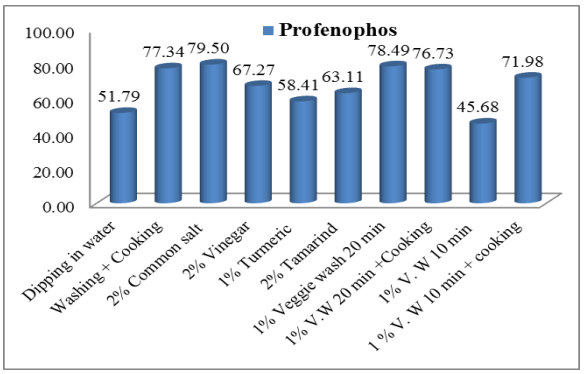
X- axis – Insecticides, Y – axis – Percentage of removal, V. W- Veggie Wash

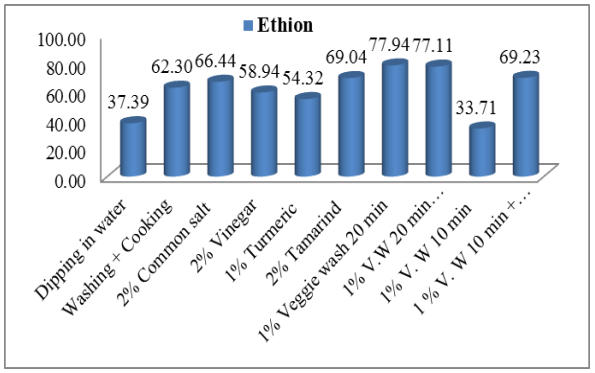


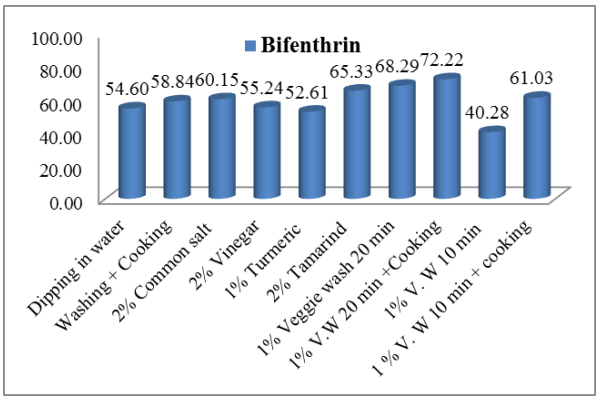


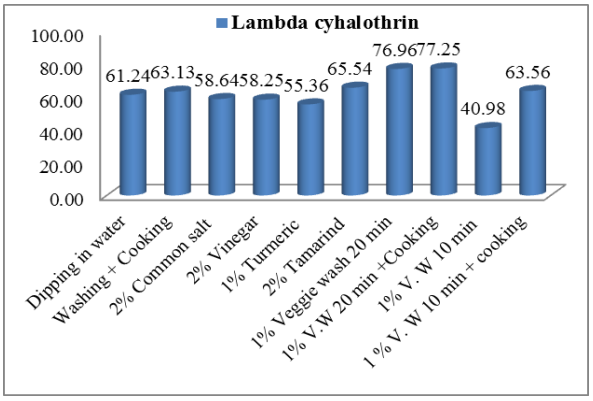


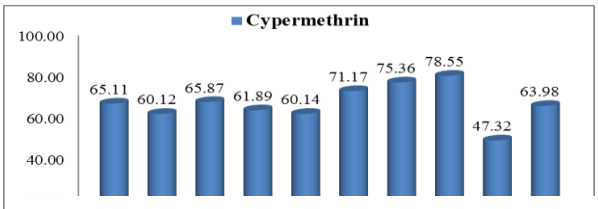












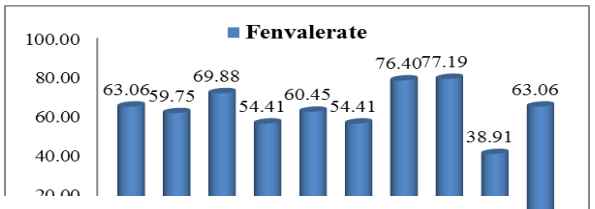
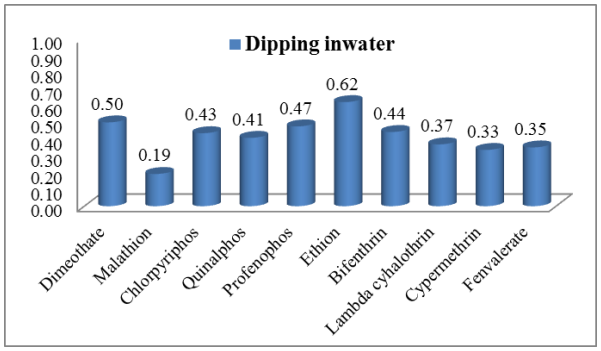
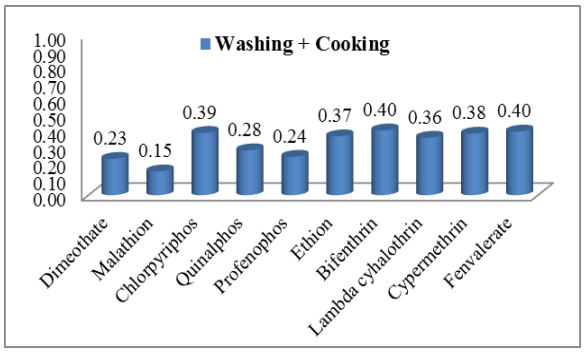
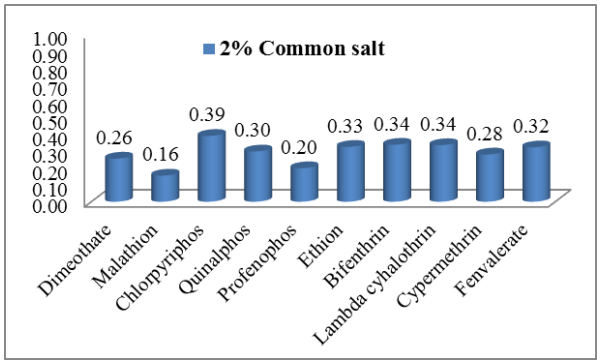


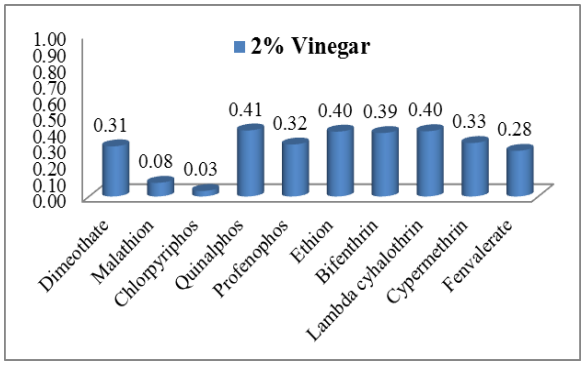
Fig 3: Effect of different treatments on the extent of removal of insecticide residues in amaranth expressed as percentage of removal-insecticide wise

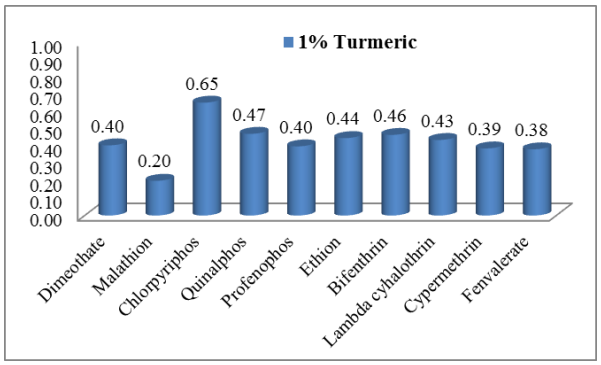
X- axis- Treatments, Y-axis- Percentage of removal, V. W- Veggie Wash

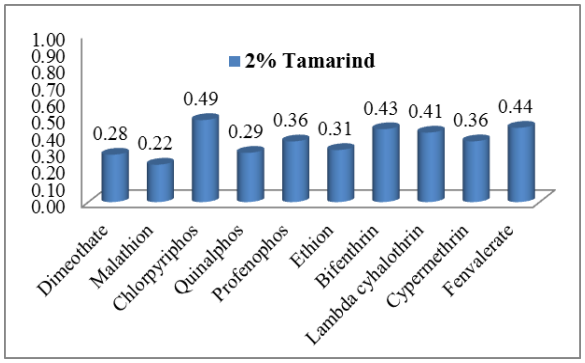

Dipping inwater
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.50 0.19 0.43 0.41 0.47 0.62 0.44 0.37 0.33 0.35
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

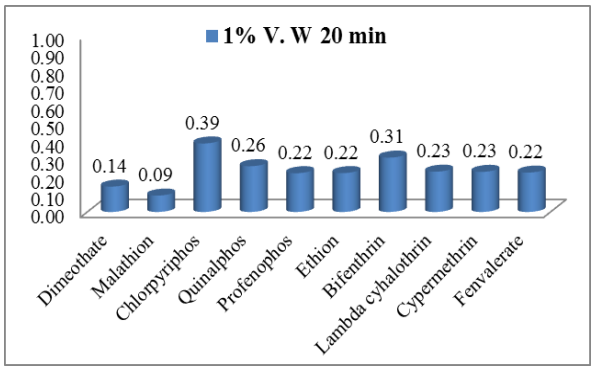

Washing + Cooking
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.23 0.15 0.39 0.28 0.24 0.37 0.40 0.36 0.38 0.40
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

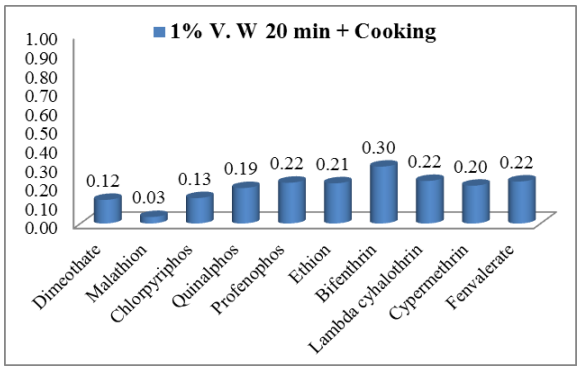

2% Common salt
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.26 0.16 0.39 0.30 0.20 0.33 0.34 0.34 0.28 0.32
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

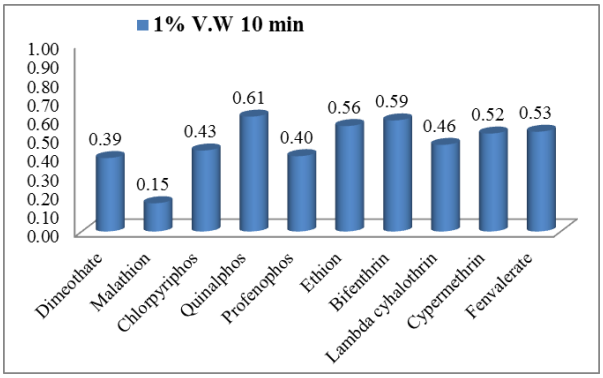

2% Vinegar
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.31 0.08 0.03 0.41 0.32 0.40 0.39 0.40 0.33 0.28
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

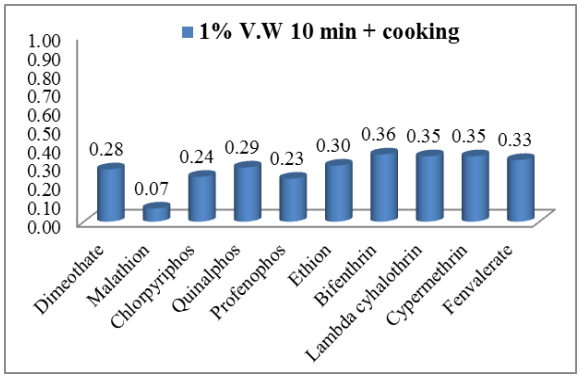

1% Turmeric
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.40 0.20 0.65 0.47 0.40 0.44 0.46 0.43 0.39 0.38
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

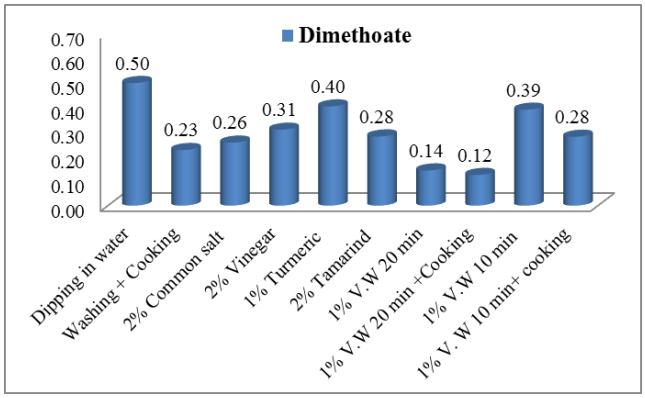

2% Tamarind
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.28 0.22 0.49 0.29 0.36 0.31 0.43 0.41 0.36 0.44
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

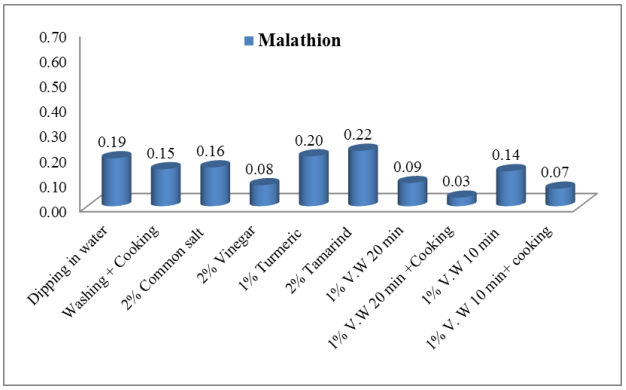

1% V. W 20 min
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.14 0.09 0.39 0.26 0.22 0.22 0.31 0.23 0.23 0.22
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

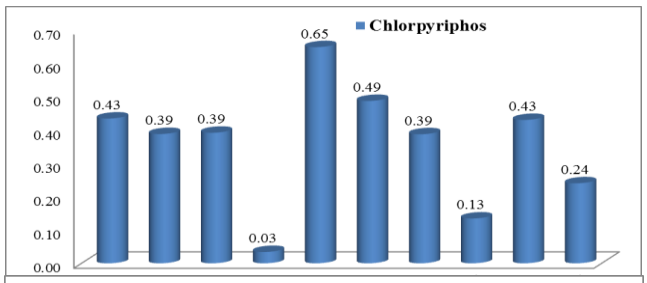

1% V. W 20 min + Cooking
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.12 0.03 0.13 0.19 0.22 0.21 0.30 0.22 0.20 0.22
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

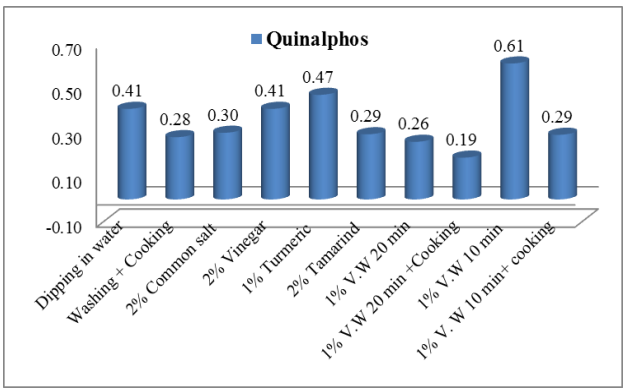

1% V.W 10 min
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.39 0.15 0.43 0.61 0.40 0.56 0.59 0.46 0.52 0.53
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

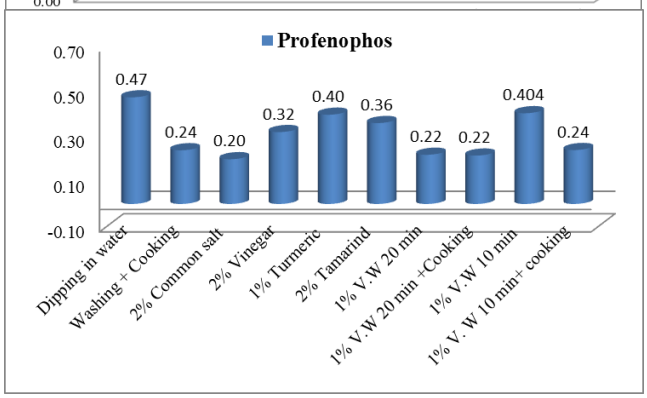

1% V.W 10 min + cooking
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.00
0.28 0.07 0.24 0.29 0.23 0.30 0.36 0.35 0.35 0.33
Dimeothate Malathion Chlorpyriphos Quinalphos Profenophos Ethion Bifenthrin Lambda cyhalothrin Cypermethrin Fenvalerate

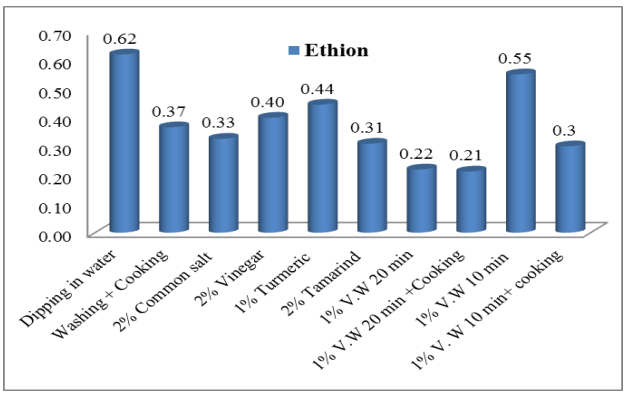

Dimethoate
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.50
0.23
0.26
0.31
0.40
0.28
0.14
0.12
0.39
0.28
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking

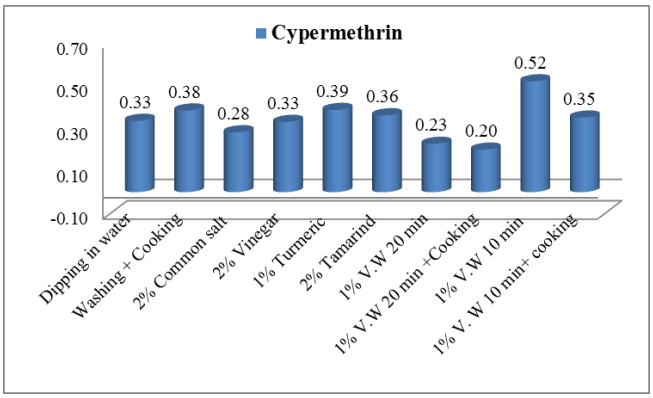

Malathion
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.19
0.15
0.16
0.08
0.20
0.22
0.09
0.03
0.14
0.07
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking

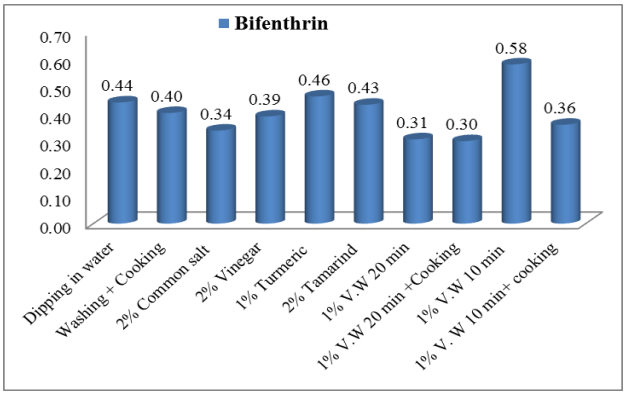

Chlorpyriphos
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.43
0.39
0.39
0.03
0.65
0.49
0.39
0.13
0.43
0.24
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking

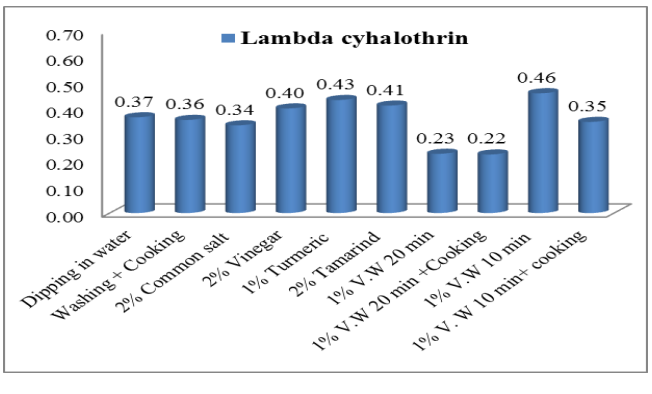

Quinalphos
0.70
0.50
0.30
0.10
-0.10
0.41
0.28
0.30
0.41
0.47
0.29
0.26
0.19
0.61
0.29
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking


Profenophos
0.70
0.50
0.30
0.10
-0.10
0.47
0.24
0.20
0.32
0.40
0.36
0.22
0.22
0.404
0.24
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking


Ethion
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.62
0.37
0.33
0.40
0.44
0.31
0.22
0.21
0.55
0.3
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking


Cypermethrin
0.70
0.50
0.30
0.10
-0.10
0.33
0.38
0.28
0.33
0.39
0.36
0.23
0.20
0.52
0.35
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking


Bifenthrin
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.44
0.40
0.34
0.39
0.46
0.43
0.31
0.30
0.58
0.36
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking


Lambda cyhalothrin
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.37
0.36
0.34
0.40
0.43
0.41
0.23
0.22
0.46
0.35
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking

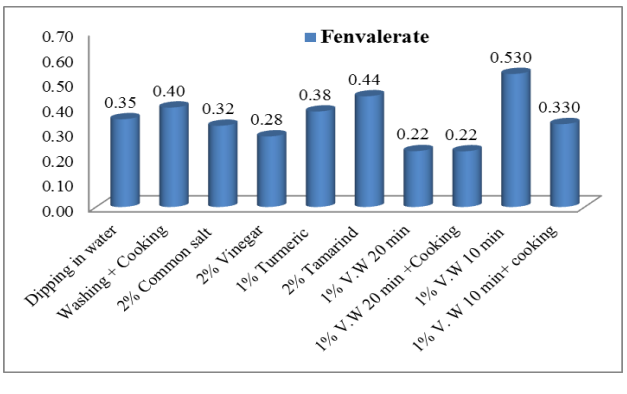

Fenvalerate
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.35
0.40
0.32
0.28
0.38
0.44
0.22
0.22
0.530
0.330
Dipping in water
Washing + Cooking
2% Common salt
2% Vinegar
1% Turmeric
2% Tamarind
1% V.W 20 min
1% V.W 20 min +Cooking
1% V.W 10 min
1% V . W 10 min+ cooking

Fig 1: Effect of different treatments on the extent of removal of insecticide residues in amaranth expressed as processing factor-insecticide wise.
X- axis-Treatments, Y-axis- Processing factor, V. W- Veggie Wash

Maximum removal of all pesticide residues was noticed in amaranth plants dipped in KAU veggie wash (1%) for 20 minutes plus washing and cooking and dipping in KAU veggie wash (1%) for 20 minutes followed by washing alone except in the case of chlorpyriphos. Among all treatments, dipping in 1 per cent KAU veggie wash for 20 minutes followed by cooking for 10 minutes, maximum reduction was observed in the case of malathion (96.47), followed by chlorpyriphos (86.45%), dimethoate (86.27 %), quinalphos (81.02 %), lambda cyhalothrin (79.25 %), fenvalerate (79.19 %), cypermethrin (78.55 %), ethion (77.11 %), profenophos (76.73 %) and bifenthrin (72.22 %). In the case of systemic insecticides washing plus cooking could remove residues to a maximum extent of 86.27 per cent (Veggie wash for 20 minutes + cooking) than other treatments. The extent of residue removal by this treatment was higher than dipping in water followed by cooking probably because of ionisation in acidic solution. The pH of veggie wash (1%) was 3.16. These results agree with the observations of Vemuri *et al.* (2015) who reported synergic effect of treatment with acidic solution and cooking which together dislodged 99 to 100 per cent residues of dimethoate, methyl parathion, quinalphos, endosulphan and profenophos.

Dipping amaranth plants in 1 per cent KAU veggie wash for 20 minutes followed by three washings with tap water also could remove residues up to the level of removal observed in dipping in KAU veggie wash (1%) for 20 minutes plus cooking. In KAU veggie wash (1 %) followed by washing treatment, the order of residue removal was descending from malathion (90.67 %) > dimethoate (85.63 %) > profenophos (78.78 %) > ethion (77.93 %) > lambda cyhalothrin (76.96 %) > fenvalerate (76.40%) > cypermethrin (75.36 %) > quinalphos (73.75 %) > bifenthrin (68.28 %) > chlorpyriphos (61.20 %). In the case of organophosphates, the residue removal ranged from 61 to 90 per cent (Table 32). Whereas dipping in plain water alone removed residues only up to 56 per cent except in the case of malathion (80.56 %). In the case of synthetic pyrethroids, all

four insecticides could be removed up to the extent dislodged by the superior treatment KAU veggie wash (20 minutes) plus (1 %) cooking (Table 33). This treatment had significant variation with dipping in water alone for all insecticides removal. The composition and pH may be the reason for the effectiveness (Mathew, personal communication, 2014). No such relevant studies were conducted but a study conducted by Rasheed (2013) pointed good adsorbtion efficiency (70 - 90 %) of lignocellulosic wastes of plant origin like coffee grounds, melon seeds and orange peels for o-nitrophenol and p-nitrotoluene. Thus, it could be the inferred that, insecticide residues degraded at such a low pH and got adsorbed on to mucilage/lignocelluloses fraction of veggie wash.

Fairly good amount of residues removed when amaranth plants were subjected to dipping in one per cent KAU veggie wash for 10 minutes followed by cooking for 10 minutes. For all insecticides (6 Ops and 4 SPs) this treatments removed up to the level removed by superior treatment one per cent KAU veggie wash for 20 minutes + cooking except for chlorpyriphos. Compared to the one per cent KAU veggie wash for 20 minutes less removal of insecticides removal was observed in one per cent KAU veggie wash for 10 minutes. From these results it is clear that time also a major factor in removal of residues from plants in washing treatments. Time may be deciding factor in this treatment. The amount of residue removal may differ when there is difference in period of washing even for same type of solution (Aktar *et al*., 2008).

Up to 96.61 per cent of residues of chlorpyriphos were removed when amaranth plants were subjected to dipping in vinegar (2 %) for 10 minutes followed by three normal washing with tap water. Vinegar was found as the better option for chlorpyriphos sprayed amaranth plants as it removed up to 40 per cent more residues when compared to simple washing with tap water. Highest removal of organophosphate insecticide chlorpyriphos (96.61%) whereas only 50 per cent of residue removed by dipping in water. At the same time no other treatment could remove chlorpyriphos up to 90 per cent other than vinegar (2 %) The decreasing order in removal by 2 per cent vinegar was malathion (90.34 %),

dimethoate (67.79 %), profenophos (67.27 %), cypermethrin (61.89 %), quinalphos (60.47 %), ethion (58.93 %), lambda cyhalothrin (58.25 %), bifenthrin (55.24 %) and fenvalerate (54.41 %). The percentage of removal of the organophosphate group of insecticide was maximum in the vinegar and this attributed by polar nature of the insecticide belonging to this group. Varghese (2011) reported that the polar nature of insecticides is the deciding factor in removal by vinegar. These results with those obtained by Nair (2013) who reported that dipping of curry leaf in two per cent vinegar for 15 minutes resulted in up to 93 per cent of organo phosphate residues and up to 66 per cent residues removal at one day after spraying.

The combination of washing with water (dipping of amaranth plants in water for 10 minutes) and cooking for 10 minutes (closed pan) had given satisfactory removal of residues of both organophosphate and synthetic pyrethroid group insecticides. The treatment eliminated insecticides in the descending order, malathion (84.86 %), profenophos (77.33 %), dimethoate (76.94 %), quinalphos (72.29 %), lambda cyhalothrin (63.13 %), ethion (62.30 %), chlorpyriphos (61.15 %), cypermethrin (60.12 %), fenvalerate (59.75 %) and bifenthrin (58.83 %). These results may be influenced by the physico-chemical properties of the pesticides. Abou-Arab (1999) found that home canning reduces organophosphates more than organo chlorine pesticide residue levels.The synergic effect of washing and cooking resulted in 39 to 100 per cent removal of pesticide residues from different food samples (Yang *et al.,* 2012). The loss of pesticide residue during heat processing may be due to evaporation, co-distillation., thermal degradation which vary with the chemical nature of the individual pesticide (Sharma *et al*. 2005 and Balinova *et al.,* 2006)

When amaranth plants were dipped in two per cent common salt solution for 10 minutes followed by three normal washing in water, maximum reduction observed malathion (83.24 %) among all insecticides and it was followed by profenophos (79.50 %), malathion (73.53 %), fenvalerate (67.88 %), quinalphos (67.60 %), ethion (66.43%), cypermethrin (65.87 %), chlorpyriphos (60.62 %)<

bifenthrin (60.15%), and lambda cyhalothrin (58.64 %). Lalah and Wandiga, (2002) reported that dipping of beans in two per cent salt solution for five minutes removed 59 per cent of malathion residues. These results agree with those of Nair *et al.,* (2014) who reported that up to 68 per cent of organophosphate and 50 per cent of synthetic pyrethroid insecticide residues were dislodged in okra by subjecting to two per cent common salt for 15 minutes. The cause and effect of the reduction in two per cent common salt washing solutions is still not known and needs further investigation.

Dipping of amaranth plants in tamarind (2 %) solution for 10 minutes followed by three washings with plain water removed impartially good amount of residues of malathion (79.61 %), fenvalerate (60.45 %), cypermethrin (60.14 %), profenophos (58.41 %), dimethoate (57.92 %), lambda cyhalothrin (55.36), ethion (54.32 %) and bifenthrin (52.61 %). Kumar (1997) reported the effectiveness of tamarind solution in removing residues of phosphamidon and monocrotophos from bittergourd and cowpea pods. Singh *et al*. (2007) reported that tamarind pulp had significant amount of organic acids, of which tartaric acid (98 %) is the major one having a pH of 2.7. Varghese and Mathew (2013) reported that two per cent tamarind solution was the best decontaminating solution in removing residues of spiromesifen (90.03 %) and propargite (96.69 %) from green chilli fruits.

In removal of organophosphate and synthetic pyrethroid insecticide residues 2 per cent tamarind had on par effect with dipping in normal water. In the case of chlorpyriphos turmeric (2 %) was inferior (34.56 %) over dipping in water (56.18 %) and superior over dipping in water (37.39 %) in the case of ethion (54.32 %) (Table 32). These results were not in agreement with the findings of Vijayasree *et al.,* (2013) and Nair (2013) who reported that turmeric solution (1%) was effective in removal of insecticide residues from cow pea and okra respectively.

The efficiency of treatments differed with respect to different insecticidal chemistries. The effect of processing depends upon many factors such as water-octanol partition coefficients, water solubility, heat stability, vapour pressure. In all above treatments more removal noticed in organophosphate insecticide residues case than in synthetic pyrethroid insecticides it may be because of higher solubility for organophosphate insecticides than synthetic pyrethroids and also because of polarity of compound (PPDB, 2015). Washing could remove more effectively in the case of surface residues. Washing is very effective in removal of residues located on surface of commodity. In the case of surface residues thermal treatment was also effective. This was supported by results of Dikshit (2001). From the above results it is clear that dipping in one per cent KAU veggie wash for 20 minutes followed by cooking and dipping in one per cent KAU veggie wash for 20 minutes followed by washing (without cooking) are recommendable treatments to remove pesticide residues from amaranth.

Summary

6. SUMMARY

Vegetable amaranth (*Amaranthus tricolor* L.) is a common leafy vegetable cultivated throughout the tropics and in many warm temperate regions. In Kerala red amaranth is a major leafy vegetable cultivated throughout the year. Leaf webber, *Hymenia recurvalis* and leaf eating caterpillar *Spodoptera litura* are major insect pest, whereas red spider mite *Tetranychus* spp is a minor pest. Wide use of insecticides against these pests resulted in development of insecticide resistance, resurgence of secondary pests and pesticide residues on plants. The present study was undertaken to conduct a preliminary survey among amaranth growers for gathering information regarding the pests in amaranth, pesticide use and pesticide residues and to evaluate the bio efficacy of new generation insecticides *viz.,* chlorantraniliprole 18.5 SC - 0.006 %, novaluron 10 EC - 0.015 %, buprofezin 25 SC - 0.03 %, flubendiamide 39.35 SC - 0.0096 %, spinosad 45 SC - 0.015 %, emamectin benzoate 5 SG - 0.002 %, indoxacarb 14.5 SC - 0.015 %, thiacloprid 21.7 SC - 0.036 % and fipronil 5 SC - 0.01 %, microbial insecticides *viz., Bacillus thuringiensis* kurstaki - 5 ml L^{-1}, *Beauveria bassiana* WP - 2 % and *Beauveria bassiana* - CFU-10^8 g^{-1} and botanicals *viz.*, Oxuron - 5 ml L^{-1} and neem seed kernel extract – 5 % with malathion 50 EC - 0.1 % against *H. recurvalis* and *S. litura.* Buprofezin 25 SC - 0.03 %, diafenthiuron 50 WP - 0.06 %, emamectin benzoate 5 SG - 0.002 %, spiromesifen 22.9 SC - 0.0192 % and fenpyroximate 5 EC - 0.003 % in comparison with ethion 50 EC - 0.15 % as check were evaluated against red spider mite. From these treatments evaluated in laboratory conditions, effective treatments were evaluated in field conditions to suggest safer, alternative new generation insecticide for management of pests in amaranth. To ensure safety of amaranth for consumption, better decontamination method was standardized from the following treatments - washing + cooking, 2 % tamarind, 2 % common salt, 1 % turmeric, 2 % vinegar, 1 % KAU veggie wash, 1 % KAU Veggie wash + cooking and water. The results are summarized here under.

- A preliminary survey conducted among amaranth growing farmers in Kalliyoor and Pappanchani locations in Kalliyoor panchayat of Thiruvananthapuram district revealed that *H. recurvalis* and *S. litura* were major insect pests and red spider mite was minor pest observed these fields. Survey also revealed that farmers prefer to use malathion, chlorpyriphos, quinalphos, dimethoate and lambda cyhalothrin on amaranth, mostly as scheduled spraying.
- The survey also revealed presence of insecticide residues in amaranth because of frequent application of insecticides. However, the awareness regarding pesticide residues among the farmers was not satisfactory.
- The samples collected from farmers during survey had residues of chlorpyriphos (1.009-1.14 ppm), quinalphos (0.04-1.20 ppm), profenophos (0.02 ppm), bifenthrin (0.09 ppm), ethion (0.03 ppm), cypermethrin (0.19 ppm), lambda-cyhalothrin (0.025 ppm) and fenvalerate (0.08 ppm).
- Bio efficacy evaluation was carried out on *H. recurvalis*, which revealed that chlorantraniliprole - 0.006 %, novaluron - 0.015 %, flubendiamide - 0.0096 %, spinosad - 0.015 %, emamectin benzoate - 0.002 %, indoxacarb - 0.015 %, thiacloprid - 0.036 %, fipronil - 0.01 % and *Bacillus thuringiensis* kurstaki - 5 ml L^{-1} were effective against second instar larvae of *H. recurvalis.*
- The bio efficacy study on second instar larvae of *S. litura* revealed that novaluron - 0.015 %, flubendiamide - 0.0096 %, emamectin benzoate - 0.002 %, indoxacarb - 0.015 % and fipronil - 0.01 % were effective.
- Laboratory experiments conducted to evaluate the efficacy of new generation insecticides against the mite *Tetranychus* spp revealed that buprofezin - 0.03 %, diafenthiuron - 0.06 %, emamectin benzoate - 0.002 %, spiromesifen - 0.0192 % and fenpyroximate - 0.003 % found to be superior over acaricide check ethion – 0.15 % with cent per cent mortality.
- The field experiment conducted with five new generation insecticides *viz.*, novaluron - 0.015 %, flubendiamide - 0.0096 %, emamectin benzoate -

0.002 %, indoxacarb - 0.015 % and fipronil - 0.01 % including one insecticidal check (malathion 0.10 %) and one untreated check against *H. recurvalis* and *S. litura* resulted in effective reduction in population and percentage of infestation.

- In the field experiment against *Tetranychus* spp mite with buprofezin – 0.03 % and spiromesifen – 0.0192 % with ethion – 0.15 % as acaricide check and an untreated check revealed that both the treatments were equally effective over acaricide check.
- Among the six insecticides *viz.,* novaluron - 0.015 %, flubendiamide - 0.0096 %, emamectin benzoate - 0.002 %, indoxacarb - 0.015 %, fipronil - 0.01 % and malathion 0.10 % treated plots highest spider population (2.19) and highest yield (75.30 g plant^{-1}) were recorded in flubendiamide treated plots.
- Satisfactory results were obtained while validating the QuEChERS method for the pesticide residue analysis of amaranth with good recovery which ranged from 74.12 to 97.86 per cent of the pesticide fortified.
- Studies conducted to assess the effect of different household practices to decontaminate pesticide residues in amaranth revealed that dipping in 1 % KAU veggie wash for 20 minutes followed by cooking (72.22 – 96.47 %) and dipping in 1 % KAU veggie wash for 20 minutes followed by three normal washings (61.20 – 90.67 %) were the best treatments which significantly reduce the residues of dimethoate, malathion, chlorpyriphos, quinalphos, profenophos, ethion, bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate residues from amaranth.

References

7. REFERENCES

Abbot, W.S. 1925. A method of computing the effectiveness of an insecticide. *J. Econo. Entomol*. 18: 265-267.

Abdel-Hafez, H. F. and Abdel-Aziz, M. A. 2010. Synergistic effects of some plant extracts to biorational product, spinosad, against the cotton leafworm, *S. littoralis* (Boisd.) (Lepidoptera: Noctuidae). *Egypt. J. Biol. Pest Control*, 20 (1): 27–32.

Abhilash, B. 2001. Biocontrol of mites on yard long bean (*Vigna unguiculata* ssp. *Sesquipedalis* (L.) Verdcourt) and chilli (*Capsicum annuum* (L.)). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, p.178.

Abou-Arab, A. A. K. 1999. Behaviour of pesticides in tomatoes during commercial and home preparation. *Food Chem.* 65: 509 - 514.

Abou-Arab, A. A. K. and Abou-Donia, M. A. 2001. Pesticide residues in some Egyptian spices and medicinal plants as affected by processing. *Food Chem.* 72: 439 - 445.

Adachi, A. and Okano, T. 2006. Pesticide residue reduction in selected vegetables using rice-bran. *J. Health Sci.* 52: 320 - 323.

Aderolu, I. A, Omooloye, A. A. and Okelana, F. A. 2013. Occurrence, Abundance and Control of the Major Insect Pests Associated with Amaranths in Ibadan, Nigeria. *Entomol. Ornithology Herpetology*, 2: 112.

Ahmed, E. M. 2004. New approaches for control of cotton bollworms. Ph.D. (Ag) thesis, Cairo University, Egypt, p.160.

Ahmed., Saleem, M. A. and Ahmad, M. 2005. Time - oriented mortality in leafworm, *Spodoptera litura* (fab.) (Lepidoptera: Noctuidae) by some new chemistry insecticides. *Pakist. Entomol.* 27(1): 243-246.

Aktar, W., Sengupta, D., Purkait, S. and Choudhary, A. 2010. Risk assessment and decontamination of quinalphos under different culinary processes in/on cabbage. *Environ. Monitoring Assess.* 163: 369–377.

Al-Taher., Fadan., Chen, Y. and Cappozzo, J. 2014. Assessing Washing Methods for Reduction of Pesticide Residues in Tomatoes and Other Produce Using LC/MS and GC/MS [on-line]. Available: http://www.agilent.com/chem [07Oct. 2014].

Ambrus, A. 2000. Within and between field variability of residue data and sampling implications. *Food Additives Contaminants*,17 (7): 519-537.

Ameta, O.P., Sharma, U.S. and Padival, N.K. 2010. Bioefficacy of Spiromesifen 240 SC against mite, *Tetranychus* spp and whitefly *Bemisia tabaci* in tomato.

Anurag, S., Rakesh, G. and Reecha, K. 2009. Larvicidal effect of some plant extracts against *Spodptera litura* and *Pieris brassicae*. *J. Entomol. Res*. 33 (3): 213-218.

Arora, S., Kanojia, A. K. and Bambawale, O. M. 2011. *Pesticides: Status, Latest WHO Ranking, Regulations and Label Claims in India* [Lecture notes]. National Centre for Pest Management, ICAR, New Delhi, p.17.

Aswal. J. S and Bisht. B. S. 2012. Bio-efficacy of insecticides against *Hymenia recurvalis* larvae in Garhwal Hills of Uttarakhand. *Ann. Plant Prot. Sci.* 20 (2): 464-509.

Ayyar, T.V.R. 1963. *Handbook of Economic Entomology for South India*, Government Press, Madras, p.508.

Babu. A., Rahman. V.K.J and Kumar. A.R. 2009. Efficacy of Fenpyroximate (Sedna) against red spider mite. J. News l-UPSAI tea research foundation. 19 (2): p.4.

Balinova, A. M., Mladenova, R. I. and Shtereva, D. D. 2006. Effects of processing on pesticide residues in peaches intended for baby food. *Food Additives Contaminants,* 23: 895-901.

Bhagirathi, D., Kapoor, S.K. and Singh, B. 2001. Persistence of malathion residues on/in bell pepper (*Capsicum annuum* Linn). *Pesticide Res. J.* 13:99–102.

Bhattacherjee, N.S. and Menon, M.G.R. 1964. Biology and control of *Hymenia recurvalis* (Fab). *Indian J. Ent.* 26: 179-183.

Bhatti, S. S., Ahmad, M., Yousaf, K. and Naeem, M. 2013. Pyrethroids and New Chemistry Insecticides Mixtures Against *Spodoptera Litura* (Noctuidae: Lepidoptera) Under Laboratory Conditions. *Asian J. Agric. Biol.* 1: 45-50.

Bheemanna, M., Hosamani, A. C., Sharanabasappa., Patil, B.V., Suresh, B. K. and Shivaleela. 2009. Field efficacy of spinosad 45 SC New A: D ratio against cotton thrips and bollworms. *Pesticide Res. J.* 21(1):52-54.

Bohlen, E. 1973. *Crop Pests in Tanzania and their Control*, Verlag Paul Parey, Berlin, p.230.

Bonnechere, A., Hanot, V., Jolie, R., Hendrickx, M., Bragard, C., Bedoret, T. and Loco, J. V. 2012. Processing factors of several pesticides and degradation products in carrots by household and industrial processing. *J. Food Res.* 1(3): 68 - 82.

Butani, D.K., 1977. Insect Pests of Vegetables: Tomato. *Pesticides* 11 (1): 33-36.

Castro, M. F. P. M., Oliveira, J. J. V., Rodrigues, J., Loredo, I. S. D., Oliveira, J. J., de-Castro, M. F. P. M. and Highley, E. A. 2002. Study on the persistence of trifluralin, chlorpyrifos, decamethrin, cypermethrin and dichlorvos in rice and beans after cooking in a commercial microwave oven. In: Credland, P. F., Armitage, D. M., Bell, C. H. and Cogan, P. M.

(eds.), *Advances in Stored Product Protection*. Proceedings of the 8th International Working Conference on Stored Product Protection, New York, U.K., pp.517 - 521.

Cengiz, M. F., Certel, M., Karakas, B. and Gocmen, H. 2006. Residue contents of DDVP (dicholrvos) and diazinon applied on cucumbers grown in green houses and their reduction by duration of a pre harvest interval and post-harvest culinary application. *Food Chem.* 98:127-135.

Cengiz, M. F., Certel, M., Karakas, B. and Gocmen, H. 2007. Residue contents of captan and procymidon applied on tomatoes grown in green houses and their reduction by duration of a pre harvest interval and post harvest culinary application. *Food Chem*. 100: 1611-1619.

Chanpaisaeng, J., Srifah, P. and Chim-anek, P. 2001. Control of diamondback moth (*Plutella xylostella*) using Thai strains of *Bacillus thuringiensis*. In: *Proceeding of the 5th National plant protection conference,* 21-23 November 2001, Thailand. National Plant Protection, Thailand,pp.179-184.

Chauhan, R., Monga, S. and Kumari, B. 2012. Dissipation and decontamination of bifenthrin residues in tomato (*Lycopersicon esculentum* Mill). *Bull. Environ. Contamination Toxicol.* 89:181-186.

Chavarri, M. J., Herrera, A. and Arino, A. 2005. The decrease in pesticides in fruit and vegetables during commercial processing. *Int. J. Food Sci.* 3: 123-126.

CIB&RC [Central Insecticide Board and Registration Committee]. 2014. CIB&RC home page [on line]. Available : http://www.cibrc.nic.in. [07 Dec. 2014].

Claeys, W. L., Schmit, J. F., Bragard, C., Rogister, G. M., Pussemier, L. and Schiffers, B. 2011. Exposure of several Belgian consumer groups to pesticide residues through fresh fruit and vegetable consumption. *Food Control*, 22(3-4): 508-516.

Collins, D., Cannon, R. and Macleod, A. 2006. Plant pest notice – Chilli thrips. Available : // www. defra. gov. uk /planth /pestnote /2006 /chilli thrips. pdf. [9 Dcember 2007].

Das, G. and Islam, T. 2014. Mortality and growth inhibition of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.) by buprofezin, a potent chitin synthesis inhibitor. *J. Entomol. Zool. Stud.* 2 (6): 282-287.

David, B.V. 2001. *Elements of Economic Entomology*, Popular Book Depot, Chennai, p.590.

Dejonckheere, W., Steurbaut, W., Drieghe, S., Verstraeten, R. and Braeckman, H. 1996. Pesticide residue concentrations in the Belgian total diet, 1991–1993. *J. AOAC Int.* 79(2): 520–528.

Dey, P.K. and Somchoudhury, A.K. 2001. Evaluation of spinosyn A + D (spinosad 48 EC) against lepidopteran pest complex of cabbage and its effect on natural enemies of diamondback moth under field conditions of West Bengal. *Pestology* 25: 54-58.

Dikshit, A. K. 2001. Persistence of cypermethrin on stored pulses and its decontamination. *Pest Res. J.* 13:141–146.

Dikshit, A. K., Lal, O. P., Sinha, S. R. and Srivastava, Y. N. 2002. Safety evaluation, persistence and bioefficacy of imidacloprid and beta cyfluthrin on okra. *Pestology*, 26: 30 - 37.

Dharmishthabahen R. S and Shukla, A. 2014. Chemical control of two-spotted spider mite, *Tetranychus urticae* (Koch.) infesting gerbera (*Gerbera*

jamesonii L.) under polyhouse condition. *Pest Manage. Hortic. Ecosyst*. 20 (2): 155-161.

Dhawan, A. K., Ashwinder, K. and Ravinder, K. 2007. Relative toxicity of new insecticides against *Spodoptera litura*. *Ann. Plant Prot. Sci.* 15(1): 235-281.

Duhan. A., Kumari, B. and Gulati, R. 2010. Effect of household processing on fenazaquin residues in okra fruits. *Bull. Environ. Contamin. Toxicol*. 84:217-220.

Ebert, A. W., Wu, T. H. and Wang, S. T. 2011. Vegetable amaranth (Amaranthus L.). International Cooperators' Guide [on-line]. Available: http://203.64.245.61/webcrops/indigenous/cooperators%20guide_amaranth_s_web.pdf [16 Feb. 2015].

Ecobichon, D. J. 1995. *Casarett and Doull's Toxicology: The Basic Science of Poisons Alternatives*. Mc Graw-Hill Publishers, New York, p.690.

Elkins, E. R. 1989. Effect of commercial processing on pesticide-residues in selected fruits and vegetables. *J. Assoc. Off. Anal. Chem.* 72 (3): 533–535.

Ellsworth, P. C. and Martinez-Carrillo, J. L. 2001. IPM for *Bemisia tabaci:* a case study from North America. *Crop Prot.* 20: 853-869.

Epenhuijsen, C. W. V. 1974. *Growing Native Vegetables In Nigeria* [Lecture notes]. FAO, Rome, 320 p.

Fahmy, N. M. 2012. Impact of two insect growth regulators on the enhancement of oxidative stress and antioxidant efficiency of the cotton leaf worm, *Spodoptera littoralis* (Biosd.). *Egypt Academic J. Biol. Sci.* 5(1):137-149.

Ferndadez-Cruz, M. L., Grimalt, S., Villaroya, M., Lopez, F. J., Lianos. S. and Baudin. J. M. G. 2006. Residue levels of Captan and Trichlorfon in field

treated kaki fruits, individual versus composite samples and after household processing. *Food Additives Contaminants,* 23(6):591-600.

Fletcher, T.B. 1914. *Some South Indian Insects,* M/s Bishen Singh Mahendra Pal Singh, Dehra Dun, p.432.

FSSAI [Food Safety and Standard Authority of India]. 2012. FSSAI home page [on line]. Available : http://www.fssai.gov.in.

Gangawar, S. K., Yadav, C. P. S., Mishra, R. K., Dadheech, L. N. and Saxena, R. C. 1980. Efficiency of *Bacillus thuringiensis* against lepidopteran pests. *Indian J. Plant Prot.* 8 (2): 157-156.

Gangopadhyay , C. and Sarkar, P. K. 2000. Relative efficacy of some acaricides and acaro insecticides against adult stages of *Polypahgotarsonemus latus* (Banks) (Tarsonemidae: Acari) infesting chilli (Cv. Suryamukhi) under West Bengal condition. *Pestology*, 24:23-27.

Gardenmo.net. 2011. Gardenmo home page [on line]. Available: http://www.gardenmo.net/vegetable-garden-2/decontamination-of-pesticide-residues-on-fruits-and-vegetables.html. [28 January 2011].

Gomez, K.A. and Gomez, A. A. 1984. *Statistical Proceeding for Agricultural Research* (2nd Ed.). John Willey and Sons Inc, Singapore, p.262.

Gour, T. B. and Sridevi, D. 2012. *Chemistry, toxicity and mode of action of insecticides.* Kalyani publisher, p.214.

Grubben, G. J. H. 1976. *The cultivation of Amaranth as a Tropical Leaf Vegetable* [Lecture notes]. Royal Tropical Institute, Amsterdam, p.420.

Gupta, G. P., Rani, S., Birah, A. and Raghuraman, M. 2004. Relative toxicity of certain new generation insecticides against *Spodoptera litura*. (Fabricius). *Pesticide Res. J.* 16(1): 45-47.

Hanumantharaju, T. H. and Awasthi, M. D. 2003. Effect of decontamination processes on fungicide residues in tomato fruits. *J. Food Sci. Technol.* 40(4): 374-377.

Hirooka, T., Nishimatsu, T., Kodama, H., Reckmann, U. and Nauen, R. 2007. The biological profile of flubendiamide, a new benzenedicarboxamide insecticide, Pflanzensch, Nachr. Bayer, 60: 183-202.

Holland, P. T., Hamilton, D., Ohlin, B. and Skidmore, M. W. 1994. Effects of storage and processing on pesticide residues in plant products. *Pure Appl. Chem*. 66: 335 - 356.

Hwang, E. S., Cash, J. N. and Zabik, M. J. 2001. Postharvest treatments for the reduction of mancozeb in fresh apples. *J Agric. Food Chem.* 49: 3127-3132.

Jayakrishnan, S., Dikshit, A. K., Singh, J. P. and Pachuri, D. C. 2005. Dissipation of lambda cyhalothrin on tomato (*Lycopersicon esculentum* Mill.) and removal of its residues by different washing processes and steaming. *Bull. Environ. Contaminantion Toxicol*. 75: 324 -328.

Jayakumar, P. and Uthamasamy, S. 2000. Bio-efficacy of some synthetic insecticides and botanicals against *Liriomyza trifolii*. *Indian J. Entomol.* 59: 347-350.

Jayanthi, K. P. D. and Padmavathamma. 2001. Joint action of microbial and chemical insecticides on *Spodoptera litura* (Fab.) (Lepidoptera:Noctuidae). *J. Trop. Agric.* 39: 142-144.

Kang, S. M. and Lee, M. G. 2005. Fate of some pesticides during brining and cooking of Chinese cabbage and spinach. *Food Sci. Biotechnol.* 14:77-81.

Kanta, G., Kumari, B. and Kathpal, T. S. 2001. Dissipation of alphamethrin residues in/on brinjal and tomato during storage and processing conditions. *J. Food Sci. Technol.* 38(1): 43-46.

Kapoor, S. 2010. Dissipation of carbaryl and endosulfan residues on tomato fruit under extreme climatic condition of Agra (U.P.). *J. Entomological Res.* 34(4): 333 - 335.

Kar, A., Mandal, K. and Singh, B. 2012. Decontamination of chlorantraniliprole residues on cabbage and cauliflower through household processing methods. *Bull. Environ. Contamination Toxicol.* 88:501–506.

Karuppaiah, V. and Srivastava, C. 2013. Relative toxicity of newer insecticide molecules against *Spodoptera litura. Ann. Plant Prot. Sci.* 21 (2): 305-308.

KAU (Kerala Agricultural University) 2011. *Package of Practices Recommendations:* Crops (14th Ed.). Kerala Agricultural University, Thrissur. p.171.

Kaur. P., Yadav, G. S., Chauhan. R. and Kumari. B. 2011. Persistence of cypermethrin and decamethrin residues in/on brinjal fruit. *Bull. Environ. Contamin. Toxicol.* 87(6): 693-698.

Kaushik, G., Satya, S. and Naik, S. N. 2009. Food processing a tool to pesticide residue dissipation- A review. *Food Res. Int.* 42: 26 - 40.

Kedar. S. C. and Kumaranag. K.M. 2013. Report on outbreak of *Spoladearecurvalis* (Fabricus) on *Trianthema portulacastrum* L. and its parasite from Haryana, India. *J. Entomol. Res.* 37 (2): 149-151.

Khadir, H. A. and Knowles, C. O. 1991. Toxicological Studies of the Thiourea Diafenthiuron in Diamondback Moths (Lepidoptera: Yponomeutidae),

Twospotted Spider Mites (Acari: Tetranychidae) and Bulb Mites (Acari: Acaridae). *J. Econ. Entomol*. 84(3):780-784.

Khalid, A., Hanumantharao, V. and Purnachandrarao, P. 2001. Promising new insecticides as potential ovicides against eggs of *Spodoptera litura* Fab. *Pestology*, 25(4): 20-21.

Khalid, A. and Prasad, V.V. S. D. 2009. Efficacy of emamectin benzoate 5% SG against thrips, *Scirtothrips dorsalis* Hood and pod borer, *Spodoptera litura* Fab. on chillies. *Pestology*, 33(7): 22-25.

Kong, Z., Shan, W., Dong, F., Xu, J., Liu, X., Li, M. and Zheng. Y. 2012. Effect of home processing on the distribution and reduction of pesticide residues in apples. *Food Additives Contaminants*, 29(8): 129-135.

Kontou, S., Tsipi, D. and Tzia, C. 2004. Stability of dithiocarbamate pesticide maneb in tomato homogenates during cold storage and thermal processing. *Food Additives Contaminants,* 52: 1212 - 1219.

Krishna, A. R. and Bhaskar, H. 2013. Ovicidal and adulticidal effect of acaropathogenic fungi, neem oil and new acaricide molecules on *Tetranycus urticae* Koch. *Entomon* 38(3): 177-182.

Krol, W. J., Arsenault, T. L., Pylypiw, H. M. and Mattina, M. J. I. 2000. Reduction of pesticide residues on produce by rinsing. *J. Agric. Food Chem*. 48 (10): 4666–4670.

Kulakarni, N.S., Mani, M and Banerjee, K. 2008. Management of mites in grapes. Newsl- *Natl res. Cent. for grapes*. 15: p.1.

Kumar, K. P., Reddy D. J., Reddy K. N., Babu T. R. and Narendranath V. V. 2000. Dissipation and decontamination of triazophos and acephate residues in chilli (*Capsicum annum* Linn) *Pest Res. J.* 12:26-29.

Kumar, S. S. R. 1997. Insecticide residues in market samples of vegetables and methods of their decontamination. M.Sc (Ag) thesis, Kerala Agricultural University, Thrissur, p.62.

Kumari B. 2008. Effects of household processing on reduction of pesticide residues in vegetables. *J. Agric. Biol. Sci.* 3(4):46-51.

Kumari, B., Kumar, R., Madan, V. K., Singh, R., Singh, J. and Kathpal, T. S. 2003. Magnitude of pesticidal contamination in winter vegetables from Hisar, Haryana. *Environ. Monitoring Assess.* 87: 311-318.

Kumari, B., Madan, V. K., Kumar, R. and Kathpal, T. S. 2002. Monitoring of seasonal vegetables for pesticide residues. *Environ. Monitoring Assess.* 74: 263-270.

Lahm, G. P., Codova, D. and Barry, J. D. 2009. New and selective ryanodine receptor activators for insect control. *Bioorganic Med. Chem.* 17 (12): 4127- 4133.

Lalah, J. O. and Wandiga, S. O. 2002. The effect of boiling on the removal of persistent malathion residues from stored grains. *J. Stored Products. Res*. 38: 1 - 10.

Lal, A. K. and Dikshit, A. K. 2001. The protection of chickpea (*Cicer arientinum* L) during storage using deltamethrin on sacks. *Pesticide Res. J.* 13 (1):27-31.

Lee, M. G. and Jung, D. I. 2009. Processing factors and removal ratios of select pesticides in hot pepper leaves by a successive process of washing, blanching and drying. *Food Sci. Biotechnol*. 18:1076–1082.

Lee, S. K., Kim, J., Cheong, S. S., Kim, Y. K., Lee, S. G. and Hwang, C. Y. 2013. Temperature-dependent development model of hawaiian beet webworm *Spoladea recurvalis* Fabricius (Lepidoptera: Pyraustinae). *Korean J. Appl. Entomol.* 52(1): 5-12.

Leena, M.K., Paulose, S and Revi. S. 2005. Evaluation of eco-friendly insecticides against amaranths *(Amaranthus tricolor* L.) leaf webber *(Hymenia recurvalis* F.). *J. Entomol. Res.*9 (3) : 207-208.

Lefroy, H. M. 1909. *Indian Insect Life.* Today & Tomorrow's Printers & Publishers, New Delhi, p.516.

Lentza-Rizos, C., Avramides, E. J. and Kokkinaki, K. 2006. Residues of azoxystrobin from grapes to raisins. *J. Agric. Food Chem.* 54(1): 138 - 141.

Lentza-Rizos, C. and Balokas, A. 2001. Residue levels of chlorpropham in individual tubers and composite samples of post harvest treated potatoes. *J. Agric. Food Chem.* 49(2): 710 - 714.

Ling, Y., Wang, H., Yong, W., Zhang, F., Sun, L., Yang, M. L., Wu, Y. N. and Chu, X. G. 2011. The effects of washing and cooking on chlorpyrifos and its toxic metabolites in vegetables. *Food Control*, 22: 54 - 58.

Long, D. W., Drummond, F. A., Groden, E. and Donahue, D. W. 2000. Modelling *Beauveria bassiana* horizontal transmission. *Agric. Entomol.* 2: 19–32.

Majula. K. N. and Kotikal. Y. K. 2015a. Crop loss estimation due to *Agrotis segetum* (Denis and Schiffermuller) and *Spoladea* (*Hymenia*) *recurvalis* (Fabricius) on palak. *Karnataka J. Agric. Sci.* 28(2): 277-278.

Majula. K. N. and Kotikal. Y. K. 2015b. Evaluation of different insecticides against *Agrotis segetum* (Denis and Schiffermuller) and *Spoladea*

(*Hymenia*) *recurvalis* (Fabricius) on amaranthus. *Karnataka J. Agric. Sci*. 28(2): 197-201.

Malarvannan. S, P. D. Murali, S. P. Shanthakumar, V. R. Prabavathy and Sudha Nair. 2010. Laboratory evaluation of the entomopathogenic fungi, Beauveria bassiana against the Tobacco caterpillar, Spodoptera litura Fabricius (Noctuidae: Lepidoptera). *J. Biopesticides,* 3(1): 126 – 131.

Mallareddy, K., Lokareddy, K., Ramesh Babu, T. and Narasimharedd, Y.K. 2004. Efficacy of certain insecticides against pests of cabbage. *Pest Manage. and Econ. Zool.* 12 (2): 153-159.

Mallikarjunappa, S., Kendappa, G.N. and Bhat, G.U. 2008, Flubendiamide 20% WG-a novel insecticide for the control of rice stemborer, *Scirphophaga incertulas* and leaf folder *Cnaphalocrosis medinalis.* In: Coleman memorial National Symp. on Plant prot., 4-6, December, Univ. Agric. Sci., GKVK, Bangalore.

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

Marasinghe, J. P., Magamage1, C., Shiromi1, M. G. D. and Aravinna, A. G. P. 2011. Organophosphate pesticides residues in food commodities in Sri Lanka (A Review). *Ann. Sri Lanka Dep. Agric.*13: 81 - 93.

Marcic, D. 2007. Sublethal effects of spirodiclofen on life history and life-table parameters of two-spotted spider mite (*Tetranychus urticae*). *Exp. Appl. Acarology*, 42: 121-129.

Marcic, D., Ogurlic, I., Mutavazidic, S. and Peric, P. 2009. The Effect of Spiromesifen on the Reproductive Potential of *Tetranychus urticae* Koch.

(Acari: Tetranychidae). *Pesticide Phytomederation.* (Belgrade), 24(3): 203-209.

Marcic, D., Peric, P. and Milenkovi, S. 2011. *Pesticides - Formulations, Effects, Fate. In: Pesticides- Formulations, Effects, Fate.* Tech Publisher, Europe, p.62.

Martinz, H., Ferre, L. and Escriche, B. 2008. Susceptibility of *Spodoptera exigua* to 9 toxins from *Bacillus thuringiensis*. *J. Invertebrate Pathol.* 97 (3): 245-250.

Martirosyan, D. M., Miroshnichenko, L. A., Kulakova, S. N., Pogojeva, A. V. and Zoloedov, V. I., 2007, Amaranth oil application for coronary heart disease and hypertension. *Lipids Health Dis.,* 6: 1.

Masanori, T., Hayami, N. and Fujioka, S. 2005. Flubendiamide, a novel insecticide highly effective against lepidopteran insect pests. *J. Pesticides Sci*. 30: 354-360.

Mathew, T. B. 2014. *Toxicology of Insecticides: Mode of Action of Insecticides*. [Lecture notes]. College of Agriculture, Vellayani, p.44.

Mathew, T. B., Beevi, S. N., Sudharma, K., Nalinakumari, T. and Mathew, M. P. 1999. Effect of washing on persistence of mancozeb in cardamom (*Elettaria cardamomum* Maton) capsules. *J. Spices Aromat. Crops* 8(1): 73 - 76.

Meena, U., Patil, A. V., Kulkarni. and Omkar, G. 2013. Bioeficacy of flubendiamide 39.35 % SC against chili fruit borer (*Spodoptera litura*). *Asian J. Biosci.* 8(2): 241-243.

Mirani. B. N., Sheikh. S. A., Nizamani. S. M. and Mahmood. N. 2013. Effect of house hold processing in removal of lufenuron in tomato. *Int. J. Agric. Sci. Res.* 3 (1): 235-243.

Mishra, H. P. 2003. Efficacy of newer insecticides in chilli leaf curl management. *Indian J. Agric. Sci.* 73(6): 358-360.

Motoba, K., Suzuki, T. and Uchida, M. 1992. Effect of a new acaricide, fenpyroximate, on energy metabolism and mitochondrial morphology in adult female *Tetranychus urticae* (two-spotted spider mite). *Pesticide Biochem. Physiol.* 43 (1): 37-44.

Nagaraj, T., Sreenivas, A. G., Patil, B. V. and Nagangoud, A. 2007. Preliminary evaluation of some new molecules against thrips *Scirtothrips dorsalis* Hood and *Polyphagotarsonemus latus* Banks mites in chilli under irrigated ecosystem. *Pest Manag . Hortic. Ecosyst.* 13(2): 185-188.

Nair, M.R.G.K. 1999. *A Monograph on Crop Pests of Kerala and their Control.* Third edition. Directorate of Extension, Kerala Agricultural University, Thrissur, 227 p.

Nair, K. P. 2013. Monitoring and decontamination of pesticide residues in agricultural commodities. M. Sc. (Ag) thesis, Kerala Agricultural University, Thiruvananthapuram, 188p.

Nair, K. P., Mathew T. B., Beevi S. N. and George, T. 2012. Effect of washing and cooking of five insecticides in basmati rice. In: *Proceedings of 22nd Swadeshi Science Congress on Ecosystem Services through Plantation Crops*, 6-8 November 2012, CPCRI, Kasargod. Swadeshi Science Movement, Kerala, Shastra Bhavan, Kochi, pp.90-93.

Nair, K. P., Mathew, T. B., Beevi S. N. and George, T. 2013a. Home processing to address food safety issues in cereals. In: *Proceedings of International Conference on Insect Science,* 14-17 February 2013, Bangalore. University of Agricultural Science, Banglore, India,pp.120 - 121.

Nair, K. P., Mathew, T. B., Beevi, S. N. and George, T. 2014. Monitoring and decontamination of pesticide residues in okra (*Abelmoschus esculentus* Moench). *Int. J. Interdisciplinary Multidisciplinary Stud.* 1(5): 242-248.

Nair, K. P., Mathew T. B., Beevi, S. N., George, T. and Rajith, R. 2013b. Monitoring and risk assessment of pesticide residues in agricultural/ horticultural commodities. *Entomon,* 38(3): 119-129.

Nair, M. R. G. K. 1975. *Insects and Mites of Crops in India.* (2nd Ed.). Indian Council of Agricultural Research, New Delhi, p.408.

Nauen, R. and Konanz, S. 2005. Spiromesifen as a new chemical option for resistance management in whiteflies and spider mites. *Pflanzenschuz-Nachrichten Bayer*, 58: 485-502.

Nayar, K.K., Ananthakrishnan, T.N. and David, B.V. 1976. *General and Applied Entomology*. Tata McGraw Hill Publishing Company Limited, New Delhi, 589.

Oberlander, H. and Silhacek, D.L. 1998. New perspectives on the mode of action of benzoylphenyl urea insecticides. In: Ishaaya I, Degheele D (Eds) *Insecticides with Novel Modes of Action*, Springer-Verlag, Berlin, pp 92-105.

PAMSTEV. 2014. *Annual report* on Pesticide residue data on leafy vegetables of Kerala under the "Production and Marketing of Safe to Eat (Pesticide free) vegetables for sale through government outlets". p:3-4.

Pande, Y. D. 2009. Some Observations on the bionomics of *Hymenia recurvalis* F. (Lepid., Pyralidae) feeding on *Trianthema monogyna* and *Amaranthus viridis* in India. *J. Appl. Entomol.* 72 (1-4): 362-366.

Parmar, K. D., Korat, D. M., Shah, P. G. and Singh, S. 2012. Dissipation and decontamination of some pesticides in/ on okra. *Pesticide Res. J.* 24(1): 42-46.

Patil, R. H., Santosh, M. N. and Athoni, B. K. 2009. Indigenous technology knowledge components for the management of defoliators in soybean. *Karnataka J. Agric. Sci.* 22(3): 491-494.

Patil R. S. 2005. Investigations on mite pests of solanaceous vegetable with special reference to brinjal. Ph.D. thesis, University of Agricultural Sciences, Dharwad, p.135.

Patil, R. S. and Nandihalli, B. S. 2007. Preliminary studies on the toxicity of pesticides to eggs and adults of *Tetranychus macfarlanei* Baker and Pritchard (Acari: Tetranychidae). *Insect Environ.* 12 (4): 168-169.

PPDB [Pesticide Property Data Base]. 2014. PPDB A to Z list [on line]. Availabe: http://sitem.herts.ac.uk/aeru/footprint/en/index.html. [04 April 2015].

Prasad, D. K., Madumathi, T., Arjunarao, P. and Srinivasarao, V. 2007. Toxicity of insecticides to resistant strain of *Spodoptera litura* (Fab.) on cotton. *Ann. Plant Prot. Sci.* 15(1): 77-82.

Prathiban, P., Baskaran, R.K.M. and Thangavel, K. 2014. Bio-efficacy of emamectin benzoate 5 WG against tobacco caterpillar and diamondback moth in cabbage. *Pesticide Res. J.* 26 (2): 175-180.

Radwan, M. A., Abu-Elamayem, M. M., Shiboob, M. H. and Abdel-Aal. A. 2005. Residual behaviour of profenofos on some field-grown vegetables and its removal using various washing solutions and household processing. *J. Food Chem. Toxicol.* 43: 553-557.

Ragaei, M. and Sabry, K. H. 2011. Impact of spinosad and buprofezin alone and in combination against the cotton leafworm, *Spodoptera littoralis* under laboratory conditions. *J. Biopesticides*, 4 (2): 156-157.

Rahula, B. V. and Shah, P. G. 2008. Degradation of lambda cyhalothrin and deltamethrin in rice due to storage and processing. *Pestic. Res. J.* 20(2): 259-262.

Rajanikanth, P., Subbaratnam, G.V. and Rahaman, S. J. 2010. Evaluation of different strains/isolates of *Beauveria bassiana* (Balsamo) Vuillemin for pathogenicity against *Spodoptera litura* Fabricius. *J. Entomol. Res*. 34(4): 287-291.

Ramangouda, S. H. and Srivastava, R. P. 2009. Bioefficacy of insecticides against tobacco caterpillar, *Spodoptera litura*. *Indian J. Plant Prot.* 71 (1/2): 14-19.

Randhawa, M. A., Anjum, F. M., Ahmed, M. A. and Randhawa, M. S. 2007. Field incurred chlorpyrifos and 3,5,6-trichloro-2-pyridinol residue in fresh and processed vegetables, *Food Chem.* 103: 1016–1023.

Rasheed, M. N. 2013. *Adsorption Technique for the Removal of Organic Pollutants from Water and Wastewater* [on line]. Available: http://dx.doi.org/10.5772/54048 [3 April 2013].

Rashwan, M. H. 2013. Biochemical Impacts of Rynaxypyr (Coragen) and Spinetoram (Radiant) on *Spodoptera littoralis* (Boisd.). *Nat. Sci.*11(8): 217-221.

Rao, A.B., Rajasekhar, P., Ramachandra rao, G. and Srinivasarao, V. 2006. Seasonal incidence and management of *Spodoptera litura* on Fenugreek. *Ann. Pl. Prot. Sci.* 14(1): 86-89.

Rawn, D.F.K., Quade, S.C., Sun, W., Fouguet, A., Belanger, A. and Smith, M. 2008. Captan residue reduction in apples as a result of rinsing and peeling. *Food Chem.* 109: 790 - 796.

Razak, T. A., Santhakumar, T., Mageswari, K. and Santhi, S. 2014. Studies on efficacy of certain neem products against *Spodoptera litura* (Fab.). *J. Biopesticides,* 7: 160-163.

Reddy, D. J. and Rao, B. N. 2002. Dissipation and decontamination of chlorpyrifos and quinalphos residues on/in grape berries. *Pest Manag. Hortic. Ecosyst.* 8(2):103-108.

Reddy, D. S. and Latha, M. P. 2013. Efficacy of certain new acaricides against two spotted spider mite, *Tetranychus urticae* Koch. on ridge gourd. *Pest Manag. Hortic. Ecosyst.* 19(2): 199-202.

Reddy, N. K., Sultan, M. A., Reddy, D. J. and Babu, T. R. 2001. Dissipation and decontamination of triazophos and lindane in brinjal. *Pestology*. 25: 51-54.

Reddy, N.A. and Kumar, C.T.A. 2004. Studies on the seasonal incidence of insect pests of tomato in Karnataka. *Pest Manag. hort. Ecosys.*10: 113-121.

Rehan, A., Saleem, M. A. and Freed, S. 2011. Baseline susceptibility and stability of insecticide resistance of *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) in the absence of selection pressure. *Pakist. J. Zool.* 43: 973-78.

Reji, G.V. 2002. Management of the American serpentine leaf miner, *Liriomyza trifolii* (Burgess) Dietars on cowpea, *Vigna unguiculata* (L.) Walp. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p.90.

Samanta. A., Chowdhury. A. and Somchoudhury. A. K. 2006 Residues of Different Insecticides in/on Brinjal and Their Effect on *Trichogramma* spp. *Pesticide Res. J.* 18 (1): 35-39.

Samriti., C. R. and Kumari. B. 2011. Persistence and effect of processing on reduction of chlorpyrifos residues in okra fruits, *Bull. Environ. Contamination Toxicol.* 87(2): 198-201.

Sannino, A., Bolzoni, L. and Bandini, M. 2004. Application of liquid chromatography with electrospray tandem mass spectrometry to the determination of a new generation of pesticides in processed fruits and vegetables. *J. Chromatography A.* 1036: 161 - 169.

Satpathy, G. 2012. Removal of organophosphorous pesticide residues from vegetables using washing solutions and boiling. *J. Agric. Sci.* 4: 71 - 76.

Sato, M. E., Silva, M. Z., Raga, A., Cangani, K. G., Veronez, B., Roberto, L. and Nicastro. 2011. Spiromesifen toxicity to the spider mite*Tetranychus urticae* and selectivity to the predator *Neoseiulus californicus. Phytoparasitica,* 39 (5):437-445.

Satpathy, G. 2012. Removal of organophosphorous pesticide residues from vegetables using washing solutions and boiling. *J. Agric. Sci.* 4: 71 - 76.

Sayyed, A. H. and Wright, D. J. 2004. Fipronil Resistance in the Diamondback Moth (Lepidoptera: Plutellidae): Inheritance and Number of Genes Involved. *J. Econ. Entomol*. 97(6): 2043-2050.

Schattenberg, H. J., Geno, P. W., Hsu, J. P., Fry, W. G. and Parker, R. P. 1996. Effect of household preparation on levels of pesticide residues in produce. *J. AOAC Int.* 79 (6): 1447–1453.

Schneider, M., Smagghe, G. and Viñuela, E. 2003. Susceptibility of *Hyposoter didymator* (Hymenoptera: Ichenumonidae) adults to several IGRs

pesticides and spinosad by different exposure methods. *IOBC/wprs Bull.* 26:111-122.

Sekh, K., Nair, N., Bag, V. and Choudary, S. A. K. 2007. Bioefficacy of Spiromesifen – 240 sc (OBERON) against Red spider mite of Brinjal and effect on its natural enemies. *Pestology*, 31(1): 25-29.

Shaila, O., Rao, S. R. K. and Babu, R. T. 2013. Chemical compatibility of avermectins and chitin synthesis inhibitors with common fungicides against *Spodoptera litura. Eur. J. Zool. Res.* 2: 116-123.

Sharma, J., Satya, S., Kumar, V., Tewary, D. K. 2005. Dissipation of pesticides during bread making. *J. Chem. Health Saf.* 12:17-22.

Sharma, P. C. and Pathania, A. 2014. Susceptibility of tobacco caterpillar, spodoptera litura (fabricius) to some insecticides and biopesticides. *Indian J. Sci. Res. Technol.* 2(6): 24-30.

Sheikh, S. A., Nizamani, S. M., Jamali, A. A., Mirani, B. N., Panhwar, A. A. and Channa, M. J. 2012. Effect of household processing on the removal of pesticide residues in okra vegetable. *J. Basic Appl. Sci*. 8(1): 74 - 78.

Shirai, Y. 2006. Flight activity, reproduction and adult nutrition of the beet webworm, Spoladea recurvalis (Lepidoptera: Pyralidae). *J. Appl. Entomol. Zool.* 41(3): 405-414.

Showler, A. T. 2001. *Spodoptera exigua* oviposition and larval feeding preferences for pigweed, *Amaranthus hybridus*, over squaring cotton, *Gossypium hirsutum* and a comparison of free amino acids in each host plant. *J. Chem. Ecol.* 27 (10): 2013-2028.

Singh, D.,Wangchu, L. and Moond, S. K. 2007. Processed products of tamarind,

Nat. Product Radiance, 6(4): 315 - 321.

Singh, S. P. and Jalali, S. K. 1997. Management of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) *Spodoptera litura* in India. In: Wightman, J. V. and Rao, G.V. R. (eds), *Proceeding of the National Scientists Forum on Spodoptera litura (F.),* ICRISAT Asia, pp. 212-215.

Singh, K.M., Singh, M.P., Sureja, A.K. and Bhardwaj, R. 2012. Insecticidal activity of certain plants of Zingiberaceae and Araceae against *Spodoptera litura* F. and *Plutella xylostella* Saunders in cabbage. *Indian J. Entomol*. 74 (1): 62-68.

Soliman, K. M. 2001. Changes in concentration of pesticide residues in potatoes during washing and home preparation. *Food Chem. Toxicol*. 39: 887 - 891.

Soujanya, P.L., Rao, A.P., Madhumathi, T. and Rao, S.V., 2004. Efficacy of some newer insecticides against *Plutella xylostella* (L.) infesting cabbage. *The Andhra Agric. J*, 50(spl): 240-242.

Srinivasan, K., Viraktamath, C.A., Gupta, M. and Tewari, G.C. 1995. Geographical distribution, host range and parasitoids of serpentine leaf miner, *Liriomyza trifolii. Pest Mgmt hort. Ecosys.* 1: 93-100.

Stanley, J., Chandrasekaran, S., Regupathy, A. and Sheeba, J. R. 2006. Baseline toxicity of emamectin and spinosad to *Spodoptera litura*. *Ann. Plant Prot. Sci.* 14: 346-349.

Suby, S. B., Singh, B. and Gupta, G. P. 2008. Efficacy of certain newer insecticides with novel modes of action on tobacco caterpillar, *Spodoptera litura* (Fabricius). *Indian J. Entomol.* 70(2): 95-99.

Talikoti, L. S., Sridevi, D. and Ratnasudhakar, T. 2012. Relative toxicity of insect growth regulators against tobacco caterpillar, *Spodoptera litura* (Fabricius). *J. Entomol. Res.* 36(1): 31-34.

Tatagar. M. H, H. D., Mohankumar, M., Shivaprasad. and R. K. Mesta. 2009. Bio-efficacy of flubendiamide 20 WG against chilli fruit borers, *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (Fb.). *Karnataka J. Agric. Sci.,* 22(3):579-581.

Taylor, M. J., Hunter, K., Hunter, K. B., Lindsay, D. and Le Bouhellec, S. 2002. Multi residue method for rapid screening and confirmation of pesticides in crude extracts of fruits and vegetables using isocratic liquid chromatography with electrospray tandem mass spectrometry. *J. Chromatography A.* 982: 225 - 236.

Thappan, P., Keawsompong, S. and Chanpaisaeng, J. 2008. Isolation, toxicity and detection of cry gene in *Bacillus thuringiensis* isolates in Krabi province, Thailand. *J. Sci. Technol.* 30 (5): 597-601.

Thmoas, M. J. 1964. Studies on the susceptibility of common caterpillar pests to infection by *Bacillus thuringiensis* Berliner. M.Sc. (Ag) thesis, Agricultural College and Research Institute, Vellayani, Thrivandram.

Tindall, H. D. 1983. *Vegetables in the Tropics.* English Language Book Society / Mc Millan Publishers, Hong Kong, 527 P.

Tukaram, A. H., Hosamani, A. C., Naveena, R., and Santoshagowda, G. B. 2014. Bioassay of flubendiamide on spodoptera litura (fab) population collected from different host crops. *Int. J. Sci. Environ. Technol*. 3(6): 2225 – 2230.

Varghese, T. S. 2011. Bioefficacy and safety evaluation of biorational insecticides for the management of sucking pest complex of chilli (*Capsicum annuum* L.). Ph D (Ag) thesis, Kerala Agricultural University, Thrissur, 150p.

Varghese, T. S. and Mathew, T. B. 2013. Pesticide residues – Home remedies for

eliminating pesticide residues from green chilli fruits. In: Proceedings of International Conference on Insect Science; 14 -17 February 2013; University of Agricultural Science, Dharvad, Karnataka, pp 120.

Vassarmidaki, M, Harizanis, P. C. and Katsikis, S. 2000. Effects of applaud on the growth of silkworm (Lepidoptera: Bombycidae). *J. Econ. Entomol.* 93: 290-292.

Vemuri, S. B., Rao, C. S., Darsi, R., Reddy, H. A., Aruna, M., Ramesh, B. and Swarupa, S. 2014. Methods for removal of pesticide residues in tomato. *Food Sci. Technol.* 2(5): 64-68.

Vemuri, S. B., Rao, C. S., Swarupa, S., Darsi, R., Reddy, H. A. and Aruna, M. 2015. Simple decontamination methods for removal of pesticide residues in brinjal. *Scholars J. Agric.Vet. Sci.* 2(1A): 27-30.

Vijayasree, V., Bai, H., Beevi, S. N., Mathew, T. B., George, T. and Xavier, G. 2015. Persistence and effect of processing on reduction of chlorantraniliprole residues on brinjal and okra fruits. *Environ. Monitoring Assess.* 187: 299.

Vijayasree, V., Bai, H., Beevi, S. N., Mathew, T. B., Kumar, V., George, T. and Xavier, G. 2013. Persistence and effects of processing on reduction of chlorantraniliprole residues on cowpea fruits. *Bull. Environ. Contamination Toxicol.* 90 (4): 494-498.

Vijayasree, V., Bai, H., Mathew, T. B., George, T., Xavier, G., Kumar, N. P. and Kumar, S. V. 2014. Dissipation kinetics and effect of different decontamination techniques on the residues of emamectin benzoate and spinosad in cowpea pods. *Environ. Monitoring Assess.* 186:4499-4506.

Walia, S., Boora, P. and Kumari, B. 2010. Effect of processing on dislodging of cypermethrin residues on brinjal. *Bull. Environ. Contaminantion Toxicol*. 84: 465 - 468.

Wheeler, W. 2002. Role of research and regulation in 50 years of pest management in agriculture. *J. Agric. Food Chem.* 50: 4151 - 4155.

WHO [World Health Organisation]. 2003. WHO Monitoring System– Food Contamination Monitoring and Assessment Programme [on line]. Available:http://www.who.int/foodsafety/chem/gems/en/index1.html.

Wyniger, R. 1962. *Pests of Crops in Warm Climates and their Control.* Verlag Fur Recht und Gessellschaft, Basel, 240 p.

Xavier, G., Chandran, M., George, T., Beevi, N. S., Mathew, T. B., Paul, A., Arimboor, R., Vijayasree, V., Kumar, G. T. P. and Rajith, R. 2014. Persistence and effect of processing on reduction of fipronil and its metabolites in chilli pepper (*Capsicum annuum* L.) fruits. *Environ. Monitoring Assess.* 186: 5429–5437.

Yamad , H., Koshihara, T. and Tanaka, K. 1979. *Biology and seasonal life history of the Hawaiian beet webworm, Hymenia recurvalis (Fabricius).* Bulletin of the vegetable ornamental crops research station Series No. 6, 171p.

Yang, A., Park. J. H., El-Aty, A. M A., Choi, J. H., Oh, J. H., Do, J. A., Kwon, K., Shim, K. H., Choi, O. J. and Shim, J. H. 2012. Synergistic effect of washing and cooking on removal of multi-classes of pesticides from various food samples, *Food Control*, 28*:* 99-10.

Zanella, R., Primel, E. G., Glonclaves, F. F. and Martins, A. F. 2000. Development and validation of high performance chromatography on the determination of cloma zone residues in surface water. *J. Chromatography*, 9: 257 – 262.

Zhang, Y., Ma, Y., Wan, P. J., Mu, L. and Li, G. Q. 2013. *Bacillus thuringiensis* Insecticidal Crystal Proteins Affect Lifespan and Reproductive Performance of *Helicoverpa armigera* and *Spodoptera exigua* Adults. *J. Econ. Entomol.* 106(2): 614-621.

Zhang, Z. Y., Liu, X. J. and Hong, X.Y. 2007. Effects of home preparation on pesticide residues in cabbage. *Food Control*, 18: 1484 - 1487.

Zohair, A. 2001. Behaviour of some organophosphorus and organochlorine pesticides in potatoes during soaking in different solutions. *Food Chem. Technol.* 39: 751-755.

Appendices

APPENDIX-I

Weather data during the survey

Period (fortnight interval)	Temperature (^{0} C)		Relative humidity (%)	Rain fall (mm)
	Max. temp	Min. temp		
March 1st fortnight	32.00	22.7	92.5	12.5
March 2nd fortnight	32.9	23.1	91.4	3.3
April 1st fortnight	32.3	24.3	90.1	12.5
April 2nd fortnight	32.5	24.7	92.7	18.0
May 1st fortnight	31.4	24.1	91.2	25.9
May 2nd fortnight	32.4	25.3	88.9	4.7
June 1st fortnight	30.5	24.9	92.8	3.4
June 2nd fortnight	31.0	25.5	92.1	2.03

APPENDIX-II

PROFORMA FOR SURVEY ON PESTICIDE USE PATTERN IN AMARANTH AGAINST PESTS OF AMARANTH

Sl. No.	Particulars	Response of farmers
1	Location	
2	Name and address of farmer	
3	Age	
4	Pesticides mainly used against	
	d) Leaf webber	
	e) Spodoptera	
	f) Mites	
5	Major pesticides used	
6	Source of technical information regarding crop protection	
	a) Agriculture officers	
	b) Company representatives	
	c) Other progressive farmers	
	d) Own decisions	
	e) Media	
7	Source of plant protection chemicals	
8	Source of information on dose of pesticides	
	a) Agricultural officers	
	b) Pesticide shops	
	c) Other progressive farmers	
	d) Own decisions	
9	Frequency of insecticide application	
	e) Three day interval	
	f) Four day interval	
	g) Five day interval	
	h) Six day interval	
10	Attention towards labels on pesticide bottles before use	Yes/No
11	Awareness regarding pesticide residues	Yes/No
12	Dosage of pesticides applied	gL^{-1} or mlL^{-1}

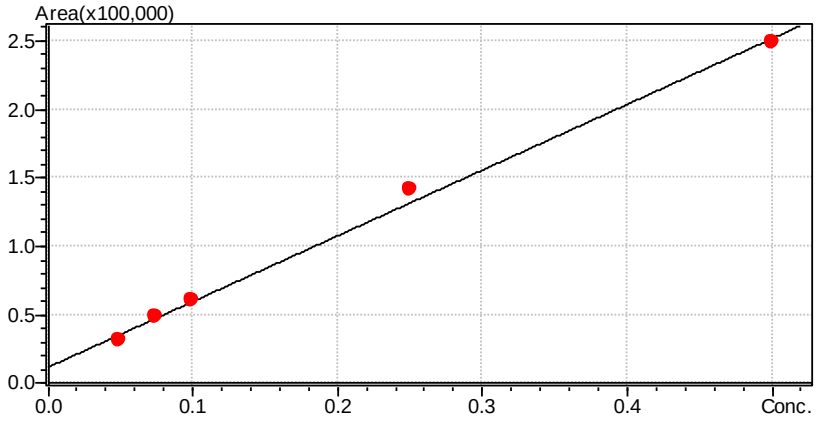
APPENDIX-III

Weather data during the crop period

Crop	Period (fortnight interval)	Temperature (^{0}C)		Relative humidity (%)	Rain fall (mm)
		Max. temp	Min. temp		
Farmers field	August 1st fortnight	29.2	23.4	85.37	11.3
	August 2nd fortnight	29.8	24.1	86.59	24.5
	September 1st fortnight	29.7	24.0	85.07	9.7
	September 2nd fortnight	30.7	24.4	84.7	5.0
Instructional Farm	October 1st fortnight	30.7	24.0	82.03	6.5
	October 2nd fortnight	30.3	23.6	87.16	8.3
	November 1st fortnight	30.8	23.4	84.8	2.7
	November 2nd fortnight	29.6	23.4	85.9	6.5

APPENDIX-IV

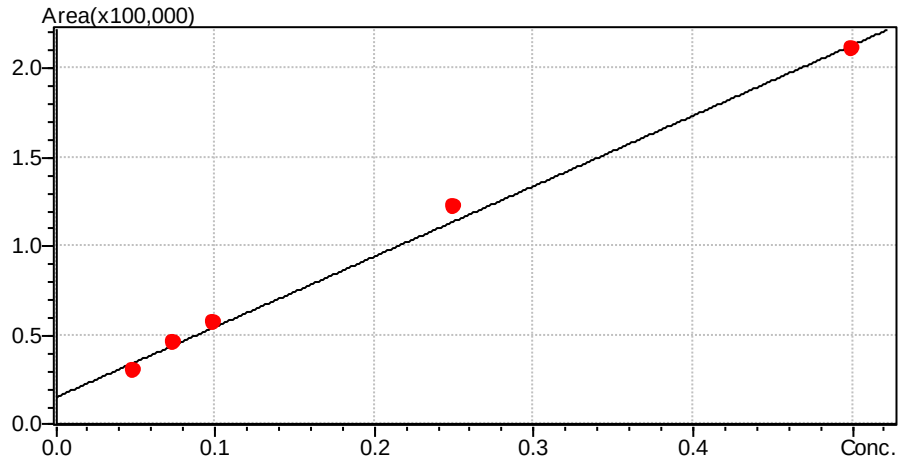
Calibration curves of insecticides



Y = aX + b, a = 479357.6, b = 12224.26, R^2 = 0.9962597, R = 0.9981281

Mean RF: 585280.0, RF SD: 54831.08, RF %RSD : 9.368349

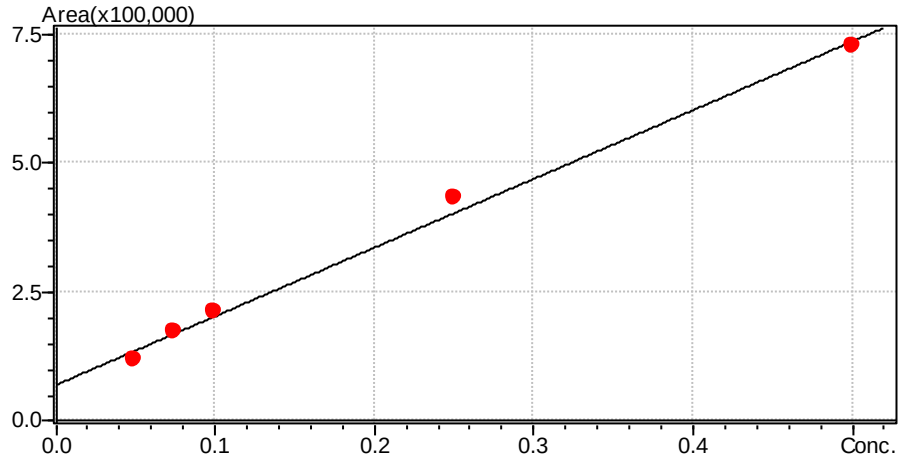
Calibration curve of dimethoate



Y = aX + b, a = 395579.2, b = 15668.6, R^2 = 0.9954473, R = 0.9977210

Mean RF : 535575.1, RF SD : 76011.49, RF %RSD : 14.19250

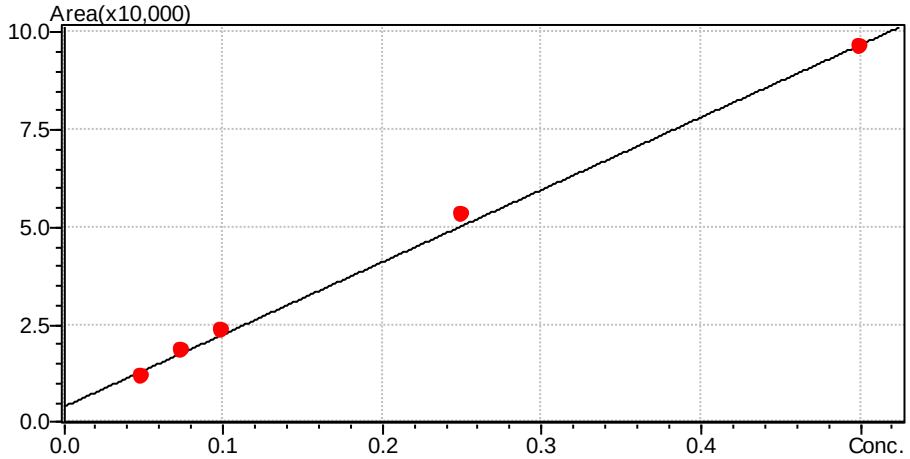
Calibration curve of malathion



Y = aX + b, a = 1332620, b = 71327.2, R^2 = 0.9946988, R = 0.9973459

Mean RF : 1982831, RF SD : 362144.3, RF %RSD : 18.26400

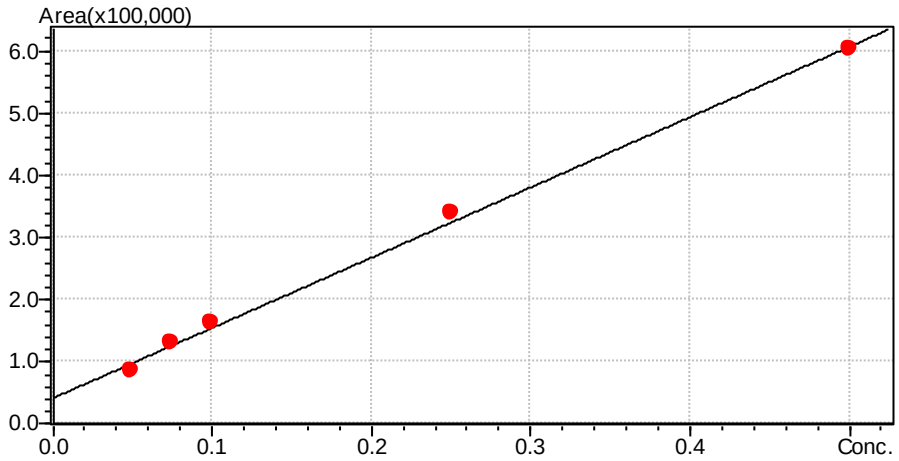
Calibration curve of chlorpyriphos



Y = aX + b, a = 185571.9, b = 4167.843, R^2 = 0.9980365, R = 0.9990178

Mean RF : 222255.5, RF SD : 19244.89, RF %RSD : 8.658903

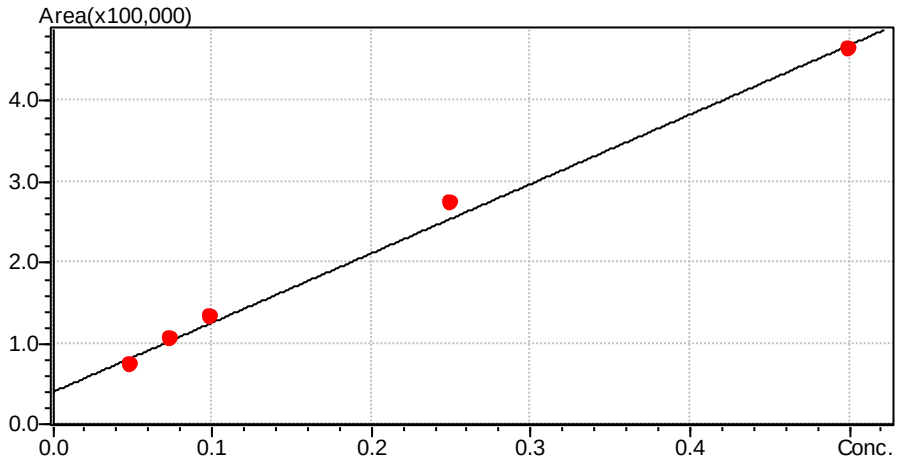
Calibration curve of quinalphos



Y = aX + b, a = 1130056, b = 42623.25, R^2 = 0.9975202, R = 0.9987593

Mean RF : 1518733, RF SD : 221534.9, RF %RSD : 14.58682

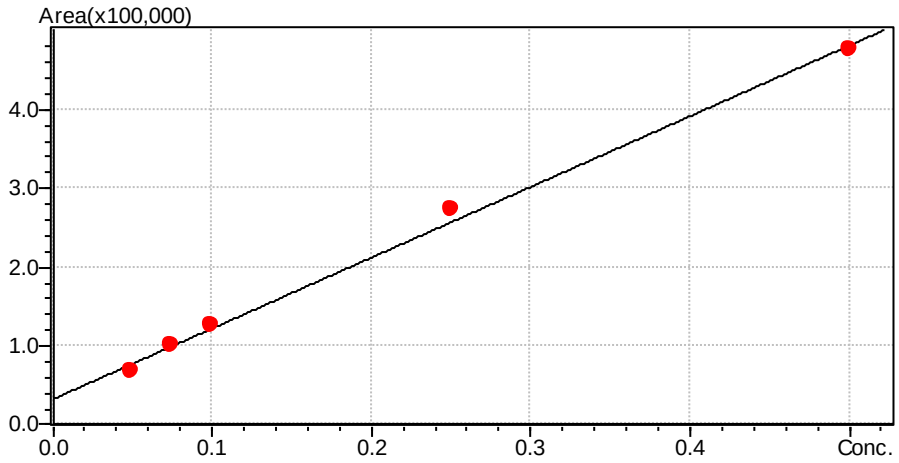
Calibration curve of profenophos



Y = aX + b, a = 856883.4, b = 41325.56, R^2 = 0.9949650, R = 0.9974793

Mean RF : 1231672, RF SD : 206077.7, RF %RSD : 16.73153

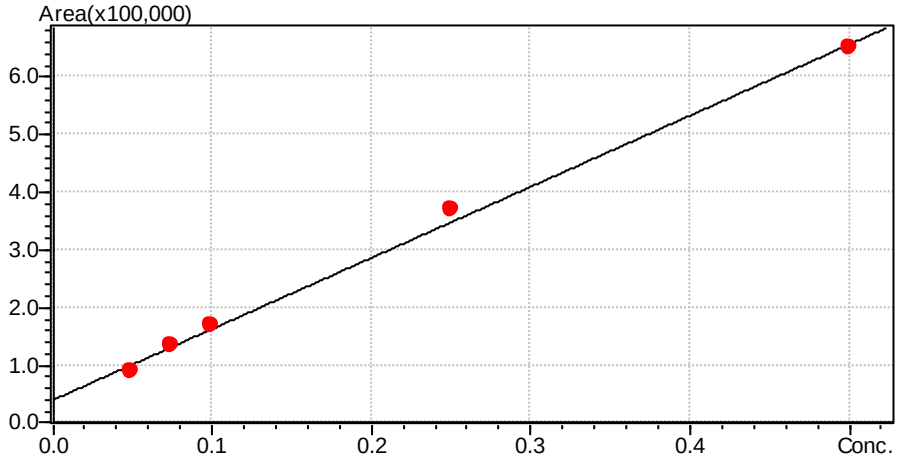
Calibration curve of ethion



Y = aX + b, a = 898096.2, b = 33188.26, R^2 = 0.9960596, R = 0.9980278

Mean RF : 1195523, RF SD : 159444.9, RF %RSD : 13.33684

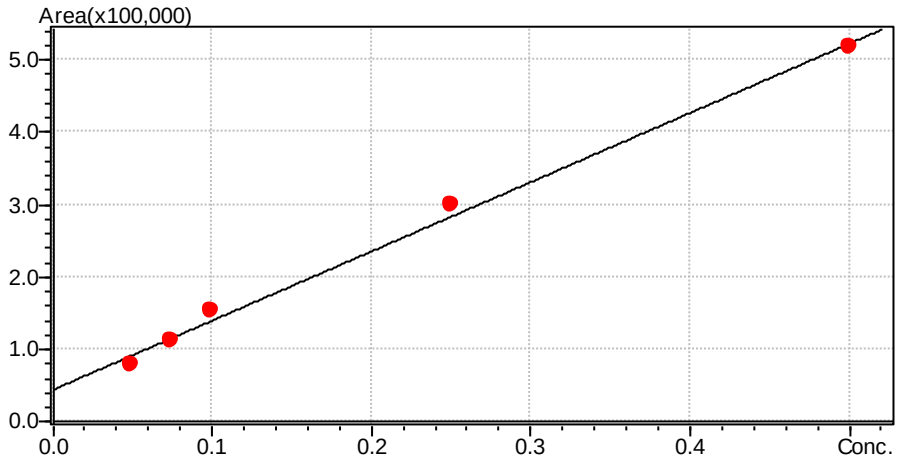
Calibration curve of bifenthrin



Y = aX + b, a = 1233170, b = 40603.28, R^2 = 0.9969946, R = 0.9984962

Mean RF : 1597709, RF SD : 196835.6, RF %RSD : 12.31986

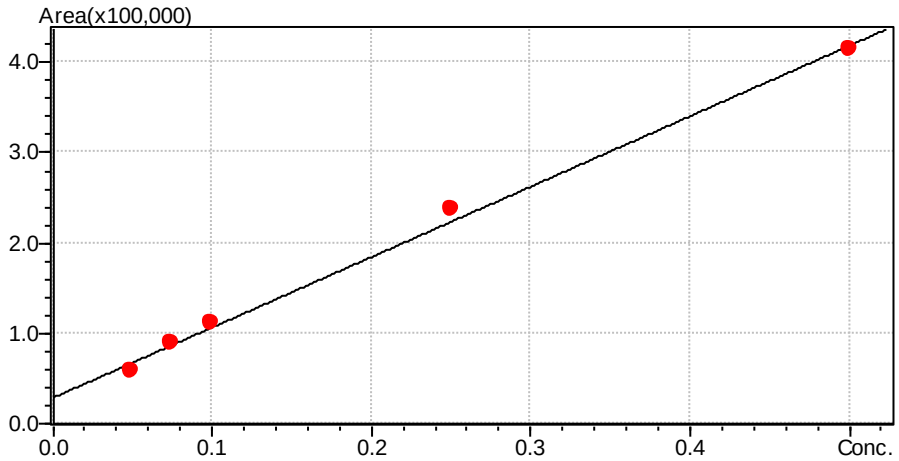
Calibration curve of lambda cyhalothrin



Y = aX + b, a = 955605.3, b = 45446.28, R^2 = 0.9951400, R = 0.9975670

Mean RF : 1367863, RF SD : 229484.3, RF %RSD : 16.77685

Calibration curve of cypermethrin

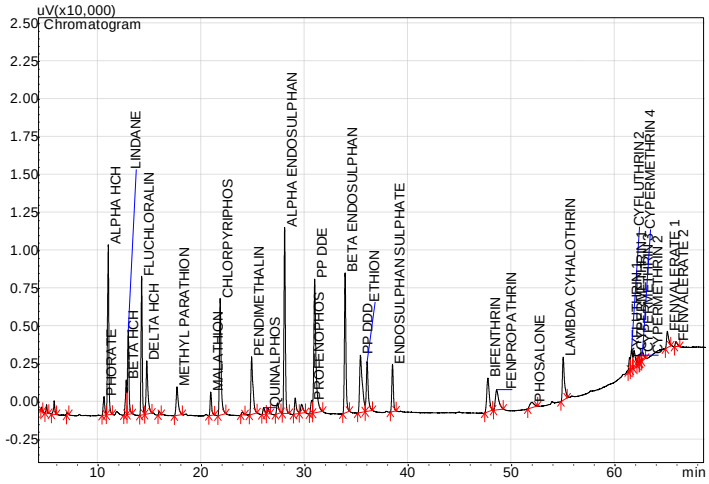


Y = aX + b, a = 777208.5, b = 29941.05, R^2 = 0.9965494, R = 0.9982732

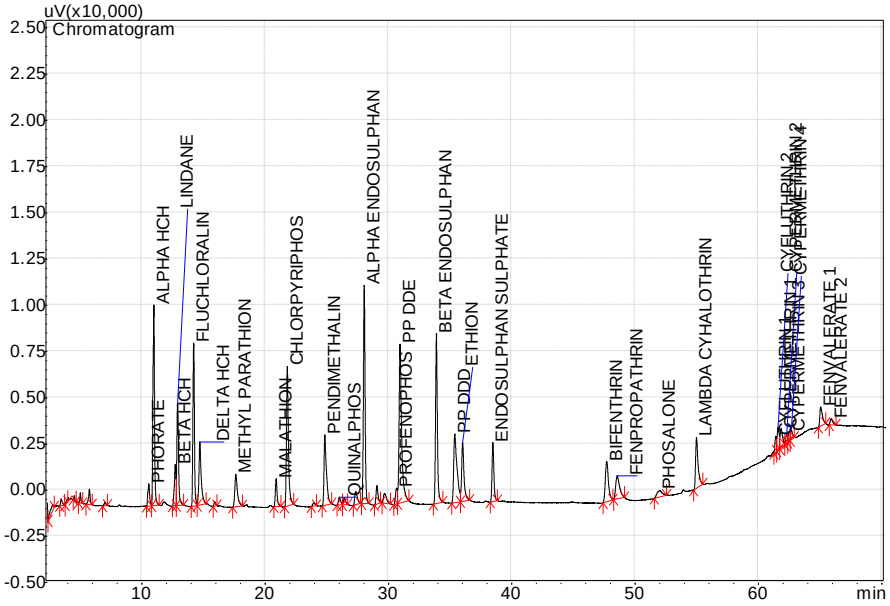
Mean RF : 1047884, RF SD : 148225.5, RF %RSD : 14.14523

Calibration curve of fenvalerate

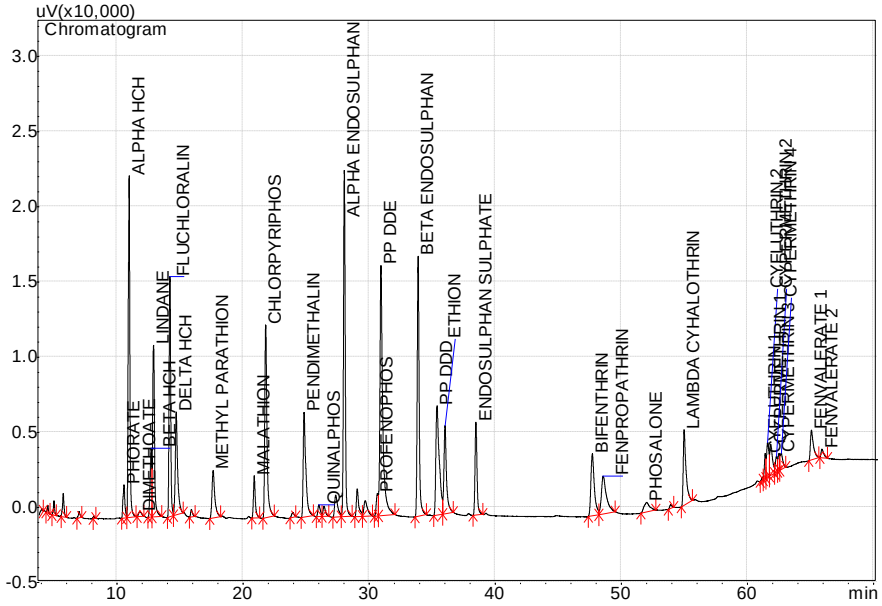
APPENDIX-V



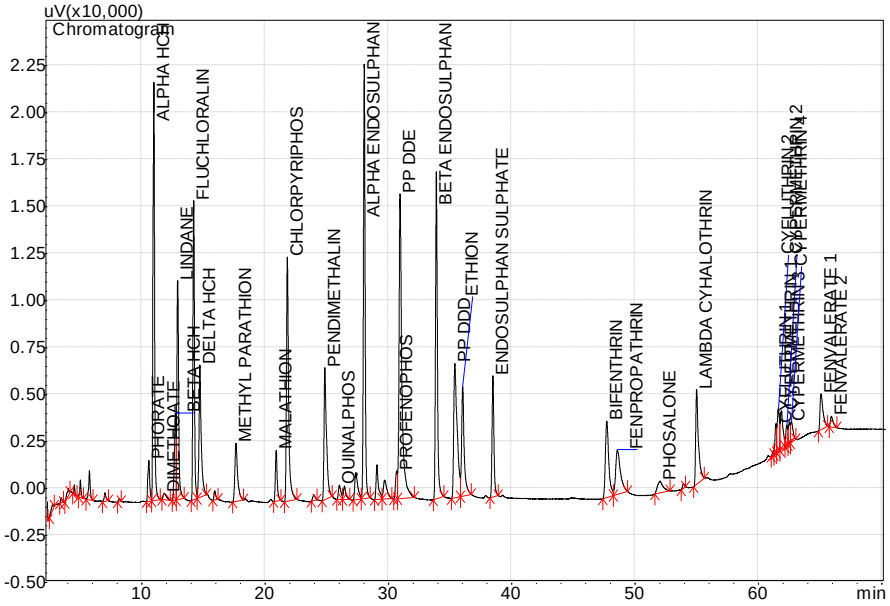
ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.563	0.05236	ppm	9	12445	1244
2	ALPHA HCH	10.972	0.05054	ppm	10	98300	11211
4	BETA HCH	12.706	0.05152	ppm	11	20965	2312
5	LINDANE	12.900	0.04984	ppm	12	53475	5585
6	FLUCHLORALIN	14.201	0.05155	ppm	13	76789	9174
7	DELTA HCH	14.696	0.05198	ppm	14	43794	3510
8	METHYL PARATHION	17.621	0.05155	ppm	16	26861	1882
9	MALATHION	20.882	0.05210	ppm	17	15526	1547
10	CHLORPYRIPHOS	21.794	0.05127	ppm	18	86235	7722
11	PENDIMETHALIN	24.840	0.05059	ppm	20	52314	3813
12	QUINALPHOS	26.010	0.04634	ppm	21	5452	435
13	ALPHA ENDOSULPHAN	28.032	0.05028	ppm	24	113855	12291
14	PROFENOPHOS	30.667	0.05686	ppm	27	10232	885
15	PP DDE	30.940	0.05051	ppm	28	125361	8853
16	BETA ENDOSULPHAN	33.880	0.05034	ppm	29	93477	9249
17	PP DDD	35.360	0.05165	ppm	30	69880	3813
18	ETHION	36.008	0.04900	ppm	31	42908	3287
19	ENDOSULPHAN SULPHATE	38.469	0.04883	ppm	32	33046	3117
21	BIFENTHRIN	47.697	0.04779	ppm	33	38193	2235
22	FENPROPATHRIN	48.536	0.04885	ppm	34	29905	1348
23	PHOSALONE	52.009	0.04635	ppm	35	10104	342
24	LAMBDA CYHALOTHRIN	54.978	0.05025	ppm	36	38787	2860
25	CYFLUTHRIN 1	61.386	0.05290	ppm	37	7650	857
26	CYFLUTHRIN 2	61.591	0.05011	ppm	38	15008	1300
27	CYPERMETHRIN 1	61.835	0.04935	ppm	39	15605	1108
28	CYPERMETHRIN 2	62.266	0.04077	ppm	40	4593	575
29	CYPERMETHRIN 3	62.490	0.04732	ppm	42	5733	605
30	CYPERMETHRIN 4	62.657	0.05232	ppm	43	7407	587
31	FENVALERATE 1	65.060	0.04784	ppm	44	15249	1088
32	FENVALERATE 2	65.886	0.05369	ppm	45	4455	324



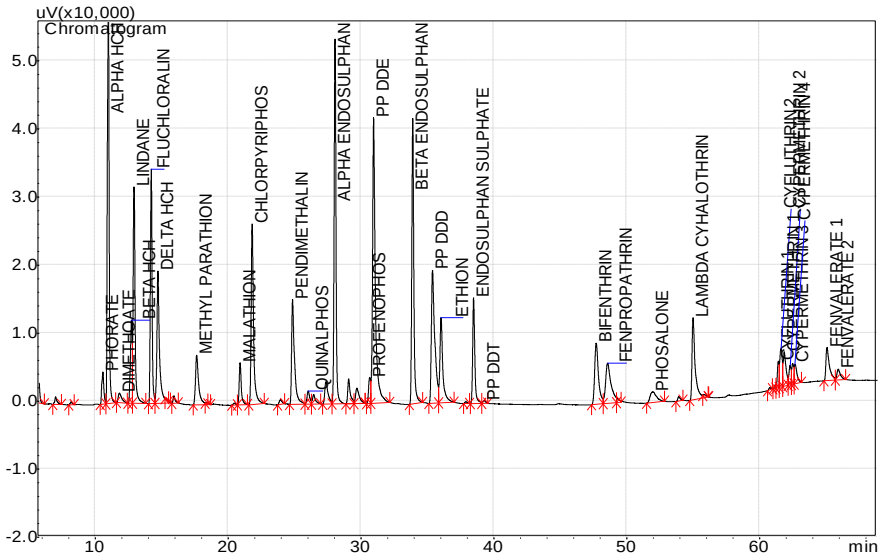
ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.559	0.05149	ppm	9	12286	1231
2	ALPHA HCH	10.971	0.05020	ppm	10	97489	10847
4	BETA HCH	12.704	0.05043	ppm	11	20399	2222
5	LINDANE	12.892	0.05048	ppm	12	54421	5543
6	FLUCHLORALIN	14.199	0.05102	ppm	13	76226	8817
7	DELTA HCH	14.697	0.05166	ppm	14	43436	3415
8	METHYL PARATHION	17.613	0.04969	ppm	16	26028	1772
9	MALATHION	20.889	0.05089	ppm	17	15226	1536
10	CHLORPYRIPHOS	21.794	0.04963	ppm	18	84391	7565
11	PENDIMETHALIN	24.838	0.05015	ppm	20	51957	3833
12	QUINALPHOS	26.013	0.04423	ppm	21	5236	420
13	ALPHA ENDOSULPHAN	28.033	0.04962	ppm	24	112580	11800
14	PROFENOPHOS	30.655	0.04935	ppm	27	8969	870
15	PP DDE	30.932	0.04980	ppm	28	123629	8592
16	BETA ENDOSULPHAN	33.886	0.05103	ppm	29	94645	9194
17	PP DDD	35.386	0.05106	ppm	30	69028	3721
18	ETHION	36.008	0.04934	ppm	31	43152	3196
19	ENDOSULPHAN SULPHATE	38.459	0.04950	ppm	32	33506	3195
21	BIFENTHRIN	47.702	0.04774	ppm	33	38161	2192
22	FENPROPATHRIN	48.558	0.04540	ppm	34	27519	1251
23	PHOSALONE	51.988	0.04707	ppm	35	10256	348
24	LAMBDA CYHALOTHRIN	54.980	0.04992	ppm	36	38541	2752
25	CYFLUTHRIN 1	61.413	0.04762	ppm	37	6936	823
26	CYFLUTHRIN 2	61.591	0.04612	ppm	38	13916	1209
27	CYPERMETHRIN 1	61.850	0.04397	ppm	39	14140	1012
28	CYPERMETHRIN 2	62.301	0.04381	ppm	40	4974	492
29	CYPERMETHRIN 3	62.520	0.04148	ppm	41	5044	508
30	CYPERMETHRIN 4	62.666	0.04436	ppm	42	6035	516
31	FENVALERATE 1	65.044	0.04690	ppm	43	14918	1034
32	FENVALERATE 2	65.914	0.05405	ppm	44	4499	329



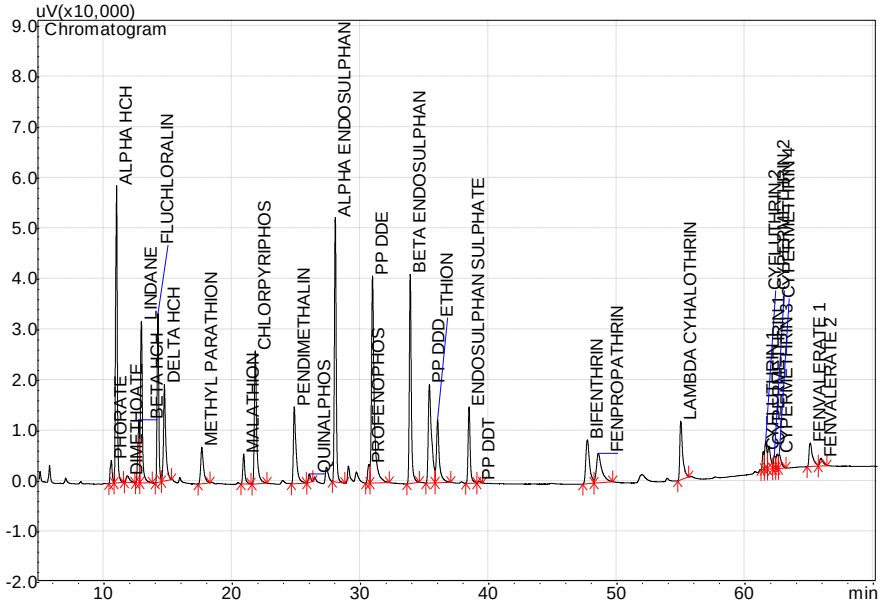
ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.565	0.11248	ppm	10	23434	2234
2	ALPHA HCH	10.972	0.09639	ppm	11	205765	22694
3	DIMETHOATE	11.816	0.09357	ppm	12	5158	326
4	BETA HCH	12.711	0.09486	ppm	13	43389	4593
5	LINDANE	12.910	0.09439	ppm	14	119028	11423
6	FLUCHLORALIN	14.205	0.11274	ppm	15	142219	15972
7	DELTA HCH	14.704	0.09280	ppm	16	89063	6865
8	METHYL PARATHION	17.632	0.10260	ppm	18	49681	3171
9	MALATHION	20.892	0.10706	ppm	19	29120	2815
10	CHLORPYRIPHOS	21.801	0.11346	ppm	20	156238	12818
11	PENDIMETHALIN	24.845	0.11181	ppm	22	101805	6978
12	QUINALPHOS	26.011	0.09846	ppm	23	10790	802
13	ALPHA ENDOSULPHAN	28.033	0.10718	ppm	26	224398	23013
14	PROFENOPHOS	30.661	0.09019	ppm	29	15827	1532
15	PP DDE	30.942	0.10455	ppm	30	256250	16653
16	BETA ENDOSULPHAN	33.889	0.10497	ppm	31	186786	17300
17	PP DDD	35.395	0.09889	ppm	32	137772	7297
18	ETHION	36.026	0.10550	ppm	33	83533	5892
19	ENDOSULPHAN SULPHATE	38.476	0.10239	ppm	34	69727	6197
21	BIFENTHRIN	47.707	0.11057	ppm	35	79208	4154
22	FENPROPATHRIN	48.556	0.10844	ppm	36	71129	2530
23	PHOSALONE	52.016	0.09573	ppm	37	20492	659
24	LAMBDA CYHALOTHRIN	54.978	0.10258	ppm	39	78012	5029
25	CYFLUTHRIN 1	61.410	0.09261	ppm	41	13023	1661
26	CYFLUTHRIN 2	61.609	0.10680	ppm	42	30505	2318
27	CYPERMETHRIN 1	61.850	0.10164	ppm	43	29843	2062
28	CYPERMETHRIN 2	62.313	0.10163	ppm	44	12229	1081
29	CYPERMETHRIN 3	62.503	0.08943	ppm	45	10699	1165
30	CYPERMETHRIN 4	62.698	0.10102	ppm	46	15798	1090
31	FENVALERATE 1	65.077	0.09857	ppm	47	33227	1985
32	FENVALERATE 2	65.910	0.08882	ppm	48	8820	586



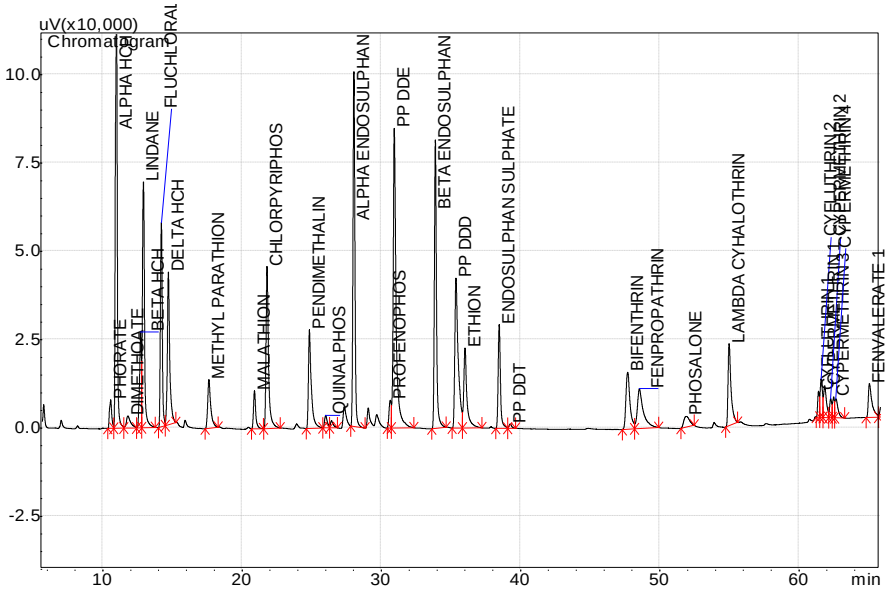
ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.563	0.11113	ppm	10	23187	2183
2	ALPHA HCH	10.972	0.09622	ppm	11	205363	22217
3	DIMETHOATE	11.827	0.10170	ppm	12	6495	348
4	BETA HCH	12.715	0.09454	ppm	13	43224	4643
5	LINDANE	12.903	0.09375	ppm	14	118089	11657
6	FLUCHLORALIN	14.201	0.11206	ppm	15	141499	15925
7	DELTA HCH	14.704	0.09223	ppm	16	88434	7052
8	METHYL PARATHION	17.628	0.10073	ppm	18	48846	3106
9	MALATHION	20.894	0.10399	ppm	19	28361	2707
10	CHLORPYRIPHOS	21.795	0.11420	ppm	20	157067	12993
11	PENDIMETHALIN	24.838	0.10676	ppm	22	97724	7026
12	QUINALPHOS	26.009	0.09954	ppm	23	10902	779
13	ALPHA ENDOSULPHAN	28.033	0.10565	ppm	26	221431	23090
14	PROFENOPHOS	30.661	0.08592	ppm	29	15110	1490
15	PP DDE	30.938	0.10472	ppm	30	256661	16219
16	BETA ENDOSULPHAN	33.878	0.10432	ppm	31	185662	17414
17	PP DDD	35.383	0.09864	ppm	32	137420	7163
18	ETHION	36.012	0.10827	ppm	33	85524	5851
19	ENDOSULPHAN SULPHATE	38.467	0.10172	ppm	34	69267	6452
21	BIFENTHRIN	47.703	0.10901	ppm	35	78189	4088
22	FENPROPATHRIN	48.560	0.10030	ppm	36	65502	2405
23	PHOSALONE	52.033	0.09410	ppm	37	20150	638
24	LAMBDA CYHALOTHRIN	54.987	0.10155	ppm	39	77243	5038
25	CYFLUTHRIN 1	61.424	0.09823	ppm	41	13783	1570
26	CYFLUTHRIN 2	61.625	0.09886	ppm	42	28335	2282
27	CYPERMETHRIN 1	61.864	0.10437	ppm	43	30588	2054
28	CYPERMETHRIN 2	62.305	0.09871	ppm	44	11862	1079
29	CYPERMETHRIN 3	62.519	0.09990	ppm	45	11934	1150
30	CYPERMETHRIN 4	62.677	0.09554	ppm	46	14855	1135
31	FENVALERATE 1	65.075	0.09715	ppm	47	32723	1909
32	FENVALERATE 2	65.918	0.08876	ppm	48	8813	583



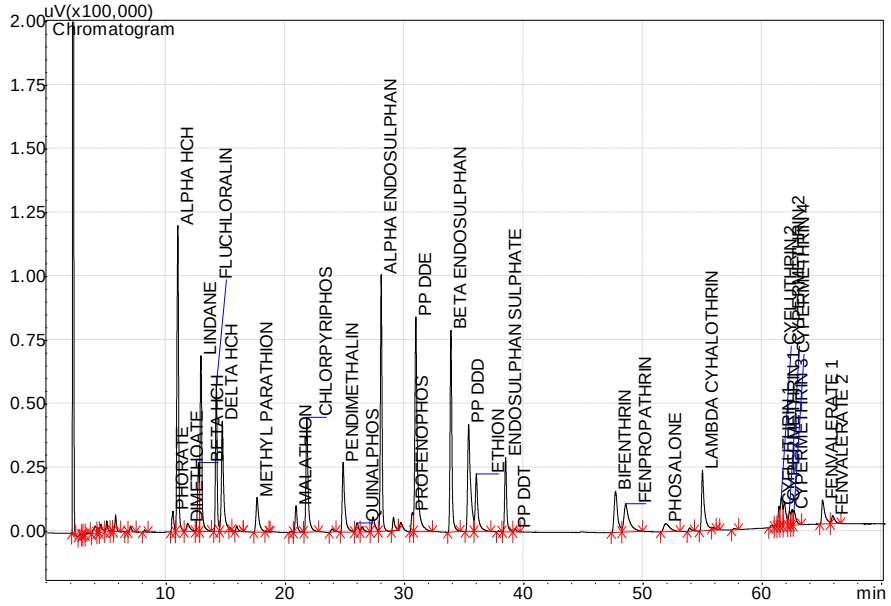
ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.561	0.26579	ppm	10	51457	4746
2	ALPHA HCH	10.976	0.24391	ppm	11	551567	59859
3	DIMETHOATE	11.810	0.22600	ppm	12	26926	1450
4	BETA HCH	12.704	0.23587	ppm	13	116362	12230
5	LINDANE	12.900	0.23828	ppm	14	330758	31798
6	FLUCHLORALIN	14.205	0.27084	ppm	15	311278	34428
7	DELTA HCH	14.706	0.25116	ppm	16	264698	19428
8	METHYL PARATHION	17.613	0.27016	ppm	19	124588	7347
9	MALATHION	20.888	0.26710	ppm	22	68714	6206
10	CHLORPYRIPHOS	21.798	0.27174	ppm	23	334386	26551
11	PENDIMETHALIN	24.838	0.27211	ppm	25	231413	15448
12	QUINALPHOS	26.015	0.27066	ppm	26	28430	1980
13	ALPHA ENDOSULPHAN	28.034	0.26197	ppm	29	525098	53532
14	PROFENOPHOS	30.644	0.24811	ppm	32	42341	3850
15	PP DDE	30.939	0.25203	ppm	33	613481	41962
16	BETA ENDOSULPHAN	33.884	0.25461	ppm	34	442364	41930
17	PP DDD	35.374	0.24621	ppm	35	349533	19548
18	ETHION	36.013	0.26202	ppm	36	196066	12547
19	ENDOSULPHAN SULPHATE	38.463	0.25366	ppm	38	173325	15507
20	PP DDT	39.255	0.25232	ppm	39	5790	453
21	BIFENTHRIN	47.692	0.26524	ppm	40	180250	9024
22	FENPROPATHRIN	48.563	0.24934	ppm	41	168604	5943
23	PHOSALONE	51.960	0.26080	ppm	43	55223	1617
24	LAMBDA CYHALOTHRIN	54.988	0.26749	ppm	45	201620	12075
25	CYFLUTHRIN 1	61.411	0.26063	ppm	49	35756	3899
26	CYFLUTHRIN 2	61.620	0.26055	ppm	50	72542	5687
27	CYPERMETHRIN 1	61.852	0.26831	ppm	51	75224	5081
28	CYPERMETHRIN 2	62.300	0.26335	ppm	52	32522	2902
29	CYPERMETHRIN 3	62.495	0.26844	ppm	53	31813	3060
30	CYPERMETHRIN 4	62.657	0.24766	ppm	54	41069	2854
31	FENVALERATE 1	65.081	0.25764	ppm	55	89594	4851
32	FENVALERATE 2	65.923	0.25347	ppm	56	29283	1600



ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.562	0.26186	ppm	1	50738	4608
2	ALPHA HCH	10.974	0.24321	ppm	2	549924	58866
3	DIMETHOATE	11.800	0.22152	ppm	3	26190	1336
4	BETA HCH	12.711	0.23731	ppm	4	117107	12512
5	LINDANE	12.906	0.24004	ppm	5	333342	31934
6	FLUCHLORALIN	14.203	0.26584	ppm	6	305935	33417
7	DELTA HCH	14.702	0.22432	ppm	7	234927	19125
8	METHYL PARATHION	17.621	0.24786	ppm	8	114617	7275
9	MALATHION	20.888	0.26327	ppm	9	67765	6028
10	CHLORPYRIPHOS	21.792	0.26829	ppm	10	330501	26294
11	PENDIMETHALIN	24.833	0.26417	ppm	11	224990	15255
12	QUINALPHOS	26.002	0.19431	ppm	12	20610	1732
13	ALPHA ENDOSULPHAN	28.030	0.25452	ppm	13	510630	52305
14	PROFENOPHOS	30.661	0.24904	ppm	14	42498	3761
15	PP DDE	30.934	0.25081	ppm	15	610525	40952
16	BETA ENDOSULPHAN	33.874	0.25303	ppm	16	439666	41398
17	PP DDD	35.376	0.24541	ppm	17	348383	19547
18	ETHION	36.017	0.26438	ppm	18	197766	12488
19	ENDOSULPHAN SULPHATE	38.470	0.25465	ppm	19	174005	15158
20	PP DDT	39.267	0.24768	ppm	20	5543	432
21	BIFENTHRIN	47.709	0.26202	ppm	21	178146	8759
22	FENPROPATHRIN	48.538	0.25421	ppm	22	171970	5866
24	LAMBDA CYHALOTHRIN	54.969	0.23937	ppm	23	180542	11609
25	CYFLUTHRIN 1	61.409	0.22386	ppm	24	30782	3576
26	CYFLUTHRIN 2	61.600	0.22991	ppm	25	64165	5521
27	CYPERMETHRIN 1	61.864	0.24200	ppm	26	68061	4545
28	CYPERMETHRIN 2	62.271	0.23826	ppm	27	29373	2617
29	CYPERMETHRIN 3	62.506	0.25350	ppm	28	30051	2884
30	CYPERMETHRIN 4	62.663	0.23893	ppm	29	39564	2723
31	FENVALERATE 1	65.093	0.25591	ppm	30	88981	4617
32	FENVALERATE 2	65.930	0.24810	ppm	31	28615	1540



ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.560	0.49139	ppm	1	92691	8208
2	ALPHA HCH	10.975	0.50444	ppm	2	1162237	122407
3	DIMETHOATE	11.803	0.51550	ppm	3	74514	3471
4	BETA HCH	12.708	0.50925	ppm	4	257837	27131
5	LINDANE	12.910	0.50533	ppm	5	723697	69545
6	FLUCHLORALIN	14.198	0.48549	ppm	6	540799	57819
7	DELTA HCH	14.703	0.47610	ppm	7	514166	43240
8	METHYL PARATHION	17.610	0.47201	ppm	8	214820	13807
9	MALATHION	20.885	0.49022	ppm	9	123911	10823
10	CHLORPYRIPHOS	21.789	0.48840	ppm	10	578247	45842
11	PENDIMETHALIN	24.833	0.48523	ppm	11	403720	28005
12	QUINALPHOS	25.995	0.46132	ppm	12	47960	3526
13	ALPHA ENDOSULPHAN	28.029	0.49714	ppm	14	981952	100281
14	PROFENOPHOS	30.639	0.50931	ppm	15	86196	7841
15	PP DDE	30.923	0.50034	ppm	16	1214924	84739
16	BETA ENDOSULPHAN	33.874	0.49770	ppm	17	857586	81627
17	PP DDD	35.356	0.50441	ppm	18	720665	42408
18	ETHION	36.008	0.49235	ppm	19	361674	22629
19	ENDOSULPHAN SULPHATE	38.465	0.49675	ppm	20	339815	29372
20	PP DDT	39.248	0.48633	ppm	21	18224	1325
21	BIFENTHRIN	47.691	0.49187	ppm	22	328305	16207
22	FENPROPATHRIN	48.531	0.49925	ppm	23	341492	11392
23	PHOSALONE	51.910	0.42156	ppm	24	89046	3067
24	LAMBDA CYHALOTHRIN	54.972	0.46365	ppm	25	348652	23299
25	CYFLUTHRIN 1	61.397	0.45836	ppm	26	62509	7376
26	CYFLUTHRIN 2	61.584	0.45273	ppm	27	125085	10839
27	CYPERMETHRIN 1	61.845	0.46627	ppm	28	129127	9000
28	CYPERMETHRIN 2	62.271	0.45898	ppm	29	57069	5387
29	CYPERMETHRIN 3	62.486	0.46041	ppm	30	54455	5934
30	CYPERMETHRIN 4	62.634	0.48412	ppm	31	81817	5363
31	FENVALERATE 1	65.051	0.50001	ppm	32	175477	9568
32	FENVALERATE 2	65.902	0.50673	ppm	33	60757	3224



ID#	Name	Ret. Time	Conc.	Units	Peak#	Area	Height
1	PHORATE	10.559	0.48992	ppm	15	92424	8160
2	ALPHA HCH	10.972	0.50405	ppm	16	1161335	119977
3	DIMETHOATE	11.794	0.50640	ppm	17	73018	3299
4	BETA HCH	12.707	0.50617	ppm	18	256242	27091
5	LINDANE	12.910	0.50829	ppm	19	728061	68811
6	FLUCHLORALIN	14.198	0.49119	ppm	20	546891	57544
7	DELTA HCH	14.694	0.53916	ppm	21	584106	43116
8	METHYL PARATHION	17.612	0.50813	ppm	24	230967	13735
9	MALATHION	20.886	0.49237	ppm	27	124443	10640
10	CHLORPYRIPHOS	21.791	0.48580	ppm	28	575330	45101
11	PENDIMETHALIN	24.832	0.49176	ppm	30	409004	27395
12	QUINALPHOS	26.010	0.52340	ppm	31	54319	3707
13	ALPHA ENDOSULPHAN	28.026	0.48974	ppm	34	967585	100634
14	PROFENOPHOS	30.644	0.49489	ppm	36	83775	7515
15	PP DDE	30.935	0.49711	ppm	37	1207099	84160
16	BETA ENDOSULPHAN	33.876	0.49702	ppm	38	856408	79026
17	PP DDD	35.364	0.50028	ppm	39	714730	42049
18	ETHION	36.007	0.49199	ppm	40	361415	22595
19	ENDOSULPHAN SULPHATE	38.466	0.49883	ppm	42	341239	29307
20	PP DDT	39.254	0.51367	ppm	43	19677	1385
21	BIFENTHRIN	47.686	0.49125	ppm	44	327902	16250
22	FENPROPATHRIN	48.529	0.49874	ppm	45	341139	11188
23	PHOSALONE	51.887	0.56852	ppm	46	119965	3322
24	LAMBDA CYHALOTHRIN	54.977	0.53251	ppm	48	400265	23757
25	CYFLUTHRIN 1	61.397	0.52831	ppm	53	71973	8049
26	CYFLUTHRIN 2	61.593	0.54106	ppm	54	149232	11650
27	CYPERMETHRIN 1	61.841	0.51659	ppm	55	142829	9608
28	CYPERMETHRIN 2	62.271	0.52958	ppm	56	65928	5881
29	CYPERMETHRIN 3	62.494	0.52430	ppm	57	61990	6158
30	CYPERMETHRIN 4	62.647	0.51668	ppm	58	87428	5806
31	FENVALERATE 1	65.044	0.49476	ppm	59	173618	9424
32	FENVALERATE 2	65.886	0.49689	ppm	60	59534	3127

Abstract

ABSTRACT

Investigations on "Management of pests and pesticide residues in vegetable amaranth (*Amaranthus tricolor* L.)" were carried out at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2013-15. The main objective of the work was to assess the bio-efficacy of new generation insecticides for the management of leaf feeding insect and mite pests of *A. tricolor* L and standardization of methods to remove pesticide residues in vegetable amaranth.

Field survey was conducted among ten farmers each from two different locations *viz*., Kalliyoor and Pappanchani. During survey, leaf webbers and leaf eating caterpillars were noticed as major insect pests while red spider mite was noticed to be minor pest. In these two locations, pesticides used by famers were malathion, chlorpyriphos, quinalphos, dimethoate and lambda cyhalothrin. The residues of pesticides detected in the farm gate samples collected from these locations were chlorpyriphos, quinalphos, profenophos, ethion, bifenthrin, lambda cyhalothrin, cypermethrin and fenvalerate.

Investigation was conducted on evaluation of bio-efficacy of new generation insecticides against *Hymenia recurvalis* and *Spodoptera litura*. The insecticides evaluated were chlorantraniliprole 0.006 %, novaluron 0.015 %, buprofezin 0.03 %, flubendiamide 0.0096 %, spinosad 0.015 %, emamectin benzoate 0.002 %, indoxacarb 0.015 %, thiacloprid 0.036 %, fipronil 0.01 %, *Bacillus thuringiensis* kurstaki 5ml L^{-1}, *Beauveria bassiana* 2 %, *B. bassiana* (ITCC 6063) CFU - $10^8 g^{-1}$, Oxuron - 5ml L^{-1}, malathion - 0.1 % and neem seed kernel extract - 5 %. These insecticides were sprayed on bulk crop under field conditions, treated leaves were taken from randomly selected plants and kept in Petri plates. Second instar *H. recurvalis* and *S. litura* larvae were released into these Petri plates separately under laboratory conditions. In laboratory investigation, emamectin benzoate, indoxacarb, thiacloprid, flubendiamide, novaluron, fipronil and *B. thuringiensis* were found to be effective against *H. recurvalis*. Against *S. litura*, emamectin benzoate, indoxacarb, flubendiamide,

novaluron and fipronil were found to be effective. Among the different treatments tested against mites, buprofezin, emamectin benzoate, spiromesifen and diafenthiuron were found to be effective. Six insecticides cum acaricides viz., buprofezin 25 SC- 0.03 %, %, emamectin benzoate 1 WG - 0.002%, diafenthiuron 50 WP - 0.06%, spiromesifen 22.9 SC- 0.018%, fenpyroximate 5 EC- 0.003% and ethion 50 EC- 0.15% were tested for efficacy against red spider mite *Tetranychus* spp. The best treatments identified in laboratory screening were evaluated under field conditions in two separate trials.

Field studies were conducted in famer's field at Nedinjal and in the Instructional farm, College of Agriculture, Vellayani by using insecticides from the above effective treatments. Among the above selected insecticides fipronil, emamectin benzoate, indoxacarb, novaluron and flubendiamide were effective against *H. recurvalis*. Against *S. litura*, emamectin benzoate, indoxacarb and flubendiamide, were found to be effective. In management of mites, buprofezin and spiromesifen were found equally effective under field conditions.

Subsequent to identification of safer new generation insecticides for field level management of insect and mite pests of amaranth, a series of laboratory experiments were conducted to standardize household practices to remove pesticide residues at consumer level. The recently launched natural product "KAU Veggie Wash" was also evaluated in addition to the presently recommended consumer items from kitchen shelf. All the insecticides detected in survey of farm gate samples were selected for the study and in addition two organophosphates *viz.,* dimethoate representing the systemic group and malathion as insecticide check were evaluated. Among the different treatments evaluated, dipping amaranth plants in 1% KAU veggie wash (20 minutes) + cooking was found to be most effective, followed by 1% KAU veggie wash (20 minutes) + washing for removal of organophosphate and synthetic pyrethroid insecticide residues from amaranth

From the above study, it is concluded that flubendiamide 39.35% SC was the most effective and safer (green labeled) new generation insecticide in managing leaf webber (*H. recurvalis*), leaf eating caterpillar (*S. litura*) and buprofezin (green labeled) was the effective and safer acaricide for the management of red spider mite. Among ten household practices evaluated for their efficacy to remove pesticide residues from amaranth, dipping in 1% KAU veggie wash for 20 minutes followed by cooking was selected as the most effective treatment capable of significant reduction of dimethoate (86.27 %), malathion (96.47 %), chlorpyriphos (86.45 %), quinalphos (81.02 %), profenophos (76.73 %), ethion (77.11%), bifenthrin (61.03 %), lambda cyhalothrin (66.05 %), cypermethrin (62.72 %) and fenvalerate (65.07 %).

Thus it may be concluded that pests of vegetable amaranth could be efficiently managed by the application of flubendiamide 0.0096 % for insect pests and buprofezin 0.03 % for red spider mite and pesticide residues in market baskets of red amaranth can be effectively managed by dipping in KAU Veggie Wash solution @ 10 ml/L of water for 20 minutes followed by two normal washings just before cooking.