EFFICACY AND BIOSAFETY OF NEW GENERATION INSECTICIDES FOR THE MANAGEMENT OF FRUIT BORERS OF COWPEA, BRINJAL AND OKRA

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(2010-21-104)

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2013

DECLARATION

I hereby declare that this thesis entitled **"Efficacy and biosafety of new generation insecticides for the management of fruit borers of cowpea, brinjal and okra"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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LIST OF ABBREVIATIONS

%	Per Cent
/m^2	Per sqare metre
@	At the rate of
a.i.	Active Ingredient
BDL	Below detectable level
C.D.	Critical Difference
cm	Centimetre(s)
CRM	Certified reference material
DAP	Days after planting
DAS	Days after spraying
EC	Emulsifiable Concentrate
et al	And others
Fig.	Figure
g	Gram
h	Hour
ha^{-1}	per hectare
kg	Kilogram
m	Metre
ml	Millilitre
mm	Millimetre
m/z	mass / charge ratio
ppm	Parts per million
RSD	Relative standard deviation
SC	Suspension Concentrate
SD	Standard deviation
SG	Soluble Granule
Spp	Species
Viz.	namely
WG	Wettable granules
WP	Wettable powder

INTRODUCTION

1. INTRODUCTION

Pests and diseases have plagued farmers since the origin of agriculture. Often, certain groups of pests dominated in the cropping systems, causing tremendous losses to agricultural crops. According to the type of damage caused, agricultural pests are recognized as stand reducers, leaf mass consumers, assimilate sappers, turgor reducers, architecture modifiers and fruit feeders (Pedigo, 2002). The fruit feeders represent a menacing group, taking heavy toll of the target crops as they directly invade the economic part of the plant. Among the fruit feeders, the borers aptly referred to as the hidden pests, are notorious on account of their obscure nature. A wide range of agricultural crops are targeted by these borers.

Vegetables, the "protective supplementary foods" of mankind are ravaged by a plethora of pests, among which the fruit borers are noxious. Yard long bean or cowpea (*Vigna unguiculata sesquipedalis*(L.) Verdc.), brinjal (*Solanum melongena* var. *esculentum*(L.) Nees) and okra (*Abelmoschus esculentus* L. (Moench)) are the most common and extensively grown vegetable in Kerala, occupying a dominant place in the food basket of Keralites. However, the productivity of these vegetables is abysmally low in the State and the increasing incidence of pests and diseases contribute to a lion share of the crop loss. Apparently, the tender and supple nature of these "soft crops" and cultivation under high moisture and input regime amplify their vulnerability to pest attack, especially the fruit borers.

The legume pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae) one of the most devastating post-flowering pests of vegetable cowpea is capable of inflicting 17 to 53 per cent yield losses (Liao and Lin, 2000). In certain cases, up to 80 per cent yield losses were also recorded (Jackai and Adalla, 1997; Sharma, 1998). The pest attacks the buds, flowers and pods and is distributed throughout the tropical and subtropical regions of the world.

Leucinodes orbonalis Guenee (Lepidoptera: Pyralidae) is the most destructive pest of brinjal, widely distributed in the Indian sub-continent. The incidence of the pest occurs either sporadically or in outbreak every year throughout the country wherever brinjal is grown. As a result of its attack on shoots and fruits, considerable damage occurs affecting adversely the quality and yield of the crop. Yield losses of 85 to 90 per cent have been reported from various states of India (Patnaik 2000; Misra 2008; Jagginavar *et al.* 2009).

The fruit borer *Earias vitella* Fabricius (Lepidoptera: Noctuidae) is found throughout the year, attacking shoots and fruits of okra. It causes extensive damage resulting in 40 to 53 per cent reduction in yield (Rabindra, 2001). The quality of the seeds is also affected due to the infestation of the borer (Singh *et al.* 1985).

Farmers rely mostly on chemical insecticides to mitigate the losses due to these pests in commercial cultivation. After hatching, the neonate larvae bore into the shoots or fruits, thus becoming inaccessible to the action of the chemicals applied. This cryptic habit of the pest reduces the chances to kill the fruit borer larvae and has resulted in misuse of pesticides. It is not unusual for the vegetable growers to give 10 to12 sprays in okra and five to six sprays in brinjal in a season. Thus, the fruits which are harvested at short intervals are likely to retain high level of pesticide residues which may be hazardous to the consumers (Sardana *et al.*, 2006). Further, the excess reliance on chemicals has led to the problems of resistance, resurgence, environmental pollution and decimation of useful fauna and flora.

The major classes of insecticides which were very popular in insect control in developing countries till now comprise organochlorines, organophosphates, carbamates and synthetic pyrethroids. The old chemistries (especially organophosphates and carbamates) attack the nervous systems of insects. Since, insects and other animals have similar tissues, reproductive, hormonal and nervous systems; these compounds have potential for non target effects. This commonality has rendered old insecticides highly toxic to non-target organisms including human.

Recently, various novel groups of pesticides with unique modes of action, low dosage requirement, more tissue-specificity and activated in different ways inside the target cells of insects have been introduced. Unlike the conventional ones, most of the new molecules have excellent toxicological and eco toxicological profiles and are widely acclaimed as potent compounds for management of borers of different vegetables. The Central Insecticide Board has approved a number of these chemicals against tissue borers of vegetables. Most of the states in India have already launched the molecules for pest management. However, no concerted effort has been undertaken in Kerala to test the new molecules and recommend them for the control of the borers of vegetables. In spite of this, several products both registered and unregistered are being used by the farmers in the State. The results of this study will help in identifying suitable new generation insecticides for managing the fruit borers of the vegetables.

As integrated pest management strategy envisaging orchestration of suitable techniques and methods against the pests in a compatible manner, integration of insecticides in the strategies should be based on its compatability with other components too. Entomopathogenic fungi *viz*., *Beauveria bassiana* (Blas.) Vuill, *Lecanicillium (Verticillium) lecanii* Humber and *Metarhizhium anisopliae* (Metsch) are the biological control agents generally included in the IPM of vegetable crops. Therefore, it is indispensable to evaluate the compatibility of the insecticides to these bioagents in case of concurrent application.

Arbitrary use of pesticides leads to undesirable loads of residues of the toxicants in marketable vegetables. Among 529 market samples of different vegetables tested throughout India, 63.5 per cent were contaminated with residues of different pesticides (Anonymous, 2003). Concurrently, national and international concern about pesticide related environmental problems and food quality is mounting. Ardent demand from the general public for reduced use of pesticides is on the increase in a number of countries. Since application of pesticides on any crop lead to unwanted residues, information on nature and quantity of chemicals which prevail is very important. Prior to the recommendation of any pesticide for field use, it is mandatory to study its degradation kinetics. The data generated would aid in fixing the waiting periods, a safety milestone for any insecticide in a crop.

Processing treatments such as washing, peeling, cooking etc. prior to consumption of foods have been instrumental in reducing the pesticide residue levels substantially. Studies on some commercial processing techniques on residues in food are a part of the registration requirements for pesticides in many countries. Apart from this, information on the efficacy of processing necessarily reassures consumers on the safety of the food. Though literature abounds with the decontamination techniques for pesticide residues in food, the emphasis has been mainly on the conventional organophosphorus, organochlorine and synthetic pyrethroid insecticides. Information on processing methods for removal of new generation insecticide residues is sketchy.

In the light of the above, the present study was undertaken with the following objectives.

- To evaluate the efficacy of new generation insecticides against fruit borers of cowpea, brinjal and okra.
- To assess the safety of these insecticides to entomopathogenic fungi.
- To determine the persistence and degradation of the insecticides.
- To standardize methods to decontaminate the insecticide residues from the fruits.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Insect pests are one of the important restrictive factors in vegetable production. Among the different groups, the lepidopteran fruit borers take a heavy toll of the various crops. The literature pertaining to the efficacy of insecticides against *M. vitrata, L. orbonalis* and *E. vitella*, the fruit borers of cowpea, brinjal and okra selected for the study are reviewed and presented here. The work on dissipation kinetics of the selected insecticides on different vegetables and the compatibility of the insecticides to the entomopathogenic fungi evaluated in the study are detailed. The literature related to practices tested in the study to decontaminate residues from vegetables too are appraised and presented.

2.1. EFFICACY OF INSECTICIDES AGAINST FRUIT BORERS OF COWPEA, BRINJAL AND OKRA

The efficacy of several groups of insecticides including the conventional organochlorines, organophosphates, carbamates and synthetic pyrethroids and the newer classes like neonicotinoids, naturalytes, diamides, phenyl pyrrazoles, thiourea compounds, oxadiazines, pyridine azomethine compounds etc. against the flower and pod borer of cowpea *M. vitrata,* the shoot and fruit borer of brinjal *L. orbonalis* and the shoot and fruit borer of okra *E. vitella* have been reported.

2.1.1. Flower and pod borer of cowpea

Conventional insecticides

Studies in Bangladesh suggested that four high volume sprays of cypermethrin 0.008% (first spray at flowering initiation, second at 50 per cent flowering, third at 100 per cent flowering and fourth at 100 per cent pod setting) were effective for protecting the pigeon pea crop against *Maruca.* This schedule also offered the highest benefit-cost ratio of 6.23 (Rahman and Rahman, 1988). Studies in

Nigeria also revealed the efficacy of one spray of a mixture of cypermethrin 0.0075 % + dimethoate 0.03% (Ezueh, 1990), cypermethrin 0.01 %, bifenthrin 0.01 % and cyhalothrin 0.003 % or two applications of cypermethrin 0.0075 % + dimethoate 0.03% at 10 days interval starting from bud formation (Amatobi, 1994) against the pod borer on cowpea. Cypermethrin 0.005 % (Ictamethrin 10 EC), acetamiprid 0.002 % (Mospilan 20 SP), deltamethrin 0.003 % (Decis 52.8 EC), and lambda-cyhalothrin (Karate) 0.0025 % were also reported to be effective against the insect, reducing the larval population and thus infestation by 80.91, 79.94, 77.12 and 76.55 per cent, respectively (Soliman, 2011). The highest mean grain yields at Minjibir were obtained from plots sprayed with imidacloprid 0.003 % + cypermethrin 0.005 % (1391 kg ha^{-1}) while highest mean grain yield (924 kg ha^{-1}) in Samaru in Nigeria was from monocrotophos 0.05% applied three times (Ajeigbe *et al.*, 2012).

Reports from India indicated that application of endosulfan 0.07 %, carbaryl 0.10 % and chlordane 0.07 % three times at an interval of 15 days, starting from the blossom stage proved very effective in controlling *M. testulalis* and other pod borers in red gram in Karnataka (Sangappa *et al.*, 1977). In Uttar Pradesh, *M. testulalis* and other pod borers on red gram were effectively controlled with sprays of endosulfan (0.07%), monocrotophos (0.03%) and dimethoate (0.03%) @ 1000 l ha^{-1} (Srivastava, 1980). Fenvalerate 0.01% + miraculan a plant growth stimulant which gave the highest yield (8.57 q ha^{-1}) followed by monocrotophos 0.04% + miraculan (8.31 q ha^{-1}), fenvalerate 0.01% (8.27 q ha^{-1}), monocrotophos 0.04% (7.38 q ha^{-1}) and endosulfan 0.07% + miraculan (7.27 q ha^{-1}) were effective in controlling the pod borer in greengram (Venkaria and Vyas, 1985). On pigeonpea, monocrotophos 0.05 % and endosulfan 0.07 % (Samolo and Patnaik, 1986); deltamethrin 0.0025% and fluvalinate 0.03 % (Bhalani and Prasana, 1987); cypermethrin 0.005% or dimethoate 0.03 % at flowering or when egg numbers reached two per meter row, and repeated at 10–15 days interval (Rahman, 1991) and cypermethrin 0.0045%, deltamethrin 0.0025 %, fenvalerate 0.005 % and endosulfan 0.05 % (three sprays) (Sontakke and Mishra,

1991) were effective against this pest. The pod borer damage on pigeon pea was low by application of lambda cyhalothrin (25 g a.i. ha^{-1}) and profenophos (100 ml ha^{-1}) (Durairaj and Ganapathy, 1998).

The cumulative pod borer damage caused by *Catechrysops cnejus* F., *M. vitrata*, *Helicoverpa armigera* Hb. and *Etiella zinckenella* Tret. was the lowest in quinalphos 0.04% (6.2 per cent) followed by profenofos 0.1% (6.5 per cent), alanycarb 0.06% (6.6 per cent), endosulfan 0.07% (7.5 per cent), dimethoate 0.03% (7.5 per cent) and acephate 0.075% (7.7 per cent). Grain yield was also maximum in quinalphos 0.04% (378.3 kg ha^{-1}) with high cost: benefit ratio (1:2.9) (Ganapathy and Durairaj, 2000). Better control and highest yield were achieved when cypermethrin at 0.007 %, azadirachtin at 0.01 % or delfin at 53.000 unit mg^{-1} were applied at 10 days interval until harvest (Abdullah *et al.*, 2001). Two sprays of chlorpyriphos @ 0.05 % at 10 days interval was effective in reducing larval population (48.86 per cent) of the pod borer in black gram (Lakshmi *et al.*, 2002). Spraying of beta cyfluthrin 25 SC @ 18.75 g a.i.ha^{-1} attributed to higher yield and less larval incidence (Das and Srivastava, 2002). Chlorpyriphos 0.04 % recorded lowest pod damage of 5.07 per cent on black gram and chlorpyriphos 0.5 kg ai ha^{-1} recorded lowest per cent damage (2.62) on red gram (AICRP, 2003). Dichlorvos (0.08%) was found effective against *M. vitrata* in pigeon pea (Srinivasan and Sridhar, 2008).

Need based application of chlorpyriphos 0.05 % during 45 days after planting at moderate incidence of pod borers in cowpea and a second spray using neem seed kernel extract 5 % at 60 days after sowing was effective against pod borers in a study conducted at Kerala Agricultural University (Suja, 2003). In another study at the institution, chlorpyriphos 0.05%, acephate 0.05 % and profenophos 0.05 % were found effective against *M. vitrata* in cowpea (Varghese, 2003).

New generation insecticides

The efficacy of several newer classes of insecticides against the pod borer has been documented. Spinosad 2.5 SC was the most promising treatment in terms of least mean pod damage (11.85 per cent) and grain damage (13.51 per cent) as against 28.65 and 41.17 per cent pod and grain damage in untreated control in pigeon pea (Bhoyar *et al.*, 2004). In chick pea, spinosad 48 SC (@ 0.2 ml l^{-1} proved significantly superior in reducing the pod borer incidence to the extent of 84.43 and 82.04 per cent after first and second spray, respectively and the treatment recorded the highest grain yield of 14.53 q ha^{-1} (Ladaji, 2004). The results of a study in blackgram revealed that spinosad 0.009% was the most effective in reducing the larval population of *M. vitrata* and pod damage resulting in a significant increase (79.37 per cent) in seed yield (Sonune *et al.,* 2010).

Novaluron @ 2.5 ml l^{-1} recorded lowest pod borer damage (0.4%) in blackgram (AICRP, 2003). At 0.01% concentration,the biorational provided good protection and registered significantly lesser incidence of *Maruca* larvae and higher yield (Srinivasan, 2008).

Chlorantraniliprole 0.009 % registered only 1.61 per cent of pod damage due to *M. vitrata* on pigeon pea (Haritha, 2008).

Indoxacarb (0.5 ml l^{-1}) was one of the best treatments against *M. vitrata* (Ladaji, 2004). Indoxacarb 30 WDG sprayed at the rates of 20, 30 and 40 g a.i. ha^{-1} significantly reduced pod borer damage in beans. Consequently, marketable yield increased significantly by 66 to 71 per cent over the untreated control plots (Quilloy *et al.*, 2007). At 0.008% concentration, the insecticide was found to be effective in reducing the larval population of *M. vitrata* and the pod damage of blackgram (Ashok kumar and Shivaraju, 2009). In black gram, significant reduction was recorded in pod borer infestation when treated with indoxacarb 0.008% (Sonune *et al.*, 2010).

Indoxacarb 14.5 SC (3.45 ml 10 l^{-1}) was found to be effective against *M. vitrata* in cowpea (Patel *et al.*, 2012).

Studies conducted in India revealed that thiodicarb at 613 ppm was effective against the pest in cowpea (Dharmasena, 1993). At 400 g a.i. ha^{-1} the insecticide proved effective against *M. testulalis* with a mean per cent control of 87.98 and highest pod-yield (4950.90 kg ha^{-1}) in cowpea (Liao and Lin, 2000). Similarly, thiodicarb 75 WP @ 750 g a.i. ha^{-1} provided good protection and registered significantly lesser incidence of *Maruca* larvae and higher yield in pigeon pea (Das and Srivastava, 2002). In black gram too, thiodicarb @ 0.04% was effective recording lower pod damage of 3.5 per cent (AICRP, 2003).

Flubendiamide 480 SC at 48 g a.i. ha^{-1} showed minimum larval population of pod borers in black gram (Patil *et al.*, 2008). The insecticide @ 48 or 36 g a.i. ha^{-1} was the most effective treatment in reducing the damage to flowers and pods by *M. testulalis* in pigeonpea (Dey *et al.*, 2012).

Though the Directorate of plant protection, quarantine and storage and the Central Insecticide Board and Registration Committee (C.I.B & R.C) under the Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India has notified different insecticides against various pests of crops in its official website, no insecticides were suggested against fruit borer of cowpea(CIBRC, 2009).

2. 1. 2 Shoot and fruit borer of brinjal

Conventional insecticides

Experiments conducted in Pakistan revealed mechanical control in combination with spraying of cypermethrin 0.05 % and monocrotophos 0.07 % alternatively at 5 per cent fruit infestation provided effective control of the borer in Bangladesh (Islam and Karim, 1994). Hand picking damaged shoots and fruits and spraying of cypermethrin 0.05 % at 15 days interval were reported to cause 25.78 and 63.93 per cent reduction in fruit infestation, respectively from another trial conducted in Bangladesh (Mannan and Begum, 1999). Marshal 20 EC @ 1.5 ml l^{-1} performed the best, ensuring the lowest shoot and fruit infestation (7.59 per cent and 4.16 per cent, respectively) rendering 78.37 per cent reduction in shoot and 88.06 per cent and 88.99 per cent reduction in fruit by number and weight, respectively. It was followed by Suntap ® 50 SP @ 5 mg l^{-1} that kept shoot and fruit infestation level at 10.77 per cent and 11.53 per cent, respectively (Rahman *et al.*, 2009).

Teotia and Sinha (1972) reported that malathion 0.05 % was most toxic to newly hatched larvae of *L. orbonalis*. Spraying of carbaryl (1 kg a.i.ha^{-1}) was superior in reducing the shoot and fruit borer incidence (Krishnaiah, 1976). Studies conducted at Marathwada Agricultural University found that malathion 0.05 % spray was the best to control *L. orbonalis* (Lande, 1976). Application of lambda-cyhalothrin (31.5 to 50.0 ppm) and deltamethrin (20.0 ppm) provided complete control of *L. orbonalis*. The other insecticides tested, including a neem formulation (Neemactin 0.15 EC; 2.5 ml l^{-1}) and malathion (0.05%) (malathion 50 EC; 1.0 ml l^{-1}), were less effective (Rajavel *et al.*, 1989). Higher dose of potash (100 kg ha^{-1}) along with all the chemical treatments, *viz.*, carbaryl 0.15% + dicofol 0.036%, malathion 0.1% and bifenthrin 0.01% were effective against this shoot and fruit borer, the per cent infestation being low i.e., 3.8, 3.9, 4.7 and 5.0, respectively (Sudhakar *et al.*, 1998). Endosulfan 0.05 % was found effective in reducing shoot infestation (Sharma and Chhibber 1999; Reddy and Srinivasa, 2005). Schedule spray of cypermethrin 0.05 % at weekly interval showed the best efficacy in reducing shoot infestation of brinjal (Rahman *et al.*, 2002). Endosulfan + deltamethrin (0.07%+0.0025%) and endosulfan + fenvalerate (0.07% + 0.005%) were highly effective against the fruit borer, recording only 13.30 per cent damage as compared to 69.80 per cent in control (Abrol and Singh, 2003). B-cyfluthrin in combination with imidacloprid was also found to be very effective for the control of *L. orbonalis* (Bhargava *et al.*, 2003). Similar efficacy against this pest was noted by spraying carbosulfan 0.05% at weekly intervals (Kabir *et al.*, 2003; Bharadiya and Patel, 2005; Reddy and Srinivasa, 2005).

Endosulfan (0.05%) and agrospray oil T (0.2%) were superior in reducing the fruit infestation by *L. orbonalis*. However, on the basis of benefit-cost ratio, agrospray oil T (0.2%), lambda-cyhalothrin (0.004%), endosulfan (0.05%) and deltamethrin (0.0028%) were superior (Anil and Sharma, 2010). The lowest mean shoot as well as fruit infestation (0.6 and 13.8 per cent) was recorded in deltamethrin applied @ 28.00 g a.i. ha^{-1} followed by its application @ 21.00 g a.i. ha^{-1} (0.80 and 14.90 per cent) and cypermethrin @ 87.50 g a.i. ha^{-1} (0.70 and 17.90 per cent), respectively. The highest marketable fruit yield of 80.70 q ha^{-1} was recorded in deltamethrin @ 28.00 g a.i. ha^{-1} followed by 77.90 q ha^{-1} in deltamethrin @ 21.00 and 66.50 q ha^{-1} in cypermethrin @ 87.50 g a.i. ha^{-1} (Yadav and Sharma, 2011). In a field experiment conducted at Bihar, the highest ICBR (1:14.41) was obtained in plots treated with fenvalerate (0.150 kg a.i. ha^{-1}) followed by 1:13.85 in cypermethrin(0.050 kg a.i. ha^{-1}) and 1:12.99 in imidacloprid (0.025 kg a.i. ha^{-1}) (Singh and Kumar, 2011).

Experiments conducted in Kerala revealed that cypermethrin 0.015% was superior to carbaryl and other synthetic pyrethroids in controlling *L. orbonalis* (Sudharma, 1981). Repeated application of carbaryl 0.15 % was suggested in case of severe infestation of the pest (Nair, 1999). Malathion 0.05 % +neem oil was found to deter *L. orbonalis* in a study at Kerala Agricultural University (Bernice, 2000).

New generation insecticides

Application of emamectin benzoate (Proclaim 5 SG) @ 200 g a.i. ha^{-1} was found effective in reducing fruit damage by *L. orbonalis* in brinjal(Kumar and Devappa, 2006). Anil and Sharma (2010) suggested that emamectin benzoate (0.002%) was effective against the pest in brinjal. Similarly the insecticide at 15 g a.i. ha^{-1} recorded low infestation of shoot (10.95 per cent) and fruit (16.66 per cent). After two need-based applications, fairly good yield was obtained from brinjal (Chakraborthy and Sarkar, 2011).

Zhao *et al.* (2007) suggested that spinosad could be considered as a good alternative to high toxicity pesticides in egg plant fields.The lowest mean shoot and fruit infestations (7.47 and 9.88 per cent) and highest marketable fruit yield of 143.50 q ha^{-1} were recorded in the plots treated with spinosad 2.5 SC (50 g a.i. ha^{-1}) followed by indoxacarb 14.5 SC 50 g a.i. ha^{-1} (8.89 and 13.13 per cent), emamectin benzoate 5 SG 15 g a.i. ha^{-1} (10.95 and 16.66 per cent), respectively in a trial conducted at Beijing. The highest marketable fruit yield of 143.50 q ha^{-1} was recorded in spinosad treatment followed by indoxacarb and emamectin benzoate with 126.90 and 121.30 q ha^{-1}, respectively (Patra *et al.*, 2009).

The effectiveness of novaluron 0.01 % against *L. orbonalis* was recorded by Chatterjee and Roy (2004) and Sawant *et al.* (2004).

Chlorantraniliprole 20 SC @ 40 and 50 g a.i. ha^{-1} gave 95 to 97 per cent reduction in the shoot damage and 87 to 90 per cent reduction in fruit damage on number basis and 88 to 90 per cent on weight basis at ten days after the fourth spray, compared to untreated control and were safe to natural enemies (Misra, 2008). The insecticide (20 SC) at 20 and 60 g a.i. ha^{-1} significantly reduced shoot and fruit infestation and increased the yield significantly. However, 40 and 60 g a.i. ha^{-1} dosages of the insecticide showed better performance and gave significantly higher yields than the lower dosages. Considering the bio-efficacy of the insecticide and yield of egg plant, rynaxypyr 20 SC at 40 g a.i. ha^{-1} was suggested for effective management of egg plant shoot and fruit borer (Mandal *et al.*, 2010). After two need-based applications of chlorantraniliprole 20 EC + NSKE 5 %, less number of larvae per plant was recorded in brinjal(Chakraborthy and Sarkar, 2011).

Fipronil belonging to the phenyl pyrazole group of insecticides was found effective for the management of shoot and fruit borer in brinjal (Sahu *et al.*, 2004).

Flubendiamide 24 WDG when sprayed @ 0.012 % at five per cent fruit infestation gave the highest net return and BCR (7.45) (Lateef *et al.,* 2009). In another study by Lateef *et al.* (2009), application of flubendiamide 24 WDG @ 0.012 % at two per cent shoot and fruit infestations resulted in significant reduction of shoot (87.46 per cent) and fruit (81.43 per cent) infestations by *L. orbonalis.* Studies conducted in Karnataka revealed that flubendiamide 480 SC @ 90 and 72 g a.i. ha^{-1} were significantly superior in reducing the shoot and fruit damage by the borer with higher fruit yields (Jagginavar, *et al.*, 2009). After two need-based applications of flubendiamide @ 72 g a.i. ha^{-1} in brinjal, fairly good yields were produced (Chakraborthy and Sarkar, 2011).

The Directorate of plant protection, quarantine and storage and the Central Insecticide Board and Registration Committee (C.I.B & R.C) under the Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India has notified the insecticides viz., lambda-cyhalothrin 5 EC 15 g a.i. ha^{-1}, chlorpyrifos 20 EC 200 g a.i. ha^{-1}, cypermethrin 10 EC 50-60 g a.i. ha^{-1}, cypermethrin 0.25DP 50-60 g a.i. ha^{-1} , cypermethrin 25 EC 37-50 g a.i. ha^{-1} , endosulfan 2 DP 500 g a.i. ha^{-1} , fenpropathrin 30 EC 75–100 g a.i. ha^{-1}, fenvalerate 20 EC 75–100 g a.i. ha^{-1}, phosalone 35 EC 500 g a.i. ha^{-1} , quinalphos 20 AF 300-350 g a.i. ha^{-1}, quinalphos 25 EC 375 g a.i. ha^{-1} and triazophos 40 EC 500 g a.i. ha^{-1} and the new generation insecticides emamectin benzoate 5 SG 10 g a.i. ha^{-1} and thiodicarb 75 WP 470-750 g a.i. ha^{-1} against fruit borer of brinjal in its official website (CIBRC, 2009).

2. 1. 3 Shoot and fruit borer of okra

Conventional insecticides

Application of monocrotophos 0.05 % at 10 days interval recorded higher number of fruits and maximum weight of 1000 seeds of okra (Philomena and David, 1989). Higher seed yield was also obtained from the okra crop sprayed with fenvalerate 0.01 % (Sarkar and Nath, 1989). Malathion 50 EC and carbaryl 50 WP at

1000 ml ha^{-1} gave significant control of the pest. Dimethoate 30 EC and permethrin 50 EC were ineffective against shoot and fruit borers (*E. vitella* and *Earias insulana* Boisd.) of okra (Konar and Rai, 1990). Various insecticides like cypermethrin, endosulfan, quinalphos etc. were also recommended for the management of the pests in okra (Prasad *et al.,* 1993; Kumar and Singh 2001; Bhargava and Bhatnagar 2001). Application of NSKE 5% + 3/4 dose of endosulfan (0.045%), monocrotophos 0.05% and NSKE 5% + 1/2 dose of endosulfan (0.03%) were found to be promising by registering lowest fruit damage of 13.05, 14.50 and 15.28 per cent, respectively (Sarode and Gabhane, 1994). Bifenthrin 0.01 % was reported to be effective against *E. vitella* in works carried out in Pakistan (Afzal *et al.*, 1995).

Maximum number of matured fruits, maximum 100 seed-weight and seed yield were obtained from the okra plot sprayed with endosulfan 0.07 % than chlorpyriphos 0.04 % (Vijaykumar, 2003). Among four modules tested, application of two rounds of endosulfan (0.035%) followed by two rounds of neem based products viz., Achook (0.15% EC) proved to be superior against *E. vitella* infesting okra (Panickar *et al.*, 2003). Minimum per cent seed damage was obtained when the crop was sprayed with fenvalerate 0.01 % (Praveen *et al.*, 2007). Lambda-cyhalothrin @ 30 g a.i.ha^{-1} and endosulfan @500 g a.i. ha^{-1} was significantly superior in controlling *E. vitella.* Maximum net benefit (Rs.7018 ha^{-1}) was obtained with lambda-cyhalothrin (Mitali *et al.*, 2008). The treatment alpha-cypermethrin @ 25 g a.i. ha^{-1} was at par with alpha-cypermethrin @ 20 g a.i. ha^{-1}. Endosulfan @ 500 g a.i. ha^{-1} was found to be least effective against okra fruit borer (Sharma and Bhati, 2008). Bifenthrin 0.01 % was reported to be effective against *E. vitella* (Gupta *et al.*, 2009). Chlorpyriphos @ 0.04% recorded the highest number of seeds per healthy fruit (Papal and Bharpoda, 2010).

Among nine insecticides evaluated for their field bioefficacy against shoot and fruit borer *E. vitella* in okra grown for seed purpose during kharif 2007, chlorpyriphos 20 EC @ 0.04 % was the most effective followed by ready mixture cypermethrin 3%+ quinalphos 20 EC @ 0.023 %, endosulfan 35 EC @ 0.07 % and ready mixture chlorpyriphos 16% + alpha cypermethrin 1% EC @ 0.017%. Plots treated with chlorpyriphos @ 0.04% produced the highest seed yield which was closely followed by cypermethrin 3% + quinalphos 20% EC @ 0.0.023% and chlorpyriphos 16% + alpha cypermethrin 1% EC @ 0.017%. The highest net insecticidal cost benefit ratio (N.I.C.B.R.) was obtained from the ready mixture chlorpyriphos 16 % + alpha cypermethrin 1% EC @ 0.017%. Chlorpyriphos 0.04 % proved more effective and economical based on overall rank (Papal and Bharpoda, 2010).

Profenophos+cypermethrin (0.044%), chlorpyriphos+cypermethrin (0.055%), cypermethrin 0.006% and profenophos 0.05%, were found to be effective in reducing the fruit infestation of okra to 6.47 to 10.52 per cent against 43.5 per cent in the control. The highest yield of healthy fruits was recorded in the treatment of profenophos+cypermethrin 0.044% (2366.30 kg ha^{-1}) followed by chlorpyriphos+cypermethrin 0.055% (2155.4 kg ha^{-1}), cypermethrin 0.006% (2127.1 kg ha^{-1}) and profenophos 0.05% (2103.9 kg ha^{-1}). The highest cost benefit ratio (1:20.3) was obtained in the treatment of cypermethrin 0.006%, followed by profenophos+cypermethrin (1:11.9), chlorpyriphos (1:10.4), chlorpyriphos+cypermethrin (1:10.2), profenophos (1:8.7), acephate (1:5.1) and methomyl (1:4.1) (Pradeshi *et al.,* 2011).

Application of carbaryl 0.15 % at fortnightly intervals gave satisfactory control of *E. vitella* (Nair, 1999). The experiments at Kerala Agricultural University suggested that profenofos 0.05 %, lambda cyhalothrin 0.02 % and beta cyfluthrin 0.04 % were superior in controlling *E. vitella* (Thamilvel, 2004).

New generation insecticides

Emamectin benzoate 5 SG @11 g a.i ha^{-1} reduced the larval population of *E. vitella* in okra (Kuttalam *et al.,* 2008). A field experiment conducted to evaluate the efficacy of rynaxypyr (coragen) 20 SC against okra fruit and shoot borer, *Earias vitella* (Fab.) during 2009-2010 at University of Agricultural Sciences, Raichur, Karnataka revealed that at 30 g a.i. ha^{-1} and 20 g a.i. ha^{-1}, the insecticide was superior in recording less larval populations, lower fruit damage (7.80 and 10.51per cent) and higher fruit yield (11.60 and 10.89 t ha^{-1}), followed by spinosad @ 56 g.a.i ha^{-1}, emamectin benzoate @15 g.a.i ha^{-1} and flubendiamide @ 45 g.a.i ha^{-1} (Chowdhary *et al.*, 2010).

The application of spinosad (Tracer) @ 90 ml ha^{-1} proved comparatively more effective in controlling fruit damage by *Earias* spp. followed by mechanical plus chemical control and mechanical control alone in the works carried out at Pakistan (Aziz *et al.*, 2012). Around 95.0 per cent mortality of larvae of the fruit borer was recorded in spinosad 48 EC @ 0.048 % treatment (Dhanaraj, 2000). Significantly low fruit infestation was noticed with the application of spinosad 45 SC @ 30 g a.i. ha^{-1} followed by abamectin 1.9 EC @30 g a.i. ha^{-1} (Sinha *et al.*, 2009).

Treatment with novaluron 10 EC @ 0.01 % recorded 92.30 per cent larval mortality of *E. vitella* by Dhanaraj, 2000 in the laboratory. In studies on the ovicidal action of the insecticide @ 0.002%, 60.00 to 76.66 per cent mortality was registered for one to four days old eggs (Nachane *et al.*, 2003). Five days after two sprays with indoxacarb @ 75g a.i. ha^{-1}, 78.6 per cent reduction in the population of the pest was recorded (Sharma and Bhati, 2008).

Indoxacarb 0.015 %, acetamiprid 0.002 % and thiamethoxam 0.005 % were highly effective in preventing the borer damage in okra (Sinha *et al.*, 2009).

Efficacy and inefficacy of fipronil against *E. vitella have* been recorded. Though Gupta *et al.* (2009) reported that fipronil 0.005 % could be used for the management of fruit borer in okra, Papal and Bharpoda (2010) observed that fipronil @ 0.005% proved least effective against the pest.

Foliar application of thiodicarb 75 SP @ 625 kg ha^{-1} achieved a BCR of 5:1 against fruit and shoot borer of okra (Prasad *et al.*, 1993).

Application of flubendiamide 480 SC @ 48 and 60 g a.i. ha^{-1} recorded minimum larval population of spotted boll worm ie 0.41 and 0.35 larvae per plant respectively (Udikeri *et al.*, 2008).

The Directorate of plant protection, quarantine and storage and the Central Insecticide Board and Registration Committee (C.I.B & R.C) under the Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India has notified the insecticides viz., lambda cyhalothrin 5 EC 15 g a.i. ha^{-1}, carbaryl 10 DP 2500 g a.i. ha^{-1}, cypermethrin 10 EC 50-60 g a.i. ha^{-1}, cypermethrin 25 EC 37-50 g a.i. ha^{-1}, deltamethrin 10-15 g a.i. ha^{-1}, endosulfan 2 DP 500 g a.i. ha^{-1}, fenpropathrin EC 75–100 g a.i. ha^{-1}, fenvalerate 20 EC 60-75g a.i. ha^{-1}, permethrin 100-125g a.i. ha^{-1}, phosalone 35 EC 525 g a.i. ha^{-1}, quinalphos 20 AF 250-300 g a.i. ha^{-1} and quinalphos 25 EC 200 g a.i. ha^{-1} and one new generation insecticide emamectin benzoate 5 SG 10 g a.i. ha^{-1} against fruit borer of okra in its official website (CIBRC, 2009).

2.2 SAFETY/ TOXICITY OF INSECTICIDES TO ENTOMOPATHOGENIC FUNGI

Microbial pathogens are extensively used for pest management. Information on their compatibility with insecticides is imperative for formulating pest management strategies. Though many experiments have been carried out to investigate effects of insecticides on entomopathogenic fungi, only the literature pertaining to *M. anisopliae, B. bassiana and L. lecanii*, the entomopathogens widely used for pest management in vegetables, is reviewed here.

2.2.1 *Metarrhizium anisopliae*

M. anisopliae is a soil borne fungus infecting over 200 hosts (Pachamuthu and Kamble 2000), thus indicating a need to evaluate its compatibility with pesticides. Data from *in vivo* compatibility studies revealed that combination of *M. anisopliae* and insecticides could have synergistic, antagonistic, or additive effects (Pachamuthu and Kamble 2000, Zurek *et al.*, 2002, Ericsson *et al.*, 2007).

Extremely toxic effects of chlorpyriphos were found on growth and sporulation of *M. anisopliae* (Li and Holdom, 1994; James and Elzen, 2001). Similarly, thiodicarb too affected the fungus adversely (Barbosa *et al.*, 1997). Imidacloprid and fipronil were less toxic to *M. anisopliae* (Moino and Alves, 1998). Detrimental effect of carbaryl (Kulkarni, 1999; Gopalkrishnan and Mohan, 2000) and fenvalerate (Gopalkrishnan and Mohan, 2000) to the entomopathogen were reported.

Significant inhibition of *M. anisopliae* occurred in the highest concentration (1.3 AR) of acetamiprid. Vegetative growth of the fungus was significantly inhibited (Neves *et al.*, 2001). Methomyl was moderately toxic to *M. anisopliae* (James and Elzen, 2001). Dichlorvos and monocrotophos were highly detrimental to the mycopathogen, inhibiting 54.22 and 54.89 per cent of growth, respectively. Malathion and dimethoate inhibited *M. anisopliae* to lesser levels (Talwar, 2005). Indoxacarb and profenophos proved to be less detrimental to the green muscardine while neonicotinoid (imidacloprid) and spinosad were found safe to the fungus by inhibiting only 11.10 and 5.10 per cent growth, respectively (Rachappa *et al.*, 2007). Fipronil induced the lowest level of inhibition on the germination, vegetative growth and sporulation of *M. anisopliae in vitro* (Rashid *et al.*, 2010). The interaction between *M. aniospliae* and spinosad indicated a synergetic effect that increased the house fly mortality as well as reduced the lethal time (Sharififard, 2011). In a study by Amutha and Banu, 2012, chlorpyriphos and econeem were recorded as hazardless to *M. anisopliae* while spinosad, acetamprid, quinalphos, endosulfan and thiodicarb were slightly toxic, imidacloprid and triazophos moderately toxic and profenophos, indoxacarb and methyldemeton highly toxic.

Flufenoxuron, lufenuron, indoxacarb and emamectin benzoate were comparatively less toxic to mycelial growth (36.78 to 48.67 per cent inhibition) and conidial germination (40.32 to 49.97 per cent inhibition) of *M. anisopliae.* Abamectin and profenophos were compatible with significantly lesser inhibition in growth (25.19 to 36.47 per cent) and conidial germination (27.78 to 43.66 per cent) of the fungi. Spinosad was found safe to conidial germination and growth of the fungi. However some insecticides significantly inhibited mycelial growth and conidial germination of the fungal pathogens. Chlorpyriphos was the most toxic insecticide to mycelial growth and conidial germination followed by methomyl, thiodicarb and chlorfenapyr (Asi *et al.,* 2010).

2.2.2 *Beauveria bassiana*

Malathion 0.3 % prevented the development of the entomopathogenic fungus, *B. bassiana* (Dirimanov and Angelova, 1962). *In vitro* studies indicated inhibition of *B. bassiana* by many pesticides (Ramarajah *et al.,* 1967; Olmert & Kenneth 1974). Imidacloprid and fipronil were less toxic to *B. bassiana* (Moino and Alves, 1998 ; James and Elzen, 2001). The use of alpha-cypermethrin and thiamethoxam formulations were recommended in coffee IPM programs since these products were compatible with the entomopathogenic fungus *B. bassiana* (CG 425) (Olievera *et al.,* 2003). Compatibility of *B. bassiana* with 12 acaricide formulations was tested and it was found that the formulations more compatible with *B. bassiana* were avermectin and the pyrethroids (De Olivera and Neves, 2004). Flufenoxuron was not compatible with *B. bassiana* and it caused complete or strong inhibition in its development (Alizadeh, 2007).

2.2.3 *Lecanicillium* spp.

Several insecticides including chloropyrifos strongly inhibited the growth of *L. lecanii* (Olmert and Kenneth, 1974). Mycelial growth in the presence of malathion was inhibited by 64 per cent in strain C-3 and 40 per cent in strain C-48 of *L. lecanii* (Hall, 1981).

Insecticidal soap and abamectin had relatively little adverse effect on the mycelial growth and sporulation of *L. lecanii* (Lin *et al.,* 1998). Imidacloprid was harmless on spore germination of isolate CS625 but inhibited spore germination of an isolate of *Lecanicillium muscarium* (Petch) Zare (Cuthbertson *et al.,* 2005). Malathion, quinolphos, dicofol and oxydemeton methyl were highly toxic to *L. lecanii* (Talwar, 2005). In the case of *Pochonia lecanii*, only one insecticide was rated as hazardless (chlorpyriphos), four insecticides as slightly toxic (econeem, acetamprid, endosulfan & thiodicarb), two insecticides as moderately toxic (spinosad & quinalphos) and five as highly toxic (profenophos, triazophos, imidacloprid, indoxacarb & methyldemeton)(Amutha and Banu, 2012).

2.3 PERSISTENCE AND DEGRADATION OF INSECTICIDES ON COWPEA, BRINJAL AND OKRA

Agricultural crops, particularly vegetables are highly contaminated with pesticide residues on account of the extensive use of these toxicants for pest control. Bourn and Preecott (2002) found after an extensive survey on vegetables that 17 to 50 per cent of conventional vegetables contained pesticide residues. Surveys conducted by institutions spread throughout India also revealed that 50 to 70 per cent of vegetables are contaminated with insecticide residues (Karanth, 2002). Information on the persistence and degradation of insecticides are imperative prior to their recommendation.The literature pertaining to the persistence and degradation of insecticides selected for the present study on vegetables are presented.

2.3.1 Emamectin benzoate

The dissipation experiments on emamectin benzoate applied @ 4.5 and 9 a.i. ha^{-1} in cabbage showed that the half-life ($T_{1/2}$) was around 1 day at 18 g a.i ha^{-1}. Residues of the insecticide were below LOQ at seven and 12 days respectively (Liu *et al.*, 2012). In another trial, the dissipation half-lives of emamectin benzoate in cabbage and soil were determined as 1.34 to 1.72 and 1.89 to 4.89 days, respectively. The final residues of the insecticide ranged from 0.001 to 0.052 mg kg^{-1} in cabbages and 0.001 to 0.089 mg kg^{-1} in soils, respectively (Wang *et al.*, 2012).

2.3.2 Spinosad

The half lives of spinosyn A and D varied with application rates. Lower persistence was recorded at the lower rates of application(Tomkins *et al.*, 1999).

The concentration of spinosyn A and D in eggplant were below 0.2 mg/kg, one day after the treatment at 6000 ml hm^2. The residues of spinosyn A and D were below LOQ seven days after treatment. The half lives were 1.81 and 1.61 days, respectively (Zhao *et al.*, 2007). The persistence of the insecticide in soil, cabbage and cauliflower was evaluated at two application rates (17.5 g a.i. ha^{-1} and 35.0 g a.i. ha^{-1}). At 17.5 g a.i. ha^{-1} spinosad persisted up to seven days in soil, cabbage and cauliflower (Sharma *et al.*, 2007). However, at 35.0 g a.i. ha^{-1}, spinosad residues persisted up to seven days in soil and ten days in cabbage and cauliflower (Sharma *et al.*, 2008a). Half life values of spinosad for the first and second phase on green chilli were found to be 1.48 days and 0.70 days respectively for 73.0 g a.i.ha^{-1} application rate, and 6.72 days and 5.55 days respectively for 146.0 g a.i.ha^{-1} application rate. No detectable residues (<0.05 µg/g) were found in red chilli and soil, sampled on the fifteenth day of application which depicts that spinosad is environmentally safe as regards soil pollution (Sharma *et al.*, 2008b).

Following three applications of spinosad (Success 2.5 SC) at 15 and 30 g a.i. ha^{-1}, the average initial deposits were observed to be 0.57 and 1.34 mg kg^{-1}, respectively in cauliflower. These residues dissipated below the limit of quantification (LOQ) of 0.02 mg kg^{-1} after 10 days at both the dosages. The half-lives were 1.20 and 1.58 days, respectively, at recommended and double the recommended dosages. A waiting period of six days was suggested for the safe consumption of spinosad treated cauliflower (Mandal *et al.*, 2009). The average initial deposits of spinosad in cabbage were observed to be 0.33 and 0.56 mg kg^{-1} at 15 and 30 g a.i. ha^{-1} application rates respectively. The residue levels dissipated below its limit of quantification of 0.01 mg kg^{-1} after five and seven days at single and double dosages, respectively. The half-life values of spinosad were 1.4 and 1.5 days at single and double dosages, respectively (Singh and Battu, 2012).

The mean initial deposits of spinosad applied at 15 and 30 g a.i.ha^{-1} were 0.57 and 1.34 mg kg^{-1} on the cauliflower curds, respectively. These deposits dissipated to 0.14 and 0.27 mg kg^{-1} after 3 days, thereby showing a loss of about 75 and 80 per cent, respectively. The residues reached below the detectable limit of 0.02 mg kg^{-1} in seven and ten days, respectively (Mandal *et al.*, 2012).

2.3.3 Novaluron

Field experiments were conducted for three seasons (1st season, July 2002; 2nd season, January 2003; 3rd season, July 2003) at Bidhan Chandra Krishi Viswavidyalaya agricultural experimental farm, West Bengal to study the dissipation kinetics of novaluron applied at 37.5 and 75 g a.i.ha^{-1} in chilli and brinjal.The initial deposit of novaluron in chilli after two hours of spraying ranged between 0.073-0.077 and 0.148-0.152 mg kg^{-1} irrespective of the seasons for the two application rates, respectively. The loss of residues over a period of time showed a steady dissipation from 64.28-86.15 per cent within five days. The residue level fell below detectable limit on the seventh and tenth day for the two application rates, respectively . The initial deposit of novaluron in brinjal after two hour of spraying varied between 0.075-0.078 and 0.149-0.156 mg kg^{-1}, irrespective of the seasons for the two application rates, respectively. The loss of residues over a period of time showed a steady dissipation from 65.55-85.66 per cent within five days. The residue level dissipated to below detectable limit on the seventh and tenth day for the two application rates, respectively . The half-life ($t_{1/2}$) of novaluron varied between 1.80-1.95 days (for chilli) and 1.80-2.08 days (for brinjal) irrespective of the seasons and application rates (Das *et al.*, 2007).

2.3.4 Chlorantraniliprole

Three applications of chlorantraniliprole (Coragen 18.5 SC) at recommended dose (9.25 g a.i.ha^{-1}) and double the recommended dose (18.50 g a.i.ha^{-1}) in cauliflower resulted in the average initial deposits of 0.18 and 0.29 mg kg^{-1} , respectively. The residues dissipated below the limit of quantification of 0.10 mg kg^{-1} after three and five days at recommended and double the recommended dosages, respectively. The half-life value ($T_{1/2}$) of chlorantraniliprole was worked out to be 1.36 days. A waiting period of one day was suggested for safe consumption of cauliflower curds (Kar *et al.*, 2013). The pre-harvest interval (PHI) of chlorantraniliprole on tomato was eight days after the treatment and half life ($t_{1/2}$) 3.30 days at the recommended rate of application i.e. 60 mL per feddan (1 feddan = 4,200 m^2) (Malhat *et al.*, 2012).

2.3.5 Indoxacarb

The mean initial deposits of indoxacarb on eggplant fruits were found to be 2.60 to 2.634 mg kg^{-1} and 3.64 to 3.68 mg kg^{-1} from the two rates of applications, 75 and 150 g a.i.ha^{-1} respectively. They declined with time and reached to non-detectable levels (< 0.02 mg kg^{-1}) after 15-20 days. The residues dissipated with a half-life of 3.0-3.8 days from both first and second-year applications. A three days waiting period for harvest of fruits after insecticide application and processing resulted in the residue levels declining below the Codex maximum residue limit (MRL) of 0.5 mg kg^{-1} thereby achieving a maximum safety and minimum risk to consumers (Saimandir and Gopal, 2009). When indoxacarb was applied at 70 and 140 g a.i. ha^{-1} on okra, the initial deposits recorded were 0.26 and 0.67 mg kg^{-1}, respectively. Analysis of samples collected 10 days after application did not reveal the presence of indoxacarb (Gupta *et al.*, 2009).

Studies on the dissipation behavior of indoxacarb 14.5 SC on brinjal following three applications at the rate of 70 and 140 g a.i. ha^{-1} indicated that the initial deposits were 0.11 and 0.209 μ g^{-1}, respectively.The residues dissipated with half-life of 1.6–2.3 days (Sinha *et al.*, 2010). The average initial deposits of 0.23 and 0.45 mg kg^{-1} were observed after last application of indoxacarb @ 52.2 and 104.4 g a.i.ha^{-1} at recommended and double the recommended dosages, respectively in cauliflower. The residues dissipated below its LOQ of 0.01 mg kg^{-1} after seven days and its half-life periods were 1.12 and 1.31 days, respectively, at single and double the dosages (Takkar *et al.*, 2011). The average initial deposits of indoxacarb on cabbage were 0.18 and 0.39 mg kg^{-1}, respectively, at @ 52.2 and 104.4 g a.i. ha^{-1}. The residues dissipated below its LOQ of 0.01 mg kg^{-1} after 7 and 10 days, respectively, at single and double dosages. The half-life was 2.88 and 1.92 days, at recommended and double the recommended dosages, respectively (Urvashi *et al.*, 2012).

2.3.6 Fipronil

Fipronil degraded slowly on vegetation and relatively slowly in soil and water, with a half-life ranging between 36 hours and 7.3 months depending on substrate and conditions. One of its main degradation products, fipronil desulfinyl is generally more toxic than the parent compound and is very persistent (Tingle *et al.*, 2003). Fipronil residues were found to be below detectable levels in vegetable applied @ 24 and 48 g a.i.hm^{-2} (Pei *et al.*, 2004). In gram, fipronil residues applied @ 50 and 100 g a.i.ha^{-1} persisted beyond seven and 13 days at low dose and high dose with half-life of 1.08 and 2.88 days, respectively. In okra, 98–100 per cent dissipation was recorded in seven days with half life varying from 0.65 to 1.12 days. On brinjal, the residues persisted beyond ten days at both the doses and half life varied from 1.84 to 2.31 days (Gupta *et al.*, 2008).

2.3.7 Thiodicarb

Squash and tomatoes were sprayed with thiodicarb 80 DF (dry flowable) at 0.5 kg feddan^{-1}, and fruit and leaf samples were collected at intervals for up to 50 days after treatment. Initial deposits were higher on squash fruits than on tomato fruits and residues were detected for 21 and 30 days after spraying, respectively. The half lives were 7.51 and 4.67 days, respectively (Antonious *et al.*, 1988). The harvest time residues of thiodicarb 70 WP at 700 and 1400 g a.i. ha^{-1} were below detectable level both in green and cured cardamom capsules (Vinothkumar and Kuttalam, 2012).

2.3.8 Flubendiamide

The initial deposits of flubendiamide on chilli were found to be 1.06 and 2.00 mg kg^{-1}, respectively, following two applications of flubendiamide 480 SC at 60 and 120 g a.i. ha^{-1} at 10 days interval. More than 80 per cent of flubendiamide residues dissipated just after three days of the last application and dissipated below detectable levels in seven and ten days at single and double dosages, respectively. The half-life ($t_{1/2}$) was observed to be 0.96 and 0.91 days at single and double dosages, respectively (Sahoo *et al.*, 2009). The initial residue deposits of the insecticide in cabbage were 0.33 and 0.49 mg kg^{-1} at 24 and 48 g a.i. ha^{-1}, respectively. The residues persisted for 10 days in both the treatments and dissipated with the half-life of 3.9 and 4.45 days, respectively. Des-iodo flubendiamide, a metabolite of flubendiamide, was not detected in cabbage at any time during the study period (Mohapatra *et al.*, 2010).

The residues of flubendiamide dissipated below LOQ of 0.01 mg kg^{-1} after three and five days following three applications of combination mixture (flubendiamide 24% + thiacloprid 24%) 480 SC (w/v) at 48 and 96 g a.i. ha^{-1} on tomato and half-life values ranged from 0.33 to 1.00 days (Kooner *et al.*, 2010).

Residues of flubendiamide applied at 60 and 120 g a.i. ha^{-1} persisted in/on brinjal till third and seventh day after the last spray, respectively. No desiodo metabolite was detected. The initial deposits of 0.17 and 0.42 μg g^{-1} in/on brinjal fruits reached below determination level of 0.05 μg g^{-1} on the fifth and tenth day, respectively. The half life of flubendiamide on brinjal fruits ranged from 2.68 to 2.55 days (Chawla *et al.*, 2011).

The fate of flubendiamide 480 SC when applied thrice at 90 and 180 g a.i.ha^{-1} at 7 days interval in/on brinjal fruits was studied. An average initial deposit of 0.33 and 0.61 mg kg^{-1} of flubendiamide was observed respectively for the single and double dosages. The residues dissipated quickly at both the dosages, and after three days, the extent of dissipation was found to be about 76 and 79 per cent, respectively. Brinjal fruit samples analysed at different time intervals did not show the presence of desiodo flubendiamide. The half-life of the insecticide was 0.62 and 0.54 days at single and double dosages, respectively. The limit of determination of flubendiamide and desiodo flubendiamide was observed to be 0.05 mg kg^{-1} (Takkar *et al.*, 2011).

The application of flubendiamide 20 WG at 50 and 100 g a.i. ha^{-1} in pigeon pea resulted in total initial deposits of 1.15 and 2.49 μg g^{-1}, respectively. The residue declined progressively with time and reduced to the level of 0.18 and 0.51 μg g^{-1}, respectively on the fifteenth day and reached below detection limit within 28 days after application at both the tested doses. The half-life periods for the parent compound were found to be in the range of 4.77 to 5.28 days. No residues of flubendiamide and des-iodo flubendiamide were detected in pigeon pea grain, shell, and straw samples at harvest at the detection limit of 0.05 μg g^{-1}. Based on the data generated, a pre harvest interval (PHI) of 28 days was recommended after two spray applications of flubendiamide 20 WDG at 50 g and 100 g a.i. ha^{-1} (Kale *et al.*, 2012).

The initial deposits of 0.28 and 0.53 µg g^{-1} in/on okra fruits reached below determination level of 0.01 µg g^{-1} on the seventh and tenth day at the application rates 24 and 48 g a.i. ha^{-1}, respectively. The half life ranged from 4.7 to 5.1 days at standard and double dose, respectively (Das *et al.,* 2012). The initial deposits of flubendiamide residues on cabbage were found to be 0.16 and 0.31 µg g^{-1} following two applications of flubendiamide 20 WG at 12.5 and 25 g a.i. ha^{-1} respectively at 10 days interval. The half-life values ($t_{1/2}$) ranged from 3.4 to 3.6 days. No detectable residues were found in cabbage and soil at harvest. Thus, a waiting period of 1.63 days was suggested for the safe consumption of treated cabbage (Paramasivam and Banerjee, 2013).

2.3.9 Carbaryl

The residues of carbaryl 0.15 % reached below detectable level four days after treatment on brinjal fruits in the experiments conducted at Kerala Agricultural University (Sudharma, 1981). Studies on dissipation of carbaryl residues in brinjal leaves and fruits indicated that the half life values were 1.076 and 1.370 days in leaves and fruits respectively (Rao *et al.,* 1985). When bottle gourd was sprayed with carbaryl 0.1% and 0.05%, the initial deposits in unpeeled and peeled fruits were 16.69 and 18.82, and 12.28 and 13.65 ppm, respectively in 0.1% concentration and 10.25 and 11.22, and 7.10 and 7.80 ppm respectively in 0.05% concentration. After one day, the residues were, 8.13 and 8.16, and 6.24 and 6.89 ppm in 0.1% concentration and 0.05% carbaryl, 5.60 and 5.90, and 4.51 and 4.73 in 0.05% concentration in peeled and unpeeled fruits, respectively. Results showed that carbaryl dissipated at a faster rate in the initial stages. One day after carbaryl application, approximately 50 per cent of the initial deposits disappeared. Within fivedays the residues were non-detectable (Dahiya and Chauhan, 1997).

The initial deposit of 11.47 ppm from 0.2 % carbaryl spray on brinjal dissipated to 9.93 ppm within one day after treatment recording 13.40 per cent decrease in the residue. Four , six , eight, ten and fifteen days after treatment, the residues observed were 6.09 ppm (46.88 per cent loss), 5.14 ppm (55.25 per cent loss), 3.93 ppm (65.73 per cent loss), 1.87 ppm (83.74 per cent loss) and 0.95 ppm(91.69 per cent loss), respectively. After twentififth day, residues were not detectable (Dhas and Srivastava, 2010).

2.3.10 Malathion

Malathion (500 and 1000 g a.i./ha) application in bell peppers resulted in initial deposits ranging from 4.65 to 4.83 mg kg^{-1} and 10.00 to 10.09 mg kg^{-1}, respectively. Approximately 91to 97 per cent of initial malathion concentration dissipated at the sixth day after application. Half-life values varied from 1.18 to 1.29 days and 1.22 to 1.36 days for lower and higher doses, respectively. A waiting period of five days was suggested for safe consumption of bell peppers following application of malathion at the doses studied (Dash *et al.,* 2001). Following application @625 l ha^{-1}, the initial deposit on metha (fenugreek) was found to be 29.31 mg $kg^{-1,}$ which dissipated at 10 days and 15 days to BDL. A waiting period of five days was recommended for the safe consumption of fenugreek (Singh *et al.,* 2006).

On rapeseed, the dissipation of malathion was faster. The initial deposits of 12.38 mg kg^{-1}, on pods dissipated on the seventh day.(Bandral and Sharma, 2009). Initial residues on brinjal treated with 2.24 l ha^{-1} dissipated from 0.8 to 0.05 mg kg^{-1} within five days (Islam *et al.,* 2009).

2.4 DECONTAMINATION OF PESTICIDE RESIDUES THROUGH HOUSEHOLD PRACTICES

Household processing of food such as washing, peeling, cooking, blanching and concentrating can reduce residue levels (Abou-arab, 1999; Zohair, 2001; Byrne and Pinkerton, 2004; Zhang *et al.,* 2007).

2.4.1 Washing

Washing is the most common form of processing which could remove pesticide residues. Loosely held residues of several pesticides were removed with a reasonable efficiency by varied types of washing processes (Street, 1969).

Washing of cabbage treated with chlorpyriphos @ 0.05 % reduced initial deposits from 13.81 to 8.56 mg kg^{-1} showing a reduction of 38.02 per cent. Though residues of quinalphos were reduced by 39.06 to 44.0 per cent, it did not bring the residues below MRL of 0.25 mg kg^{-1} (Nagesh and Verma, 1997). Washing of okra fruits resulted in 42.2 and 35.7 per cent reduction of b-cyfluthrin residues (Dikshit *et al.*, 2002). Similarly, when okra fruits were washed with tap water, 41.2 to 48.3 per cent cypermethrin residues were removed from the zero day samples and 37.1 to 46.0 per cent from fifth day samples. In the case of fluvalinate, the reduction in residues was 38.0 to 44.2 per cent in zero day and 32.4-41.8 per cent in fifth day samples (Singh *et al.*, 2004).

Residues of lamda cyhalothrin on tomato in zero and third day samples were reduced by 9.0 and 30.0 per cent, respectively through washing (Jayakrishnan *et al.*, 2005). Washing of cauliflower treated with chlorpyriphos, quinalphos, endosulfan, fenvalerate and deltamethrin reduced 28.92 to 78.64 per cent residues of these insecticides (Dhiman *et al.*, 2006). Maximum (77 per cent) reduction of organophosphate insecticides was observed in brinjal, followed by cauliflower (74 per cent) and okra (50 per cent) by washing (Kumari, 2008). On an average 20.00 to 69.60 per cent of quinalphos and 25.58 to 65.44 per cent of methomyl residues were removed from okra after washing (Aktar *et al.*, 2008). Similarly,washing under running tap water removed 27.72 to 32.48 per cent of quinalphos residues from cabbage head (Aktar *et al.*, 2010). Residues of cypermethrin were removed by by 39.10 per cent from brinjal fruits when washed under tap water (Walia *et al.*, 2010). In the case of acetamiprid, mere water wash of chilli fruits removed 97.69 per cent of the residues where as treatments like lemon (42.86 per cent), lemon+salt (33.46 per cent), baking soda (35.77 per cent) and tamarind (16.08 per cent) were found less effective (Varghese, 2011). Around 17 to 40 per cent of chlorantraniliprole residues were removed from cabbage and cauliflower when washed with tap water (Kar *et al.*, 2012). Water soluble contact newer classes of insecticides like imidacloprid and emamectin benzoate can be effectively removed from okra by plain washing (Sheikh *et al.*, 2012)

2.4.2. Scrubbing

Decontamination studies of Barooah and Yein (1996) on brinjal revealed that washing coupled with gentle rubbing by hand under tap water for one minute dislodged pesticide residues significantly. The initial diazinon residue deposits (0.822 ppm) on cucumber and procymdone (0.86 ppm) residue levels on tomatoes were decreased by 22.30 and 68 per cent, respectively through washing for 15 seconds followed by scrubbing under running water (Cengiz *et al.*, 2007). Captan residues in apples washed for 10–15 seconds with continuous hand scrubbing were 50 per cent lower than those in apples that received no post harvest washing and scrubbing (Rawn *et al.*, 2008).

2.4.2 Heat treatments

Common household heat processing leads to decreased pesticide residues in various produce (Byrne and Pinkerton, 2004). Unwashed cabbage heads when boiled or cooked for 15 minutes decontaminated the residues of methyl-o-demeton to the extent of 87.39, 80.05, 57.70, 45.45, 83.44 and 100 per cent at zero, three, five, seven and ten days after application of insecticides, respectively (Pareek and Gotam, 1994). Cooking after washing mitigated five days old residues by 94.49, 37.97 and 11.64 per cent from recommended rates of application of endosulfan, fenvalerate and monocrotophos, respectively (Dinabandhoo and Sharma 1994). Washing and cooking were effective in lowering the alphamethrin (0.005 %) residues in brinjal. However reduction of residues was more due to cooking than simple washing (25 to 33 per cent). In tomato, both the processes reduced the residues almost to the same extent (11 to 33 per cent) (Kanta *et al.*, 2001). Washing and steaming of chickpea grains completely removed the deltamethrin residues from initial residues of 0.051 ppm (Lal and Dikshit, 2001). There was 41.30 per cent reduction in b-cypermethrin residues on zero day and 34.60 per cent residue reduction on third day on cooking of okra fruits (Dikshit *et al.*, 2002). Substantial reduction of pesticide residues in washed and cooked vegetables was noted by Naseemabeevi *et al.*(2003). Reduction of 67.54 to 76.69 per cent of k-cyhalothrin residues on tomato in washing plus cooking was observed (Jayakrishnan *et al.*, 2005). Cooking of various vegetables including okra resulted in 12 to 48 per cent decrease in chlorpyriphos residues (Randhawa *et al.*, 2007). Stir frying at 100°C for five minutes reduced the residues of cypermethrin by 84.70 per cent in cabbage (Zhang *et al.*, 2007).

The effect of different household processes (washing and boiling/cooking) on reduction of residues of organochlorine (OC), synthetic pyrethroids (SP), organophosphates (OP) and carbamates were determined in three vegetables viz. brinjal, cauliflower and okra. In all the three vegetables washing reduced the residues by 20 to 77 per cent and boiling by 32 to 100 per cent. By boiling process, 100 per cent of the residues were removed from brinjal followed by 92 per cent from cauliflower and 75 per cent from okra (Kumari, 2008). Cooking after washing caused 25.50 to 76.52 per cent reduction of residues of quinalphos and 31.39 to 81.50 per cent of methomyl on okra(Aktar *et al.*, 2008). Similarly, washing followed by boiling reduced residues of cypermethrin on brinjal by 37 per cent (Kumari, 2008). Maximum reduction of fenazaquin residues in okra fruits (60 to 61 per cent) was obtained through washing+ boiling followed by boiling/cooking (38 to 40 per cent) in zero day samples(Duhan, 2010).

Dislodging of cypermethrin residues from brinjal fruits one day after treatment was more in grilling (50.12 per cent) followed by cooking in oil (45.20 per cent), cooking in water (41.40 per cent) and microwave cooking (40.89 per cent).

Cooking of brinjal fruits in oil resulted in reduction of residues to 0.860 from 1.570 mg g^{-1} on the first day. The residues were further reduced to 0.545 and 0.466 μg g^{-1} on the second and third day, respectively (Walia *et al.*, 2010). Processing was found very effective in reducing the levels of chlorpyriphos residues in okra fruits. Maximum reduction (64 to 77 per cent) was observed by washing, boiling followed by washing (13 to 35 per cent) (Samrithi *et al.*, 2011). With boiling, the removal of chlorpyriphos and malathion from tomato, okra and cauliflower was more difficult than from other vegetables. The removal of parathion, methyl parathion and formothion residues by cooking was higher than that of washing, indicating thre efficacy of cooking over washing in removing the residues (Satpathy *et al.*, 2011).

Emamectin benzoate residues were high in unwashed okra (0.51 ppm as against MRLs of 0.2 ppm), however, its residues were reduced to MRLs by detergent washing and subsequent processing by frying, thermal dehydration or sun-drying of detergent washed okra (Sheikh *et al.*, 2012). However, boiling removed 100 per cent of chlorantraniliprole residues on both cabbage and cauliflower (Kar *et al.*, 2012).

2.4.3 Other chemicals

Solutions formulated from chemicals readily available in a household kitchen too can reduce the residues of pesticides in commodities (Krol *et al.*, 2000).The chemicals recommended for the purpose included salt, baking soda, distilled vinegar and potassium permagnate (Extension Toxicology Network, 1996).

Washing of vegetables with soap solution removed 85 to 96 per cent of gordona, 75 to 79 per cent of azodrin, 92 to 100 per cent of dichlorvos, and 82 to 96 per cent of malathion. Similarly, washing vegetables with dilute NaOH solution (0. 1 %) removed 64.5 to 74.3 per cent of gordona, 65.9 to 82.8 per cent of azodrin; 79.6 to 94.5 per cent of dichlorvos and 82 to 94.3 per cent of malathion. Only 30 to 50 per cent removal of pesticide residues was achieved using pottassium permanganate or acetic acid (Tantawy *et al.,* 1975). Removal efficiency of malathion by detergent washing was significantly higher than by water washings only (Shim *et al.,* 1984).

The best combination for the decontamination of methomyl from eggplant was non toxic edible alkali + $KMnO_4$ since the recovery of residue was only 2.71 and 2.94 mg kg^{-1} with a per cent removal of 44.11 and 65.04. Calcium hydroxide was reported for degradation of beta-cyfluthrin by Sinha and Gopal (2002). A mixture of alkali and pottassium permanganate which removed 67.50 per cent and 59.20 per cent residues of indoxacarb from brinjal fruits spiked at 5 and 10 μg g^{-1} was also found to be the best combination of chemicals for decontaminating the insecticide (Saimandir and Gopal, 2009). Thiacloprid residues in the third day field samples of cabbage could be reduced below Japanese MRL (1.0 mg kg^{-1}) by treating with 0.5 % $NaHCO_3$ solution for one hour (Dutta *et al.,* 2012). Residues of imidacloprid (0.31 ppm) in unwashed okra was reduced to 0.082 ppm by detergent washing, registering 73 per cent removal of the residues (Sheikh *et al.,* 2012).

Tamarind solution 2 % proved best in reducing endosulfan residues from tomato fruits at immediately after spraying and on fifth day(Gopichand *et al.,* 1999). The treatment of okra fruits with 2 % tamarind solution dip for five minutes followed by tap water wash and steam cooking for 10 minutes was found to remove the residues of monocrotophos, carbaryl and fenvalerate to an extent of 41.81, 100 and 100 per cent, respectively (Srinivas *et al.,* 1996). Dipping insecticide treated chilli fruits in 2 % tamarind solution for twenty minutes followed by washing in water removed maximum amount of residues of spiromesifen, imidacloprid, propargite and dimethoate. In the case of ethion also, tamarind treatment removed fairly good amount of residues. Owing to this majority, dipping in tamarind solution (2 %) was recommended as a good option for removing insecticide residues from fruits and vegetables (Varghese, 2011). Washing of brinjal, bhendi, cabbage and cauliflower in tamarind solution 2% for 30 seconds reduced insecticide deposits to nearly 50 per cent followed by sodium bicarbonate 40 per cent , brine and water washing (30 per cent) (Suresh *et al*., 2012). Dipping of okra fruits and curry leaves in 2 % tamarind solution for 15 minutes followed by washing in tap water was found to be the most effective treatment in removing the residues of malathion, methyl parathion, fenvalerate, profenophos, cypermethrin, chlorpyriphos and quinalphos (Nair *et al*.,, 2013).

Dipping of vegetables in 2% salt water for one hour removed more than 90 per cent residues of monocrotophos and phosphamidon (Santhoshkumar, 1997). Around 62 per cent of spiromesifen residues could be removed when chilli fruits were dipped in 2 % salt solution followed by washing in water (Varghese, 2011). Similarly, dipping curry leaves in 2 % common salt (processing factor: 0.22-0.41) effectively removed residues of malathion, methyl parathion, fenvalerate, profenophos, cypermethrin, chlorpyriphos and quinalphos (processing factor: 0.35-0.60) (Nair *et al*., 2013).

Dipping curry leaves and chilli in 2 % vinegar and 1 % turmeric was also effective in removing the residues of malathion, methyl parathion, fenvalerate, profenophos, cypermethrin, chlorpyriphos and quinalphos from (Nair *et al*., 2012; Nair *et al*., 2013).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Laboratory and field experiments were conducted to evaluate the efficacy of selected new generation insecticides in managing the fruit borers of cowpea, brinjal and okra. The safety/toxicity of the insecticides to entomopathogenic fungi commonly used for vegetable pest management too was evaluated. The persistence and dissipation kinetics of the insecticides and processing methods for decontaminating the residues were also studied. The materials used and the methods adopted are detailed here under.

3.1. LABORATORY EVALUATION OF NEW GENERATION INSECTICDES

Eight new generation insecticides (Table 1) were evaluated for their efficacy against *M. vitrata*, *L. orbonalis* and *E. vitella*, the fruit borers of cowpea, brinjal and okra, respectively in comparison with two insecticide checks and an untreated check. The experiments were laid out in completely randomized block design (CRD) with three replications.

3.1.1 Rearing of test insects

The larvae of the fruit borers were reared on appropriate fresh natural diets to ensure sufficient population for conducting the laboratory trials.

M. vitrata

Infested flowers and fruits of cowpea were collected from unsprayed fields and the caterpillars of *M. vitrata* obtained were released on fresh pods kept in cylindrical glass jars of 20 cm height and 15 cm diameter. The open end of the jars were covered with muslin cloth and secured tightly with a rubber band. The pods were replaced with fresh ones every alternate day to ensure their suitability for the larvae. The pupae were transferred to polyvinyl containers of 20 cm high and 15 cm diameter with multilayered tissue paper bed at the base, for adult emergence and mating. Cotton bolls soaked in ten per cent honey solution were

Table 1. Insecticides evaluated for their efficacy against the fruit borers of cowpea, brinjal and okra

Sl No:	Common Name	Trade Name	Dosage (g a.i.ha^{-1})	Manufacturer
1	Emamectin benzoate	Proclaim 5 SG	10	Syngenta India Ltd.
2	Spinosad	Tracer 45 SC	75	Dow Agro Sciences India Pvt Ltd.
3	Novaluron	Rimon 10 EC	100	Indofil Chemical Company Ltd.
4	Chlorantraniliprole	Coragen 18.5 SC	30	E.I. DuPont India Pvt. Ltd.
5	Indoxacarb	Avaunt 14.5 SC	60	Gujarat Insecticides Ltd.
6	Fipronil	Jump 80 WG	50	Bayer Crop Science India Ltd.
7	Thiodicarb	Larvin 75 WP	750	Bayer Crop Science India Ltd.
8	Flubendiamide	Fame 480 SC	100	Bayer Crop Science India Ltd.
9	Carbaryl*	Sevin 50 WP	750	Bayer Crop Science India Ltd.
10	Malathion*	Hilmala 50 EC	500	Hindustan Insecticide Ltd.

* The insecticidal checks included in the field experiment.

provided as food source for the emerging moths. Pieces of muslin cloth were placed inside to facilitate oviposition. The cloth pieces with the eggs were later transferred to glass jars for hatching. Bits of fresh cowpea fruits of 6 cm length were introduced into the jars for the neonates to feed. The second instar larvae were transferred to cylindrical glass jars containing tender cowpea pods. The processes were repeated as described above to get adequate number of third instar larvae for conducting the experiments.

L. orbonalis

Brinjal fruits infested with *L. orbonalis* were collected from unsprayed fields, cut open with a disinfected knife and the caterpillars transferred to cleaned potatoes in cylindrical glass jars with a camel hair brush. Four days after feeding, the larvae were again transferred to fresh fruits in polyvinyl containers with a multilayered tissue paper bed at the bottom. The pupae were transferred to separate polyvinyl containers for adult emergence and mating. Ten per cent honey solution soaked in cotton wad was provided as food for the emerging moths. Strips of chart paper were hung in the containers for oviposition. Subsequently, the paper strips with the deposited eggs were spread in a separate container for hatching. Two small potatoes were also kept in the containers so that immediately after hatching the larvae could move to its natural diet. The second instar larvae were transferred to whole potatoes for feeding till pupation. The rearing was continued to get enough larvae required for the experiments.

E. vitella

The larvae from infested okra fruits collected from unsprayed fields formed the source for the laboratory culture. The caterpillars were reared on okra fruits till pupation in cylindrical glass jars. The fruits were changed on alternate days to maintain their freshness. The pupae were placed in polyvinyl containers for adult emergence and mating. Ten per cent honey solution was provided as food for the moths. Pieces of muslin cloth were also provided for oviposition. On egg laying, the cloth pieces with the eggs were transferred to glass jars with okra fruit for hatching. The diet was changed every alternate day. The rearing steps were repeated to get adequate number of third instar larvae.

3.1.2 Raising of test plants

Test plants were raised with seeds of cowpea variety Jyothika and okra variety Varsha Upahar and one month old seedlings of brinjal variety Haritha procured from the Olericulture Department, College of Agriculture, Vellayani. For raising cowpea, plots of 2 x 2 m^2 was prepared, three rows of 1.5 m length taken 50 cm apart and seeds sown @ of four per pit at a spacing of 50 cm. Brinjal was planted in a 2 x 2 m^2 plots @ of four seedlings per pit with a spacing of 75 x 60 cm. Similarly, okra seeds were sown @ of four seeds per pit with a spacing of 60 x 45 cm in 2 x 2 m^2 plots. Two weeks after germination/transplanting, the excess seedlings were thinned to two per pit and maintained as per the recommended package of practices of Kerala Agricultural University (KAU, 2007).

3.1.3 Evaluation of insecticides

The respective crops were sprayed with the insecticides at the required concentrations as detailed in Table 1 during the active fruiting stage. One, three, five, seven and ten days after treatment, five harvestable fruits of cowpea and three each of brinjal and okra were excised from the sprayed plants and placed in polyvinyl containers. Ten third instar larvae of each test insect obtained from the respective cultures maintained in the laboratory were released on the fruits of the corresponding host plant. Three replications were maintained for each treatment. The mortality of the caterpillars was recorded twenty four and forty eight hours after release. The percentage mortality was corrected using Abbot's formula (Abbot, 1925).

3.2 FIELD EVALUATION OF NEW GENERATION INSECTICDES

All the eight new generation insecticides evaluated in the laboratory along with the insecticide checks and an untreated check were tested in the field also for determining their efficacy against fruit borers of cowpea, brinjal and okra. The experiments were laid out in randomized block design (RBD) with three replications in the Instructional farm, College of Agriculture, Vellayani.

3.2.1 Cowpea

Two sets of experiments were conducted in the field to evaluate the efficacy of the insecticides. In the first experiment, the initial insecticide spray was given on need basis at 60 days after planting and the second after a fortnight. In the second trial, two consecutive sprays of neem seed kernel extract 5% were given at fortnightly interval starting from the flower bud initiation stage (40 days after planting). The neem spray was followed by an insecticide spray after two weeks.

3.2.1.1 Raising of cowpea

Plots of 7 x 4 m^2 were prepared and three trenches of 15 cm width and 6 m length were taken 1.25 m apart. Seeds of cowpea variety Jyothika were sown @ four seeds per pit at the centre of the trenches with a spacing of 0.6 m. The excess seedlings were thinned two weeks after germination and only two seedlings were maintained in a pit. The plants were individually trailed on coir ropes tied between poles erected along rows of plants. The crop was maintained as per the recommended package of practices of Kerala Agricultural University (KAU, 2007).

3.2.1.2 Assessment of damage

Flower damage

Ten two to three day old unopened buds were collected at random from each plot three, five, seven, ten and fifteen days after spraying and the number of buds damaged by *M. vitrata* recorded.

Fruit damage

Ten harvestable fruits were collected at random from each plot three, five, seven, ten and fifteen days after spraying and the number of fruits damaged by the fruit borer were recorded.

The extent of flower / fruit infestation was computed using the formula:

$$\text{Percent flower/fruit damage} = \frac{\text{Number of infested flowers / fruits}}{\text{Total number of flowers/fruits}} \times 100$$

3.2.2 Brinjal

Brinjal seeds (variety Haritha) were sown in plots of 2 x 2 m^2 to raise the seedlings. One month old seedlings were transplanted to 3 × 3 m^2 plots at a spacing of 75 x 60 cm. Three replications were maintained for each treatment. Each plot had a density of 20 plants with one plant per pit. The plants were maintained as per the recommended package of practices of Kerala Agricultural University (KAU, 2007).

The insecticide sprays were given on need basis. The first spray was given one month after transplanting when shoot damage was noticed. This was followed by a second spray 60 days after transplanting and a third spray 80 days after transplanting. The control plots were sprayed with water alone.

3.3.2.1 Assessment of damage

The damage caused by the pest to the crop was assessed in terms of the shoot and fruit damages.

Shoot damage

The number of shoots damaged by the fruit borer was recorded three, five, seven, ten and 15 days after spraying from each plot. The damaged shoots were tagged and the count of freshly damaged shoots was taken during each observation.

Fruit damage

The fruits harvested five, ten and fifteen days after spraying were categorized into healthy and infested, counted and recorded from each plot.

The extent of damage was computed as

$$\text{Percent shoot/fruit damage} = \frac{\text{Number of infested shoots / fruits}}{\text{Total number of shoots /fruits}} \times 100$$

3.3.3 Okra

The seeds of okra variety Varsha Upahar were sown in plots of 3 × 2 m^2 with a spacing of 60 x 45 cm. Three replications were maintained for each treatment. The plants were maintained as per the recommended package of practices of Kerala Agricultural University (KAU, 2007). The first insecticidal spray was given when shoot damage was noticed 25 days after planting. This was followed by a second spray 45 days after planting and a third spray two weeks after the second spray. The control plots were sprayed with water alone.

3.3.3.1 Assessment of damage

Shoot damage

The total number of shoots and the number of shoots damaged by the fruit borer per plot were recorded five, seven, ten and 15 days after spraying. The damaged shoots were tagged and the count of freshly damaged shoots was taken from each plot during each observation.

Fruit damage

The total number of fruits and the number of damaged fruits were recorded at harvest three, five, seven, ten and fifteen days after spraying from each plot. The extent of damage was computed as

$$\text{Percent shoot/fruit damage} = \frac{\text{Number of infested shoots / fruits}}{\text{Total number of shoots /fruits}} \times 100$$

3.3.4 Yield and benefit cost ratio

The weight of fruits of cowpea, brinjal and okra harvested were recorded and expressed as kg/plot and converted to t ha^{-1}. The parameters viz., increase in yield over control; monetary returns over control and additional cost of plant protection measures were calculated to compute the benefit cost ratio due to the insecticide treatments. The benefit cost ratio for each treatment was obtained by dividing additional monetary returns by additional cost of plant protection.

3.3 SAFETY EVALUATION OF INSECTICIDES TO ENTOMOPATHOGENIC FUNGI

The insecticide molecules evaluated against the fruit borers were tested for their safety to *B. bassiana*, *L. lecanii* and *M. anisopliae*, the entomopathogenic fungi commonly used for pest management in vegetable ecosystem following the poison food technique (Nene and Thapliyal, 1993).

The required quantity of insecticide solutions were added in separate conical flasks each containing 100 ml of melted potato dextrose agar (PDA). The poisoned media were poured into sterile petri plates of nine cm diameter. After solidification, the poisoned media in the petri plates were inoculated with one mm fungal discs cut out from twelve day old cultures of *B. bassiana, L. lecanii* and *M. anisopliae* using a cork borer. The dishes were incubated at room temperature (30±1°C) along with dishes containing PDA without insecticide inoculated with the different fungi. Radial growth of the fungal colony was measured at definite intervals, till the fungus in the control covered the entire plate.

3.4. PERSISTENCE AND DEGRADATION KINETICS OF INSECTICIDE RESIDUES

The studies on the persistence and degradation of the insecticides were done in the Pesticide Residue Research and Analytical Laboratory of the All India Network Project on Pesticide Residues, KAU Centre, College of Agriculture, Vellayani.

3.4.1 Raising of test plants

Cowpea, brinjal and okra were raised as detailed in 3.1.2, The experiments were laid out in RBD with ten treatments replicated thrice including an untreated control. The insecticides (Table 2) were applied at the active fruiting stage and the fruits were collected two hours, one, three, five, seven, fifteen and twenty days after treatment for the dissipation studies.

3.4.2 Glass wares and reagents

The following glasswares, reagents and equipments were used for the study.

Laboratory glasswares	Chemical reagents	Equipments
Centrifuge tubes 15 ml and 50 ml	Acetonitrile (HPLC grade)	Analytical balance
Micropipette 100 µl, 1ml and 5 ml	Magnesium sulphate (anhydrous) (GR grade)	Vortex shaker
Turbovap tubes 20 ml and 30 ml	Sodium chloride (GR grade)	Turbovap LV
Graduated Test tubes 5ml and 10 ml	n-Hexane (HPLC grade)	Laboratory centrifuge
Microsyringe 10 µl and 500 µl	Acetone (HPLC grade)	Mechanical shaker
Conical flasks 250 ml	Sodium sulphate (anhydrous) GR grade	Rotary vacuum flash evaporator
Beakers 100, 250, 500 ml	Primary Secondary Amine (PSA)	Hot air oven
Standard flasks 10 ml, 25 ml, 50 ml, 100 ml.		UPLC-MS/MS system: AB Sciex API 3200 mass spectrometer with Waters Acquity UPLC system

The glass wares were initially washed with clean tap water followed by washing with 1 per cent laboline and again with tap water and distilled water followed by rinsing with acetone and kept inverted at room temperature for drying. Fully dried glass wares were stored in a hot air oven at 50^0C. Syringes were thoroughly rinsed with acetone followed by hexane. The solvents were distilled with glass distillation apparatus. Sodium sulphate was pre-washed with acetone, dried at room temperature, activated in an oven at 110 ^{0}C for three hours and stored under moisture free condition.

3.4.3 Method Validation

3.4.3.1 Preparation of standard insecticide mixtures

Certified reference materials of different pesticides viz., emamectin benzoate, spinosad, novaluron, chlorantraniliprole, indoxacarb, fipronil, thiodicarb, flubendiamide, carbaryl, malathion and malaoxon with 99.4, 97.6, 99.4, 98.1, 93.7, 97.5, 99.9, 98.8, 99.3, 99.8, 97.2 and 95.2 per cent purity, respectively were purchased from M/s Sigma Aldrich and desiodoflubendiamide of 98.1 per cent purity from Bayer Crop Science India Ltd. Stock solutions (1000 $\mu g\ ml^{-1}$) of the insecticides were prepared by dissolving a weighed quantity of the analytical grade material in HPLC grade methanol. The stock solutions were serially diluted to prepare an intermediate stock of 100 $\mu g\ ml^{-1}$. The intermediate stock solutions were further diluted with HPLC grade methanol to prepare working standard mixtures (10 $\mu g\ ml^{-1}$) of both the insecticides to be analyzed by positive electro spray ionization (emamectin benzoate, spinosad, chlorantraniliprole, indoxacarb, fipronil, thiodicarb, carbaryl, malathion and malaoxon) and by negative electrospray ionization (novaluron, flubendiamide, desiodoflubendiamide). The working standard mixtures were then serially diluted to obtain 1.00, 0.50, 0.25, 0.10, 0.075, 0.05, 0.025, 0.01 and 0.005 $\mu g\ ml^{-1}$ concentrations of analytical grade insecticides.

3.4.3.2 Determination of Limit of Detection (LOD)

Ten micro litres of the working standards of 1.00, 0.50, 0.25, 0.10, 0.075, 0.05, 0.025, 0.01 and 0.005 $\mu g\ ml^{-1}$ concentrations were injected under set standard UPLC-MS/MS conditions. Each standard was injected thrice and the limit of detection of the instrument for each pesticide was calculated based on the lowest quantity of pesticide standard that could be identified under standard UPLC-MS/MS conditions. The lowest concentration for which a signal to noise (S/N) ratio greater than three was considered as LOD of the particular compound.

3.4.3.3 Preparation of Calibration Curve

A calibration curve (linearity response line) was prepared by plotting concentration vs. peak area.

3.4.3.4 Fortification and Recovery experiment

Cowpea, brinjal and okra fruits (500 g) harvested from control plots were chopped and ground to a fine paste. Five replicates of ten g representative samples of the fruits were taken in 50 ml centrifuge tubes and spiked with 0.01 ml, 0.1 ml and 0.5 ml of 10 μg ml^{-1} working standard mixtures of the insecticides. The extraction and clean up was done following the QuEChERS method (Anastassiades *et al.*, 2003) and quantified using UPLC-MS/MS under optimized conditions. The recovery of insecticides in the range of 70- 110 per cent with a relative standard deviation less than 20 was considered to be the ideal method, the lowest spiking level of which is considered as LOQ.

3.4.4. Dissipation of the insecticides

3.4.4.1. Sampling

Insecticide sprayed harvestable fruits of cowpea, brinjal and okra were collected from each plot two hours, one, three, five, seven, ten, fifteen and twenty days after spraying, brought to the laboratory in polythene bags and processed immediately for residue analysis.

3.4.4.2 Residue extraction

The multiresidue estimation procedure recommended for fruits and vegetables as per QuEChERS method with suitable modifications was adopted for residue extraction and clean up in cowpea, brinjal and okra. The harvested fruits were macerated as such in a high-speed blender (BLIXER 6 vv Robot Coupe) for three minutes and a representative sample of 10 g of ground fruits of each vegetable was taken in a 50 ml centrifuge tube. HPLC grade acetonitrile (20 ml) was added to the samples and homogenised with a high speed tissue homogenizer (Heidolph Silent Crusher-M) at 14000 rpm for three minutes. This was followed by the addition of 4.5 g activated sodium chloride (NaCl) and vortexing for two minutes for separation of the acetonitrile layer. The samples were then centrifuged for five minutes at 2500 rpm and 12 ml of the clear upper layer was transferred into 50 ml centrifuge tubes containing five g pre-activated sodium sulphate and vortexed for two minutes. The acetonitrile extracts were subjected to clean up by dispersive solid phase extraction (DSPE). For this, 8 ml of the upper layer was transferred into centifuge tubes (15 ml) containing 0.125 g PSA and 0.8 g anhydrous magnesium sulphate. The mixtures were then shaken in vortex for two minutes and again centrifuged for five minutes at 2500 rpm. The supernatant liquids (5ml each) were transferred to turbovap tube and evaporated to dryness under a gentle stream of nitrogen using a Turbovap set at 40°C and 7.5 psi nitrogen flow. The residues were reconstituted in 2 ml of methanol and filtered through a 0.2 micron filter prior to estimation in LC-MS/MS.

3.4.4.3 Residue Estimation

The chromatographic separation was achieved using Waters Acquity UPLC system equipped with a reversed phase Atlantis C-18 (2.1 x 100 mm, 5 micron particle size) column. A gradient system involving the following two eluent components: A: 10 % methanol in water + 0.1 % formic acid + 50 mM ammonium acetate; B: 10 % water in methanol + 0.1 % formic acid +50 mM ammonium acetate was used as mobile phase for the separation of residues. The gradient elution was as follows: 0 min isocratic 20 % B, 0.0–4.0 min linear from 20 % to 90 % B, 4.0–5 min linear from 90 % to 95 % B, and 5–6.6 min linear from 95 % to 100 % B, with 6.6–7 min for initial conditions of 20 % B. The flow rate remained constant at 0.8 ml min^{-1} and injection volume was 10 µl. The column temperature was maintained at 40°C.The effluent from the LC system was introduced into Triple quadrapole API 3200 MS/MS system equipped with an electrospray ionization interface (ESI), operating in the positive ion mode. The source parameters were temperature 600 ^{0}C; ion gas (GS1) 50 psi, ion gas (GS2) 60 psi, ion spray voltage 5,500 V, curtain gas 13 psi. Under these operating conditions the retention time of chlorantraniliprole, indoxacarb, fipronil, thiodicarb, carbaryl, malathion and malaoxon was found to be 3.04, 4.32, 3.81, 2.72, 2.43, 3.42 and 2.34 minutes, respectively. The retention time for spinosyn A and spinosyn D were 4.20 and 4.38 minutes, respectively and that of emamectin B1b1 and emamectin B1a1 were 4.50 and 4.6 minute, respectively. The multiple reaction monitoring (MRM) transitions used for the quantitative estimation of chlorantraniliprole, indoxacarb, fipronil, thiodicarb, carbaryl, malathion and malaoxon were m/z 484 → 285.9, m/z 528→203, m/z 453.9→368.1, m/z 355→88, m/z 202.1→145.1, m/z 331.4→127.1 and m/z 315.1→127, respectively and for qualitative estimation 484 → 452.9, 528→150, 453.9→255.1, 355→79, 202.1→127.1, 331.4→ 99.1 and m/z 315.1→99.1, respectively. The MRM transitions used for the quantitative estimation of spinosyn A, spinosyn D, emamectin B1b1 and emamectin B1a1 were m/z 732.6 → 98.2, m/z 746.5 → 98.2, m/z 872.5 → 126 m/z 886.6 → 126.2 respectively and for qualitative estimation 732.6 → 142.2, 746.5 → 142.2, 872.5 → 158.2 and 886.6 → 158.2, respectively.

For molecules undergoing negative ionization, the operation of the LC gradient involved the following two eluent components: A: 10 % methanol in water + 0.1 % formic acid + 50 mM ammonium acetate; B: 10 % water in methanol + 0.1 % formic acid +50 mM ammonium acetate. The gradient elution was as follows: 0 min isocratic 20 % B, 0.0–1.0 min linear from 20 % to 50 % B, 1.0–2 min linear from 50 % to 70 % B, 2–4.0 min linear from 70 % to 90 % B, with 4.0–6 min linear from 90 % to 100 % B and with 6.0–8 min for initial conditions of 20 % B. The flow rate remained constant at 0.75 ml min^{-1} and injection volume was 10 µl. The column temperature was kept at 40°C. The effluent from the LC system was introduced into Triple quadrapole API 3200 MS/MS system equipped with an electrospray ionization interface (ESI), operating in the negative ion mode. The source parameters were temperature 550 ^{0}C; ion gas (GS1) 50 psi, ion gas (GS2) 60 psi, ion spray voltage $^-$4500 V, curtain gas 13 psi. Under these operating conditions the retention time of novaluron, flubendiamide and desiodoflubendiamide was found to be 4.05, 3.24 and 3.06 minutes respectively. The MRM transitions used for the quantitative estimation of novaluron, flubendiamide and desiodoflubendiamide were m/z 491 → 471, m/z 681→ 254 and m/z 555→254 respectively and for qualitative estimation 491 → 156, 681→274 and 555→146, respectively.

3.4.4.4 Residue quantification

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

Residue = Concentration obtained from chromatogram by using calibration curve X Dilution factor

$$\text{Dilution factor} = \frac{\text{Volume of the solvent added} \times \text{Final volume of extract}}{\text{Weight of sample (g)} \times \text{Volume of extract taken for conc.}}$$

The persistence of insecticides is generally expressed in terms of half life (DT_{50}) i.e., time for disappearance of pesticide to 50 per cent of its initial concentration. The half life (DT_{50}) as well as time required to reach below tolerance level (T_{tol}) were calculated using Hoskins formula (Hoskin, 1961).

3.5 STANDARDISATION OF DOMESTIC PRACTICES FOR INSECTICIDE RESIDUE DECONTAMINATION

The following practices/ treatments were evaluated for their efficacy in removing residues of the insecticides listed under section 3.1 detected in fruits of cowpea, brinjal and okra.

- Common salt 2% (20 g of common salt dissolved in one litre of water)
- Tamarind 2% (20 g of preserved tamarind pulp extracted in one litre of water)
- Vinegar 2% (20 ml of vinegar diluted in one litre of water)
- Slaked lime 2% (20 g of hydrated lime dissolved in one litre of water)

- Baking soda 2% (20 g of baking soda ($NaHCO_3$) dissolved in one litre of water)
- Turmeric 1% (10 g of turmeric powder dissolved in one litre of water)
- Scrubbing for 2 minutes
- Washing in water and steaming for 10 minutes
- Washing in water for 10 minutes.

Fruits of the crops harvested two hours and three days after application of the different insecticides from each replicate were brought to the laboratory and 250 g cowpea, 250 g okra and 300 g brinjal were dipped in the decontaminating solutions for 20 minutes and then washed in running water. Three replications were maintained for each treatment. The extraction and clean up of the decontaminated fruit samples were done as described in 3.4.4.2, 3.4.4.3, and 3.4.4.4. The residues present in the unprocessed and processed fruits were estimated and percentage reduction of residues was worked out. The processing factor was calculated by using the following formula

$$\text{Processing factor} = \frac{\text{Residue in fruits after processing}}{\text{Residue in fruits before processing}}$$

3.6 DATA ANALYSIS

Data relating to each aspect were analyzed statistically. Appropriate transformations were made wherever necessary. The F test was done by analysis of variance (Panse and Suhatme, 1985). Significant results were compared on the basis of critical differences.

The overall efficacy of the insecticides against the fruit borers was worked out for which the insecticides were ranked based on their performance in each parameter (pest control, yield, waiting period and compatibility with entomopathogens) studied. The mean rank for each crop was worked out and overall efficacy was determined.

RESULTS

4. RESULTS

The results of the laboratory and field trials on the efficacy of the new generation insecticides in managing the fruit borers of cowpea, brinjal and okra, the compatibility of the insecticides with entomopathogens, persistence and degradation kinetics of the new molecules and the effectiveness of the decontamination techniques in removing the residues are presented in and Tables 2 to 57.

4.1. LABORATORY EVALUATION OF NEW GENERATION INSECTICIDES

The relative efficacy of the eight new generation insecticides *viz.,* emamectin benzoate 5SG @10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, novaluron 10 EC @ 100 g a.i. ha^{-1}, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1}, fipronil 80 WG @ 50 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1} and flubendiamide 480 SC @ 100 g a.i. ha^{-1} in comparison with two conventional insecticides (carbaryl 50 WP @ 750 g a.i. ha^{-1} and malathion 50 EC @ 500 g a.i. ha^{-1}) when tested in the laboratory against *M. vitrata, E. vitella* and *L. orbonalis* depicted in Table 2 indicated that the insecticides were on par in their effect on the pests.

High mortality of the cowpea pod borer, *M. vitrata* was recorded when released on pods harvested one day after spraying the insecticides, the mortality ranging from 72.22 to 92.96 per cent. Release of the third instar caterpillars on fruits harvested three, five, seven and ten days after spraying resulted in low mortality of the pest ranging from 38.15 to 51.49, 2.14 to 23.12, 0 to 20.00 and 0 to 13.33 per cent, respectively.

The extent of mortality against *L. orbonalis* was high (62.44 to 92.94 per cent) when the caterpillars were released on fruits harvested one day after treatment with insecticides. On the third day of spraying, the larval mortality ranged from 41.97 to 62.44 per cent. When released on fruits collected five days after spraying, all the insecticides recorded low larval mortality (5.47 to 16.31).

Table 2. Mortality of fruit borers of cowpea, brinjal and okra when exposed to fruits treated with new generation insecticides

Treatments	Dosage (g a.i.ha^{-1})	Larval mortality (%)														
		Cowpea *Maruca vitrata*					Brinjal *Leucinodes orbonalis*					Okra *Earias vitella*				
		1DAS	3 DAS	5 DAS	7 DAS	10 DAS	1DAS	3 DAS	5 DAS	7 DAS	10 DAS	1DAS	3 DAS	5 DAS	7 DAS	10 DAS
Emamectin benzoate	10	86.67	51.48	12.98 (3.74)	10.00	3.33	72.23 (8.59)	41.97 (6.65)	5.47	2.14	0.00	86.67	51.48	13.33	5.47 (2.54)	2.14
Spinosad	75	75.56	48.52	10.00 (3.32)	6.67	0.00	75.62 (8.78)	45.38 (6.90)	5.47	2.14	0.00	80.00	48.15	13.33	5.47 (2.54)	0.00
Novaluron	100	72.22	44.44	20.00 (4.58)	10.00	6.67	62.44 (8.02)	45.38 (6.90)	5.47	2.14	2.14	66.67	44.81	23.33	7.80 (2.97)	0.00
Chlorantraniliprole	30	89.63	51.49	10.00 (3.32)	6.67	3.33	89.59 (9.53)	48.57 (7.12)	5.47	5.47	0.00	93.33	51.85	13.33	10.00 (3.32)	0.00
Indoxacarb	60	92.96	44.81	7.80 (2.97)	6.67	3.33	89.59 (9.53)	45.38 (6.90)	7.80	0.00	0.00	90.00	44.81	10.00	0.00 (1.00)	0.00
Fipronil	50	72.22	44.81	20.00 (4.58)	20.00	13.33	69.10 (8.41)	52.21 (7.36)	16.31	3.81	5.47	66.67	44.44	26.67	26.45 (5.24)	12.98
Thiodicarb	750	89.26	41.48	16.31 (4.16)	6.67	6.67	92.94 (9.70)	62.44 (8.02)	7.80	2.14	2.14	90.00	41.11	23.33	7.80 (2.97)	5.47
Flubendiamide	100	85.93	44.44	23.12 (4.91)	16.67	6.667	79.35 (8.99)	45.38 (6.90)	16.31	5.47	2.14	90.00	44.81	23.33	12.98 (3.74)	2.14
Carbaryl	750	78.89	38.15	19.15 (4.49)	16.67	6.67	72.68 (8.62)	45.38 (6.90)	10.48	2.14	5.47	80.00	37.78	23.33	16.31 (4.16)	5.47
Malathion	500	86.30	38.15	2.14 (1.77)	0.00	0.00	86.31 (9.36)	41.97 (6.65)	2.14	0.00	0.00	86.67	37.41	3.33	0.00 (1.00)	2.14
CD (0.05)		NS	NS	(1.49)	NS	-	(1.21)	(0.98)	NS	NS	NS	NS	NS	NS	(1.76)	-

Figures in parentheses are $\sqrt{x+1}$ transformed values

DAS-Days after spraying

NS- Not significant

The mortality of the pest was in the range of 0 to 5.47 per cent in the different insecticides when released on fruits harvested seven and ten days after spraying.

Similarly, when the third instar caterpillars were released on fruits of okra collected one day after spraying, the mortality of *E. vitella* was high r in all the treatments, ranging from 66.67 to 90.00 per cent. The larval mortality was further reduced to 37.41 to 51.85 per cent when released on fruits harvested three days after spraying. On the fifth day of spraying, the larval mortality declined to 3.33 to 26.67 per cent. Very low mortality of the larvae was observed when released on fruits harvested seven days after spraying (0 to 26.45 per cent). The mortality of the larvae in various insecticide treatments was negligible on the tenth day (0 to 12.98 per cent).

4.2. FIELD EVALUATION OF NEW GENERATION INSECTICIDES

The new generation insecticides *viz.* emamectin benzoate 5SG @10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, novaluron 10 EC @ 100 g a.i. ha^{-1}, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1}, fipronil 80 WG @ 50 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1} and flubendiamide 480 SC @ 100 g a.i. ha^{-1} and the conventional insecticides (carbaryl 50 WP @ 750 g a.i. ha^{-1} and malathion 50 EC @ 500 g a.i. $ha^{-1)}$ varied in their efficacy in managing the fruit borers of cowpea, brinjal and okra under field conditions and the results are depicted in Tables 3 to 13.

4.2.1. Cowpea pod borer

The results of the two field trials *viz.*, spraying of the selected insecticides alone and neem seed kernel extract 5 % + selected insecticides conducted to determine the relative efficacy of the treatments in managing the flower and pod borer *M. vitrata* assessed in terms of the percentage of flowers and pods damaged are presented in Tables 3 to 6.

4.2.1.1. Efficacy of selected insecticides

The data on the flower and pod damages recorded at definite intervals subsequent to the insecticide sprays are presented here under.

4.2.1.1.1. First Spray

Damage of flowers

No significant reduction was observed in the flowers damaged in the various insecticide sprayed plots on the third day after spraying, the extent of damage of flowers ranging from 23.33 to 30.00 per cent as against 53.33 per cent in the unsprayed plot (Table 3).

On the fifth day after spraying, damage to cowpea flowers by *M. vitrata* was significantly reduced in all the insecticide treated plots when compared to the untreated control which recorded 46.55 per cent damage of the flowers. Maximum reduction in the damage of flowers was recorded in plots sprayed with indoxacarb which was on par with chlorantraniliprole, emamectin benzoate, fipronil, spinosad and novaluron, the damage recorded in the treatments being 12.98, 12.98, 12.98, 16.31 and 19.15 per cent, respectively. The new generation insecticides were on par with malathion (12.98 per cent), the insecticide check in their efficacy. The other insecticides *viz.*, thiodicarb (23.12 per cent) and flubendiamide (23.12 per cent) too recorded lower damage and was on par with the insecticide check, carbaryl (23.12 per cent).

Seven days after spraying too significant reduction was noted in the flowers' damaged in the insecticide treatments. Plots sprayed with chlorantraniliprole recorded minimum damage of 7.80 per cent and was on par with indoxacarb (10 per cent), emamectin benzoate (10 per cent), fipronil (10.48 per cent), thiodicarb (12.98 per cent), spinosad (16.31 per cent), novaluron(16.31 per cent), flubendiamide (19.15 per cent) and malathion(19.15 per cent) as against 43.21 per cent damaged flowers in the untreated plots. The extent of damage in carbaryl was 23.12 per cent.

All the treatments were significantly superior to untreated control even on the tenth day after spraying, the damage of flowers declining drastically in chlorantraniliprole (4.53 per cent), indoxacarb (4.53 per cent) and emamectin benzoate (4.53 per cent) treated plots. The treatments were on par with fipronil

Table 3. Damage of flowers and pods by *Maruca vitrata* in cowpea plots treated with new generation insecticides 60 days after planting

Treatments	Dosage (g a.i.ha^{-1})	Flower damage (%)					Pod damage (%)				
		3 DAS	5 DAS*	7 DAS*	10 DAS**	15 DAS*	3 DAS	5 DAS*	7 DAS*	10 DAS*	15 DAS*
Emamectin benzoate	10	30.00	12.98 (3.74)	10.00 (3.32)	4.53 (12.29)	10 .00 (3.32)	13.33	5.47 (2.54)	2.14 (1.77)	2.14 (1.77)	7.80 (2.97)
Spinosad	75	26.67	16.31 (4.16)	16.31 (4.16)	19.31 (26.07)	23.12 (4.91)	13.33	12.98 (3.74)	7.80 (2.97)	12.98 (3.74)	12.98 (3.74)
Novaluron	100	30.00	19.15 (4.49)	16.31 (4.16)	20.00 (26.57)	23.12 (4.91)	13.33	15.54 (4.07)	12.98 (3.74)	12.98 (3.74)	16.31 (4.16)
Chlorantraniliprole	30	30.00	12.98 (3.74)	7.80 (2.97)	4.53 (12.29)	7.80 (2.97)	10.00	2.14 (1.77)	5.47 (2.54)	7.80 (2.97)	2.14 (1.77)
Indoxacarb	60	30.00	7.80 (2.97)	10 .00 (3.32)	4.53 (12.29)	7.80 (2.97)	10.00	5.47 (2.54)	5.47 (2.54)	5.47 (2.54)	12.98 (3.74)
Fipronil	50	26.67	12.98 (3.74)	10.48 (3.39)	16.36 (23.86)	12.98 (3.74)	16.67	12.98 (3.74)	7.80 (2.97)	2.14 (1.77)	12.98 (3.74)
Thiodicarb	750	23.33	23.12 (4.91)	12.98 (3.74)	16.36 (23.86)	16.31 (4.16)	13.33	7.80 (2.97)	5.47 (2.54)	2.14 (1.77)	15.54 (4.07)
Flubendiamide	100	30.00	23.12 (4.91)	19.15 (4.49)	19.31 (26.07)	12.98 (3.74)	13.33	7.80 (2.97)	10.00 (3.32)	7.80 (2.97)	16.31 (4.16)
Carbaryl	750	26.67	23.12 (4.91)	23.12 (4.91)	23.18 (28.78)	19.15 (4.49)	16.67	12.98 (3.74)	16.31 (4.16)	12.98 (3.74)	19.15 (4.50)
Malathion	500	30.00	12.98 (3.74)	19.15 (4.49)	23.18 (28.78)	26.45 (5.24)	13.33	16.31 (4.16)	7.80 (2.97)	10 .00 (3.32)	23.12 (4.91)
Untreated control		53.33	46.55 (6.90)	43.21 (6.65)	46.65 (43.08)	43.21 (6.65)	40.00	46.55 (6.90)	43.21 (6.65)	40 .00 (6.40)	42.78 (6.62)
CD(0.05)		NS	(1.56)	(1.83)	(13.18)	(1.75)	10.27	(2.03)	(2.22)	(2.07)	(1.51)

Figures in parentheses are transformed values

*Square root transformed, **Angular transformed, DAS - Days after spraying and thiodicarb, both of which registered 16.36 per cent infested flowers. The per cent damage of flowers was 19.31 in flubendiamide and spinosad, 20.00 in novaluron and 23.18 in both carbaryl and malathion, the insecticide checks.

Significant reduction in the pest infestation on the flowers was also seen on the fifteenth day after spraying in chlorantraniliprole (7.80 per cent), indoxacarb (7.80 per cent), emamectin benzoate (10 per cent) fipronil (12.98 per cent) flubendiamide (12.98 per cent) thiodicarb (16.31 per cent) and carbaryl (19.15 per cent) treated plots when compared to control. However, the damage of flowers in spinosad (23.12 per cent) novaluron (23.12 per cent) and malathion (26.45 per cent) treated plots did not differ significantly from that in the untreated plot (43.21 per cent).

Damage of pods

The new generation insecticides and the conventional insecticides (check) were found significantly effective in reducing the damage by *M. vitrata* on cowpea fruits on the third day after treatment (Table 3). The percentage of damage of pods in chlorantraniliprole, indoxacarb, emamectin benzoate, spinosad, novaluron, thiodicarb, flubendiamide, malathion, fipronil and carbaryl treatments were 10.00, 10.00, 13.33, 13.33, 13.33, 13.33, 13.33, 13.33, 16.67 and 16.67, respectively as against 40.00 per cent damage of pods in the untreated plot.

Chlorantraniliprole treated plots recorded the lowest damage of pods (2.14 per cent) on the fifth day and the treatment was on par with indoxacarb (5.47 per cent), emamectin benzoate (5.47 per cent), thiodicarb (7.80 per cent), flubendiamide (7.80 per cent), spinosad (12.98 per cent), fipronil (12.98 per cent) and carbaryl (12.98 per cent). Spraying of novaluron and malathion resulted in 15.54 per cent and 16.31 per cent damage of pods compared to 46.55 per cent damage of pods in the unsprayed plot.

The damage of pods was significantly low in emamectin benzoate (2.14 per cent), chlorantraniliprole (5.47 per cent), indoxacarb (5.47 per cent), thiodicarb (5.47 per cent), Spinosad (7.80 per cent), fipronil (7.80 per cent), malathion (7.80 per cent), flubendiamide (10 per cent) and novaluron (12.98 per cent) sprayed plots on the seventh day as against 43.21 per cent damage in the untreated check. Compared to the newer molecules, the damage of pods was higher in the carbaryl treated plot (16.31 per cent).

Ten days after spraying, damage to the fruits declined significantly in thiodicarb, emamectin benzoate, fipronil, indoxacarb, flubendiamide, chlorantraniliprole, malathion, novaluron, spinosad and carbaryl treated plots with the percentage of fruits damaged being 2.14, 2.14, 2.14, 5.47 and 5.47, 7.80, 7.80, 10, 12.98 and 12.98, respectively. The insecticides were on par in their effect. The damage in the control plot was 40 per cent.

Fifteen days after spraying, only 2.14 per cent damage of pods was recorded in chlorantraniliprole sprayed plants and the treatment was on par with emamectin benzoate having damage of pods of 7.80 per cent. In the rest of the treatments, the percentage of fruits damaged ranged from 12.98 to 23.12 and were superior to untreated plants (42.78 per cent).

4.2.1.1.2. Second spray

Damage of flowers

On the third day of spraying, the damage to flowers was the lowest in thiodicarb (10 per cent) sprayed plot. The insecticide was on par with indoxacarb (12.98 per cent), fipronil (12.98 per cent), chlorantraniliprole (16.31 per cent), flubendiamide (16.31 per cent), emamectin benzoate (19.15 per cent), novaluron (19.15 per cent), and carbaryl (19.15 per cent) in its efficacy (Table 4). Spinosad (23.12 per cent) and malathion (23.12 per cent) too registered significantly lower damage of flowers by *M. vitrata* when compared to the control plot (39.59 per cent).

The damage declined further on the fifth day after spraying wherein emamectin benzoate, spinosad and indoxacarb recorded lower damage of flowers of 5.47, 5.47 and 7.80 per cent, respectively and were on par with chlorantraniliprole (10 per cent), fipronil (16.31 per cent), thiodicarb (16.31 per

Table 4. Damage of flowers and pods by *Maruca vitrata* in cowpea plots treated with new generation insecticides 75 days after planting

Treatments	Dosage (g a.i.ha^{-1})	Flower damage (%)					Pod damage (%)				
		3 DAS	5 DAS	7 DAS	10 DAS	15 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
Emamectin benzoate	10	19.15 (4.49)	5.47 (2.54)	5.47 (2.54)	2.14 (1.77)	5.47 (2.54)	10.00	5.47 (2.54)	5.47 (2.54)	5.47 (2.54)	19.15 (4.49)
Spinosad	75	23.12 (4.91)	5.47 (2.54)	16.31 (4.16)	16.31 (4.16)	12.98 (3.74)	13.33	12.98 (3.74)	12.98 (3.74)	12.98 (3.74)	19.15 (4.49)
Novaluron	100	19.15 (4.49)	16.31 (4.16)	16.31 (4.16)	12.98 (3.74)	16.31 (4.16)	20.00	7.80 (2.97)	16.31 (4.16)	16.31 (4.16)	21.73 (4.77)
Chlorantraniliprole	30	16.31 (4.16)	10.00 (3.32)	5.47 (2.54)	10.00 (3.32)	10.00 (3.32)	10.00	7.80 (2.97)	5.47 (2.54)	5.47 (2.54)	7.80 (2.97)
Indoxacarb	60	12.98 (3.74)	7.80 (2.97)	5.47 (2.54)	5.47 (2.54)	5.47 (2.54)	10.00	10.00 (3.32)	5.47 (2.54)	5.47 (2.54)	10 .00 (3.32)
Fipronil	50	12.98 (3.74)	16.31 (4.16)	16.31 (4.16)	12.98 (3.74)	5.47 (2.54)	13.33	5.47 (2.54)	10 .00 (3.32)	16.31 (4.16)	16.31 (4.16)
Thiodicarb	750	10.00 (3.32)	16.31 (4.16)	12.98 (3.74)	16.31 (4.16)	10.00 (3.32)	10.00	5.47 (2.54)	5.47 (2.54)	12.98 (3.74)	19.15 (4.49)
Flubendiamide	100	16.31 (4.16)	16.31 (4.16)	15.54 (4.07)	16.31 (4.16)	12.98 (3.74)	16.67	5.47 (2.54)	5.47 (2.54)	12.98 (3.74)	16.31 (4.16)
Carbaryl	750	19.15 (4.49)	20.00 (4.58)	21.73 (4.77)	23.12 (4.91)	12.98 (3.74)	16.67	12.98 (3.74)	12.98 (3.74)	12.98 (3.74)	23.12 (4.91)
Malathion	500	23.12 (4.91)	23.12 (4.91)	20.00 (4.58)	19.15 (4.49)	10.48 (3.39)	13.33	12.98 (3.74)	7.80 (2.97)	16.31 (4.16)	26. 45 (5.24)
Untreated control		39.59 (6.37)	43.21 (6.65)	33.18 (5.85)	36.12 (6.09)	35.51 (6.04)	36.67	43.21 (6.65)	40.00 (6.40)	43.21 (6.65)	46.55 (6.90)
CD(0.05)		(1.34)	(1.64)	(1.75)	(1.45)	NS	6.89	(2.11)	(1.98)	(1.52)	(1.71)

Figures in parentheses are square root transformed values

DAS - Days after spraying

cent), flubendiamide(16.31 per cent) and novaluron (16.31 per cent). The insecticide checks, carbaryl (20 per cent) and malathion (23.12 per cent) were statistically on par, and superior over untreated plants (43.21 per cent).

Seven days after spraying, the damage by the pest continued to be low in chlorantraniliprole (5.47 per cent), emamectin benzoate (5.47 per cent), indoxacarb (5.47 per cent), thiodicarb (12.98 per cent) and flubendiamide (15.54 per cent) and the treatments were significantly superior to the other insecticides. The damage of flowers in spinosad, fipronil, novaluron and the insecticide checks (malathion and carbaryl) ranged from 16.31 to 21.73 per cent and did not vary significantly from that in the untreated plot (33.18 per cent).

On the tenth day, emamectin benzoate and indoxacarb with of 2.14 and 5.47 per cent damage of flowers proved to be more effective in controlling *M. vitrata*. The insecticides were on par in their efficacy. Chlorantraniliprole (10 per cent), novaluron (12.98 per cent) and fipronil (12.98 per cent) too reduced the damage of flowers substantially. The extent of damage of flowers in thiodicarb (16.31 per cent), flubendiamide (16.31 per cent), novaluron (16.31 per cent), Spinosad (16.31 per cent) and malathion (23.12 per cent) sprayed plots too was significantly lower than that in the control plot (36.12 per cent). However, carbaryl (20 per cent) was found to be ineffective, the damage of flowers in the treatment being on par with that in the control plot.

No significant difference was observed between the different treatments when compared with the control (35.51 per cent) on the fifteenth day of spraying, the percentage damage of flowers ranging from 5.47 to 16.31.

Damage of pods

The damage to cowpea pods was significantly reduced in all the plots sprayed with the new generation insecticides and the insecticide checks on the third day of spraying, the extent of damage ranging from 10 to 16.67 per cent compared to 36.67 per cent in the unsprayed plot (Table 4).

On the fifth day after spraying too, lower percentage of damage of pods was recorded in all the insecticide sprayed plots *viz.*, fipronil (5.47 per cent), thiodicarb(5.47), flubendiamide (5.47 per cent), emamectin benzoate (5.47 per cent), novaluron (7.80 per cent), chlorantraniliprole (7.80 per cent), indoxacarb (10 per cent), spinosad (12.98 per cent), carbaryl (12.98 per cent) and malathion (12.98 per cent). The treatments were at par and superior than untreated control (43.21 per cent).

A similar trend was noticed on the seventh day too. The extent of damage of pods was low in the insecticide sprayed plots. The treatments emamectin benzoate (5.47 per cent), indoxacarb (5.47 per cent), thiodicarb(5.47 per cent), flubendiamide(5.47 per cent), chlorantraniliprole(5.47 per cent), malathion(7.80 per cent), fipronil(10 per cent), spinosad (12.98 per cent), carbaryl (12.98 per cent) and novaluron (16.31 per cent) were statistically on par and significantly superior over untreated plants (40 per cent).

Emamectin benzoate (5.47 per cent), chlorantraniliprole (5.47 per cent) and indoxacarb (5.47 per cent), spinosad (12.98 per cent), thiodicarb (12.98 per cent), flubendiamide (12.98 per cent) and carbaryl (12.98 per cent) were on par in their efficacy in reducing the pest infestation on the fruits on the tenth day after spraying. Novaluron (16.31 per cent), fipronil (16.31 per cent), and malathion (7.80 per cent) too were effective in reducing the damage of pods when compared with the untreated plot (43.21 per cent).

With the exception of malathion, all the other treatments registered significantly lower damage of pods (7.80 to 23.12 per cent) when compared to the untreated plots (46.55 per cent) on the fifteenth day after spraying. Malathion sprayed plots which recorded 26.45 per cent damage was on par with untreated control.

4.2.1.1.3. Yield and Benefit – Cost Ratio

The insecticide treatments *viz*, indoxacarb (14.50 kg/ plot), chlorantraniliprole (13.88 kg/ plot) and emamectin benzoate (13.20 kg/ plot) recorded significantly higher yield compared to other treatments (Table 5). The other treatments fipronil (12.25 kg/ plot), flubendiamide (12.23 kg/ plot), thiodicarb (11.73 kg/ plot), spinosad (11.34 kg/ plot) and malathion (10.88 kg/ plot) were on par with each other. The treatments carbaryl and novaluron recorded 10.33 and 10.00 kg of cowpea fruits per plot, respectively and were on par with that of control plot (9.90 kg/ plot).

The data on the benefit-cost ratio revealed that indoxacarb gave Rs 8.13 in return for every one rupee invested on plant protection measures. The returns from plots treated with chlorantraniliprole, emamectin benzoate and fipronil were also high being Rs. 6.43, 5.27 and 4.26, respectively for every one rupee invested. The returns from flubendiamide, thiodicarb, spinosad, malathion, were Rs. 3.96, 2.73, 2.38 and 2.04, respectively. Application of carbaryl and novaluron did not give any appreciable monetary benefits

4.2.1.2. Efficacy of Neem seed kernel extract 5 % + Insecticides

The results of the trial are presented in Table 6.

Damage of flowers

On the third day after spraying of the insecticides, indoxacarb (10 per cent), chlorantraniliprole (10 per cent), fipronil (12.98 per cent), emamectin benzoate (15.54 per cent), spinosad (16.31 per cent), and novaluron (16.31 per cent) treated plots recorded significantly lower damage to the flowers. The damage of flowers in all other treatments *viz.*, carbaryl, thiodicarb, flubendiamide and malathion was on par recording damage of 20.00, 23.12, 23.12 and 23.12 per cent, which was superior to control (43.21 per cent).

Five days after spraying, the flowers damaged was significantly low in emamectin benzoate, chlorantraniliprole and indoxacarb treated plants (2.14 per cent) and the insecticides were superior to fipronil, spinosad, novaluron, carbaryl, malathion and thiodicarb which recorded 10, 12.98, 16.31, 16.31, 16.31 and 20 per cent damaged flowers, respectively. Among the different insecticidal treatments, maximum damage to flowers was recorded in plots sprayed with

Table 5. Yield of cowpea and benefit: cost ratio of insecticidal treatments

Treatments	Dosage (g a.i.ha^{-1})	Yield			Monetary benefits (Rs ha^{-1})	Expenses for insecticides (Rs ha^{-1})	B: C ratio
		(kg/18 m² plot)	(t/ha)	Increase over control (%)			
Emamectin benzoate	10	13.20	7.33	33.33	73333.33	3916/-	5.27:1
Spinosad	75	11.34	6.30	14.55	32000.00	3456/-	2.38:1
Novaluron	100	10.30	5.72	4.04	8888.89	5340/-	-
Chlorantraniliprole	30	13.88	7.71	40.20	88444.44	3750/-	6.48:1
Indoxacarb	60	14.50	8.05	46.46	102222.20	2570/-	8.13:1
Fipronil	50	12.25	6.81	23.74	52222.22	2268/-	4.26:1
Thiodicarb	750	11.73	6.52	18.48	40666.67	4900/-	2.73:1
Flubendiamide	100	12.23	6.79	23.54	51777.78	3080/-	5.00:1
Carbaryl	750	10.33	5.74	4.34	9555.56	1750/-	-
Malathion	500	10.88	6.04	9.90	21777.78	675/-	2.01:1
Untreated control		9.90	5.50				-
CD(0.05)		1.58					

flubendiamide (23.12 per cent.) However, the damage was significantly low when compared to that in the untreated plot (43.21 per cent).

On the seventh day also the same trend of reduction in damage of flower was noticed, with emamectin benzoate (2.14 per cent), indoxacarb (2.14 per cent) and chlorantraniliprole (3.81 per cent) registering superiority over the other insecticidal treatments in reducing damage by *M. vitrata*. Fipronil(12.98 per cent), spinosad (16.31 per cent), thiodicarb (16.31 per cent), flubendiamide (16.31 per cent), carbaryl (16.31 per cent), malathion (16.31 per cent) and novaluron (20 per cent) were on par in their efficacy and were significantly superior over untreated check (43.21 per cent).

Emamectin benzoate, indoxacarb and chlorantraniliprole again were the better treatments on the tenth day with 2.14, 2.14 and 7.80 per cent damage of flowers, respectively. Novaluron (12.98 per cent), spinosad (15.54 per cent), fipronil (16.31 per cent), thiodicarb (16.31 per cent), flubendiamide (16.31 per cent), malathion (16.31 per cent) and carbaryl (20 per cent) too reduced the damage of flowers significantly when compared to the untreated plot (46.55 per cent).

The lowest damage of flowers was recorded in indoxacarb (2.14 per cent) sprayed plot on the fifteenth day followed by that in chlorantraniliprole (5.47 per cent) and emamectin benzoate (5.47 per cent) treated plots. Novaluron (12.98 per cent), fipronil (16.31 per cent), Spinosad (19.15per cent), thiodicarb (20 per cent), carbaryl (20 per cent), flubendiamide (20 per cent) and malathion (23.12 per cent) too were superior in their efficacy in managing the pod borer as evidenced by the reduced damage of flowers in the treatments when compared to the control plot (46.23 per cent).

Damage of pods

The damage to cowpea pods was noted to be significantly reduced in the various treatments. Low damage was recorded in plots sprayed with emamectin benzoate (6.67 per cent), indoxacarb (6.67 per cent), novaluron (10 per cent),

Table 6. Damage of flowers and pods by *Maruca vitrata* in cowpea plots treated with NSKE followed by new generation insecticides.

Treatments	Dosage (g a.i.ha^{-1})	Flower damage (%)					Fruit damage (%)				
		3 DAS	5 DAS	7 DAS	10 DAS	15 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
Emamectin benzoate	10	15.54 (4.07)	2.14 (1.77)	2.14 (1.77)	2.14 (1.77)	5.47 (2.54)	6.67	2.14 (1.77)	2.14 (1.77)	7.80 (2.97)	7.80 (2.97)
Spinosad	75	16.31 (4.16)	12.98 (3.74)	16.31(4.16)	15.54 (4.07)	19.15 (4.49)	16.67	10.00 (3.32)	10.00 (3.32)	10.00 (3.32)	12.98 (3.74)
Novaluron	100	16.31 (4.16)	16.31(4.16)	20 (4.58)	12.98 (3.74)	12.98 (3.74)	10.00	10.00(3.32)	10 .00 (3.32)	12.98 (3.74)	12.98 (3.74)
Chlorantraniliprole	30	10 (3.32)	2.14 (1.77)	3.81(2.19)	7.80 (2.97)	5.47 (2.54)	10.00	2.14 (1.77)	3.81(2.19)	2.14 (1.77)	2.14 (1.77)
Indoxacarb	60	10 (3.32)	2.14 (1.77)	2.14 (1.77)	2.14 (1.77)	2.14 (1.77)	6.67	2.14 (1.77)	2.14 (1.77)	5.47 (2.54)	10.00 (3.32)
Fipronil	50	12.98 (3.74)	10.00 (3.32)	12.98 (3.74)	16.31(4.16)	16.31 (4.16)	16.67	7.80 (2.97)	5.47 (2.54)	12.98 (3.74)	12.98 (3.74)
Thiodicarb	750	23.12 (4.91)	20.00 (4.58)	16.31 (4.16)	16.31(4.16)	20.00 (4.58)	10.00	5.47 (2.54)	5.47 (2.54)	5.47 (2.54)	15.54 (4.07)
Flubendiamide	100	23.12 (4.91)	23.12 (4.91)	16.31 (4.16)	16.31(4.16)	20.00(4.58)	16.67	12.98 (3.74)	10.00 (3.32)	12.98 (3.74)	16.31 (4.16)
Carbaryl	750	20 (4.58)	16.31(4.16)	16.31(4.16)	20.00 (4.58)	20.00 (4.58)	16.67	12.98 (3.74)	12.98 (3.74)	16.31(4.16)	20.00 (4.58)
Malathion	500	23.12 (4.91)	16.31(4.16)	16.31(4.16)	16.31(4.16)	23.12 (4.91)	13.33	10 .00(3.32)	12.98 (3.74)	16.31 (4.16)	24.97 (5.10)
Untreated control		43.21 (6.65)	43.21 (6.65)	43.21 (6.65)	46.55 (6.90)	46.23(6.87)	36.67	39.59 (6.37)	39.59 (6.37)	46.55 (6.90)	46.55 (6.90)
CD(0.05)		(1.11)	(1.41)	(1.65)	(1.76)	(1.59)	9.38	(1.76)	(1.87)	(1.68)	(1.83)

Figures in parentheses are square root transformed values

DAS - Days after spraying

chlorantraniliprole (10 per cent), thiodicarb (10 per cent) and malathion (13.33 per cent) on the third day, the treatments being at par. Spinosad (16.67 per cent), fipronil (16.67 per cent), flubendiamide (16.67 per cent) and carbaryl (16.67 per cent) too were effective against the pest, recording significantly lower damage than that in the untreated plot (36.67 per cent).

On the fifth day, damage of pods was again significantly low in emamectin benzoate (2.14 per cent), chlorantraniliprole (2.14 per cent), indoxacarb (2.14 per cent), thiodicarb (5.47 per cent), fipronil (7.80 per cent), novaluron (10per cent), Spinosad (10 per cent) and malathion (10 per cent) treated plots, the treatments being on par. Flubendiamide (12.98 per cent) and carbaryl (12.98 per cent) were on par with each other in their effect on *M. vitrata* infestation and was superior to control (39.59 per cent).

The lowest damage was recorded on the seventh day in emamectin benzoate and indoxacarb sprayed plots with only 2.14 per cent damage of pods and the treatments were on par with chlorantraniliprole (3.81 per cent), fipronil (5.47 per cent), thiodicarb (5.47 per cent), novaluron (10 per cent), spinosad(10 per cent) and flubendiamide (10 per cent). This was followed by carbaryl (12.98 per cent) and malathion (12.98 per cent) which were on par with each other and superior to control (39.59 per cent).

The pod damage on the tenth day was the least in chlorantraniliprole treated plots (2.14 per cent) and the treatment was statistically on par with indoxacarb (5.47 per cent), thiodicarb (5.47 per cent), emamectin benzoate (7.80 per cent), and spinosad (10 per cent). Novaluron (12.98 per cent), fipronil (12.98 per cent), flubendiamide (12.98 per cent), carbaryl (16.31 per cent) and malathion (16.31 per cent) were the other insecticides ranked in the order of their effectiveness in reducing the damage of pods when compared with the highest damage in untreated plots (46.55 per cent).

On the fifteenth day, the same trend was noticed in chlorantraniliprole (2.14 per cent), emamectin benzoate (7.80 per cent) and indoxacarb (10 per cent) treated plots with low damage of pods followed by the other insecticidal treatments. Malathion (24.97 per cent) which was on par with control (46.55 per cent).

4.2.2 Brinjal shoot and fruit borer

4.2.2.1 First spray

Damage of shoots

On the fifth day after spraying, all the treatments were superior in suppressing the infestation by *L. orbonalis* on shoots of brinjal (Table 7). While 2.23 per cent shoots were bored by the pest in the unsprayed plot, only 0.12, 0.22, 0.25, 0.29, 0.43, 0.57, 0.69, 0.67 and 0.73 per cent shoots were damaged in chlorantraniliprole, fipronil, emamectin benzoate, flubendiamide, spinosad, indoxacarb, novaluron, malathion and carbaryl treated plots, respectively, the treatments being on par. The extent of damage in plots sprayed with thiodicarb was 0.89 per cent.

On the tenth day after treatment also, all the insecticides *viz.*, chlorantraniliprole (0.43 per cent), thiodicarb (0.68 per cent), indoxacarb (0.73 per cent), carbaryl (0.78 per cent), malathion (0.85 per cent), flubendiamide (0.95 per cent), spinosad (1.14 per cent), fipronil (1.17 per cent), emamectin benzoate (1.26 per cent) and novaluron (1.28 per cent) recorded significantly lower damage than that in the control (3.20 per cent).

Significantly lower infestation by *L. orbonalis* was also recorded from all the treated plots on the fifteenth day after spraying. The newer molecules chlorantraniliprole (0.43 per cent), indoxacarb (0.61 per cent), spinosad (0.66 per cent), flubendiamide (0.73 per cent) and the insecticide checks malathion (1.08 per cent) and carbaryl (1.37 per cent) were statistically on par in their efficacy. The extent of damage in the other treatments ranged from 1.57 to 2.77 per cent compared to 3.31 per cent in the control plot.

Table 7. Damage of shoots by *Leucinodes orbonalis* in brinjal plots treated with new generation insecticides 30 days after transplanting

Treatments	Dosage (g a.i.ha^{-1})	5 DAS	10 DAS	15 DAS
Emamectin benzoate	10	0.25 (1.12)	1.26 (1.50)	2.77 (1.94)
Spinosad	75	0.43 (1.19)	1.14 (1.46)	0.66 (1.29)
Novaluron	100	0.69 (1.30)	1.28 (1.51)	1.58 (1.61)
Chlorantraniliprole	30	0.12 (1.06)	0.43 (1.19)	0.43 (1.19)
Indoxacarb	60	0.57 (1.25)	0.73 (1.31)	0.61 (1.27)
Fipronil	50	0.22 (1.10)	1.17 (1.47)	1.57 (1.60)
Thiodicarb	750	0.89 (1.37)	0.68 (1.30)	1.70 (1.64)
Flubendiamide	100	0.29 (1.14)	0.95 (1.40)	0.73 (1.32)
Carbaryl	750	0.73 (1.31)	0.78 (1.33)	1.37 (1.54)
Malathion	500	0.67 (1.29)	0.85 (1.36)	1.08 (1.44)
Untreated control		2.23 (1.80)	3.20 (2.04)	3.31 (2.08)
CD(0.05)		(0.29)	(0.40)	(0.37)

Figures in parentheses are square root transformed values

DAS - Days after spraying

4.2.2.2 Second spray

Damage of shoots

On the fifth day after spraying, all the treatments suppressed the infestation by *L. orbonalis* (2.38 per cent) significantly (Table 8). Chlorantraniliprole showed the lowest damage (0.24 per cent) and was on par with flubendiamide (0.30 per cent), spinosad (0.43 per cent), emamectin benzoate (0.53 per cent), novaluron (0.56 per cent), indoxacarb (0.57 per cent), fipronil(0.61 per cent), thiodicarb (0.72 per cent), carbaryl (0.73 per cent) and malathion (0.82 per cent) in controlling the infestation by *L. orbonalis*.

A comparable effect was exhibited by all the treatments on the tenth day after spraying also, the damage of shootsd ranging from 0.43 to 1.17 per cent as against 3.20 per cent damage of shoots in the control plot.

Again on the fifteenth day, significant reduction in the damage of shoots was noted in all the treatments compared to control (3.53 per cent). The insecticides *viz*., chlorantraniliprole (0.62 per cent), indoxacarb (0.57 per cent) spinosad (0.68 per cent), flubendiamide (1.09 per cent), fipronil (1.11 per cent) and malathion (1.18 per cent) were statistically at par in their efficacy. The extent of damage of shoots in the other insecticide treatments were 1.30 (novaluron), 1.34 (carbaryl) ,1.70 (thiodicarb) and 1.80 per cent (emamectin benzoate).

Damage of fruits

Remarkable reduction in the infestation by *L. orbonalis* was observed (Table 8) in the plots sprayed with chlorantraniliprole (2.34 per cent), indoxacarb (5.24 per cent), emamectin benzoate (6.27 per cent), flubendiamide (6.82 per cent), fipronil (13.08 per cent) and spinosad (14.03 per cent) on the fifth day. Thiodicarb (17.37 per cent), malathion (18.13 per cent), carbaryl (19.16 per cent) and novaluron (19.53 per cent) too recorded lower damage of fruits when compared to the unsprayed plot (33.04 per cent).

On the tenth day, the extent of damage was significantly low in indoxacarb (13.40 per cent), emamectin benzoate (16.48 per cent), chlorantraniliprole (15.99

Table 8. Damage of shoots and fruits by *Leucinodes orbonalis* in brinjal plots treated with new generation insecticides 60 days after transplanting

Treatments	Dosage (g a.i.ha^{-1})	Shoot damage (%)			Fruit damage (%)		
		5 DAS	10 DAS	15 DAS	5 DAS	10 DAS	15 DAS
Emamectin benzoate	10	0.53 (1.24)	1.03 (1.43)	1.80 (1.67)	6.27 (2.70)	16.48	17.35
Spinosad	75	0.43 (1.19)	1.02 (1.42)	0.68 (1.30)	14.03 (3.88)	18.65	31.22
Novaluron	100	0.56 (1.25)	1.00 (1.41)	1.30 (1.52)	19.53 (4.53)	26.11	25.76
Chlorantraniliprole	30	0.24 (1.11)	0.43 (1.19)	0.57 (1.25)	2.34 (1.83)	15.99	18.33
Indoxacarb	60	0.57 (1.25)	0.73 (1.31)	0.62 (1.27)	5.24 (2.50)	13. 40	18.60
Fipronil	50	0.61 (1.27)	1.17 (1.47)	1.11 (1.45)	13.08 (3.75)	26.95	19.57
Thiodicarb	750	0.72 (1.31)	0.86 (1.36)	1.70 (1.64)	17.37 (4.29)	31.79	26.14
Flubendiamide	100	0.30 (1.14)	0.95 (1.40)	1.09 (1.44)	6.82 (2.80)	24.66	26.24
Carbaryl	750	0.73 (1.31)	0.95 (1.40)	1.34 (1.53)	19.16 (4.49)	37.35	41.11
Malathion	500	0.82 (1.35)	1.04 (1.43)	1.18 (1.48)	18.13 (4.37)	39.26	37.91
Untreated control		2.38 (1.83)	3.20 (2.05)	3.53 (2.13)	33.04 (5.83)	51.48	46.63
CD(0.05)		(0.33)	(0.40)	(0.26)	(2.06)	17.64	15.60

Figures in parentheses are square root transformed values

DAS - Days after spraying

per cent), spinosad (18.65 per cent), flubendiamide (24.66 per cent), novaluron (26.11 per cent) and fipronil (26.95 per cent) treated plots. Though thiodicarb, carbaryl and malathion with percentage damage ranging from 31.79 to 39.26 were at par in their efficacy, statistically carbaryl (37.35 per cent) and malathion (39.26 per cent) were on par with control (51.48 per cent).

On the fifteenth day also, the better treatments included emamectin benzoate (17.35 per cent), chlorantraniliprole (18.33 per cent), indoxacarb (18.60 per cent), fipronil (19.57 per cent), novaluron (25.76 per cent), thiodicarb (26.14 per cent), flubendiamide (26.24 per cent) and spinosad (31.22 per cent) registering significantly lower damage than that in the control plot(46.63 per cent). However, the insecticide checks *viz.*, malathion and carbaryl with 37.91 and 41.11 per cent damaged fruits, respectively were on par with the untreated check.

4.2.2.3 Third spray

Damage of shoots

The new generation insecticides chlorantraniliprole (0.24 per cent), flubendiamide (0.29 per cent), emamectin benzoate (0.40 per cent), indoxacarb (0.41 per cent), spinosad (0.46 per cent), thiodicarb(0.60 per cent), novaluron (0.68 per cent)and fipronil (0.73 per cent) and the insecticide checks malathion (0.63 per cent) and carbaryl (0.73 per cent) proved superior in suppressing the infestation by *L. orbonalis* when compared to control (2.15 per cent) on the fifth day after spraying (Table 9).

An effect akin to the one recorded on the fifth day after spraying was noted on the tenth day also. All the insecticides *viz.*, chlorantraniliprole (0.45 per cent), spinosad (0.57 per cent), thiodicarb (0.68per cent), indoxacarb (0.73per cent), novaluron (0.80 per cent) malathion (0.91 per cent), flubendiamide (0.95per cent), carbaryl (0.95 per cent), emamectin benzoate (1.03 per cent) and fipronil (1.06 per cent) reduced damage of shoots significantly when compared to control (2.79 per cent).

Table 9. Damage of shoots and fruits by *Leucinodes orbonalis* in brinjal plots treated with new generation insecticides 80 days after transplanting

Treatments	Dosage (g a.i.ha^{-1})	Shoot damage (%)			Fruit damage (%)		
		5 DAS	10DAS	15DAS	5 DAS	10DAS	15DAS
Emamectin benzoate	10	0.40(1.18)	1.03(1.43)	1.37(1.54)	5.04 (2.46)	13.39	29.81
Spinosad	75	0.46(1.21)	0.57(1.25)	0.91(1.38)	11.26 (3.50)	21.37	31.30
Novaluron	100	0.68(1.30)	0.80(1.34)	1.19(1.48)	14.65 (3.96)	25.36	31.79
Chlorantraniliprole	30	0.24(1.11)	0.45(1.21)	0.70(1.30)	1.98 (1.73)	10.87	23.28
Indoxacarb	60	0.41(1.19)	0.73(1.31)	0.84(1.36)	5.04 (2.46)	13.03	23.54
Fipronil	50	0.73(1.32)	1.06(1.44)	1.11(1.45)	9.78 (3.28)	14.85	21.43
Thiodicarb	750	0.60(1.26)	0.68(1.30)	1.16(1.47)	8.65 (3.11)	22.79	30.53
Flubendiamide	100	0.29(1.14)	0.95(1.40)	1.09(1.44)	4.36 (2.32)	18.23	24.13
Carbaryl	750	0.73(1.31)	0.95(1.40)	1.10(1.45)	15.17 (4.02)	27.50	38.36
Malathion	500	0.63(1.28)	0.91(1.38)	0.95(1.40)	9.13 (3.18)	26.19	43.07
Untreated control		2.15(1.77)	2.79(1.95)	2.38(1.84)	31.09 (5.66)	50.46	46.14
CD(0.05)		(0.28)	(0.30)	(0.23)	(1.35)	13.68	20.80

Figures in parentheses are square root transformed values, DAS - Days after spraying

With the exception of emamectin benzoate (1.37 per cent) which was on par with control (2.38 per cent), all the treatments significantly reduced the infestation by *L. orbonalis,* the percentage infestation ranging from 0.70 to 1.19 on the fifteenth day of spraying.

Damage of fruits

Five day after spraying, the infestation by *L. orbonalis* was significantly low in plots treated with chlorantraniliprole, flubendiamide, indoxacarb and emamectin benzoate which recorded only 1.98, 4.36 5.04 and 5.04 per cent damage of fruits, respectively compared to 31.09 per cent damage of fruits in the unsprayed plot (Table 9). These were followed by thiodicarb (8.65 per cent), malathion (9.13 per cent), fipronil (9.78 per cent), spinosad (11.26 per cent), novaluron (14.65 per cent) and carbaryl (15.17 per cent) which too recorded significantly lower damage than that in the control plot.

The highest reduction in the infestation by *L. orbonalis* on the tenth day was observed in plants treated with chlorantraniliprole (10.87 per cent)which was on par with indoxacarb (13.03 per cent), emamectin benzoate (13.39 per cent), fipronil (14.85 per cent), flubendiamide (18.23 per cent), spinosad (21.37 per cent) and thiodicarb (22.79 per cent). Novaluron (25.36 per cent), malathion (26.19 per cent) and carbaryl (27.50 per cent) were on par in their effect and superior to control where the infestation by *L. orbonalis* was 50.46 per cent.

On the fifteenth day, fipronil (14.85 per cent), chlorantraniliprole (10.87 per cent), indoxacarb (13.03 per cent) and flubendiamide (18.23 per cent) reduced the damage of fruits significantly. The extent of damage of fruits (21.43 to 38.36 per cent) in all the other insecticide treatments did not differ significantly from that of the untreated check (46.14 per cent).

4.2.2.4. Yield and Benefit – Cost Ratio

The data on the yield of brinjal presented in Table 10 indicated that all the treatments resulted in significantly higher yield when compared to the control plot (12.38 kg/ plot). The insecticide treatments *viz,* flubendiamide (17.82/ plot),

Table 10. Yield of brinjal and benefit: cost ratio of insecticidal treatments

Treatments	Dosage (g a.i.ha^{-1})	Yield			Monetary benefits (Rs ha^{-1})	Expenses for insecticides (Rs ha^{-1})	B: C ratio
		(kg/9 m² plot)	(t/ha)	Increase over control (%)			
Emamectin benzoate	10	16.51	18.34	33.76	68833.27	2.32	2.32:1
Spinosad	75	15.34	17.04	23.91	168666.67	1.54	1.54:1
Novaluron	100	15.74	17.49	27.14	175333.33	1.63	1.63:1
Chlorantraniliprole	30	17.52	19.47	41.52	205000.00	5.55	5.55:1
Indoxacarb	60	17.63	19.59	42.41	206833.33	5.28	5.28:1
Fipronil	50	15.70	17.44	26.82	174666.67	1.63	1.63:1
Thiodicarb	750	15.24	16.94	23.10	167000.00	-	-
Flubendiamide	100	17.82	19.80	43.94	210000.00	5.35	5.35:1
Carbaryl	750	14.47	16.08	16.88	154166.67	2.27	2.27:1
Malathion	500	14.52	16.13	17.29	155000.00	1.97	1.97:1
Untreated control		12.38	13.76			-	-
CD(0.05)		1.43					

indoxacarb (17.63 kg/ plot) chlorantraniliprole(17.52 kg/ plot) and emamectin benzoate (16.51 kg/ plot) recorded significantly higher yield compared to the other treatments. Novaluron (15.74 kg/ plot), fipronil (15.70 kg/ plot), spinosad (15.34 kg/ plot), thiodicarb (15.24 kg/ plot), malathion (14.52 kg/ plot) and carbaryl (14.47 kg/ plot) were on par with each other.

The data on the benefit-cost ratio of brinjal revealed that chlorantraniliprole, and flubendiamide gave Rs 5.55 and 5.35 in return for every one rupee invested on plant protection measures. The returns from indoxacarb, emamectin benzoate and carbaryl, were Rs.5.28, 2.32 and 2.27 respectively. The benefit: cost ratio of malathion, fipronil, novaluron and spinosad ranged from Rs.1.54 to 1.94.

4.2.3 Okra shoot and fruit borer

4.2.3.1. First spray

Damage of shoots

None of the treatments recorded significant reduction in shoot infestation (0.93-1.91 per cent) by *E. vitella* when compared to control (5.06 per cent) three day after spraying (Table 11).

On the fifth day, all the treatments suppressed the infestation by *E. vitella* significantly (8.05 per cent in control plot). Chlorantraniliprole showed the lowest damage (0.69 per cent) followed by indoxacarb (0.73 per cent), flubendiamide (0.75 per cent), emamectin benzoate (1.25 per cent), carbaryl (1.61 per cent), malathion (1.61 per cent) thiodicarb (1.62 per cent), novaluron (1.63 per cent), fipronil (1.66 per cent), and spinosad (2.46 per cent), all the insecticides being statistically on par.

On the seventh day too significantly lower damage of shoot than that observed in the control plot (12.88 per cent) was recorded from flubendiamide (1.53 per cent), indoxacarb (1.57 per cent), fipronil (1.61 per cent), chlorantraniliprole (1.63 per cent), emamectin benzoate (2.18 per cent), thiodicarb

Table 11. Damage of shoots by *Earias vittella* in okra plots treated with new generation insecticides 25 days after planting

Treatments	Dosage (g a.i.ha^{-1})	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
Emamectin benzoate	10	0.93	1.25 (1.50)	2.18 (1.78)	4.08 (2.25)	4.01
Spinosad	75	1.91	2.46 (1.86)	2.97 (1.99)	3.42 (2.10)	5.09
Novaluron	100	1.98	1.63 (1.62)	2.59 (1.89)	4.18 (2.28)	4.15
Chlorantraniliprole	30	0.98	0.69 (1.30)	1.63 (1.62)	2.97 (1.99)	3.26
Indoxacarb	60	0.93	0.73 (1.31)	1.57 (1.60)	3.32 (2.08)	4.13
Fipronil	50	1.89	1.66 (1.63)	1.61 (1.62)	2.63 (1.91)	5.03
Thiodicarb	750	1.80	1.62 (1.62)	2.26 (1.81)	3.37 (2.09)	4.92
Flubendiamide	100	0.89	0.75 (1.32)	1.53 (1.59)	3.32 (2.08)	3.29
Carbaryl	750	0.98	1.61 (1.62)	3.42 (2.10)	4.16 (2.27)	5.78
Malathion	500	1.04	1.61 (1.62)	3.40 (2.10)	4.17 (2.27)	5.81
Untreated control	-	5.06	8.05 (3.01)	12.88 (3.73)	12.59 (3.69)	11.14
CD(0.05)	-	-	(1.00)	(0.98)	(0.68)	3.68

Figures in parentheses are square root transformed values, DAS - Days after spraying

(2.26 per cent), novaluron (2.59 per cent), spinosad (2.97 per cent), malathion (3.40 per cent), and carbaryl (3.42 per cent) sprayed plots.

On the tenth day after treatment, statistically the same effect was exhibited by all the treatments. The percentage infestation in the various insecticide sprayed plots ranged from 2.63 to 4.18 while 12.59 per cent damage of shoot was recorded in the untreated plot.

Even on the fifteenth day after spraying, all the treatments reduced the infestation by *E. vitella* significantly as evidenced by the higher damage recorded in control (11.14 per cent). Moreover, the treatments were found to be statistically on par in their effectiveness, the percentage infestation ranging from 3.26 to 5.81.

4.2.3.2. Second spray

Damage of fruits

No significant difference was recorded in the damage of fruits by *E. vitella* in the various insecticide treated and untreated plots on the third day after spraying, the damaged fruits observed ranging from 0 – 6.67 per cent in the sprayed plots and 11.96 in the unsprayed plot (Table 12).

The newer molecules chlorantraniliprole (1.84 per cent), flubendiamide (3.10 per cent), fipronil (5.92 per cent), indoxacarb (6.09 per cent), thiodicarb (8.51 per cent) and spinosad (10.44 per cent) recorded significant lower fruit infestation on the fifth day while the infestation in the emamectin benzoate (14.60 per cent), malathion (16.87 per cent) novaluron (18.92 per cent) and carbaryl (19.29 per cent) did not differ significantly from that in the untreated plot (34.32 per cent).

The damage of fruits was the lowest in chlorantraniliprole (4.69 per cent) on the seventh day and it was on par with that of flubendiamide (6.67 per cent) and indoxacarb (7.20 per cent). With the exception of malathion (27.65 per cent), all the other treatments with damage of fruits ranging from 12.20 to 19.03 per cent recorded significantly lower damage than in the control (35.71 per cent) plot.

Table 12. Damage of fruits by *Earias vittella* in okra plots treated with new generation insecticides 45 and 60 days after planting

Treatments	Dosage (g a.i.ha^{-1})	45 DAP					60 DAP				
		3 DAS	5 DAS	7 DAS	10 DAS	15 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
Emamectin benzoate	10	2.56	14.60 (3.95)	12.51 (3.68)	14.52	18.66	0	7.66	13.06	23.89	24.81
Spinosad	75	3.03	10.44 (3.38)	19.03 (4.48)	13.68	22.22	4.17	14.98	19.52	16.98	22.91
Novaluron	100	6.67	18.92 (4.46)	12.59 (3.69)	19.07	41.67	5.56	11.36	13.61	22.84	27.30
Chlorantraniliprole	30	0.00	1.84 (1.69)	4.69 (2.39)	8.40	11.67	0.00	4.88	4.69	7.29	11.81
Indoxacarb	60	0.00	6.09 (2.66)	7.20 (2.86)	7.22	15.86	1.67	8.62	7.26	12.17	18.03
Fipronil	50	2.22	5.92 (2.63)	18.71 (4.44)	19.24	29.42	4.30	10.04	19.72	19.95	23.23
Thiodicarb	750	0.00	8.51 (3.08)	12.20 (3.63)	15.40	14.35	3.03	13.15	12.33	18.58	25.32
Flubendiamide	100	0.00	3.10 (2.24)	6.59 (2.75)	11.19	12.15	2.78	6.46	6.67	7.78	17.85
Carbaryl	750	2.56	19.29 (4.50)	18.26 (4.39)	22.55	32.22	3.33	12.57	18.28	21.85	24.44
Malathion	500	0.00	16.87 (4.23)	27.65 (5.35)	20.32	24.21	0.95	17.60	27.78	25.45	24.17
Untreated control		11.96	34.32 (5.94)	35.71 (6.06)	37.37	47.78	9.14	34.72	35.83	35.15	44.81
CD(0.05)		-	(2.14)	(1.21)	8.06	15.61	-	9.80	10.17	10.37	13.72

Figures in parentheses are square root transformed values

DAP-Days after planting, DAS - Days after spraying

Indoxacarb (7.66 per cent), chlorantraniliprole (8.40 per cent), flubendiamide (11.19 per cent), spinosad (13.68 per cent) and emamectin benzoate (14.52 per cent) registered lower damage of fruits on the tenth day. The other insecticides *viz.*, thiodicarb (15.40 per cent), novaluron (19.07 per cent), fipronil (19.24 per cent), malathion (20.32 per cent), and carbaryl (22.55 per cent) also had significantly lower damage of fruits when compared to control (37.37 per cent).

Fifteen days after spraying, chlorantraniliprole, flubendiamide, thiodicarb, indoxacarb, emamectin benzoate, spinosad and malathion whose percentage infestation ranged from 11.67 to 24.21 were superior to carbaryl (32.22 per cent) and novaluron (41.67 per cent) in their efficacy. The damage in the two insecticides did not differ significantly from that in the unsprayed plot (47.78 per cent).

4.2.3.3. Third spray

Damage of fruits

The damage of fruits by *E. vitella* in both the treated plots (0-5.56 per cent) and untreated plot (9.14 per cent) did not vary significantly when observed three days after spraying (Table 12).

On the fifth day, infestation by *E. vitella* was the lowest in chlorantraniliprole (4.88 per cent) which in turn was on par with flubendiamide (6.46 per cent), emamectin benzoate (7.66 per cent) , indoxacarb (8.62 per cent), fipronil (10.04 per cent), novaluron (11.36 per cent), carbaryl (12.57 per cent) and thiodicarb (13.15 per cent) in its efficacy in checking the pest damage. Spinosad (14.98 per cent) and malathion (17.60 per cent) also reduced the infestation significantly when compared to the unsprayed plot (34.72 per cent).

Maximum reduction in the damage by the shoot and fruit borer was obtained on the seventh day with chlorantraniliprole (4.69 per cent) which recorded the same effect as that of flubendiamide (6.67 per cent), indoxacarb (7.26 per cent), thiodicarb (12.33 per cent), emamectin benzoate (13.06 per cent), novaluron (13.61 per cent). This was followed by carbaryl (18.28 per cent), spinosad (19.52 per cent) and fipronil (19.72 per cent). The damage in malathion sprayed plot (27.78 per cent) did not differ significantly from that in the control plot (35.83 per cent).

Chlorantraniliprole (7.29 per cent), flubendiamide (7.78 per cent) indoxacarb (12.17 per cent) and spinosad (16.98 per cent) were significantly superior to thiodicarb, fipronil, carbaryl, novaluron and emamectin benzoate in reducing the infestation by *E. vitella* on the tenth day after spraying, the damage of fruits in these insecticides ranging from 18.58 to 23.89 per cent. The unsprayed plot recorded a percentage infestation of 35.83 which was on par with that of malathion treated plot (27.78 per cent).

Significantly reduced infestation was noted in all the treatments on the fifteenth day with the damage of fruits ranging from 11.81 to 27.30 when compared to the control (44.81 per cent).

4.2.3.4 Yield and Benefit – Cost Ratio

The data on the yield of okra are presented in Table 13. The insecticide treatments *viz*, chlorantraniliprole (5.80 kg), flubendiamide (5.61 kg) and indoxacarb (5.50 kg) recorded significantly higher yield compared to other treatments. The other treatments emamectin benzoate (4.48 kg), carbaryl (4.31 kg), novaluron (4.26 kg), spinosad (4.13 kg), malathion (4.13 kg), fipronil (4.11 kg) and thiodicarb (3.95 kg) were on par with each other. The control plot recorded 3.51 kg of okra fruits per plot.

The data on the benefit-cost ratio of okra revealed that indoxacarb flubendiamide and chlorantraniliprole, gave Rs 6.96, 6.93 and 6.23 in return for every one rupee invested on plant protection measures. The returns from emamectin benzoate, fipronil, spinosad, novaluron, and thiodicarb were also high being Rs. 4.95, 4.51, 3.67, 3.65 and 3.20 respectively in return for every one rupee spent. The returns from malathion and carbaryl,which were Rs. 3.34 2.96, in return for every one rupee invested on plant protection measures, respectively.

Table 13. Yield of okra and benefit: cost ratio of insecticidal treatments

Treatments	Dosage (g a.i.ha^{-1})	Yield			Monetary benefits (Rs ha^{-1})	Expenses for insecticides (Rs ha^{-1})	B: C ratio
		(kg/6 m^2 plot)	(t/ha)	Increase over control (%)			
Emamectin benzoate	10	4.48	4.97	27.64	33333.33	5874/-	4.95:1
Spinosad	75	4.13	4.59	17.66	21666.67	5184/-	3.67:1
Novaluron	100	4.26	4.74	21.37	26000.00	8010/-	3.65:1
Chlorantraniliprole	30	5.80	6.45	65.24	77333.33	5625/-	6.23:1
Indoxacarb	60	5.50	6.11	56.70	67333.33	3855/-	6.96:1
Fipronil	50	4.11	4.57	17.09	21000.00	3402/-	4.51:1
Thiodicarb	750	3.95	4.39	12.54	15666.67	7350/-	3.20:1
Flubendiamide	100	5.61	6.23	59.83	71000.00	4620/-	6.93:1
Carbaryl	750	4.31	4.79	22.79	27666.67	2625/-	2.96:1
Malathion	500	4.13	4.59	17.66	21666.67	1013/-	3.34:1
Untreated control		3.51	3.89				-
CD(0.05)		0.80					

4.3. SAFETY/TOXICITY OF INSECTICIDES TO ENTOMOPATHOGENIC FUNGI

The results of the trials conducted on the safety/toxicity of the insecticide molecules to *B. bassiana, L. lecanii* and *M. anisopliae,* the entomopathogenic fungi commonly used for pest management in vegetable ecosystem expressed as colony diameter are presented in Tables 14.

4.3.1 *Beauveria bassiana*

None of the insecticides affected the growth of *B. bassiana* adversely. Moreover, significantly higher mycelial growth of the fungi was observed in indoxacarb (1.70 cm), chlorantraniliprole (1.67 cm) and spinosad (1.50 cm), three days after inoculation indicating a probable synergistic effect. The growth of the fungi in thiodicarb (1.33 cm), emamectin benzoate (1.20 cm), malathion (1.20 cm), fipronil (1.17 cm), novaluron (1.13 cm), flubendiamide (1.13 cm), and carbaryl (1.13 cm) was on par with that of control (1.13 cm) three days after inoculation. On the ninth day too significantly better growth was recorded in indoxacarb (4.27 cm), chlorantraniliprole (3.87 cm), spinosad (3.17 cm) and emamectin benzoate (3.08 cm) when compared to control (2.10 cm). Among the four insecticides, indoxacarb and chlorantraniliprole showed higher radial growth. The growth of the fungi in malathion (2.90 cm), fipronil (2.57 cm), thiodicarb (2.57 cm), carbaryl (2.20 cm), flubendiamide (2.13 cm) and novaluron (2.13 cm) was on par with that of control. Again on the fifteenth day, significantly superior mycelial growth was recorded in indoxacarb, emamectin benzoate, chlorantraniliprole and the colony diameter being 4.87 cm, 4.43 cm and 4.33 cm respectively. The growth of the fungus in malathion (3.77 cm), spinosad (3.70 cm), fipronil (3.60 cm), thiodicarb (3.37 cm), carbaryl (2.80 cm), novaluron (2.73 cm) and flubendiamide (2.60 cm) was on par with control (3.07 cm). Significantly superior growth was noticed on twenty first day too in indoxacarb and emamectin benzoate with radial growth of 6.40 cm and 6.03 cm. The extent of growth in chlorantraniliprole was 5.10 cm. The growth of the fungus in control (4.00 cm) was on par with that of malathion (4.73 cm), fipronil (4.57 cm), thiodicarb (4.40

Table 14. Growth of *Beauveria bassiana, Lecanicillium lecanii* and *Metarrhizium anisopliae* on PDA media poisoned with different insecticides

Treatment	Dosage ($g\ a.i.ha^{-1}$)	Mean mycelial growth(cm)														
		Beauveria bassiana					*Lecanicillium lecanii*						*Metarrhizium anisopliae*			
		3 DAI	9 DAI	15 DAI	21 DAI	27 DAI	3 DAI	9 DAI	15 DAI	21 DAI	27 DAI	33 DAI	3 DAI	9 DAI	15 DAI	21 DAI
Emamectin benzoate	10	1.20	3.08	4.43	6.03	6.23	1.1	1.90	2.67	3.27	5.43	5.63	1.90	3.70	5.53	6.80
Spinosad	75	1.50	3.17	3.70	3.85	3.33	1.17	1.80	2.77	3.97	5.17	5.37	1.95	3.67	8.80	9.00
Novaluron	100	1.13	2.13	2.73	3.53	3.60	1.13	1.73	2.73	4.10	6.30	6.73	2.23	6.25	7.20	7.73
Chlorantraniliprole	30	1.67	3.87	4.33	5.10	5.23	1.13	2.33	3.57	4.73	7.17	7.50	2.30	4.20	8.33	9.00
Indoxacarb	60	1.70	4.27	4.87	6.40	6.63	1.17	2.30	3.33	4.37	6.03	6.47	2.33	8.33	8.73	9.00
Fipronil	50	1.17	2.57	3.60	4.57	4.73	1.17	1.57	2.73	4.13	6.93	7.13	2.28	4.17	6.83	7.77
Thiodicarb	750	1.33	2.57	3.37	4.40	4.50	1.10	1.27	2.50	3.73	5.77	6.03	1.93	3.80	5.77	6.67
Flubendiamide	100	1.13	2.13	2.60	3.47	3.63	1.07	1.47	2.10	2.33	2.53	2.80	1.50	4.40	6.42	7.67
Carbaryl	750	1.13	2.20	2.80	3.93	4.00	1.13	1.23	1.53	1.80	2.13	2.30	1.97	4.35	6.60	9.00
Malathion	500	1.20	2.90	3.77	4.73	4.83	1.10	1.37	3.10	3.40	4.90	5.10	2.27	5.30	7.47	9.00
Control		1.13	2.10	3.07	4.00	4.07	1.17	1.40	2.57	3.87	6.60	7.23	2.50	3.97	6.87	9.00
CD(0.05)		0.23	0.93	1.22	0.856	0.67	0.144	0.36	0.56	0.55	0.22	0.29	0.424	1.32	1.84	1.38

DAI - Days after inoculation

cm), carbaryl (3.93 cm), spinosad (3.85 cm), novaluron (3.53 cm) and flubendiamide (3.47 cm).

By the twenty seventh day, when the growth of the fungus stabilized in the control (4.07 cm), synergistic effect was again noted in indoxacarb (6.63 cm), emamectin benzoate (6.23 cm), chlorantraniliprole (5.23 cm), and malathion (4.83 cm) wherein the growth of the fungus was profuse. The radial growth of the fungus in all the other treatments *viz.*, fipronil (4.73 cm), thiodicarb (4.50 cm) carbaryl (4.00 cm), flubendiamide (3.63 cm), novaluron (3.60 cm), and spinosad (3.33 cm) too was on par with that of control indicating their safety to the fungus.

4.3.2 *Lecanicillium (Verticillium) lecanii*

The data on the radial growth of the fungus in various insecticide treatments revealed no significant variation among the different treatments (1.07 to 1.17 cm) on the growth of *L. lecanii* on the third day after inoculation. The growth of fungus was significantly higher in chlorantraniliprole (2.33 cm), indoxacarb (2.30 cm) and emamectin benzoate (1.90 cm) on the ninth day and that in spinosad (1.80 cm), novaluron (1.73 cm), fipronil (1.57 cm), flubendiamide (1.47 cm), malathion (1.37 cm), thiodicarb (1.27cm) and carbaryl (1.23 cm) were on par with that of control (1.40 cm). On the fifteenth day, higher growth was observed in chlorantraniliprole (3.57 cm), indoxacarb (3.33 cm). The growth of the fungus in malathion (3.10 cm), spinosad (2.77 cm), novaluron (2.73 cm), fipronil (2.73 cm), emamectin benzoate (2.67 cm), thiodicarb (2.5 cm) and flubendiamide (2.10 cm) was on par with that of control (2.57 cm). However, the growth of the fungus was significantly reduced in carbaryl (1.53 cm). Significantly superior growth of *L. lecanii* was observed on twenty first day in chlorantraniliprole with a radial growth of 4.73 cm. The growth in indoxacarb fipronil, novaluron, spinosad thiodicarb, malathion having radial growth of 4.37 cm, 4.13 cm, 4.10 cm, 3.97 cm, 3.73 cm and 3.40 cm was on par with that of control (3.87 cm). The growth was suppressed in emamectin benzoate, flubendiamide and carbaryl with radial growth of 3.27, 2.33 and 1.80 cm respectively. On twenty seventh day, significantly superior mycelial growth was recorded in chlorantraniliprole and fipronil with 7.17 and 6.93 cm as colony growth. But the growth was suppressed in novaluron, indoxacarb, thiodicarb, emamectin benzoate, spinosad, malathion and flubendiamide, having radial growth of 6.3, 6.03, 5.77, 5.43, 5.17, 4.9 and 2.53 cm respectively when compared with that of control (6.60cm).. The least growth was recorded in carbaryl (2.13 cm). However, when the growth of the fungus was at maximum on the thirty third day after inoculation in control (7.23 cm), chlorantraniliprole having colony diameter as 7.5 cm and fipronil with 7.13 cm as radial growth were on par. The growth of the fungus was on par in novaluron (6.73 cm), indoxacarb (6.47 cm), thiodicarb(6.03 cm), emamectin benzoate (5.63 cm), spinosad (5.37 cm), malathion (5.10 cm). Significant suppression of growth was observed in flubendiamide (2.80 cm) and carbaryl (2.30 cm).

4.3.3 *Metarrhizium anisopliae*

Significant variation in the growth of *M. anisopliae* was recorded in the various insecticide treatments. On the third day of inoculation, the growth of *M. anisopliae* in indoxacarb (2.33 cm), chlorantraniliprole (2.30 cm), fipronil (2.28 cm), malathion (2.27 cm) and novaluron (2.23 cm) was on par with that of control (2.5 cm). The growth of the fungi was significantly reduced in carbaryl (1.97 cm), spinosad (1.95 cm), thiodicarb (1.93 cm), emamectin benzoate (1.9 cm) and flubendiamide (1.5 cm) when compared to control. On the ninth day significantly higher growth of *M. anisopliae* was observed in indoxacarb (8.33 cm), novaluron (6.25 cm) and malathion (5.30 cm). All the other treatments *viz*., flubendiamide, carbaryl, chlorantraniliprole, fipronil, thiodicarb, emamectin benzoate and spinosad with a radial growth of 4.4 cm, 4.35 cm, 4.2 cm, 4.17 cm, 3.8 cm, 3.7 cm and 3.67 cm, respectively were on par with that of control (3.97 cm).

On the fifteenth day, the colony growth recorded in spinosad (8.8 cm) and indoxacarb (8.73 cm) was significantly superior to that in the unpoisoned check. The growth of the fungus in chlorantraniliprole, malathion, novaluron fipronil, carbaryl, flubendiamide thiodicarb and emamectin benzoate having radial growth of 8.33 cm, 7.47 cm, 7.2 cm, 6.83 cm, 6.60 cm, 6.42 cm, 5.77 cm and 5.53 cm respectively were on par with that of control (6.87 cm). With the exception of emamectin benzoate(6.8 cm) and thiodicarb (5.77 cm), the growth of the fungus in all the other treatments *viz*., malathion (9 cm), carbaryl(9 cm), chlorantraniliprole (9 cm), indoxacarb (9 cm), spinosad (9 cm), fipronil (7.77 cm), novaluron (7.73 cm) and flubendiamide (7.67 cm) were on par with that of control (9 cm) on the twenty first day indicating the safety of the chemicals to the fungus.

4.4. DISSIPATION OF NEW GENERATION INSECTIDES

The results on the persistence of the selected insecticides on cowpea, brinjal and okra fruits are presented in Tables 15 to 50.

4.4.1 Cowpea

4.4.1 .1 Method validation

The method validated for the estimation of the different insecticides in cowpea pods gave good recovery of the target residues. The per cent recovery ranged from 85.34 to 116.40 (Table 15).

At the fortification level of 0.01 ppm, the mean per cent recovery of the insecticides in the descending order was emamectin benzoate (116.40), fipronil (106.20), chlorantraniliprole (101.68), spinosad (101.60), carbaryl (101.36), malathion (100.00), indoxacarb (99.32), thiodicarb (95.94), flubendiamide (95.84), malaoxon (95.60), desiodoflubendiamide (93.20) and novaluron (91.82), with a relative standard deviation in the range of 2.52 to 14.32.

At the 0.1 ppm fortification level, mean per cent recovery of the insecticides in the descending order was chlorantraniliprole (110.00), carbaryl (101.94), emamectin benzoate (101.40), malathion (100.00), spinosad (99.50), indoxacarb (96.22), fipronil (96.04), thiodicarb (94.44), malaoxon (93.40), flubendiamide (87.90), novaluron (85.34) and desiodoflubendiamide (85.16) with a relative standard deviation in the range of 2.75 to 16.69.

Table 15. Recovery of various insecticides and metabolites from cowpea fruits fortified at different levels

Insecticides /Metabolites	Level of fortification(ppm)					
	0.01		0.1		0.5	
	Mean % recovery	RSD	Mean % recovery	RSD	Mean % recovery	RSD
Emamectin benzoate	116.40	4.80	101.40	6.17	101.40	5.30
Spinosad	101.60	6.71	99.50	8.46	104.76	7.36
Novaluron	91.82	5.16	85.34	8.64	89.00	3.62
Chlorantraniliprole	101.68	16.69	110.00	14.32	109.16	15.31
Indoxacarb	99.32	9.99	96.22	8.26	104.50	11.78
Fipronil	106.20	6.21	96.04	4.12	104.96	4.26
Thiodicarb	95.94	2.75	94.44	2.52	96.32	4.12
Flubendiamide	95.84	5.49	87.90	11.76	92.52	13.93
Desiodoflubendiamide	93.20	6.47	85.16	7.92	89.12	3.34
Carbaryl	101.36	2.75	101.94	2.52	101.24	4.12
Malathion	100.00	7.69	100.00	7.69	106.48	4.19
Malaoxon	95.60	5.80	93.40	6.60	96.10	7.20

Number of replicates at each level (n) =5

RSD - Relative standard deviation for reproducibility

At the higher fortification level of 0.5 ppm, the mean per cent recovery among the pesticides in the descending order were chlorantraniliprole (109.16) malathion (106.48), fipronil (104.96), spinosad (104.76), indoxacarb (104.50), emamectin benzoate (101.40), carbaryl (101.24), thiodicarb (96.32), malaoxon (96.10), flubendiamide (92.52), desiodoflubendiamide (89.12) and novaluron (89.00), with a relative standard deviation in the range of 3.34 to 15.31.

4.4.1.2 Calibration curve

The calibration curve prepared for instrument linearity indicated good linearity within the range of 0.01-0.5 mg kg^{-1} concentration for all the insecticides (Appendix Ia to Xb).

4.4.1.3 LOQ and LOD

The limit of quantitation (LOQ) of emamectin benzoate, spinosad, novaluron, chlorantraniliprole, indoxacarb, fipronil, thiodicarb, flubendiamide, malathion, and carbaryl was found to be 0.01 mg kg^{-1} and limit of detection (LOD) being 0.005 mg kg^{-1}.

4.4.1.4 Dissipation of insecticide residues

Emamectin benzoate

Two hours after spraying of emamectin benzoate @ 10 g a.i. ha^{-1}, an initial deposit of 0.07 mg kg^{-1} was detected in cowpea pods (Table 16). One day after spraying, the insecticide residue degraded to 0.02 mg kg^{-1}, which was 73.51 per cent lesser than the initial residue. On the third day, the residue dissipated by 83.12 per cent (0.01 mg kg^{-1}). No residue was detected from the fifth day of spraying.

Spinosad

Spinosad applied at the rate of 73 g ai ha^{-1} resulted in an initial deposit of 0.94 mg kg^{-1} on cowpea fruits two hours after spraying (Table 17). On the next day, the residue dissipated to 0.61 mg kg^{-1} with a reduction of 34.94 per cent. On the third day, 88.38 per cent of the residue degraded, the concentration of residue

Table 16. Residues of emamectin benzoate in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.08	0.07	0.07	0.07±0.006	
1	0.02	0.02	0.02	0.02±0.001	73.51
3	0.02	0.01	0.01	0.01±0.003	83.12
5	BDL	BDL	BDL		

Table 17. Residues of spinosad in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.94	0.94	0.94	0.94±0.002	
1	0.66	0.57	0.61	0.61±0.046	34.94
3	0.11	0.11	0.11	0.11±0.003	88.38
5	0.04	0.05	0.04	0.04±0.006	95.57
7	BDL	BDL	BDL		

BDL - Below Detectable Level

recorded from the fruits being 0.11 mg kg $^{-1}$. The residues declined by 95.57 per cent on the fifth day, the concentration detected being 0.04 mg kg $^{-1}$. By the seventh day, the residues reached below detectable level.

Novaluron

Spraying of novaluron at the rate of 75 g ai ha $^{-1}$ resulted in an initial deposit of 2.72 mg kg $^{-1}$ on cowpea fruits when estimated two hours after the application (Table 18). The residue declined to 1.83 mg kg $^{-1}$, on the next day of spraying, recording 32.6 per cent reduction in the initial deposit. The concentration of residue on the third day was 1.28 mg kg $^{-1}$, the dissipation percentage being 52.94. The residues degraded to 0.48 mg kg $^{-1}$ reducing the initial deposit to 82.5 per cent of the initial concentration on the fifth day. On the seventh day, only 0.12 mg kg $^{-1}$ residue was recorded, indicating 95.58 per cent reduction of the initial deposit. The dissipation continued on the tenth day and the residue level came down to 0.05 mg kg $^{-1}$, recording 98.15 per cent dissipation. The residue reached below detectable level on the fifteenth day of spraying.

Chlorantraniliprole

The initial deposit of 0.56 mg kg $^{-1}$ of chlorantraniliprole recorded on cowpea fruits two hours after spraying reduced to 0.46 mg kg $^{-1}$ with a dissipation percentage of 17.17 on the next day (Table 19). On the third day, the residue was reduced to 62.27 per cent of the initial deposit, the concentration of residue detected being 0.21 mg kg $^{-1}$. An average residue deposit of 0.03 mg kg $^{-1}$ was recorded on the fifth day, the dissipation percentage increasing to 94.47 per cent. On the seventh day, 0.02 mg kg $^{-1}$ of residue was recorded on the fruits with a dissipation percentage of 96.55 per cent. By the tenth day, the residue reached below the detectable level.

Indoxacarb

An initial residue deposit of 0.56 mg kg $^{-1}$ was recorded two hours after spraying. One day after spraying, the residue reduced to 0.40 mg kg $^{-1}$, recording a reduction of 29.07 per cent (Table 20). On the third day, the residue was reduced

Table 18. Residues of novaluron in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	2.78	2.66	2.72	2.72±0.06	
1	1.77	1.88	1.85	1.83±0.06	32.60
3	1.27	1.24	1.33	1.28±0.05	52.94
5	0.47	0.47	0. 50	0.48±0.02	82.50
7	0.12	0.12	0.12	0.12±0.002	95.58
10	0.05	0.05	0.05	0.05±0.003	98.15
15	BDL	BDL	BDL		

Table 19. Residues of chlorantraniliprole in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.60	0.50	0.58	0.56±0.06	
1	0.51	0.43	0.45	0.46±0.04	17.17
3	0.21	0.22	0.20	0.21±0.009	62.27
5	0.03	0.03	0.03	0.03±0.002	94.47
7	0.02	0.02	0.02	0.02±0.004	96.55
10	BDL	BDL	BDL		

BDL - Below Detectable Level

to 0.07 mg kg $^{-1}$ and the dissipation percentage increased to 87.16. On the fifth day the residue decreased by 95.96 per cent, the residue concentration detected being 0.02 mg kg $^{-1}$. From the seventh day onwards, residue of indoxacarb was below detectable level.

Fipronil

Fipronil applied at the rate of 50 g ai ha $^{-1}$ in cowpea resulted in an initial deposit of 1.12 mg kg $^{-1}$ on cowpea fruits two hours after spraying (Table 21). On the next day the residue became 0.41 mg kg $^{-1}$, indicating 63.84 per cent dissipation of the residues. On the third day, the dissipation increased to 86.82 per cent and the concentration of residue recorded was 0.15 mg kg $^{-1}$. The residues degraded by 98.1 per cent on the fifth day, registering a concentration of 0.02 mg kg $^{-1}$. From the initial deposit, 98.72 per cent of the residues got dissociated on the seventh day, whereby the concentration was recorded to be 0.01 mg kg $^{-1}$. No residues were detected from the tenth day of spraying.

Thiodicarb

On the day of spraying, the cowpea fruits recorded an average initial deposit of 4.13 mg kg $^{-1}$which dissipated to 0.86 mg kg $^{-1}$ on the next day, registering 79.24 per cent decline of the residues (Table 22). The residue level was 0.22 mg kg $^{-1}$ on the third day, the dissipation percentage being 94.8 which reached below detectable level on the fifth day of spraying.

Flubendiamide

An initial deposit of 1.14 mg kg $^{-1}$ residues of flubendiamide was recorded two hours after spraying and the residues reduced to 0.63 mg kg $^{-1}$ with a dissipation percentage of 44.55 after one day(Table 23). On the third day, 77.62 per cent reduction in the initial deposit of the residues was noted, the concentration of residues being 0.25 mg kg $^{-1}$. Fifth day recorded an average residue deposit of 0.22 mg kg $^{-1}$ and the dissipation percentage increased to 80.10. On the seventh day, an average residue of 0.08 mg kg $^{-1}$ was recorded on cowpea fruits with a dissipation percentage of 92.79. On the tenth day, 0.03 mg kg $^{-1}$

Table 20. Residues of indoxacarb in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.50	0.63	0.55	0.56±0.06	
1	0.37	0.42	0.40	0.40±0.03	29.07
3	0.07	0.08	0.07	0.07±0.004	87.16
5	0.02	0.03	0.02	0.02±0.004	95.96
7	BDL	BDL	BDL		

Table 21. Residues of fipronil in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.02	1.19	1.15	1.12±0.09	
1	0.36	0.45	0.40	0.41±0.04	63.84
3	0.17	0.13	0.14	0.15±0.02	86.82
5	0.02	0.02	0.02	0.02±0.002	98.10
7	0.01	0.02	0.01	0.01±0.002	98.72
10	BDL	BDL	BDL		

BDL-Below Detectable Level

Table 22. Residues of thiodicarb in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	3.72	4.45	4.22	4.13±0.37	
1	0.71	1.00	0.87	0.86±0.15	79.24
3	0.20	0.23	0.21	0.22±0.017	94.80
5	BDL	BDL	BDL		

Table 23. Residues of flubendiamide in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.08	1.13	1.2	1.14±0.06	
1	0.60	0.65	0.65	0.63±0.03	44.55
3	0.25	0.26	0.26	0.25±0.008	77.62
5	0.22	0.23	0.19	0.22±0.02	80.1
7	0.08	0.08	0.08	0.08±0.003	92.79
10	0.03	0.03	0.03	0.03±0.0006	97.65
15	BDL	BDL	BDL		

BDL - Below Detectable Level

residues of flubendiamide was recorded, the extent of degradation being 97.65 per cent. By the fifteenth day, no residues were recovered from cowpea fruits.

Carbaryl

The initial deposit of 4.69 mg kg $^{-1}$ carbaryl residues (Table 24) estimated on cowpea fruits two hours after spraying dissipated by 29.52 per cent on the next day, the concentration of carbaryl recorded being 3.3 mg kg $^{-1}$. The third day recorded 0.87 mg kg $^{-1}$ residue and the dissipation percentage was 81.42. On the fifth day, 90.90 per cent of the residues dissipated, the deposit recorded being 0.43 mg kg $^{-1}$. On the seventh day, the carbaryl residues reduced to 0.16 mg kg $^{-1}$ dissipating by 96.65 per cent from the initial load and on the tenth day 0.06 mgkg $^{-1}$ of residues were detected by degrading 98.81 per cent of the initial residue level. No residues were detected on the fifteenth day of spraying.

Malathion

Two hours after spraying, an initial deposit of 2.91 mg kg $^{-1}$ malathion was recorded on cowpea fruits (Table 25). On the next day, 88.68 per cent of the residues dissipated, the concentration in the fruits being 0.33 mg kg $^{-1}$. On the third day the residue level was to the tune of 0.10 mg kg $^{-1}$ with a dissipation percentage of 96.59. No residues were detected from the fifth day of spraying.

4.4.1.5 Half life and waiting period

Remarkable variation was noted in the half life and waiting period of the selected insecticides (Table 26). Emamectin benzoate when sprayed on cowpea fruits had a half life of 1.25 days and a waiting period of 2.99 days. The time taken for half of spinosad to degrade was 0.92 days. The waiting period estimated for the insecticide was 1.06 days. Novaluron recorded the half life of 1.66 days and a long waiting period 13.76 days. Contrarily, chlorantraniliprole registered a half life of 1.31 days with a short waiting period of 0.62 days. Indoxacarb sprayed on cowpea fruits took 1.08 days to degrade its residue to half of the initial deposit and the waiting period computed was 5.33 days. The half life and waiting period calculated for fipronil were 1.08 and 8.09 days, respectively. Thiodicarb

Table 24. Residues of carbaryl in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	4.63	4.78	4.65	4.69±0.08	
1	3.18	3.45	3.28	3.30±0.14	29.52
3	0.90	0.84	0.88	0.87±0.03	81.42
5	0.45	0.41	0.43	0.43±0.02	90.90
7	0.15	0.17	0.15	0.16±0.01	96.65
10	0.05	0.06	0.06	0.06±0.005	98.81
15	BDL	BDL	BDL		

Table 25. Residues of malathion in/on cowpea fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	2.77	3.11	2.84	2.91±0.18	
1	0.34	0.32	0.33	0.33±0.008	88.68
3	0.16	0.06	0.08	0.10±0.05	96.59
5	BDL	BDL	BDL		

BDL - Below Detectable Level

Table 26. Half life and waiting period of different insecticides in cowpea

Sl. No:	Insecticide	MRL(EU) $mgkg^{-1}$	r	R^2	Linear equation	$T_{1/2}$ (days)	$T_{tol/WP}$ (days)
1	Emamectin benzoate	0.01	-0.96	0.92	Y=-0.27x+0.80	1.25	2.99
2	Spinosad	0.50	-0.99	0.98	Y=-0.29x+2.01	0.92	1.09
3	Novaluron	0.01	-0.99	0.98	Y=-0.18x+2.50	1.66	13.76
4	Chlorantraniliprole	0.50	-0.98	0.96	Y=-0.23x+1.85	1.31	0.62
5	Indoxacarb	0.02	-0.99	0.99	Y=-0.30x+1.82	1.08	5.33
6	Fipronil	0.005	-0.98	0.96	Y=-0.28x+1.97	1.08	8.09
7	Thiodicarb	0.02	-0.99	0.98	Y=-0.45x+2.56	0.50	5.10
8	Flubendiamide	0.40	-0.99	0.98	Y=-0.16x+2.00	1.95	2.55
9	Carbaryl	0.05	-0.99	0.99	Y=-0.20x+2.65	1.53	2.83
10	Malathion	0.02	-0.93	0.86	Y=-0.47x+2.29	0.54	6.65

MRL - Maximum Residue Limit,
EU - European Union,
r - Correlation coefficient,
R^2 - Coefficient of determination
$T_{1/2}$ - Half Life,
T_{tol} - Waiting period (WP)

degraded its residues to half of its initial deposit in 0.50 days, the waiting period being 5.10 days. Flubendiamide had a half life of 1.95 days and waiting period of 2.55 days on cowpea fruits. Carbaryl had a half life of 1.53 days and a waiting period of 2.83 days. Malathion recorded a half life of 0.54 days and a waiting period of 6.65 days.

4.4.2 Brinjal

4. 4. 2 .1 Method validation

The method validated for the estimation of the selected insecticides from brinjal fruits gave good recovery of the residues (85.34 to 116.40) and the data is presented in Table 27.

At the fortification level of 0.01 ppm, the per cent recovery of residues of insecticides in the descending order was fipronil (101.70), indoxacarb (101.10), novaluron (99.60), spinosad (98.50), malathion (98.20), malaoxon (94.70), thiodicarb (91.40), chlorantraniliprole (88.40), flubendiamide (86.50), emamectin benzoate (84.20), desiodoflubendiamide (83.20), and carbaryl (78.80), with a relative standard deviation of 2.50 to 11.60.

At 0.1 ppm, the mean per cent recovery among the pesticides in the descending order was flubendiamide (107.60), malaoxon (107.20), novaluron (105.30), fipronil (104.60), malathion (102.90), indoxacarb (95.60) emamectin benzoate (94.40), carbaryl (90.50), chlorantraniliprole (88.70), desiodoflubendiamide (88.70), thiodicarb (83.20), and spinosad (73.20) with a relative standard deviation of 2.40 to 11.10.

At the fortification level of 0.5 ppm, the mean per cent recovery among the pesticides in the descending order was carbaryl (109.40), malaoxon (109.00), fipronil (103.80), thiodicarb (103.60), malathion (103.60), novaluron (102.50), indoxacarb (99.10), flubendiamide (94.70), chlorantraniliprole (91.60), desiodoflubendiamide (90.32), emamectin benzoate (82.70) and spinosad (74.20) and with a relative standard deviation of 2.30 to 13.50.

4.4.2.2 Calibration curve

The calibration curve prepared for instrument linearity indicated good linearity within the range of 0.01-0.5 mg kg^{-1} concentration for all the insecticides (Appendix Ia to Xb).

4.4.2.3 LOQ and LOD

The limit of quantitation (LOQ) of emamectin benzoate, spinosad, novaluron, chlorantraniliprole, indoxacarb, fipronil, thiodicarb, flubendiamide, malathion, and carbaryl was found to be 0.01 mg kg^{-1} and limit of detection (LOD) being 0.005 mg kg^{-1}.

4.4.2.4 Dissipation of insecticide residues

Emamectin benzoate

Brinjal fruits collected two hours after spraying of emamectin benzoate @ 11 g a.i.ha^{-1} recorded an average initial deposit of 0.10 mg kg^{-1} (Table 28). On the next day 93.30 per cent of the residues dissipated and the level reached 0.06 mg kg^{-1}. Fruits collected on the third day recorded an average residue level of 0.025 mg kg^{-1}, the dissipation percentage being 97.34. On the fifth day, no residue was detected (LOQ-0.01 mg kg^{-1}) on the fruits.

Spinosad

On the day of spraying, an initial deposit of 0.58 mg kg^{-1} (Table 29) was recorded on brinjal fruits two hours after application which got reduced to 0.43 mg kg^{-1} with a dissipation percentage of 25.72 on the next day. On the third day, the concentration of the residues declined to 0.21 mg kg^{-1} the dissipation percentage increasing to 63.22. On the fifth day, the fruits recorded an average residue of 0.15 mg kg^{-1} and the dissipation percentage increased to 74.51 per cent. On the seventh day, 0.01 mg kg^{-1} residues were recorded on the fruits with the dissipation percentage increasing to 98.11 per cent. On the tenth day, no residue was detected in the brinjal fruits.

Table 27. Recovery of various insecticides and metabolites from brinjal fruits fortified at different levels

Insecticides	Level of fortification(ppm)					
	0.01		0.1		0.5	
	Mean % recovery	RSD	Mean % recovery	RSD	Mean % recovery	RSD
Emamectin benzoate	84.20	2.50	94.40	7.10	82.70	13.50
Spinosad	98.50	2.70	73.20	3.30	74.20	3.40
Novaluron	99.60	6.50	105.30	3.40	102.50	10.40
Chlorantraniliprole	88.40	4.90	88.70	5.70	91.60	3.60
Indoxacarb	101.10	10.20	95.60	11.0	99.10	7.90
Fipronil	101.70	5.60	104.60	6.90	103.80	9.90
Thiodicarb	91.40	11.30	83.20	8.40	103.60	8.00
Flubendiamide	86.50	11.60	107.60	8.90	94.70	7.60
Desiodo flubendiamide	83.20	8.56	88.70	7.53	90.32	6.46
Carbaryl	78.80	6.30	90.50	6.90	109.40	2.30
Malathion	98.20	5.30	102.90	11.10	103.60	4.70
Malaoxon	94.70	6.90	107.20	2.40	109.00	5.30

Number of replicates at each level (n) =5
RSD - Relative standard deviation for reproducibility

Table 28. Residues of emamectin benzoate in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.10	0.11	0.10	0.10±0.009	
1	0.07	0.06	0.06	0.06±0.009	93.30
3	0.03	0.02	0.03	0.025+0.001	97.34
5	BDL	BDL	BDL		

Table 29. Residues of spinosad in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.61	0.56	0.58	0.58±0.024	
1	0.46	0.42	0.42	0.43±0.021	25.72
3	0.22	0.20	0.22	0.21±0.0136	63.22
5	0.14	0.15	0.15	0.15±0.007	74.51
7	0.01	0.01	0.01	0.01±0.001	98.11
10	BDL	BDL	BDL		

BDL - Below Detectable Level

Novaluron

The mean residue of novaluron detected at different intervals presented in Table 30 showed that the initial deposit of 1.21 mg kg $^{-1}$, dissipated to 0.89 mg kg $^{-1}$, with a reduction of 67.40 per cent one day after spraying. On the third day, the residue was reduced to 0.74 mg kg $^{-1}$ and the dissipation percentage increased to 72.73. The decline of the insecticide residue was at a slower pace on the fifth day. it got reduced by 83.41 per cent and the residue level lowered to 0.45 mg kg $^{-1}$ On the seventh day, the fruit sampled recorded a residue level of 0.18 mg kg $^{-1}$ and the degradation percentage increased to 93.27. The residue level reached 0.07 with a high dissipation percentage of 97.60 on the tenth day. The residue degraded to below detectable level on the fifteenth day of spraying.

Chlorantraniliprole

Two hours after spraying, an initial deposit of 0.72 mg kg $^{-1}$ of residues (Table 31) of chlorantraniliprole was recorded from brinjal fruits. The initial deposit reduced to 0.50 mg kg $^{-1}$ with a dissipation percentage of 30.56, one day after spraying. On the third day, the residue declined by 68.06 per cent of the initial deposit, the concentration of residue being 0.23 mg kg $^{-1}$. Fifth day recorded an average residue deposit of 0.12 mg kg $^{-1}$ and the dissipation percentage increased to 82.87 per cent. On the seventh day,an average residue of 0.03 mgkg $^{-1}$ was recorded on brinjal fruits with a dissipation percentage of 95.37 per cent. The residue was below the detectable level from the tenth day.

Indoxacarb

Indoxacarb applied at the rate of 60 g a.i. ha $^{-1}$ in brinjal resulted in an initial deposit of 0.28 mg kg $^{-1}$ on brinjal fruits two hours after spraying (Table 32). The residue declined to 0.25 mg kg $^{-1}$, resulting in 10.79 per cent dissipation one day after spraying. On the third day, 25.54 per cent of the residue got dissipated, the residue level being 0.21 mg kg $^{-1}$. The residues degraded further by 40.41 per cent on the fifth day, the residue level recorded being 0.17 mg kg $^{-1}$. A remarkable dissipation (81.06 per cent) of initial deposit was noted on the seventh

Table 30. Residues of novaluron in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.23	1.10	1.30	1.21±0.005	
1	0.9	0.89	0.87	0.89±0.005	67.40
3	0.78	0.71	0.74	0.74±0.005	72.73
5	0.48	0.43	0.45	0.45±0.003	83.41
7	0.19	0.18	0.19	0.18±0.003	93.27
10	0.07	0.07	0.06	0.07±0.0006	97.60
15	BDL	BDL	BDL		

Table 31. Residues of chlorantraniliprole in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.69	0.74	0.72	0.72±0.025	
1	0.53	0.48	0.49	0.50±0.026	30.56
3	0.24	0.22	0.23	0.23±0.010	68.06
5	0.12	0.12	0.13	0.12±0.006	82.87
7	0.04	0.03	0.03	0.03±0.006	95.37
10	BDL	BDL	BDL		

BDL - Below Detectable Level

day where the concentration recorded was e 0.05 mg kg $^{-1}$. By the tenth day the residue level reduced to 0.02 mg kg $^{-1}$ recording 94.36 per cent dissipation. No residue was detected thereafter from the fifteenth day of spraying.

Fipronil

Fipronil applied at the rate of 50 g ai ha $^{-1}$ in brinjal resulted in a deposit of 0.57 mg kg $^{-1}$ on brinjal fruits (Table 33) on the day of spraying which dissipated to 0.49 mg kg $^{-1}$, (12.60 per cent) on the first day of spraying. On the third day, 53.95 per cent of the residue dissipated and the concentration of residue recorded was 0.26 mg kg $^{-1}$. The residues degraded further by 61.07 per cent on the fifth day, the concentration of residue detected being 0.22 mg kg $^{-1}$. On the seventh day 94.52 per cent of the residues from the initial deposit got dissociated and the concentration was recorded to be 0.03 mg kg $^{-1}$. No residue was detected from the tenth day of spraying.

Thiodicarb

The initial deposit of 5.07 mg kg $^{-1}$ (Table 34) recorded on brinjal fruits two hours after spraying reduced to 4.38 mg kg $^{-1}$ with a dissipation percentage of 13.68 after one day. On the third day, the extent of residue reduction was 34.06 per cent of the initial deposit and the concentration became 3.34 mg kg $^{-1}$. On the fifth day, the fruits recorded an average residue of 1.54 mg kg $^{-1}$ and the dissipation percentage increased to 69.56 per cent. On the seventh day, 0.90 mg kg $^{-1}$ residue was recorded on the brinjal fruits with a dissipation percentage of 82.24. The quantity of residue detected in the fruits collected on the tenth day was 0.56 recording a dissipation percentage of 88.99 and on the fifteenth day the residue dissipated at a faster rate of 99.79 per cent. No residue was detected from the twentieth day.

Flubendiamide

Flubendiamide applied at the rate of 100 g ai ha $^{-1}$ resulted in an initial deposit of 0.79 mg kg $^{-1}$ on the fruits two hours after spraying (Table 35). Subsequently, on the next day the residue became 0.53 mg kg $^{-1}$, registering 53.37

Table 32. Residues of indoxacarb in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.28	0.27	0.28	0.28±0.005	
1	0.24	0.25	0.25	0.25±0.005	10.79
3	0.20	0.21	0.21	0.21±0.005	25.54
5	0.16	0.17	0.17	0.17±0.003	40.41
7	0.06	0.05	0.05	0.05±0.003	81.06
10	0.02	0.02	0.02	0.02±0.0006	94.36
15	BDL	BDL	BDL		

Table 33. Residues of fipronil in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.58	0.55	0.57	0.57±0.013	
1	0.49	0.50	0. 50	0.49±0.004	12.60
3	0.27	0.26	0.26	0.26±0.006	53.95
5	0.22	0.22	0.22	0.22±0.002	61.07
7	0.04	0.03	0.03	0.03±0.004	94.52
10	BDL	BDL	BDL		

BDL -Below Detectable Level

Table 34. Residues of thiodicarb in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	5. 00	5.14	5.08	5.07±0.070	
1	4.48	4.3	4.35	4.38±0.093	13.68
3	3.18	3. 58	3.27	3.34±0.210	34.06
5	1.57	1.52	1.54	1.54±0.025	69.56
7	0.88	0.94	0.89	0.90±0.0318	82.24
10	0.56	0.57	0.55	0.56±0.008	88.99
15	0.01	0.01	0.01	0.01±0.001	99.79
20	BDL	BDL	BDL		

Table 35. Residues of flubendiamide in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.77	0.80	0.80	0.79±0.019	
1	0.52	0.54	0.53	0.53±0.008	53.37
3	0.46	0.46	0.46	0.46±0.004	59.65
5	0.28	0.32	0.30	0.30±0.016	73.72
7	0.12	0.11	0.12	0.12±0.006	89.56
10	0.06	0.06	0.06	0.06±0.0004	94.55
15	BDL	BDL	BDL		

BDL-Below Detectable Level

per cent reduction. On the third day, 59.65 per cent of the initial residue dissipated, the concentration of residue recorded being 0.46 mg kg $^{-1}$. The residues degraded by 73.72 per cent on the fifth day. On the seventh day, a residue level of 0.12 mg kg $^{-1}$ was recorded and the degradation percentage increased to 89.56. On the tenth day, the residue became 0.06 mg kg $^{-1}$, where 94.55 per cent of the residues got dissipated and no residue was detected from the fifteenth day.

Carbaryl

The initial deposit of 5.21 mg kg $^{-1}$ carbaryl recorded two hours after spraying dissipated to 4.04 mg kg $^{-1}$, with a reduction of 22.39 per cent one day after spraying (Table 36). On the third day, the residue got reduced to 1.46 mg kg $^{-1}$ and the dissipation percentage increased to 71.98. The residue decline of carbaryl was at a slower pace on the fifth day, it got reduced by 81.95 per cent, the residue level lowering to 0.96 mg kg $^{-1}$. On the seventh day, the fruit sampled recorded a residue level of 0.64 mg kg $^{-1}$ and the degradation percentage increased to 87.68. On the tenth day, the residue became 0.38 mg kg $^{-1}$, where 92.76 per cent of the residues got dissipated and the residue decreased to 0.01 with a higher dissipation percentage of 99.79 on the fifteenth day. The residue was below the detectable level from the twentieth day.

Malathion

After one day, the initial deposit of 2.45 mg kg $^{-1}$ (Table 37) recorded reduced to 2.02 mg kg $^{-1}$ with a dissipation percentage of 17.69. On the third day, the residue reduced remarkably to 57.14 per cent of the initial deposit with the residue level becoming 1.05 mg kg $^{-1}$. On the fifth day, the fruits recorded a residue of 1.54 mg kg $^{-1}$ and the dissipation percentage increased to 69.56 per cent. On the seventh day, an average residue of 0.47 mg kg $^{-1}$ was recorded on brinjal fruits with a dissipation percentage of 80.86. On the tenth day, a residue of 0.05 mg kg $^{-1}$ was detected in fruits, recording a dissipation percentage of 97.77. The residue dissipated at a faster rate of 98.60 per cent on the fifteenth day and a residue level of 0.03 mg kg $^{-1}$ was recorded. No residues were detected from the twentieth day.

Table 36. Residues of carbaryl in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	5.23	5.19	5.21	5.21±0.02	
1	4.06	4.04	4.03	4.04±0.015	22.39
3	1.49	1.46	1.43	1.46±0.03	71.98
5	0.96	0. 96	0.95	0.96±0.005	81.65
7	0.65	0.65	0.63	0.64±0.011	87.68
10	0.37	0.39	0.38	0.38±0.011	92.76
15	0.01	0.01	0.01	0.01±0.001	99.79
20	BDL	BDL	BDL		

Table 37. Residues of malathion in/on brinjal fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	2.56	2.38	2.4	2.45±0.099	
1	2.06	1.96	2.03	2.02±0.051	17.69
3	1.07	1.05	1.03	1.05±0.02	57.14
5	0.55	0.43	0.43	0.47±0.073	80.86
7	0.06	0.05	0.06	0.05±0.002	97.77
10	0.03	0.04	0.03	0.03±0.003	98.60
15	BDL	BDL	BDL	BDL	

BDL - Below Detectable Level

4.4.2.5 Half life and waiting period

The half life and waiting period of the different new generation insecticides calculated based on the MRL values prescribed by Central Insecticide Board and Registration Committee and European Union (Table 38) indicated that emamectin benzoate, when sprayed on brinjal fruits had a half life of 1.28 days and waiting period of 4.40 days. Spinosad degraded to half its initial deposit in 1.35 days and the waiting period estimated was zero days. The half life recorded for novaluron was 2.39 days and it had the longest waiting period of 17.10 days. Chlorantraniliprole had a half life of 1.63 days and waiting period of 0.61 days. It took 2.42 days to degrade residue of indoxacarb to reach half of the initial deposit and the waiting period recorded was zero days. For fipronil the half life and waiting period calculated were 1.83 and 13.19 days, respectively. The half life was calculated as 1.81 days for thiodicarb and the waiting period 9.88 days on brinjal fruits. The half life of flubendiamide was 2.72 days and the waiting period 5.58 days. Carbaryl had a half life of 1.84 days and waiting period of 12.87days on brinjal fruits while malathion had a half life of 1.46 days and a waiting period of 10.70 days.

4.4.3 Okra

4.4.3.1 Method validation

Good recovery of the residues fortified in okra fruits ranging from 85.34 to 116.40 per cent (Table 39) were obtained in the method validated for the estimation of insecticides.

At the fortification level of 0.01 ppm, the mean per cent recovery of the insecticides in the descending order were indoxacarb (98.00), novaluron (87.40), carbaryl (95.3), chlorantraniliprole (94.90), malaoxon (85.70), desiodoflubendiamide (85.70), flubendiamide (85.20), spinosad (84.30), thiodicarb (80.40), emamectin benzoate (79.10), fipronil (97.50) and malathion (78.70) with a relative standard deviation of 4.30 to 11.70.

Table 38. Half life and waiting period of different insecticides in brinjal

Sl. No.	Insecticide	MRL (EU) mg kg^{-1}	r	R^2	Linear equation	$T_{½}$ (days)	$T_{tol/WP}$ (days)
1	Emamectin benzoate	0.01	-1.00	1.00	y=-0.24X+1.04	1.28	4.40
2	Spinosad	1.0	-0.93	0.86	y=-0.22X+1.87	1.35	1
3	Novaluron	0.01	-0.98	0.96	y=-0.13X+2.15	2.39	17.10
4	Chlorantraniliprole	0.60	-0.99	0.98	y=-0.18X+1.89	1.63	0.61
5	Indoxacarb	0.5	-0.95	0.90	y=-0.12X+1.59	2.42	1
6	Fipronil	0.005	-0.92	0.85	y=-0.16X+1.87	1.83	13.19
7	Thiodicarb	0.02	-0.95	0.90	y=-0.17X+2.95	1.81	9.88
8	Flubendiamide	0.20	-0.98	0.97	y=-0.11X+1.92	2.72	5.58
9	Carbaryl	0.05	-0.97	0.93	y=-0.16X+2.80	1.84	12.87
10	Malathion	0.02	-0.97	0.94	y=-0.21X+2.51	1.46	10.70

MRL - Maximum Residue Limit,
EU - European Union,
r - Correlation coefficient,
R^2 - Coefficient of determination
$T_{1/2}$ - Half Life,
T_{tol} - Waiting period (WP)

Table 39. Recovery of various insecticides and metabolites from okra fruits fortified at different levels

Insecticides	Level of fortification (ppm)					
	0.01		0.1		0.5	
	Mean % recovery	RSD	Mean % recovery	RSD	Mean % recovery	RSD
Emamectin benzoate	79.10	4.30	79.30	6.80	85.70	15.60
Spinosad	84.30	7.50	75.30	5.20	77.60	8.00
Novaluron	87.40	10.70-	82.90	8.80	96.40	6.80
Chlorantraniliprole	94.90	11.70	81.80	9.00	84.00	8.30
Indoxacarb	98.00	10.30	77.50	8.90	88.60	14.60
Fipronil	97.50	6.70	88.90	11.30	102.30	5.80
Thiodicarb	80.40	10.30	81.80	7.00	90.60	17.00
Flubendiamide	85.20	8.50	79.70	6.40	95.45	9.70
Desiodoflubendiamide	85.70	10.23	90.32	8.66	93.85	5.78
Carbaryl	95.30	3.80	87.50	6.30	85.60	6.50
Malathion	78.70	6.10	79.70	3.30	84.60	10.50
Malaoxon	85.7	11.10	92.00	5.70	88.10	7.90

Number of replicates at each level (n) = 5
RSD - Relative standard deviation for reproducibility

At the fortification level of 0.1 ppm, the mean per cent recovery among the insecticides in the descending order were malaoxon (92.00), desiodoflubendiamide (90.32), fipronil (88.90), carbaryl (87.50), novaluron (82.90), chlorantraniliprole (81.80), thiodicarb (81.80), flubendiamide (79.70), malathion (79.70), emamectin benzoate (79.30), indoxacarb (77.50) and spinosad (75.30) with a relative standard deviation of 3.30 to 11.30.

At the fortification level of 0.5 ppm, the mean per cent recovery among the insecticides in the descending order were fipronil (102.30), novaluron (96.40), flubendiamide (95.45), desiodoflubendiamide (93.85), thiodicarb (90.60), indoxacarb (88.60), malaoxon (88.10), emamectin benzoate (85.70), carbaryl (85.6), malathion (84.60), chlorantraniliprole (84.00) and spinosad (77.60) with a relative standard deviation of 5.78 to 17.00.

4.4.3.2 Calibration curve

The calibration curve prepared for instrument linearity indicated good linearity within the range of 0.01-0.5 mg kg^{-1} concentration for all the insecticides (Appendix Ia to Xb).

4.4.3.3 LOQ and LOD

The limit of quantitation (LOQ) of emamectin benzoate, spinosad, novaluron, chlorantraniliprole, indoxacarb, fipronil, thiodicarb, flubendiamide, malathion, and carbaryl was found to be 0.01 mg kg^{-1} and limit of detection (LOD) being 0.005 mg kg^{-1}.

4.4.3.4 Dissipation of insecticide residues

Emamectin benzoate

An initial deposit of 0.13 mg kg^{-1} of emamectin benzoate was detected on okra fruits when estimated two hours after spraying (Table 40). The residue of the insecticide was found to be 0.07 mg kg^{-1}, which was 45.07 per cent lesser than the initial residue on the next day. On the third day, the insecticide residue (0.03 mg kg^{-1}) dissipated by 78.39 per cent. No residue was detected above the level of quantitation (LOQ) at 0.01 $\mu g\ g^{-1}$ from the fifth day of spraying.

Spinosad

On the day of spraying, okra fruits collected 2 hours after treatment recorded an average initial deposit of 1.73 mg kg $^{-1}$ of spinosad. On the next day 37.90 per cent of the residues got dissipated and the level reached 1.08 mg kg $^{-1}$ (Table 41). Fruits collected on the third day recorded an average residue level of 0.25 mg kg $^{-1}$ with a dissipation percentage of 85.86. On the fifth day, 93.60 per cent of the residues got degraded and the concentration of spinosad on okra fruits became 0.11 mg kg $^{-1}$. The level of insecticide on okra fruits reduced to 0.01 mg kg $^{-1}$ on the seventh day, recording a dissipation percentage of 99.18. No residue was detected (LOQ-0.01 mg kg $^{-1}$) on the tenth day of spraying.

Novaluron

The initial deposit of novaluron on okra fruits following application at the rate of 100 g a.i.ha $^{-1}$ was found to be 1.30 mg kg $^{-1}$ (Table 42), which dissipated to 0.93 mg kg $^{-1}$ on the first day of spraying, the extent of dissipation being 65.80 per cent. On the third day, 74.68 per cent of the initial residue dissipated and the residue level became 0.69 mg kg $^{-1}$. The dissipation continued at a slower pace and on the fifth day, the residue reduced to 0.59 mg kg $^{-1}$ with a dissipation percentage of 78.15. On the seventh day, 93.65 per cent of the residue dissipated, recording an average level of 0.17 mg kg $^{-1}$. On the tenth day, 98.00 per cent of the residue dissipated and reached an average level of 0.05 mg kg $^{-1}$ on the fruits. On the fifteenth day no residue was detected above detectable level.

Chlorantraniliprole

Two hours after spraying, an initial deposit of 0.48 mg kg $^{-1}$ of chlorantraniliprole residues was recorded on okra fruits (Table 43) which after one day degraded to 0.33 mg kg $^{-1}$ with a dissipation percentage of 30.56. On the third day, the residue reduced to 61.81 per cent of the initial deposit, the concentration of the residue in the fruits being 0.18 mg kg $^{-1}$. By the fifth day an average residue deposit of 0.09 mg kg $^{-1}$ was recorded and the dissipation

Table 40. Residues of emamectin benzoate in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.12	0.14	0.12	0.13±0.009	
1	0.07	0.07	0.07	0.07±0.004	45.07
3	0.03	0.03	0.02	0.03±0.003	78.39
5	BDL	BDL	BDL		

Table 41. Residues of spinosad in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.75	1.72	1.72	1.73±0.020	
1	1.11	1.02	1.09	1.08±0.048	37.90
3	0.24	0.26	0.24	0.25±0.011	85.86
5	0.12	0.10	0.11	0.11±0.014	93.60
7	0.01	0.01	0.01	0.01±0.0003	99.18
10	BDL	BDL	BDL		

BDL - Below Detectable Level

Table 42. Residues of novaluron in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.51	1.14	1.25	1.30±0.19	
1	0.85	1.01	0.93	0.93±0.08	65.80
3	0.73	0.65	0.69	0.69±0.04	74.68
5	0.57	0.62	0.59	0.59±0.03	78.15
7	0.07	0.07	0.06	0.17±0.002	93.65
10	0.05	0.05	0.06	0.05±0.006	98.00
15	BDL	BDL	BDL		

Table 43. Residues of chlorantraniliprole in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.47	0.47	0.49	0.48±0.0115	
1	0.36	0.34	0.30	0.33±0.031	30.56
3	0.16	0.21	0.18	0.18±0.025	61.81
5	0.09	0.09	0.08	0.09±0.006	81.94
7	0.03	0.02	0.02	0.02±0.006	95.14
10	BDL	BDL	BDL		

BDL - Below Detectable Level

percentage increased to 81.94 per cent. On the seventh day, an average residue of 0.02 mg kg $^{-1}$ was detected on okra fruits with a dissipation percentage of 95.14 per cent. From the tenth day onwards, the residue was below detectable level.

Indoxacarb

The initial deposit of 1.08 mg kg $^{-1}$ (Table 44) recorded on okra fruits two hours after spraying reduced to 0.86 mg kg $^{-1}$ on the next day with a dissipation percentage of 20.40. On the third day, 85.30 per cent of the initial deposit was dissipated and the concentration became 0.16 mg kg $^{-1}$. Five days after spraying, the fruits recorded 0.07 mg kg $^{-1}$ of indoxacarb residue and the dissipation increased to 93.10 per cent. On the seventh day, 0.02 mg kg $^{-1}$ residue was recorded with a dissipation percentage of 98.48 per cent. The residue level reached below quantification on the tenth day.

Fipronil

Fipronil applied at the rate of 50 g ai ha $^{-1}$ resulted in an initial deposit of 0.78 mg kg $^{-1}$ on okra fruits two hours after spraying (Table 45). The residue degraded to 0.54 mg kg $^{-1}$ 24 hours after the spray, the extent of reduction being 30.07 per cent. On the third day, 79.32 per cent of the residue dissipated and the concentration of residue became 0.16 mg kg $^{-1}$. The residues degraded by 95.75 per cent on the fifth day, the residue concentration detected being 0.03 mg kg $^{-1}$. No residues were detected from the seventh day of spraying.

Thiodicarb

An initial deposit of 2.71 mg kg $^{-1}$ (Table 46) recorded on okra fruits, on the day of spraying degraded to 1.30 mg kg $^{-1}$ with a dissipation percentage of 52.27 after 24 hours. On the third day, the residue reduced to 90.37 per cent of the initial deposit, the level of residue detected being 0.26 mg kg $^{-1}$. On the fifth day, an average residue of 0.06 mg kg $^{-1}$was recorded on okra fruits with a dissipation percentage of 97.78. On the tenth day, no residue was detected in the fruits.

Table 44. Residues of indoxacarb in/on okra fruits

Days after spraying	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.11	1.04	1.08	1.08±0.035	
1	0.84	0.88	0.85	0.86±0.020	20.40
3	0.16	0.15	0.16	0.16±0.006	85.30
5	0.08	0.07	0.08	0.07±0.007	93.10
7	0.02	0.02	0.02	0.02±0.002	98.48
10	BDL	BDL	BDL		

Table 45. Residues of fipronil in/on okra fruits

Days after spraying	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	0.74	0.81	0.78	0.78±0.035	
1	0.57	0.53	0.53	0.54±0.023	30.07
3	0.19	0.15	0.15	0.16±0.023	79.32
5	0.03	0.03	0.03	0.03±0.001	95.75
7	BDL	BDL	BDL		

BDL - Below Detectable Level

Table 46. Residues of thiodicarb in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	2.87	2.69	2.58	2.71±0.15	
1	1.22	1.34	1.33	1.30±0.07	52.27
3	0.26	0.26	0.26	0.26±0.002	90.37
5	0.06	0.06	0.06	0.06±0.0007	97.78
7	BDL	BDL	BDL		

Table 47. Residues of flubendiamide in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.29	1.12	1.21	1.21±0.09	
1	1.03	1.08	0.99	1.03±0.05	14.37
3	0.58	0.49	0.51	0.53±0.05	56.35
5	0.37	0.40	0.39	0.39±0.02	67.90
7	0.12	0.13	0.13	0.13±0.003	89.64
10	0.06	0.06	0.06	0.06±0.002	95.30
15	BDL	BDL	BDL		

BDL - Below Detectable Level

Flubendiamide

The initial deposit of flubendiamide on okra fruits following application at the rate of 100 g a.i.ha $^{-1}$ was found to be 1.21 mg kg $^{-1}$ (Table 47), which got dissipated to 1.03 mg kg $^{-1}$ one day after spraying with a dissipation percentage of 14.37. On the third day, 56.35 per cent of the initial residue dissipated and the residue level became 0.53 mg kg $^{-1}$. The dissipation continued on the fifth day, the residue detected being 0.39 mg kg $^{-1}$ and dissipation percentage 67.90. On the seventh day, 89.64 per cent of the residue dissipated which recording an average level of 0.13 mg kg $^{-1}$. No residue was detected on the tenth day of spraying.

Carbaryl

The mean residue of carbaryl recorded at different intervals depicted in Table indicated an initial deposit of 5.32 mg kg $^{-1}$, which dissipated to 4.44 mg kg $^{-1}$, with a reduction of 16.55 per cent on the first day (Table 48). A remarkable reduction in the residue (2.10 mg kg^{-1}) was noted on the third day, the dissipation percentage increasing to 60.44. The residue decline was at a slower pace on the fifth day, (79.69 per cent), the residue level registered being 1.08 mg kg $^{-1}$. On the seventh day, the fruits sampled recorded a residue level of 0.10 mg kg $^{-1}$ and the degradation percentage increased to 98.15. The residue level reached BDL on the tenth day of spraying.

Malathion

The initial deposit after two hours of spraying of malathion on okra fruits was 1.34 mg kg $^{-1}$ (Table 49). After one day, the residue got reduced to 0.60 mg kg $^{-1}$ with a dissipation percentage of 54.95. On the third day, the residue degraded to 98.06 per cent of the initial deposit and the concentration became 0.03 mg kg $^{-1}$. No residue was detected in okra fruits collected on the seventh day after spraying.

4.4.3.5 Half life and waiting period

Emamectin benzoate registered a half life of 1.34 days and waiting period of 4.89 days (Table 50). The time taken for half of the spinosad residues to degrade were 1.03 days and the waiting period estimated was 7.93 days. The half

Table 48. Residues of carbaryl in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	5.53	5.24	5.18	5.32±0.187	
1	4.68	4.13	4.50	4.44±0.280	16.55
3	2.24	1.97	2.10	2.10±0.135	60.44
5	1.04	1.12	1.08	1.08±0.04	79.69
7	0.10	0.09	0.10	0.10±0.007	98.15
10	BDL	BDL	BDL		

Table 49. Residues of malathion in/on okra fruits

Days after spraying (DAS)	Residue (mg kg^{-1})			Mean ± SD	Dissipation %
	R1	R2	R3		
0 (2 hr after spraying)	1.37	1.30	1.35	1.34±0.036	
1	0.61	0.60	0.60	0.60±0.006	54.95
3	0.03	0.03	0.03	0.03±0.001	98.06
5	BDL	BDL	BDL		

BDL - Below Detectable Level

Table 50. Half life and waiting period of different insecticides in okra

Sl. No	Insecticide	MRL (EU) mg kg^{-1}	r	R^2	Linear equation	$T_{½}$ (days)	T_{tol} / WP (days)
1	Emamectin benzoate	0.01	-1.00	0.99	y=-0.225X+1.099	1.34	4.89
2	Spinosad	1.0	-0.99	0.98	y=-0.291X+2.309	1.03	7.93
3	Novaluron	0.01	-0.97	0.93	y=-0.1344X+2.159	2.24	16.03
4	Chlorantraniliprole	0.60	-0.99	0.97	y=-0.1813X+1.738	2.21	0
5	Indoxacarb	0.02	-0.99	0.99	y=-0.2655X+2.104	1.13	1.53
6	Fipronil	0.005	-0.99	0.99	y=-0.2821X+1.98	1.07	8.08
7	Thiodicarb	0.02	-1.00	1.00	y=-0.3378X+1.903	0.89	2.24
8	Flubendiamide	0.01	-0.98	0.96	y=-0.1359X+2.138	2.18	12.48
9	Carbaryl	0.05	-0.95	0.90	y=-0.234X+2.897	1.29	9.40
10	Malathion	0.05	-0.99	0.99	y=-0.606X+2.269	0.50	3.25

MRL - Maximum Residue Limit,
EU - European Union
R - Correlation coefficient,
R^2 - Coefficient of determination
$T_{1/2}$ - Half Life
T_{tol} - Waiting period (WP)

life computed for novaluron was 2.24 days and the waiting period 16.03 days. From the dissipation data of chlorantraniliprole, the half life was calculated as 2.21 days and waiting period zero days. Indoxacarb residues on okra fruits took 1.13 days to degrade to half of the initial deposit. The waiting period recorded for the insecticide was 1.53 days. For fipronil the half life and waiting period calculated were 1.07 and 8.08 days, respectively. The half life was calculated as 0.89 days for thiodicarb and the waiting period as 2.24 days on okra fruits. Flubendiamide had a half life of 2.18 days and a long waiting period of 12.48 days on okra fruits whereas carbaryl had a half life of 1.29 days and waiting period of 9.40 days. Malathion had the lowest half life (0.50 days) and waiting period (3.25 days) in the vegetable

4.5 DECONTAMINATION OF INSECTICIDE RESIDUES

4.5.1 Cowpea

The efficacy of different house hold processing measures in removing insecticide residues from cowpea fruits are presented in Table 51 and Table 52.

4.5.1.1. Two hours after spraying

Emamectin benzoate

All the decontaminating treatments significantly reduced the initial residue (0.074 mg kg $^{-1}$) of emamectin benzoate detected in cowpea pods two hours after spraying significantly. However, they differed in their efficacy in removing the residue. The residue load came down to BDL when the cowpea fruits were immersed in 2 % solutions of slaked lime and tamarind for 20 minutes followed by washing in water and on scrubbing and steaming. Immersing of pods in 1 % turmeric solution for 20 minutes followed by washing in water was also effective in removing the insecticide residues to the tune of 85.69 per cent with the initial residual load becoming 0.010 mg kg $^{-1}$. Similarly, more than eighty per cent of the residues were removed, when the fruits were immersed in 2 % salt solution (84.70 per cent) for 20 minutes followed by washing in plain water, the residue load detected being only 0.011 mg kg^{-1}. Washing in plain water alone for 20 minutes

Table 51. Extent of removal of insecticide residues from cowpea pods when subjected to different treatments two hours after spraying

Treatments	pH	Emamectin benzoate		Spinosad		Novaluron		Chlorantraniliprole		Indoxacarb		Fipronil		Thiodicarb		Flubendiamide		Carbaryl		Malathion	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Un processed		0.074 (1.87)		0.937		2.717		0.554 (1.74)		0.553		1.117		4.103 (3.61)		1.137		4.217		2.910	
Common salt 2%	4.72	0.011 (0.88)	84.70	0.224	76.09	1.213	55.34	0.140 (1.15)	74.77	0.233	57.81	0.467	60.11	0.031 (1.50)	99.24	0.347	69.50	2.047	51.46	0.860	70.34
Tamarind 2%	2.72	BDL	100	0.154	83.56	1.727	36.45	0.281 (1.45)	49.22	0.223	59.61	0.433	62.96	0.043 (1.64)	98.95	0.673	40.76	2.127	49.57	0.473	83.68
Vinegar 2%	3.14	0.040 (1.60)	45.96	0.252	73.07	0.650	76.08	0.065 (0.82)	88.20	0.220	60.22	0.433	62.96	0.021 (1.33)	99.48	0.143	87.39	1.753	58.42	0.743	74.37
Slaked lime 2%	12	BDL	100	0.118	87.44	0.257	90.55	0.054 (0.73)	90.26	0.123	77.70	0.343	70.66	BDL	100	0.253	77.71	1.763	58.41	0.413	85.75
Baking soda 2%	8.87	0.030 (1.48)	59.47	0.544	41.94	1.780	34.49	0.300 (1.48)	45.81	0.317	42.74	0.663	43.30	0.063 (1.80)	98.47	0.647	43.11	2.913	30.91	1.647	43.22
Turmeric 1%	6.4	0.010 (1.02)	85.69	0.134	85.73	0.950	65.03	0.088 (0.94)	84.12	0.127	77.09	0.330	71.79	0.062 (1.79)	98.48	0.233	79.47	1.973	53.20	0.600	79.31
Steaming		BDL	100	0.103	89.01	0.420	84.54	0.189 (1.28)	65.88	0.223	59.67	0.203	82.65	0.111 (2.05)	97.29	0.650	39.30	2.753	17.35	0.270	90.69
Scrubbing		BDL	100	0.145	84.49	0.513	81.11	0.053 (0.73)	90.41	0.133	75.89	0.417	64.39	0.058 (1.76)	98.59	0.690	67.16	2.05	51.38	1.263	56.44
Water	5.67	0.017 (1.24)	76.74	0.256	72.64	1.350	50.31	0.171 (1.23)	69.21	0.197	64.44	0.517	55.84	0.047 (1.67)	98.86	0.373	42.82	2.13	49.49	2.423	16.44
CD(0.05)		(0.08)		0.02		0.04		(0.11)		0.01		0.01		(0.13)		0.28		0.29		0.01	

Figures in the parenthesis are square root transformed values

A - Residue (mg kg^{-1})

B - Removal (%)

BDL - Below Detectable Level

decreased the insecticide load to 0.017 mg kg $^{-1}$, the extent of residue dissipation being 76.74 per cent. Comparatively, the extent of removal of the residues was lower when the cowpea fruits were immersed in 2 % baking soda (59.47 per cent) and 2 % vinegar (45.96 per cent) solutions, respectively followed by washing in water. The residue in these cases turned out to be 0.030 and 0.040 mg kg $^{-1}$ respectively.

Spinosad

Significant reduction in spinosad residue (0.937 mg kg $^{-1)}$ was recorded when cowpea fruits sprayed with this naturalyte were subjected to various decontaminating treatments. Steaming was the most effective process which reduced the residue load by 89.01 per cent, the concentration of the residue becoming 0.103 mg kg $^{-1}$. Dipping the fruits in 2 % slaked lime for 20 minutes also resulted in significantly higher removal of spinosad residue (87.44 per cent), the residue load on the fruits being 0.118 mg kg $^{-1}$. Dipping the fruits in turmeric (1 %) solution for 20 minutes followed by washing in water removed 85.73 per cent of the residue, the residue load recorded on the fruits being 0.134 mg kg $^{-1}$. Scrubbing of cowpea pods reduced the residue load to 0.145 mg kg $^{-1}$ there by removing 84.49 per cent of the residue. Similarly, dipping the pods in tamarind 2 % solution removed the residues to the extent of 83.56 per cent, the residue concentration on the fruits being 0.154 mg kg $^{-1}$. About 76.09 per cent of the residues were removed when the fruits were dipped in common salt 2 % solution followed by washing in plain water, the residue level on the fruits coming down to 0.224 mg kg $^{-1}$. Dipping in vinegar 2 % solution too reduced 73.07 per cent of the residues when compared to the unprocessed fruits. The residue load on cowpea fruits was reduced to 0.252 mg kg $^{-1}$. When dipped in water, the residue level was reduced to 0.256 mg kg $^{-1}$ there by removing 72.64 per cent of the initial residues. Baking soda solution 2 % was found to be least effective in removing spinosad residues (41.94 per cent).

Novaluron

The decontamination processes effectively removed residues of novaluron on cowpea fruits (2.717 mg kg $^{-1}$) and the treatments differed significantly from each other in their efficacy. About 90.55 per cent of the residue (0.257 mg kg $^{-1}$) was removed when the pods were immersed in slaked lime 2 % solution for twenty minutes followed by washing in water and the treatment was found to be significantly superior to all the other treatments. On steaming, the residue got reduced by 84.54 per cent and the concentration of residue became 0.420 mg kg $^{-1}$. Scrubbing removed 81.11 per cent of the residue, the residue concentration detected being 0.513 mg kg $^{-1}$. Immersing the fruits in vinegar 2 % and turmeric 1 % solutions followed by washing with plain water removed residues to the extent of 76.08 per cent and 65.03 per cent respectively, the residue concentration on the fruits decreasing to 0.650 and 0.950 mg kg $^{-1}$, respectively. When the fruits were immersed in common salt 2 % solution for 20 minutes followed by washing the residue level came down to 1.213 mg kg $^{-1}$, the extent of removal being 55.34 per cent. Washing in plain water was also found to be effective in reducing the residue (50.31 per cent), the washed fruits recording residue to the tune of 1.350 mg kg $^{-1}$. Processing in 2 % solutions of tamarind and baking soda removed residues to the tune of 36.45 per cent and 34.49 per cent respectively, the residue concentration of novaluron in the treatments being 1.727 mg kg $^{-1}$ and 1.780 mg kg $^{-1}$ respectively.

Chlorantraniliprole

Unprocessed cowpea fruits had a residue load of 0.554 mg kg $^{-1}$ chlorantraniliprole when estimated 2 hours after spraying. Scrubbing and immersing in slaked lime 2 % and vinegar 2 % solutions were the better treatments for removing the residues, the treatments being on par in their efficacy. On scrubbing the residues reduced by 90.41 per cent and the concentration of residues recorded was 0.053 mg kg $^{-1}$. Immersing of cowpea fruits in slaked lime and vinegar for 20 minutes followed by washing recorded a removal of 90.26 and 88.20 per cent, respectively with a residue concentration of 0.054 mg kg $^{-1}$ and

0.065 mg kg $^{-1}$, respectively. Turmeric 1 % solution recorded a removal of 84.12 per cent and a residue concentration of 0.088 mg kg $^{-1}$. Immersing in common salt 2 % solution and also washing in plain water could remove 74.77 per cent and 69.21 per cent of the initial residues, respectively and the residue load on the fruits came down to 0.140 and 0.171 mg kg $^{-1}$, respectively. When the pods were immersed in tamarind 2 % solution for twenty minutes followed by washing, the residues were reduced to 0.281 mg kg $^{-1}$, removing 49.22 per cent of the toxicant. Immersing in baking soda 2 % solution reduced the residue concentration to 0.300 mg kg $^{-1}$, thus removing 45.81 per cent of the insecticide.

Indoxacarb

The decontaminating treatments differed significantly in their efficacy in removing the insecticide residues of indoxacarb (0.553 mg kg $^{-1)}$ from the fruits. Maximum residues were removed when the pods were immersed in slaked lime 2 % and turmeric solution 2 % solutions and on scrubbing. More than 75 per cent of the residues were removed, when the fruits were immersed in slaked lime 2 % solution (77.70 per cent) turmeric 1 % solution (77.09 per cent) and scrubbing (75.89 per cent), the residue concentration decreasing to 0.123 mg kg $^{-1}$0.127 and 0.133 mg kg $^{-1}$ respectively. On washing in plain water, the residue detected was 0.197 mg kg $^{-1}$ and the percentage reduction was 64.44. When immersed in 2 % solution of vinegar, the residue concentration on the fruits became 0.220 mg kg $^{-1}$, thereby removing 60.22 per cent of the residue. Immersing in tamarind 2 % solution could remove 59.61 per cent of the residues and the concentration became 0.223 mg kg $^{-1}$. Processing in common salt 2 % solution (57.81 per cent) for twenty minutes followed by washing in water also removed more than 50% of the residue. However, only less than fifty per cent of the residue was removed, when the pods were immersed in baking soda 2 % solution (42.74 per cent).

Fipronil

Cowpea fruits immersed in turmeric 1 % and slaked lime 2 % solutions could remove 71.79 and 70.66 per cent of the initial residues (1.117 mg kg $^{-1),}$ the residue load coming down to 0.330 and 0.343 mg kg $^{-1}$, respectively. Scrubbing removed 64.39 per cent of fipronil residue and the residue load on fruits became 0.417 mg kg $^{-1}$. Immersing in tamarind 2 % solution for 20 minutes followed by washing (62.96 per cent removal) recorded a residue concentration of 0.433 mg kg $^{-1}$. Immersing in vinegar 2 % solution reduced 62.96 per cent of the residues when compared to the unprocessed fruits, the residue load being degraded to 0.433 mg kg $^{-1}$. Washing in water alone, reduced the residues to 0.517 mg kg $^{-1}$, removing 55.84 per cent of the contaminant. A decline of 60.11 per cent in the residue concentration was registered when immersed in common salt 2% solution, the level of residue detected being 0.467 mg kg $^{-1}$. The least removal of residue (43.30 per cent) was observed, when the fruits were immersed in baking soda 2 % solution, the residue concentration on the fruits recorded being 0.663 mg kg $^{-1}$.

Thiodicarb

The various decontaminating treatments removed thiodicarb residues (4.103 mg kg $^{-1}$) significantly from cowpea fruits. The residue level was below detectable level when the fruits were immersed in slaked lime 2 % solution and on steaming. Immersing in 2 % solutions of vinegar and common salt removed 99.48 and 99.24 per cent of the residues respectively, the residue concentration noted on the fruits being 0.021 mg kg $^{-1}$, and 0.031 mg kg $^{-1}$ respectively. Similarly, immersing in tamarind 2 %, washing in plain water, scrubbing, immersing in turmeric 1 % and baking soda 2 % solutions reduced 98.94, 98.86, 98.59, 98.48 and 98.47 per cent of the residues, respectively. The residue load quantified in these decontaminating treatments were 0.043 mg kg $^{-1}$, 0.047 mg kg $^{-1}$, 0.058 mg kg $^{-1}$ 0.062 mg kg $^{-1}$ and 0.063 mg kg $^{-1}$ respectively.

Flubendiamide

All the decontaminating treatments differed significantly in their efficacy in removing flubendiamide residues (1.137 mg kg $^{-1}$). The best treatment was 2 % solution of vinegar which decreased the residue concentration to 0.143 mg kg $^{-1}$, resulting in 87.39 per cent reduction of the toxicant. This was followed by turmeric 1 % and slaked lime 2 % solutions which could remove 79.47 and 77.71

per cent of the residues, respectively. The quantities of residues recorded in the treatments were 0.233 mg kg $^{-1}$ and 0.253 mg kg $^{-1}$ respectively. Immersing in 2 % solution of common salt and washing reduced the residue load to 0.347 and 0.373 mg kg $^{-1}$ respectively and the percentage removal of residue was 69.50 and 67.16 per cent respectively. Removal of the insecticide residue in the other processing methods was comparatively low. Immersing in baking soda 2 % and tamarind 2 % solutions for twenty minutes followed by washing in water removed 43.11 and 40.76 per cent of residues, the residue concentrations detected being 0.647mgkg $^{-1}$ and 0.673 mg kg $^{-1}$ respectively. Scrubbing of the fruits could remove only 39.30 per cent of the residue.

Carbaryl

Compared to other insecticides, the removal of carbaryl residue (4.217 mg kg $^{-1}$) from cowpea pods was low when subjected to the various decontaminating treatments. Immersing the fruits in 2 % vinegar solution for 20 minutes followed by washing in plain water removed maximum residue (58.42 per cent) and the residue load on fruits became 1.753 mg kg $^{-1}$. When immersed in 2 % slaked lime, 1 % turmeric and 2 % common salt solutions, 58.41, 53.20 and 51.46 per cent of the residues could be removed , the residue level detected being 1.763 mg kg $^{-1}$, 1.973 mg kg $^{-1}$ and 2.047 mg kg $^{-1}$ respectively. Scrubbing the cowpea fruits reduced the residue load to the extent of 2.05 mg kg $^{-1}$ thereby removing 51.38 per cent of the residues. When treated with 2 % tamarind solution and when washed in water, the residue level reduced to 2.127 and 2.13 mg kg $^{-1}$, removing 49.57 and 49.49 per cent of the initial residues, respectively. Baking soda was found to be least effective which removed only 30.91 per cent of the residues and the residue load was found to be 2.913 mg kg $^{-1}$.

Malathion

The decontaminating treatments differed significantly in their efficacy in removing malathion residues from cowpea fruits. While the unprocessed pods had a residue concentration of 2.910 mg kg $^{-1}$, processing in 2 % slaked lime solution removed 85.75 per cent of the residue, the concentration decreasing to 0.413 mg kg $^{-1}$. Immersing in 2 % tamarind solution could remove 83.68 per cent of the surface residues thereby reducing the residue concentration to 0.743 mg kg $^{-1}$. About 79.31 per cent of the residues were removed when the fruits were immersed in turmeric 1 % and the residue concentration came down to 0.600 mg kg $^{-1}$. Processing in 2 % vinegar and 2 % common salt solutions removed 74.37 and 70.34 per cent of the residues, recording a concentration of 0.743 mg kg $^{-1}$and 0.860 mg kg $^{-1}$ respectively. On scrubbing, the residue reduced to 1.263 mg kg $^{-1}$ thus eliminating 56.44 per cent of the toxicant. When the fruits were immersed in 2 % baking soda and plain water for 20 minutes, the residue concentration declined to 647 mg kg $^{-1}$ and 2.423 mg kg $^{-1}$ respectively and the percentage removal recorded was 43.22 per cent and 16.44 per cent, respectively.

4.5.1.2. Three days after spraying

Emamectin benzoate

Three days after spraying, the unprocessed cowpea fruits recorded an initial residue load of 0.012 mg kg $^{-1}$. All the processing methods reduced the residues to below detectable level.

Spinosad

The residues of spinosad detected three days after spraying (0.109 mg kg $^{-1}$) were removed to varying extent by the decontaminating treatments. Steaming was the most effective treatment, reducing the initial residue below quantitation limit. This was followed by slaked lime (2 %) and tamarind (2 %) solutions which removed 67.60 and 66.98 per cent of the residue, the concentrations detected being 0.035 mg kg $^{-1}$ and 0.036 mg kg $^{-1}$ respectively. Both the treatments were on par in their effect. Immersing in plain water, 2 % common salt and 2 % vinegar solutions removed 58.03, 58.36 and 50.93 per cent of the residues respectively, the residue concentration declining to 0.045 mg kg $^{-1}$0.045 mg kg $^{-1}$ and 0.053 mg kg $^{-1}$ respectively. Scrubbing reduced the residue to 0.055 mg kg $^{-1}$ thus removing 49.08 per cent of the residues. When the fruits were immersed in 2 % baking soda and 1 % turmeric solutions for 20 minutes, the residue concentration declined to

Table 52. Extent of removal of insecticide residues from cowpea pods when subjected to different treatments three days after spraying

Treatments	pH	Emamectin benzoate		Spinosad		Novaluron		Chlorantraniliprole		Indoxacarb		Fipronil		Thiodicarb		Flubendiamide		Carbaryl		Malathion	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Un processed		0.012		0.109 (1.03)		1.273		0.215 (1.33)		0.066 (1.82)		0.143 (1.16)		0.206 (1.31)		0.245 (1.39)		0.913		0.099 (0.99)	
Common salt 2%	4.72	BDL	100	0.045 (0.65)	58.36	0.957	24.85	0.099 (1.00)	53.80	0.033 (1.52)	49.97	0.090 (0.95)	37.32	0.077 (0.88)	62.86	0.120 (1.08)	51.13	0.683	25.16	0.039 (0.60)	59.60
Tamarind 2%	2.72	BDL	100	0.036 (0.55)	66.98	0.600	52.87	0.068 (0.84)	68.16	0.016 (1.20)	75.95	0.046 (0.67)	67.54	0.022 (0.35)	89.09	0.129 (1.11)	47.35	0.557	39.03	0.02 (0.29)	80.14
Vinegar 2%	3.14	BDL	100	0.053 (0.72)	50.93	0.587	53.91	0.061 (0.78)	71.79	0.018 (1.26)	72.47	0.049 (0.69)	65.51	0.074 (0.87)	63.92	0.113 (1.05)	53.77	0.533	41.58	0.02 (0.30)	79.81
Slaked lime 2%	12	BDL	100	0.035 (0.54)	67.60	0.230	81.93	0.024 (0.38)	88.72	0.023 (1.36)	65.31	0.066 (0.82)	53.50	BDL	100	0.08 (0.9)	67.51	0.677	25.89	0.031 (0.49)	68.70
Baking soda 2%	8.87	BDL	100	0.066 (0.82)	38.89	1.093	14.11	0.111 (1.05)	48.39	0.046 (1.67)	24.24	0.120 (1.08)	16.28	0.076 (0.88)	62.97	0.176 (1.25)	28.06	0.710	22.23	0.059 (0.77)	40.77
Turmeric 1%	6.4	BDL	100	0.066 (0.82)	38.89	0.420	67.01	0.039 (0.59)	81.71	0.013 (1.10)	80.91	0.053 (0.73)	62.84	0.023 (0.37)	88.70	0.062 (0.79)	74.63	0.467	48.89	0.051 (0.70)	48.84
Steaming		BDL	100	BDL	100	0.080	93.72	BDL	100	0.010 (1.01)	84.85	0.030 (0.48)	79. 03	0.023 (0.36)	88.92	0.220 (1.34)	10.33	0.020	97.85	0.08 (0.90)	18.89
Scrubbing		BDL	100	0.055 (0.74)	49.08	0.240	81.15	0.054 (0.73)	74.99	0.010 (1.00)	84.36	0.040 (0.60)	72.03	0.026 (0.41)	87.38	0.033 (0.52)	86.52	0.417	54.36	0.060 (0.78)	39.74
Water	5.67	BDL	100	0.045 (0.66)	58.03	0.767	39.77	0.090 (0.95)	58.30	0.018 (1.26)	72.47	0.090 (0.95)	37.32	0.067 (0.83)	67.49	0.120 (1.08)	51.13	0.71	22.23	0.060 (0.78)	39.74
CD(0.05)		-		(0.02)		0.07		(0.09)		(0.24)		(0.08)		(0.30)		(0.10)		0.01		(0.02)	

Figures in the parenthesis are square root transformed values

A - Residue (mg kg^{-1})

B - Removal (%)

BDL - Below Detectable Level

0.066 mg kg $^{-1}$ in both the treatments, the percentage removal noted being 38.89 per cent.

Novaluron

Processing of the fruits harvested three days after spraying in the different decontaminating treatments reduced the residue load (1.273 mg kg $^{-1)}$ prevailing on the cowpea fruits significantly. On steaming, the residue got reduced by 93.72 per cent and the concentration of residue became 0.080 mg kg $^{-1}$. Only 0.230 mg kg $^{-1}$ residue of novaluron could be detected in the fruits when immersed in slaked lime registering 81.93 per cent removal of the residue. Scrubbing too reduced the residue load on the fruits (0.240 mg kg $^{-1}$) the extent of removal being 81.15 per cent. Immersing of the fruits in 1 % turmeric solution removed 67.01 per cent of the residue (0.420 mg kg $^{-1}$). Similarly immersing in 2 % vinegar and tamarind solutions reduced the residue load to 0.587 mg kg $^{-1}$ and 0.600 mg kg $^{-1}$ respectively there by removing 53.91 and 52.87 per cent of residues respectively. About 39.77 per cent of the residues were removed when the pods were washed in plain water and the residue level came down to 0.767 mg kg $^{-1}$. Processing in 2 % common salt and 2 % baking soda solutions removed only 24.85 and 14.11 per cent of the residues.

Chlorantraniliprole

Processing in 2% slaked lime and 1 % turmeric solutions were observed to be the better treatments for removing residues of chlorantraniliprole (0.215 mg kg $^{-1}$) on the third day after spraying. The treatments removed 88.72 and 81.71 per cent residues, respectively and the residue load on fruits became 0.024 mg kg $^{-1}$ and 0.039 mg kg $^{-1}$ respectively. When scrubbed the fruits showed a reduced residue of 0.054 mg kg $^{-1}$, registering 74.99 per cent reduction in the initial deposit. Vinegar 2 % solution could reduce the residue load to the extent of 0.061 mg kg $^{-1}$ there by removing 71.79 per cent of residues. The fruits immersed in 2 % tamarind solution had 0.068 mg kg $^{-1}$residues, showing 68.16 per cent reduction in the toxicant. About 58.30 and 53.80 per cent of the residues were removed when the cowpea fruits were immersed in plain water and 2% common salt solution, residue level coming down to 0.090 mg kg $^{-1}$ and 0.099 mg kg $^{-1}$, respectively. Baking soda 2 % solution recorded the least residue removal of 48.39 per cent and a residue concentration of 0.111 mg kg $^{-1}$.

Indoxacarb

The decontaminating treatments differed significantly in their efficacy in reducing the residue load on cowpea fruits on the third day. Steaming (84.85 per cent) and scrubbing (84.36 per cent) removed maximum indoxacarb residue from cowpea fruits and the residue load on fruits became 0.010 mg kg $^{-1}$. Immersing the fruits in 1 % turmeric solution for 20 minutes followed by washing in water removed 80.91 per cent of the residue and the residue load on the fruits became 0.013 mg kg $^{-1}$. About 75.95 per cent of the residues were removed when the cowpea fruits were processed in 2 % tamarind solution and the residue level on cowpea fruits came down to 0.016 mg kg $^{-1}$. Washing the cowpea fruits and immersing in vinegar 2 % solution removed the residues to the extent of 72.47 per cent and the residue concentration on cowpea fruits became 0.018 mg kg $^{-1}$. Immersing in slaked lime removed 65.31 per cent of residues and the residue load came down to 0.023 mg kg $^{-1}$. Immersing cowpea fruits in salt (2 %) solution reduced 49.97 per cent of the residues when compared to the unprocessed fruits and the residue load on cowpea fruits reduced to 0.033 mg kg $^{-1}$. When the cowpea fruits were immersed in 2 % baking soda, the residue level reduced to 0.046 there by removing only 24.24 per cent of the initial residues.

Fipronil

Scrubbing reduced the residues (0.143 mg kg $^{-1}$) seen on cowpea fruits three days after spraying to 0.040 mg kg $^{-1}$ recording a 72.03 per cent reduction. Immersing in 2 % tamarind solution for 20 minutes followed by washing recorded a residue concentration of 0.046 mg kg $^{-1}$, thus removing 67.54 per cent of the residue. Vinegar 2 % and turmeric 1 % solutions were the next best treatments recording a residue removal of 65.51 per cent and 62.84 per cent, respectively the residue concentration recorded being 0.049 mg kg $^{-1}$ and 0.053 mg kg $^{-1}$ respectively. Immersing cowpea fruits in 2 % slaked lime solution reduced 53.50

per cent of the residues However, processing in 2% common salt solution and washing in plain water could remove only 37.32 per cent of the initial residues,the residue load on the fruits in both cases coming down to 0.090 mg kg $^{-1}$.Among the decontaminating treatments, baking soda 2 % solution was the least effective. The residue concentration on the fruits was reduced to 0.120 mg kg $^{-1}$, thereby registering only 16.28 per cent removal of the residues.

Thiodicarb

Processing in slaked lime 2 % solution was the best treatment for removing thiodicarb residues (0.206 mg kg $^{-1}$).The residue was reduced to below detectable level when cowpea pods were immersed in the solution for 20 minutes, the treatment being superior to all the other processes in its efficacy. Immersing in tamarind 2 % solution, steaming, immersing in turmeric 1 % solution and scrubbing too degraded the residues significantly to 0.022 mg kg $^{-1}$, 0.023 mg kg $^{-1}$,0.023 mg kg $^{-1}$ and 0.026 mg kg $^{-1}$ respectively. The extent of dissipation in the treatments was 89.09, 88.92, 88.70 and 87.38 per cent, respectively. About 67.49 per cent of the residues were removed when the cowpea fruits were immersed in Washing in plain water and immersing in vinegar 2 % , baking soda 2 % and salt 2 % solutions lowered the residue level to 0.067 mg kg $^{-1}$, 0.074 mg kg $^{-1}$, 0.076 mg kg $^{-1}$ and 0.077 mg kg $^{-1}$ respectively. The percentage of residues degraded through these treatments were 67.49, 63.92, 62.97and 62.86 respectively.

Flubendiamide

The decontaminating treatments differed significantly in their efficacy in removing flubendiamide residues (0.245 mg kg $^{-1}$) from cowpea fruits seen on the third day after spraying. Maximum residue was removed through scrubbing the fruits (86.52 per cent) and the residue concentration was reduced to 0.033 mg kg $^{-1}$. This was followed by 1 % solution of turmeric solution which decreased the residue level to 0.062 mg kg $^{-1}$, the reduction of residue in the pods being 74.63 per cent. Immersing in 2 % slaked lime solution could remove 67.51 per cent of the residues, the concentration declining to 0.08 mg kg $^{-1}$. Vinegar 2 % and common salt 2% solutions, washing in plain water and tamarind 2 % solution were on par in their efficacy, removing 53.77 ,51.13, 49.6 and 47.35 per cent of the residue respectively, the initial residue being reduced to 0.113, 0.129 0.120 and 0.120 mg kg $^{-1}$ respectively. The extent of removal of the insecticide residue was low when the pods were immersed in 2 % baking soda solution (28.06 per cent). Similarly, steaming removed only 10.33 per cent of the residues.

Carbaryl

Steaming was significantly the best method for removing residues of carbaryl (0.913 mg kg $^{-1}$). The residue was degraded to 0.020 mg kg $^{-1}$, recording 97.85 per cent reduction in the residue. Comparatively, the extent of removal of carbaryl residues by the other processing methods was low. On scrubbing, the initial load of 0.913 mg kg $^{-1}$ residue was reduced to 0.417 mg kg $^{-1}$, the extent of reduction being 54.36. Forty eight per cent residues of carbaryl were removed and when the fruits were immersed in 1 % turmeric, residue estimated being 0.467 mg kg $^{-1}$. Vinegar solution and tamarind 2 % solutions reduced the residue load cowpea to 0.533 mg kg $^{-1}$ and 0.557 mg kg $^{-1}$ there by removing 41.58 and 39.03 per cent of the residue, respectively. Processing in 2 % slaked lime , common salt and baking soda solutions and washing in plain water removed only 25.89, 25.00 22.23 and 22.23 per cent of the residue.

Malathion

Immersing of cowpea fruits in 2 % tamarind and 2 % vinegar solutions for twenty minutes followed by water wash reduced the initial residue of 0.099 mg kg $^{-1}$ to 0.02 mg kg $^{-1}$, thus removing 80.14 per cent and 79.81 per cent of the residues. When immersed in 2 % slaked lime solution, 68.70 per cent removal of malathion residues was noted, recording a residue concentration of 0.031 mg kg $^{-1}$. Salt 2 % and turmeric 1 % solutions reduced the residue to 0.039 mg kg $^{-1}$ and 0.051 mg kg $^{-1}$ respectively, indicating 59.60 and 48.84 per cent reduction in the residue content. Scrubbing, steaming and immersing in 2 % baking soda solution the removed 39.74, 39.74 and 40.04 per cent of the residues respectively. Simple washing could remove only 18.89 per cent of the initial residues.

4.5.2 BRINJAL

The efficacy of different house hold processing measures in removing insecticide residues from brinjal fruits are presented in Table 53 and Table 54.

4.5.2.1 Two hours after spraying

Emamectin benzoate

The decontaminating treatments removed the emamectin benzoate residues (0.102 mg kg^{-1}) seen on brinjal fruits two hours after spraying significantly. With the exception of 1% turmeric solution, all the other methods were on par in their efficacy in removing the insecticide residue. When brinjal fruits were processed in 2% baking soda solution, 2% salt solution, washed with plain water, 2% slaked lime solution, scrubbed, 2% tamarind solution, 2% vinegar solution and steamed, the residue concentration on the fruits decreased to 0.015, 0.016, 0.017, 0.017, 0.021, 0.025, 0.032 and 0.033 mg kg^{-1} recording a loss of 85.44, 84.75, 83.24, 82.95, 79.94, 76.08, 69.20 and 67.52, respectively. When the fruits were immersed in turmeric solution, only 25.02 per cent of the surface residues were removed, reducing the residue concentration to 0.057 mg kg^{-1}.

Spinosad

The spinosad residues in the unprocessed brinjal fruits were found to be 0.581 mg kg^{-1} at 2 hours after spraying. The decontaminating treatments were very effective in removing the insecticide load on the brinjal fruits. Simple washing of the fruits and treatments with baking soda, common salt, turmeric scrubbing, tamarind and slaked lime removed the residues by 94.91, 92.98, 92.85, 92.77, 87.05, 85.82 and 84.80 per cent, residue concentration on the fruits decreasing to 0.030, 0.041, 0.041 0.042 0.075, 0.082, and 0.088 mg kg^{-1} , respectively. When the brinjal fruits were processed by steaming and immersing in 2% vinegar solution, the residue concentration on the fruits decreased to 0.147 and 0.173 mg kg^{-1} recording a loss of 74.76 and 60.02, respectively.

Table 53. Extent of removal of insecticide residues from brinjal fruits when subjected to different treatments two hours after spraying

Treatments	pH	Emamectin benzoate		Spinosad		Novaluron		Chlorantraniliprole		Indoxacarb		Fipronil		Thiodicarb		Flubendiamide		Carbaryl		Malathion	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Un processed		0.102 (3.20)		0.581 (7.62)		1.196		0.730 (8.55)		0.268 (5.18)		0.564		5.107		0.793 (8.96)		5.258		2.450	
Common salt 2%	4.72	0.016 (1.25)	84.75	0.041 (2.04)	92.85	0.336	71.91	0.068 (2.61)	90.66	0.086 (2.93)	67.95	0.146	74.16	0.030 (1.72)	99.42	0.066 (2.77)	91.60	1.283	75.60	0.194 (4.41)	92.06
Tamarind 2%	2.72	0.025 (1.57)	76.08	0.082 (2.87)	85.82	0.713	40.37	0.165 (4.06)	77.47	0.050 (2.23)	81.40	0.237	57.89	0.087 (2.94)	98.28	0.188 (4.45)	76.19	3.237	38.45	0.084 (2.90)	96.55
Vinegar 2%	3.14	0.032 (1.78)	69.20	0.173 (4.16)	60.02	0.488	59.23	0.173 (4.16)	76.32	0.118 (3.43)	55.99	0.207	63.25	0.382 (6.18)	92.51	0.194 (4.51)	75.55	1.407	73.25	0.243 (4.93)	90.07
Slaked lime 2%	12	0.017 (1.32)	82.95	0.088 (2.97)	84.80	0.194	83.77	0.051 (2.25)	93.07	0.077 (2.77)	71.34	0.251	55.56	0.019 (1.37)	99.62	0.100 (3.31)	87.41	2.305	56.17	0.388 (6.22)	84.15
Baking soda 2%	8.87	0.015 (1.22)	85.44	0.041 (2.02)	92.98	0.101	91.55	0.125 (3.53)	82.95	0.040 (1.99)	85.18	0.135	76.07	BDL	100	BDL	100	1.287	75.53	0.542 (7.36)	77.89
Turmeric 1%	6.4	0.057 (2.39)	25.02	0.042 (2.05)	92.77	0.455	61.97	0.098 (3.14)	86.52	0.067 (2.58)	75.04	0.130	76.93	0.060 (2.46)	98.82	0.105 (3.39)	86.79	1.246	76.31	0.134 (3.66)	94.51
Steaming		0.033 (1.83)	67.52	0.147 (3.83)	74.76	1.001	16.29	0.200 (4.42)	73.29	0.245 (4.95)	8.66	0.363	35.71	0.019 (1.36)	99.63	0.335 (5.87)	57.73	1.341	74.51	1.082	55.84
Scrubbing		0.021 (1.43)	79.94	0.075 (2.74)	87.05	0.186	84.50	0.102 (3.19)	86.08	0.052 (2.27)	80.71	0.140	75.13	0.310 (5.57)	93.90	0.072 (2.87)	90.86	1.251	76.21	0.497 (7.05)	79.72
Water	5.67	0.017 (1.32)	83.24	0.030 (1.72)	94.91	0.291	75.65	0.099 (3.15)	86.38	0.044 (2.11)	83.46	0.310	45.06	0.084 (2.89)	98.35	0.086 (3.11)	89.09	0.873	83.39	0.146 (3.82)	94.05
CD(0.05)		(0.94)		(1.61)		0.08		(1.18)		(0.16)		0.01		(0.52)		(1.20)		0.21		(0.31)	

Figures in the parenthesis are square root transformed values

A - Residue (mg kg^{-1})

B - Removal (%)

BDL - Below Detectable Level

Novaluron

The decontaminating treatments varied in their efficacy in reducing the residue load on brinjal fruits (1.196 mg kg $^{-1}$) detected two hours after spraying. Immersing the fruits in 2 % baking soda solution for 20 minutes followed by washing in water was the most effective treatment which removed 91.55 per cent residue from brinjal fruits, the residue load on fruits becoming 0.101 mg kg $^{-1}$. Scrubbing and immersing the fruits in 2 % slaked lime solution for 20 minutes followed by washing in water removed 84.50 and 83.77 per cent of the residue, respectively, the residue load on the fruits being reduced to 0.186 and 0.191 mg kg $^{-1}$ respectively. About 75.65 and 71.91 per cent of the residues were removed when the brinjal fruits were washed in plain water and immersed in 2% salt solution, the residue level coming down to 0.291 and 0.336 mg kg $^{-1}$, respectively. Immersing in 1 % turmeric and 2 % vinegar solutions reduced the residue load on brinjal fruits to the extent of 0.455 and 0.488 mg kg $^{-1}$ there by removing 61.97 and 59.23 per cent of the residue, respectively. Immersing in 2 % tamarind solution removed the residues by 40.37 per cent and the residue concentration on brinjal fruits became 0.713 mg kg $^{-1}$. Steaming was least effective, the residue level being reduced to 1.001 mg kg $^{-1}$, and thereby removing 16.29 per cent of the initial residues.

Chlorantraniliprole

When the brinjal fruits were immersed in 2% slaked lime and 2% salt solutions, 93.07 and 90.66 per cent of the initial residues (0.730 mg kg $^{-1}$) were removed, the concentration detected being 0.051 mg kg $^{-1}$ and 0.068 mg kg $^{-1}$ respectively. Immersing in 1% turmeric, washing, scrubbing and immersing in 2 % baking soda solution removed 86.52 per cent, 86.38 per cent, 86.08 per cent and 82.95 per cent, respectively of the residues, keeping the residue concentration at a lower level of 0.098 mg kg $^{-1}$, 0.099 mg kg $^{-1}$, 0.102 mg kg $^{-1}$ and 0.125 mg kg $^{-1}$, respectively. The brinjal fruits when immersed in 2 % tamarind and 2 % vinegar solutions and when steamed removed 77.47 per cent, 76.32 per cent and

73.29 per cent of the residue and the residue concentration on the brinjal fruits decreased to 0.165, 0.173 and 0.200 mg kg $^{-1}$, respectively.

Indoxacarb

The unprocessed fruits two hours after spraying showed a residue concentration of 0.268 mg kg $^{-1}$. About 85.18 per cent and 83.46 per cent of the initial residues were removed when the fruits were immersed in 2 % baking soda solution and also simply washed, residue concentration decreasing to 0.040 and 0.044 mg kg $^{-1}$. Both the treatments were on par in their effect and were superior to the other decontaminating treatments. Immersing in 2 % tamarind solution and scrubbing, removed 81.40 and 80.71 per cent of the residues and the residue concentration on the fruits became 0.050 and 0.052 mg kg $^{-1}$. When the brinjal fruits were immersed in 1 % turmeric solution, 75.04 per cent of the residues were removed recording a residue concentration of 0.067 mg kg $^{-1}$. In the alkaline medium, *viz.*, 2 % slaked lime solution 71.34 per cent of the residues were removed recording a residue concentration of 0.077 mg kg $^{-1}$. Only 67.95 per cent of the residues were removed when the brinjal fruits were immersed in 2 %salt solution and residue concentration became 0 .086 mg kg $^{-1}$. When the fruits were immersed in 2 % vinegar for twenty minutes, 55.99 per cent of the residues were removed and the residue on the fruits became 0.118 mg kg $^{-1}$. Steaming of the fruits for 10 minutes, could remove only 8.66 per cent of the residues.

Fipronil

Compared to other insecticides, the extent of removal of fipronil residues (0.564 mg kg $^{-1}$) from brinjal fruits through the decontaminating treatments was low. Among the processing methods, immersing in solutions of turmeric 1 % (76.93 per cent), baking soda 2 % (76.07 per cent) and scrubbing (75.13 per cent) for twenty minutes proved significantly better in decontaminating the fruits, the residue concentration in the treatments being 0.130, 0.135 and 0.140 mg kg $^{-1}$ respectively. Brinjal fruits immersed in salt 2 % solution could remove 74.16 per cent of the residues and the concentration became 0.146 mg kg $^{-1}$. When the brinjal fruits were immersed in 2 % solutions of vinegar and tamarind, the residue concentration on the fruits became 0.207 and 0.237 mg kg $^{-1}$, thereby removing 63.25 and 57.89 per cent of the residues, respectively. When the fruits were immersed in slaked lime, the residue concentration on the fruits reduced to 0.251 mg kg $^{-1}$, thereby reducing 55.56 per cent and washing, reduced the residue to 0.310 mg kg $^{-1}$, with residue removal of 45.06 per cent. Steaming was found least effective, removing only 35.71 per cent of fipronil residues from brinjal fruits; the residue concentration recorded being 0.363 mg kg $^{-1}$ respectively.

Thiodicarb

The different processing methods were found to be highly effective in removing thiodicarb residues from brinjal fruits. The residue concentration of 5.107 mg kg $^{-1}$ recorded in the unprocessed fruits dissipated below detectable level when immersed in 2 % baking soda solution, the treatments being statistically superior to all other processing methods. When the fruits were steamed, immersed in 2 % slaked lime and 2 % salt solutions, the residue level came down to 0.019, 0.019 and 0.030 mg kg $^{-1}$, recording 99.63, 99.62 and 99.42 per cent removal respectively. The treatments were on par in their efficacy. Immersing in 1 % turmeric solution, washing in plain water and immersing in 2 % tamarind solution could remove 98.82, 98.35 and 98.28 per cent of the insecticide residues, respectively and the residue concentration became 0.060, 0.084 and 0.087 mg kg $^{-1}$, respectively. Scrubbing and immersing in 2 % vinegar solution too removed 93.90 and 92.51 per cent of the residues the residue concentration being 0.310 and 0.382 mg kg $^{-1}$, respectively.

Flubendiamide

The decontaminating treatments significantly reduced the residue concentration of flubendiamide of brinjal fruits (0.793 mg kg $^{-1}$). The residues dissipated below detectable level when the fruits were immersed in 2 % baking soda solution. Higher quantity of residues were removed when the brinjal fruits were immersed in common salt 2 % solution (91.60 per cent) by scrubbing (90.86 per cent) washing (89.09 per cent) turmeric 1 % solution (86.79 per cent) and slaked lime solution (83.32 per cent) and the residue concentration in the treated brinjal fruits became 0.066, 0.072, 0.086, 0.105 and 0.132 mg kg $^{-1}$ respectively. The brinjal fruits immersed in 2 % tamarind and vinegar solutions for twenty minutes followed by washing removed 76.19 per cent and 75.55 per cent residue, respectively, reducing the residue concentration to the extent of 0.188 and 0.194 mg kg $^{-1}$ respectively. Steaming had the least effect which removed only 57.73 per cent of residues from the brinjal fruits; the residues recorded being 0.335 mg kg $^{-1}$.

Carbaryl

All the decontaminating treatments differed significantly in their efficacy in removing carbaryl residues from brinjal fruits (5.258 mg kg $^{-1}$). Maximum residue was removed (83.39 per cent) when the fruits were washed with water and the residue concentration decreased to 0.873 mg kg $^{-1}$. The treatment was superior to all the other treatments. Immersing in 1 % turmeric solution, scrubbing, immersing in 2 % salt and 2 % baking soda solutions, steaming and 2 % vinegar solution could remove 76.31 per cent, 76.21 per cent, 75.60 per cent, 75.53 per cent, 74.51 per cent and 73.25 per cent of the residues, respectively, all the processing methods being on par in their efficacy. The residues recorded on the fruits in these treatments were 1.246, 1.251, 1.283, 1.287, 1.341 and 1.407 mg kg $^{-1}$, respectively. Brinjal fruits immersed in slaked lime 2 % solution recorded 56.17 per cent reduction in the residues, the concentration noted being 2.305 mg kg $^{-1}$. When immersed in 2 % tamarind solution only 38.45 per cent of the residues could be removed.

Malathion

Two hours after spraying the unprocessed fruits recorded a residue concentration of 2.450 mg kg $^{-1}$. Among the various processing methods tested, immersing in 2 % tamarind solution proved to be the most effective treatment in removing malathion residues and the treatment was statistically superior to all other processing methods. The residue was reduced to 0.084 mg kg $^{-1}$registering 96.55 per cent removal of the toxicant. Immersing of brinjal fruits in 1 %turmeric solution and washing in water could remove 94.51 per cent and 94.05 per cent of the residues, respectively. The malathion residues which remained on the brinjal fruits in these treatments were 0.134 and 0.146 mg kg $^{-1}$ respectively. Immersing of the sprayed fruits in 2 % common salt solution for 20 minutes could remove 92.06 per cent of the residues, there by bringing down the residue concentration to 0.194 mg kg $^{-1}$. When the fruits were immersed in 2 % vinegar solution, 90.07 per cent of the residues were removed from fruits keeping the residue concentration at a lower level 0.243 mg kg $^{-1}$. Processing with slaked lime too removed 84.15 per cent of the residue and the residue concentration on the brinjal fruits decreased to 0.388 mg kg $^{-1}$. Scrubbing of brinjal fruits and immersing in 2 % baking soda solution for twenty minutes recorded a concentration of 0.497 and 0.542 mg kg $^{-1}$ respectively, thereby removing 79.72 per cent and 77.89 per cent of the initial residue. Both the treatments were on par in their efficacy. Through steaming of the fruits, only 55.84 per cent of the initial residues were removed and the residue concentration became 1.082 mg kg $^{-1}$.

4.5.2.2 Three days after spraying

Emamectin benzoate

Three days after spraying, 0.025 mg kg $^{-1}$ residues of emamectin benzoate were recorded on brinjal fruits. The residues dissipated below detectable level in all the different processing methods.

Spinosad

The spinosad residues (0.211 mg kg $^{-1}$) estimated on brinjal three days after spraying dissipated below detectable level by the different processing methods *viz.*, slaked lime, vinegar, baking soda, simple washing and steaming. About 94.96, 94.85, and 94.51 per cent of spinosad residues were removed when the brinjal fruits were immersed in common salt, turmeric and tamarind solution for twenty minutes followed by washing in water resulting in a residue concentration of 0.011, 0.011 and 0.012 mg kg $^{-1}$ and the treatments were found to be significantly superior over scrubbing (71.05 per cent) with residue of 0.061mgkg $^{-1}$.

Table 54. Extent of removal of insecticide residues from brinjal fruits when subjected to different treatments three days after spraying

Treatments	pH	Emamectin benzoate		Spinosad		Novaluron		Chlorantraniliprole		Indoxacarb		Fipronil		Thiodicarb		Flubendiamide		Carbaryl		Malathion	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Un processed		0.025		0.211		0.729 (8.54)		0.217 (4.65)		0.200 (4.47)		0.259 (5.09)		3.268		0.464 (6.81)		1.250		1.050	
Common salt 2%	4.72	BDL	100	0.011	94.96	0.244 (4.94)	66.49	0.038 (1.95)	82.45	0.030 (1.75)	84.68	0.106 (2.80)	59.04	0.158 (3.97)	95.17	0.162 (4.02)	65.12	0.285	79.13	0.025 (1.57)	97.66
Tamarind 2%	2.72	BDL	100	0.012	94.51	0.260 (5.09)	64.38	0.043 (2.08)	79.96	0.043 (2.09)	78.13	0.036 (1.89)	86.07	0.331 (5.76)	89.86	0.177 (4.20)	61.87	0.463	66.09	0.122 (3.48)	88.36
Vinegar 2%	3.14	BDL	100	BDL	100	0.074 (2.72)	89.82	BDL	100	BDL	100	BDL	100	0.011 (1.04)	99.67	0.029 (1.70)	93.76	0.115	91.57	BDL	100
Slaked lime 2%	12	BDL	100	BDL	100	0.075 (2.74)	89.65	0.011 (1.07)	94.70	0.013 (1.12)	93.69	0.014 (1.17)	94.69	0.039 (1.96)	98.82	0.060 (2.45)	87.01	0.234	82.89	0.016 (1.28)	98.43
Baking soda 2%	8.87	BDL	100	BDL	100	0.052 (2.28)	92.84	BDL	100	BDL	100	BDL	100	BDL	100	BDL	100	0.101	92.57	BDL	100
Turmeric 1%	6.4	BDL	100	0.011	94.85	0.188 (4.34)	74.22	0.024 (1.59)	88.79	0.022 (1.50)	88.76	0.017 (1.29)	93.53	0.043 (2.06)	98.70	0.110 (3.31)	76.38	0.223	83.67	BDL	100
Steaming		BDL	100	BDL	100	0.230 (4.73)	68.49	0.016 (1.59)	92.61	0.035 (1.87)	82.45	0.015 (1.24)	94.07	0.028 (1.66)	99.15	0.163 (4.04)	64.88	0.113	91.75	BDL	100
Scrubbing		BDL	100	0.061	71.05	0.055 (2.34)	92.50	BDL	100	BDL	100	0.010 (1.02)	95.96	0.018 (1.34)	99.45	BDL	100	0.216	84.16	0.012 (1.10)	98.84
Water	5.67	BDL	100	BDL	100	0.157 (3.96)	78.43	0.024 (1.59)	88.78	BDL	100	BDL	100	0.055 (2.35)	98.31	0.140 (3.73)	69.91	0.097	92.89	BDL	100
CD(0.05)		-		-		(0.57)		(0.09)		(0.14)		(1.10)		(0.19)		(0.20)		0.02		(0.22)	

Figures in the parenthesis are square root transformed values

A - Residue (mg kg^{-1})

B - Removal (%)

BDL - Below Detectable Level

Novaluron

Immersing of brinjal fruits in 2 % baking soda solution for 20 minutes (92.84 per cent) and scrubbing (92.50 per cent) proved to be the best treatments in removing novaluron residues (0.729 mg kg $^{-1}$) from brinjal fruits three days after spraying, recording a residue concentration of 0.052 and 0.055 mg kg $^{-1}$.The treatments were on par with 2 % vinegar (89.82 per cent) and 2 % slaked lime solutions (89.65 per cent) with 0.074 and 0.075 mg kg $^{-1}$ of residue, respectively. Simple washing reduced the residues to 0.157 mg kg $^{-1}$ thereby removing 78.43 per cent of the initial residues. Brinjal fruits immersed in 1 % turmeric solution for 20 minutes followed by washing in water recorded 0.188 mg kg $^{-1}$ of the insecticide residue, recording 74.22 per cent reduction in the initial residue. Steaming and treatments with common salt and tamarind removed residues to the extent of 68.49, 66.49 and 64.38 per cent respectively with the residue concentration on brinjal fruits decreasing to 0.230, 0.244 and 0.260 mg kg $^{-1}$, respectively.

Chlorantraniliprole

Processing of brinjal fruits in 2 % vinegar and 2 % baking soda solutions and scrubbing could bring down the chlorantraniliprole residues (0.217 mg kg $^{-1}$) seen on brinjal fruits three days after spraying to below detectable level. Immersing in 2 % slaked lime) solution (94.70 per cent) decreased the residue concentration on the fruits to 0.011 mg kg $^{-1}$. Steaming for ten minutes, immersing in 1% turmeric solution and washing could remove 92.61, 88.79 and 88.78 per cent, respectively of the residues thereby reducing the residue concentration to 0.016, 0.024 and 0.024 mg kg $^{-1}$, respectively. About 82.45 and 79.96 per cent of the residues were removed when the brinjal fruits were immersed in 2 % common salt and 2 % tamarind solutions the residue concentration declining to 0.038 and 0.043 mg kg $^{-1}$.

Indoxacarb

Maximum residue removal was reported on immersing of brinjal fruits in 2 % vinegar and 2 % baking soda solutions, washing in plain water and scrubbing which brought down the residues (0.200 mg kg $^{-1}$) to below detectable level. In the alkaline medium, *viz* slaked lime 2 % solution, about 93.69 per cent of the residues were removed recording a residue concentration of 0.013 mg kg $^{-1}$. When the brinjal fruits were immersed in turmeric 1 % solution for twenty minutes (88.76 per cent) the residue came down to 0.022 mg kg $^{-1}$. Immersing in salt 2 % solution removed 84.68 per cent of the residues and the residue level became 0.030 mg kg $^{-1}$. The residue concentration became 0.035 and 0.043 mg kg $^{-1}$ on steaming and when immersed in tamarind 2 % solution there by removing 82.45 and 78.13 per cent of the initial residues, respectively.

Fipronil

While the unprocessed fruits recorded a residue concentration of 0.259 mg kg $^{-1}$, no residues were detected in fruits immersed in vinegar 2 % and baking soda 2 % solutions and the treatments were significantly superior to all the other decontaminating processes. Scrubbing (95.96 per cent), immersing in slaked lime 2 % (94.69 per cent), steaming (94.07 per cent), immersing in turmeric 1 % (86.07 per cent) and tamarind 2 % (93.53 per cent) solutions for twenty minutes reduced the residue on fruits to 0.010, 0.014, 0.015, 0.017 and 0.036 mg kg $^{-1}$, respectively. Immersing in common salt 2 % solution could remove only 59.04 per cent of the initial residues with the residue concentration declining to 0.106 mg kg $^{-1}$.

Thiodicarb

All the decontaminating treatments were found to be highly effective in removing thiodicarb residues (3.268 mg kg $^{-1}$) found on the brinjal fruits three days after spraying. The residues dissipated below detectable level when the fruits were immersed in baking soda 2 % solution. Immersing in vinegar 2 % solution brought down the residues to 0.011 mg kg $^{-1}$ there by removing 99.67 per cent of the toxicant. About 99.45 per cent of the residues were removed recording a residue concentration of 0.018 mg kg $^{-1}$ by scrubbing and 99.15 per cent (0.028 mg kg $^{-1}$) by steaming. When the fruits were immersed in slaked lime 2 % solution and turmeric 1% solution for twenty minutes followed by washing in water the residue came down to 0.039(98.82 per cent) and 0.043 mg kg $^{-1}$(98.70 per cent), respectively. On washing and when immersed in salt 2 % solution for twenty minutes, 98.31 and 95.17 per cent of the residues were removed and the residue level degrading to 0.055 and 0.158 mg kg $^{-1}$, respectively. Similarly, when processed in tamarind 2 % solution, only 0.331 mg kg $^{-1}$ residues were detected in the brinjal fruits registering 89.86 per cent reduction in the initial residue content.

Flubendiamide

All the decontaminating treatments differed significantly in their efficacy in removing flubendiamide residues (0.464 mg kg $^{-1}$) from brinjal fruits. The residues dissipated below detectable level when the brinjal fruits were immersed in baking soda 2 % solution and on scrubbing. Maximum flubendiamide residues were removed (93.76 per cent) when the brinjal fruits were immersed in vinegar 2 % solution for 20 minutes, the residue concentration decreasing to 0.029 mg kg $^{-1}$. Immersing in slaked lime 2 % solution removed 87.01 per cent of the insecticide residue and the residue concentration became 0.060 mg kg $^{-1}$. When immersed in turmeric 1 % solution and when washed with plain water, the residue level in the fruits declined to 0.110 and 0.140 mg kg $^{-1}$ there by removing 76.38 and 69.91 per cent of the initial residues. Salt 2 % solution and steaming could remove 65.12 and 64.88 per cent of residues. Comparatively, tamarind 2 % solution was found less effective in removing the residues. Only 61.87 per cent of the residues were removed, residue concentration detected being 0.177 mg kg $^{-1}$.

Carbaryl

The different decontaminating treatments proved effective in removing carbaryl residues (1.250 mg kg $^{-1}$) from the brinjal fruits. The best treatment was washing which removed 92.89 per cent of the residues, and the recorded concentration was 0.097 mg kg $^{-1}$. The treatment was on par in its efficacy with baking soda (92.57 per cent), steaming (91.75 per cent) and vinegar (91.57 per cent) with residue concentrations of 0.101, 0.113 and 0.115 mg kg $^{-1}$, respectively. Scrubbing, immersing in turmeric (1 %) and slaked lime (2 %) for twenty minutes removed 84.16, 83.67 and 82.89 per cent of the residues, the residue on fruits declining to 0.216, 0.223 and 0.234 mg kg $^{-1}$, respectively. All the treatments were on par in their efficacy. Immersing brinjal fruits in salt 2 % and tamarind 2% solutions could remove 79.13 and 66.09 per cent of the insecticide residues, respectively and the residue concentration lowered to 0.285 and 0.463 mg kg $^{-1}$, respectively.

Malathion

All the decontaminating treatments were found effective in removing the malathion residues (1.050 mg kg $^{-1}$) detected on fruits at 3 days after spraying. The residues in the fruits dissipated below detectable level when treated with vinegar 2%, baking soda 2% and turmeric 1% solutions and on washing and steaming. By scrubbing 98.84 per cent of the residues were removed, recording a residue concentration of 0.012 mg kg $^{-1}$. When the fruits were immersed in 2 % solutions of common salt (97.66 per cent) and slaked lime (98.43 per cent), the residue concentration of the treatments came down to 0.025 and 0.016 mg kg $^{-1}$. Immersing in tamarind 2 % solution could remove 88.36 per cent of the insecticide residues and the residue concentration became 0.122 mg kg $^{-1}$.

4.5.3 Okra

The efficacy of different house hold processing measures in removing insecticide residues from okra fruits are presented in Table 55 and Table 56.

4.5.3.1 Two hours after spraying

Emamectin benzoate

Two hours after spraying, a residue deposit of 0.127 mg kg $^{-1}$ was recorded on okra fruits. When subjected to various decontaminating treatments, the extent of removal of the residue differed among the treatments significantly. On immersing the insecticide sprayed fruits in baking soda 2 %, salt 2 % and slaked

Table 55. Extent of removal of insecticide residues from okra fruits when subjected to different treatments two hours after spraying

Treatments	pH	Emamectin benzoate		Spinosad		Novaluron		Chlorantraniliprole		Indoxacarb		Fipronil		Thiodicarb		Flubendiamide		Carbaryl		Malathion	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Un processed		0.127 (1.27)		1. 697		1.370		0.499 (7.06)		1.050		0.771		2.533		1.227		5.330		1.337	
Common salt 2%	4.72	0.019 (0.19)	84.70	0.411	75.80	0.681	50.27	0.115 (3.38)	77.04	0.575	45.27	0.404	47.53	0.025	98.36	0.592	51.71	2.637	50.53	0.427	68.08
Tamarind 2%	2.72	0.031 (0.31)	75.27	0.285	83.22	0.906	33.87	0.261 (5.10)	47.78	0.509	51.49	0.308	60.03	0.046	96.95	0.525	57.20	2.593	51.34	0.265	80.20
Vinegar 2%	3.14	0.040 (0.40)	68.51	0.402	76.33	0.394	71.24	0.065 (2.55)	86.10	0.516	50.86	0.321	58.35	0.239	84.11	0.571	53.45	2.376	55.42	0.388	70.97
Slaked lime 2%	12	0.022 (0.22)	82.74	0.214	87.37	0.227	83.45	0.070 (2.65)	85.91	0.298	71.62	0.280	63.62	0.146	90.34	0.356	71.01	2.278	57.27	0.262	80.42
Baking soda 2%	8.87	0.018 (0.18)	85.38	0.993	41.45	0.946	30.97	0.259 (5.09)	48.09	0.722	31.24	0.477	38.15	0.060	96.05	0.733	40.27	3.50	34.33	0.831	37.86
Turmeric 1%	6.4	0.096 (0.96)	23.55	0.250	85.27	0.548	60.04	0.078 (2.80)	84.33	0.290	72.38	0.233	69.82	0.123	91.87	0.368	70.00	2.657	50.14	0.246	81.62
Steaming		0.042 (0.40)	66.55	0.900	46.97	1.114	18.65	0.265 (5.15)	46.81	0.851	18.98	0.530	31.27	BDL	100	0.805	34.40	2.791	47.57	0.741	44.56
Scrubbing		0.026 (0.31)	79.48	0.276	83.73	0.327	76.16	0.071 (2.66)	85.87	0.356	66.06	0.343	55.55	0.230	84.76	0.498	59.38	1.835	65.55	0.605	54.74
Water	5.67	0.022 (0.26)	82.51	0.475	72.00	0.769	43.89	0.166 (4.07)	66.74	0.360	65.68	0.374	51.43	0.119	92.07	0.597	51.36	2.854	46.45	1.052	21.30
CD(0.05)		(0.04)		0.03		0.04		(0.10)		0.02		0.007		0.001		0.01		0.02		0.04	

Figures in the parenthesis are square root transformed values

A - Residue (mg kg^{-1})

B - Removal (%)

BDL - Below Detectable Level

lime 2 % solutions for 20 minutes followed by washing in water, 85.38, 84.70 and 82.74 per cent of the residues were removed and the treatments proved to be significantly superior to all the other treatments. The residue load degraded to 0.018, 0.019 and 0.022 mg kg $^{-1}$ respectively when treated in these solutions. When subjected to simple washing in water, 82.51 per cent of the initial residues were removed; the deposit recorded being 0.022 mg kg $^{-1}$. When the fruits were immersed in 2 % tamarind solution for 20 minutes followed by washing in plain water, the residue load reduced to 0.031 mg kg $^{-1}$ resulting in 75.27 per cent reduction of the toxicant. Scrubbing reduced the residue to 0.026 mg kg $^{-1}$ (79.48 per cent). About 68.51 and 66.55 per cent of the residues were removed when the fruits were immersed in vinegar 2 % solution followed by washing in water and steaming, respectively, the residues recorded being 0.040 and 0.042 mg kg $^{-1}$, respectively. Immersing in 1 % turmeric solution for 20 minutes was the least effective treatment removing only 23.55 per cent of the residue.

Spinosad

The spinosad residues in okra fruits were found to be 1.690 mg kg $^{-1}$ at 2 hours after spraying. The decontaminating treatments differed in their efficacy on removing the insecticide residues on the fruit. Maximum reduction(87.37 per cent) was noted when the okra fruits were immersed in 2 % slaked lime solution , the initial load being reduced to 0.214 mg kg $^{-1}$ .and the treatment was found to be significantly superior. Immersing of the fruits in turmeric 1% solution, scrubbing and immersing in tamarind 2 % solution removed residues to an extent of 85.27 per cent, 83.73 per cent and 83.22 per cent, respectively with the residue concentration on okra fruits decreasing to 0.250, 0.276 and 0.285 mg kg $^{-1}$, respectively. When the fruits were immersed in vinegar 2 % and salt 2 % solutions for 20 minutes followed by washing, the residue level came down to 0.402 and 0.411 mg kg $^{-1}$ recording a removal of 76.33 and 75.80 per cent residue respectively. The next best treatment found effective in reducing the residue was simple washing in water (72 per cent) and the treated fruits recorded residue to the tune of 0.475 mg kg $^{-1}$. Steaming of the fruits and the alkaline treatment of immersing in baking soda 2 % solution were less effective in removing residues of spinosad. The treatments resulted in only 46.97 per cent (0.90 mg kg $^{-1}$) and 41.45 per cent (0.993 mg kg $^{-1}$) removal of the residue.

Novaluron

Among the decontaminating treatments, slaked lime 2 % solution was found to be the most effective treatment in removing residues of novaluron prevalent on okra fruits (1.370 mg kg $^{-1}$) two hours after spraying. Immersing of the fruits in the solution reduced the residue deposit to 0.227 mg kg $^{-1}$, thus reducing the residue content to 83.45 per cent. The treatment was statistically superior to all other treatments. Scrubbing and immersing the fruits in 2 % vinegar solution for 20 minutes followed by washing in water removed 76.16 and 71.24 per cent of the residue respectively and the residue load on the fruits degraded to 0.327 and 0.394 mg kg $^{-1}$, respectively. Immersing in 1 % turmeric solution reduced the residue load to the extent of 0.548 mg kg $^{-1}$ there by removing 60.04 per cent of the residues. When the fruits were immersed in salt 2 % solution, 50.27 per cent of the residues were removed, the residue deposit dissipating to 0.681 mg kg $^{-1}$. Simple washing in plain water (0.769 mg kg $^{-1}$), immersing in 2 % tamarind (0.906 mg kg $^{-1}$) and 2 % baking soda (0.946 mg kg $^{-1}$) solutions and steaming (1.114 mg kg $^{-1}$) were less effective in removing the residue, the extent of removal being 43.89, 33.87, 30.97 and18.65 per cent.

Chlorantraniliprole

The efficacy of the treatments differed significantly from each other .in removing the chlorantraniliprole residues (0.499 mg kg^{-1}). However immersing in 2 % vinegar, 2 % slaked lime (2 %) solution followed by water wash were the most effective decontaminating treatments, the residues removed being to 86.10 per cent and 85.91 per cent respectively, the residue concentration declining to 0.065 and 0.070 mg kg $^{-1}$ respectively. Scrubbing of the fruits too removed the residue substantially (85.87 per cent), the residue level recorded being 0.071 mg kg $^{-1}$. Immersing of the chlorantraniliprole sprayed fruits in 1 % turmeric solution for 20 minutes followed by washing in water could remove 84.33 per cent of the residues, thereby bringing down the residue concentration to 0.078 mg kg $^{-1}$. Okra fruits immersed in 2 % salt solution for twenty minutes followed by washing in plain water and washing recorded a residue concentration of 0.115 and 0.166 mg kg $^{-1}$ respectively, degrading 77.04 and 66.74 per cent of the initial residue concentration, respectively. Baking soda 2 %, tamarind 2 % solution and steaming removed only 48.09, 47.78 and 46.81 per cent of the residues, respectively and the residue concentration on the okra fruits decreased to 0.259, 0.261 and 0.265 mg kg^{-1} respectively.

Indoxacarb

The unprocessed fruits showed a residue deposit of 1.050 mg kg $^{-1}$. When immersed in turmeric 1 % and slaked lime, 2 % solutions, 72.38 and 71.62 per cent of the residues were removed, respectively, recording a residue concentration of 0.290 mg kg $^{-1}$ and 0.298 mg kg $^{-1}$ respectively. Scrubbing of the fruits and simple washing in water could remove 66.06 and 65.68 per cent of residues, respectively and the residue became 0.356 and 0.360 mg kg $^{-1}$. When the fruits were immersed in 2 % solutions of tamarind (51.49 per cent) and vinegar (50.86 per cent) for twenty minutes followed by washing in water, the residue concentration of both the treatments came down to 0.509 and 0.516 mg kg $^{-1}$ respectively. Okra fruits immersed in salt 2 % solution could remove 45.27 per cent of the residues and the concentration became 0.576 mg kg $^{-1}$. The alkaline treatment, baking soda 2 % and steaming were least effective, removing only 31.24 per cent and 18.98 per cent of indoxacarb residues from okra fruits.

Fipronil

Maximum fipronil residues were removed (69.82 per cent) when the okra fruits were immersed in turmeric 1 % solution for 20 minute followed by washing in water and the residue concentration decreased to 0.233 mg kg $^{-1}$. Slaked lime 2 % solution reduced the residue load to 0.280 mg kg $^{-1}$ the extent of reduction achieved being 63.62 per cent. Tamarind 2 % and vinegar 2 % solutions degraded the residue to 0.308 and 0.321 mg kg $^{-1}$ respectively thereby removing 60.03 and 58.35 per cent of the residues, respectively. On scrubbing, 55.55 per cent of the residues were removed and residue on the fruits turned out to be 0.343 mg kg $^{-1}$ and, 51.43 per cent residue removal on washing and the residue being 0.374 mg kg $^{-1}$. Only less than fifty percentages of the residues were removed, when the okra fruits were immersed in 2% solutions of salt (47.53 per cent) and baking soda (38.15 per cent) for twenty minutes followed by washing in water. Steaming was least effective, removing 31.27 per cent of fipronil residues.

Thiodicarb

The unprocessed fruits showed a residue concentration of 2.533 mg kg $^{-1}$. which dissipated below detectable level when steamed for 10 minutes. Immersing in salt, tamarind and baking soda solutions too reduced the residue content significantly (0.025, 0.046 and 0.060 mg kg $^{-1}$) recording a degradation of 98.36, 96.95 and 96.05 per cent respectively. Similarly, washing in plain water, turmeric and slaked lime solutions could remove 92.07, 91.87 and 90.34 per cent of the insecticide residues, respectively and the residue concentration became 0.119, 0.123 and 0.146 mg kg $^{-1}$, respectively. Only 84.76 and 84.11 per cent of the residues were removed by scrubbing and on vinegar treatment and the residue concentration became 0.230 and 0.239 mg kg $^{-1}$, respectively.

Flubendiamide

The decontaminating treatments differed significantly from each other in degrading the residue concentration of 1.227 mg kg $^{-1}$ recorded on okra fruits. Immersing in slaked lime 2 % solution for 20 minutes followed by washing was the most effective method wihch removed 71.01 per cent of the residues, the toxicant remaining on the fruits being 0.356 mg kg $^{-1}$. The next best treatment was turmeric 1 % solution which lowered the residue to 0.368 mg kg $^{-1}$ registering 70.00 per cent reduction in the residue content. This was followed by scrubbing of the fruits which degraded the flubendiamide residues to 0.498 mg kg $^{-1}$, registering 59.38 per cent reduction. Immersing okra fruits in tamarind 2 % solution followed by washing could remove only 57.20 per cent of the residues there by reducing the residue concentration to 0.525 mg kg $^{-1}$. The okra fruits immersed in vinegar and salt 2 % solutions for twenty minutes followed by washing removed 53.45

per cent and 51.71 per cent residue, respectively, reducing the residue concentration to the extent of 0.57 mg kg $^{-1}$ and 0.592 mg kg $^{-1}$, respectively. When the okra fruits were washed in water, 51.36 per cent of the residues were removed and the residue deposit on the fruits turned out to be 0.597 mg kg $^{-1}$. Immersing the fruits in baking soda 2 % solution could remove only 40.27 per cent of the residue and the residue concentration on fruits reduced to 0.733 mg kg $^{-1}$. Steaming had the least effect, dissipating only residues 34.40 per cent of the residues.

Carbaryl

All the decontaminating treatments differed significantly in their efficacy in removing carbaryl residues (5.330 mg kg $^{-1}$) from okra fruits. Maximum carbaryl residues were removed (65.55 per cent) when the fruits were scrubbed and the residue concentration decreased to 1.835 mg kg $^{-1}$. Okra fruits immersed in slaked lime 2 % solution could remove 57.27 per cent of the residues, the deposit degrading to 2.278 mg kg $^{-1}$. The residue concentration became 2.376 mg kg $^{-1}$, thereby removing 55.48 per cent of the residues, when the fruits were immersed in 2 % solution of vinegar. Tamarind 2 % and salt 2 % solutions dissipated 51.34 and 50.53 per cent of the initial residues, respectively and the residue concentration became 2.593 mg kg $^{-1}$ and 2.637 mg kg $^{-1}$, respectively. Less than fifty per cent of the residues were removed on steaming (47.57 per cent) and washing in water (46.45 per cent). Baking soda 2 % could degrade only 34.33 per cent of the residues from okra fruits.

Malathion

Turmeric 1 %, slaked lime 2 % and tamarind 2 % solutions removed 81.62, 80.42 and 80.20 per cent of the initial residue (1.337 mg kg $^{-1}$) , respectively and the treatments were on par. The malathion residues that remained on the fruits were 0.246, 0.262 and 0.265 mg kg $^{-1}$ respectively. Vinegar 2 % and salt 2 % solutions degraded the residues to 0.338 mg kg $^{-1}$ and 0.427 mg kg $^{-1}$ respectively, the extent of reduction being 70.97 and 68.08 per cent respectively. Scrubbing of the fruits resulted in 54.74 per cent removal of the residue and the residue concentration on the okra fruits decreased to 0.605 mg kg $^{-1}$. Steaming and treating with baking soda 2 % solution for twenty minutes followed by washing in plain water recorded a residue concentration of 0.741 and 0.831 mg kg $^{-1}$ respectively, thereby removing only 44.56 per cent and 37.86 per cent of the initial residue concentration. Only 21.30 per cent of the initial residue was removed on washing in water.

4.5.3.2 Three days after spraying

Emamectin benzoate

Three days after spraying, 0.029 mg kg $^{-1}$ insecticide residue was detected on okra fruits. With the exception of vinegar and turmeric, all the other treatments *viz.*, immersing in 2 % solutions of common salt, tamarind, slaked lime and baking soda, scrubbing, simple washing in water and steaming dissipated the residues to below detectable level. While vinegar 2 % solution removed 63.59 per cent of the residues were, thereby reducing the residue level to 0.01 mg kg $^{-1}$, 1 % turmeric solution was less effective removing only 31.34 per cent of the residues.

Spinosad

On the third day after spraying, the insecticide residue on the okra fruits (0.245 mg kg $^{-1}$) was brought down below detectable level when processed in 2% solutions of salt, tamarind, vinegar and slaked lime and turmeric 1% solution. Similarly, scrubbing and washing in plain water also degraded the residue to below detectable levels. On the other hand, steaming and immersing in baking soda 2 % solution reduced the residue level only by 49.09 and 36.54 per cent, respectively and recording a residue concentration of 0.015 and 0.019 mg kg $^{-1}$ respectively.

Novaluron

Scrubbing (81.48 per cent removal) and immersing of okra fruits in slaked lime (2 %) solution for 20 minutes followed by washing (78.20 per cent removal) proved to be the better treatments in removing novaluron residues from okra fruits (0.657 mg kg $^{-1}$) at 3 DAS, recording a residue concentration of 0.122 and 0.143

Table 56. Extent of removal of insecticide residues from okra fruits when subjected to different treatments three days after spraying

Treatments	pH	Emamectin benzoate		Spinosad		Novaluron		Chlorantraniliprole		Indoxacarb		Fipronil		Thiodicarb		Flubendiamide		Carbaryl		Malathion	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Un processed		0.029		0.245		0.657		0.184 (4.28)		0.155 (3.94)		0.149 (3.86)		0.273		0.534		2.207		0.031	
Common salt 2%	4.72	BDL	100	BDL	100	0.451	31.30	0.090 (3.00)	50.94	0.078 (2.79)	57.48	0.100 (3.16)	33.11	0.037	82.48	0.349	34.62	1.110	49.69	BDL	100
Tamarind 2%	2.72	BDL	100	BDL	100	0.365	44.39	0.065 (2.54)	64.86	0.053 (2.30)	71.13	0.057 (2.39)	61.72	0.041	80.38	0.154	71.24	1.271	42.41	0.010	66.30
Vinegar 2%	3.14	0.011	63.59	BDL	100	0.317	51.75	0.057 (2.38)	69.04	0.039 (1.96)	78.85	0.046 (2.15)	68.97	0.043	79.70	0.194	63.63	1.202	45.54	BDL	100
Slaked lime 2%	12	BDL	100	BDL	100	0.143	78.20	0.025 (1.58)	86.48	0.067 (2.58)	63.43	0.067 (2.58)	55.21	0.016	92.37	0.254	52.46	1.329	39.79	BDL	100
Baking soda 2%	8.87	BDL	100	0.019	36.54	0.484	26.28	0.107 (3.27)	41.77	0.118 (3.43)	35.47	0.119 (3.45)	19.91	0.060	71.54	0.428	19.89	1.123	49.10	BDL	100
Turmeric 1%	6.4	0.020	31.34	BDL	100	0.285	56.67	0.045 (2.11)	75.66	0.027 (1.64)	85.20	0.058 (2.40)	61.28	0.022	89.52	0.201	62.31	1.200	45.61	BDL	100
Steaming		BDL	100	0.015	49.09	0.342	47.10	0.096 (3.09)	47.95	0.094 (3.07)	48.32	0.041 (2.02)	72.57	BDL	100	0.405	24.27	0.750	66.02	0.011	62.61
Scrubbing		BDL	100	BDL	100	0.122	81.48	0.053 (2.24)	71.13	0.032 (1.79)	82.35	0.050 (2.22)	66.78	0.015	92.85	0.202	62.26	0.905	58.99	BDL	100
Water	5.67	BDL	100	BDL	100	0.405	38.36	0.080 (2.82)	56.35	0.057 (2.38)	68.10	0.090 (3.00)	39.69	0.073	65.37	0.359	32.75	0.951	56.91	BDL	100
CD(0.05)		-		-		0.02		(0.07)		(0.14)		(0.11)		0.01		0.01		0.02		-	

Figures in the parenthesis are square root transformed values

A - Residue (mg kg^{-1})

B - Removal (%)

BDL - Below Detectable Level

mg kg $^{-1}$, respectively. Immersing in turmeric 1 % and vinegar (2 %)solution solution for 20 minutes followed by washing in water could remove only 56.67 and 51.75 per cent of the initial residues and the residue load on the fruits degraded to 0.285 and 0.317 mg kg $^{-1}$ respectively. The extent of removal of novaluron residues in all the other decontamination treatments were low being below 50 per cent. Steaming recorded 47.10 per cent removal of the residue. While immersing the fruits in tamarind 2 %solution for twenty minutes followed by water wash reduced the residues to 0.365 mg kg $^{-1}$, removing 44.39 per cent of the residues, simple washing reduced the residues on okra fruits to 0.405 mg kg $^{-1}$ (38.36 per cent). Salt 2 % and baking soda 2 % solutions removed only 31.30 and 26.28 per cent of the residue.

Chlorantraniliprole

All the decontaminating treatments differed significantly in their efficacy in degrading chlorantraniliprole residues (0.184 mg kg $^{-1}$) seen three days after spraying. Maximum residue removal (86.48 per cent) was recorded when the okra fruits were immersed in 2 % slaked lime solution the residue concentration on the fruits decreasing from to 0.025 mg kg $^{-1}$. Immersing in turmeric 1 % solution, scrubbing, immersing in vinegar 2 % and tamarind 2 % solutions could remove 75.66 per cent, 71.13 per cent, 69.04 per cent and 64.86 per cent of the residues, respectively. The chlorantraniliprole deposits remaining on the okra fruits in these treatments were 0.045, 0.053, 0.057 and 0.065 mg kg $^{-1}$, respectively. On washing the residue reduction was 56.35 per cent with residue concentration of 0.080 mg kg $^{-1}$. Immersing in 2 % common salt solution removed 50.94 per cent of the residues thereby reducing the residue concentration to 0.09 mg kg $^{-1}$. However on steaming and immersing in baking soda 2 % solution only 47.95 and 41.77 per cent of the residues were removed respectively.

Indoxacarb

Substantial removal of residues of indoxacarb was observed when the okra fruits were immersed in turmeric 1 % solution for twenty minutes followed by washing in water (85.20 per cent) and scrubbing (82.35 per cent), the initial residue of 0.155 mg kg $^{-1}$ residue degrading to 0.027 and 0.032 mg kg $^{-1}$ respectively. The residue concentration in okra fruits immersed in vinegar 2 % solution was 0.039 mg kg $^{-1}$ registering 78.85 per cent removal of the deposit. The residue concentration became 0.053 and 0.057 mg kg $^{-1}$ when the okra fruits were immersed in tamarind 2 % solution and when washed in water, there by removing 71.13 and 68.10 per cent of the initial residues. In the alkaline medium, *viz.*, slaked lime 2 % solution, 63.43 per cent of the residues were removed recording a residue concentration of .067 mg kg $^{-1}$. Salt 2 % solution dislodged 57.48 per cent of the residues, the residue level degrading to 0.078 mg kg $^{-1}$. Steaming and baking soda 2 % solution removed only 48.32 and 35.47 per cent of the residues.

Fipronil

Maximum quantity of residue was removed (72.57 per cent) when the okra fruits harvested three days after spraying were steamed, the residue level degrading from the initial concentration of 0.149 mg kg $^{-1}$ to 0.041 mg kg $^{-1}$. This was followed by immersing in vinegar 2 % solution and scrubbing which removed 68.97 and 66.78 per cent of the insecticide residues, respectively with the residue concentration dissipating to 0.046 and 0.050 mg kg $^{-1}$. The residue concentration degraded to 0.057 and 0.058 mg kg $^{-1}$ when the fruits were immersed in tamarind 2 % and turmeric 1 % solutions registering 61.72 and 61.28 per cent reduction in the deposit, respectively. When immersed in slaked lime 2 % solution for twenty minutes, 55.21 per cent of the residues were removed and the residue on fruits became 0.067 mg kg $^{-1}$. Mere washing in water could remove only 39.69 per cent of the residues. Least removal of the residue was noted when the fruits were immersed in baking soda 2 % solution (19.91 per cent).

Thiodicarb

The residues of thiodicarb (0.273 mg kg $^{-1}$) dissipated below detectable level when the okra fruits were steamed. Scrubbing, slaked lime and turmeric treatments reduced the residue content to 0.015 mg kg $^{-1}$, 0.016 mg kg $^{-1}$ and 0.022 mg kg $^{-1}$ respectively resulting in 92.85, 92.37 and 89.52 per cent reduction in the residue concentration. Immersing of the fruits in salt, tamarind and vinegar 2 %

solutions for twenty minutes followed by washing in water caused a reduction of 82.48, 80.38 and 79.70 per cent of residues respectively , keeping a residue content of 0.037, 0.041 and 0.043 mg kg $^{-1}$ respectively on the fruits. Baking soda 2% and on washing in water dislodged 71.54 and 65.37 per cent of the residues respectively, the deposit detected on the fruits being 0.060 and 0.073 mg kg $^{-1}$ respectively.

Flubendiamide

Immersing in tamarind 2 % solution for 20 minute followed by washing in water was the most effective treatment for removing flubendiamide residues (0.534 mg kg $^{-1}$) from okra fruits, the residue concentration being decreased to 0.154 mg kg $^{-1.}$ The reduction recorded was 71.24 per cent. The residue concentration became 0.193, 0.201 and 0.202 mg kg $^{-1}$ when the okra fruits were immersed in vinegar 2 % and turmeric 1 % solution and scrubbing there by removing 63.63, 62.31 and 62.26 per cent of the initial residues. In the alkaline medium, *viz* slaked lime 2 % solution, 52.46 per cent of the residues were removed recording a concentration of 0.254 mg kg $^{-1}$. Salt 2 % solution, washing in water and steaming could remove only 34.62 32. 75 and 24.27 per cent of residues .treatment with baking soda 2 % solution was ineffective, removing only 19.89 per cent of the residues.

Carbaryl

Among the decontaminating treatments steaming which removed 66.02 per cent of the initial residues (2.207 mg kg^{-1}) was the most effective. When the okra fruits were scrubbed, the residue came down to 0.905 mg kg $^{-1}$ recording 58.99 per cent reduction. When the okra fruits were immersed in common salt 2 % and baking soda 2 % solutions for twenty minutes, 49.69 and 49.10 per cent of the residues were removed and the residues on fruits lowered to 1.110 and 1.123 mg kg $^{-1}$, respectively. Immersing in turmeric 1 % and vinegar 2 % solutions could remove 45.61 and 45.54 per cent of the insecticide residues, respectively and the residue concentration detected being 1.20 and 1.202 mg kg $^{-1}$ respectively. The residue concentration became 1.27 and 1.329 mg kg $^{-1}$ when the okra fruits were

Table 57. Ranking of insecticides based on their efficacy and bio safety

Treatments	COWPEA					BRINJAL					OKRA					Overall Mean rank	COMPATABILITY WITH ENTOMOPATHOGENS			Overall rank
	Reduction in Damage		Yield	WP	Mean rank	Reduction in Damage		Yield	WP	Mean rank	Reduction in Damage		Yield	WP	Mean rank		*B. b*	*M. a*	*L. l*	
	Fruits	Flowers				Fruits	Shoots				Fruits	Shoots								
Chlorantraniliprole (30 g a.i.ha^{-1})	1	2	2	1	1.5	1	1	3	1	1.5	1	1	1	1	1	1.33	C	C	C	1
Indoxacarb (60g a.i.ha^{-1})	2	1	1	6	2.5	1	2	2	1	1.5	2	3	3	2	2.5	2.17	C	C	C	2
Emamectin benzoate (10g a.i.ha^{-1})	3	3	3	3	3	3	10	4	6	5.75	5	4	4	5	4.5	4.42	C	C	C	3
Flubendiamide (100g a.i.ha^{-1})	5	6	5	3	4.75	4	3	1	7	3.75	3	2	2	9	4	4.17	C	C	NC	4
Fipronil (50g a.i.ha^{-1})	6	4	4	8	5.5	5	5	6	9	6.25	7	5	8	6	6.5	6.08	C	C	C	6
Thiodicarb (750g a.i.ha^{-1})	4	5	6	6	5.25	7	8	8	8	7.75	4	6	10	2	5.5	6.17	C	C	C	7
Spinosad (75g a.i.ha^{-1})	7	7	7	1	5.5	6	4	7	1	4.5	6	8	7	6	6.75	5.58	C	C	C	5
Novaluron (100g a.i.ha^{-1})	10	8	9	10	9.25	8	9	5	10	8	9	7	6	10	8	8.42	C	C	C	10
Carbaryl (750g a.i.ha^{-1})	9	9	8	3	7.25	10	6	9	1	6.5	8	9	5	8	7.5	7.08	C	C	NC	8
Malathion (500g a.i.ha^{-1})	8	10	10	8	9	9	7	10	1	6.75	10	10	9	4	8.25	8.00	C	C	C	9

WP- Waiting period, C-Compatible, NC- Non compatible *B. b- B. bassiana* *M.a- M. anisopliae* *L.l- L. lecani* immersed in tamarind and slaked lime 2 % solutions there by removing 42.41 and 39.79 per cent of the initial residues.

Malathion

All the decontaminating treatments effectively removed the malathion residues on okra fruits at 3 days after spraying. The residue concentration of 0.031 mg kg $^{-1}$ in the fruits was dissipated to below detectable level by all the treatments, excepting tamarind 2 % solution and steaming. Both the treatments degraded the residue concentration to 0.01 and 0.011 mg kg $^{-1}$ respectively, resulting in 66.30 and 62.61 per cent reduction in the residue content.

4.6. RANKING OF NEW GENERATION INSECTICIDES BASED ON OVERALL EFFICACY

Ranking of the new generation insecticides based on their performance in each parameter studied (Table 57) revealed that chlorantraniliprole was the best insecticide for the control of pod borer followed by indoxacarb, emamectin benzoate and flubendiamide. In brinjal, chlorantraniliprole, indoxacarb, flubendiamide and spinosad were the better insecticides against *L. orbonalis*. Similarly for okra, chlorantraniliprole was the best, followed by indoxacarb, flubendiamide and emamectin benzoate. Considering the overall efficacy of the insecticide in relation to the compatibility with entomopathogens, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1} and emamectin benzoate 5SG @10 g a.i. ha^{-1} were identified as the better treatments for the management of the fruit borers of cowpea, brinjal and okra.

DISCUSSION

5. DISCUSSION

Cowpea, brinjal and okra are the three popular vegetables of India available throughout the year at affordable prices for both the rural and urban poor. Cultivation of these vegetables has become increasingly costly and hazardous, particularly due to the ravages of the fruit borers. In fact, most of the vegetable growers consider these borers as the most serious pests and nearly all of them use only chemical insecticides to combat them. However, farmers almost never follow governmental recommendations on the appropriate chemicals, dosages, and time intervals between spraying and harvesting in their attempt to control these enigmatic borers. Pesticide retailers, rather than authorised extension personnel are their major source of information on the selection of chemicals and their dosages. Such irrational use of insecticides has created obdurate problems like toxic residues on vegetables in the market impacting general consumer health and the environment, pesticide resistance, trade implications, poisoning, hazards to non-target organisms, increased production costs etc. (Pedigo, 2002; Alam *et al.*, 2003). Currently, numerous classes of insecticides with varied modes of action, target selectivity and benign ecological, ecotoxicological and environmental profiles are available which could be exploited for pest management.

Microbial control of pests is extensively practised to reduce population of insect pests below damaging levels. Their compatibility with other management tactics fits them suitably in integrated pest management programmes. Fungal pathogens like *B. bassiana, L. lecanii* and *M. anisopliae* are generally utilized in vegetable ecosystem on account of their wide host range. Hence, information on the compatibility of the new generation insecticides with these bio agents is a pre requisite for developing suitable IPM strategies for vegetable crops.

Inevitably, pesticide usage will deposit some residues on food crops. However, if the chemicals are used in accordance with good agricultural practices, the residual level will not affect human health. The primary purposes of setting MRLs in food are to protect the health of consumers and provide an indicator for the trade. Based on MRL values and the degradation pattern of insecticide residues, the waiting period / harvest interval of different insecticides can be fixed. As pesticide contaminated fresh fruits and vegetables form an important portal for the toxicants to human body, their safety should be ensured. To a large extent, this could be achieved through some simple domestic decontamination procedures which could reduce the pesticide load in raw agricultural commodities.

The results of the present study undertaken to explore these issues are discussed in this chapter. The data and relevant information garnered from the laboratory and field evaluations on the efficacy of the new classes of insecticides against fruit borers of cowpea, brinjal and okra and their compatibility with entomopathogenic fungi commonly used in the vegetable ecosystems, dissipation kinetics of the insecticides, their waiting periods and the efficacy of different household processing practices in removing the insecticide residues from these vegetables are discussed under the following heads.

5.1. MANAGEMENT OF FRUIT BORERS

The eight new generation insecticides *viz.,* emamectin benzoate 5SG @10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, novaluron 10 EC @ 100 g a.i. ha^{-1}, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1}, fipronil 80 WG @ 50 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1} and flubendiamide 480 SC @ 100 g a.i. ha^{-1} and the conventional insecticides carbaryl 50 WP @ 750 g a.i. ha^{-1} and malathion 50 EC @ 500 g a.i. ha^{-1} were on par in their efficacy against the fruit borers of cowpea, brinjal and okra when tested in the laboratory. Though high mortalities of the larvae were recorded on the first and third day of release, the extent of mortality decreased considerably from the fifth day onwards.

Since a specific conclusion could not be drawn from the laboratory trials on the relative efficacy of the insecticides, all the toxicants were screened in the field too. The results indicated that all the insecticidal treatments were effective in controlling the pests when compared to the untreated control. The damage by *M. vitrata* to cowpea flowers was reduced significantly, the reduction ranging from 53.97 to 76.86 per cent in the new generation insecticide treated plots (Fig. 1). The reduction in the damage of flowers in plots sprayed with the conventional insecticides ranged from 49.55 to 50.64 per cent only. Among the newer molecules, indoxacarb (76.86 per cent), emamectin benzoate (74.98 per cent) and chlorantraniliprole (72.68 per cent) were superior. Damage to fruits was significantly reduced in the treated plots, the extent of reduction ranging from 63.69 to 84.82 per cent in the new generation insecticide treated plots and 62.86 per cent (carbaryl) and 65.08 per cent (malathion) in the conventional insecticide treated plots (Fig. 2). Chlorantraniliprole (84.82), emamectin benzoate (81.89 and indoxacarb (80.97) again proved to be the superior insecticides in checking the pest. Consequent to the reduced pest incidence, significantly higher yield was also obtained from these plots being 14.50, 13.88 and 13.20 kg per 18 sq. m plot from indoxacarb, chlorantraniliprole and emamectin benzoate treated plots, respectively. The economic returns from the treatments were Rs 8.13, 6.48 and 5.27 respectively for every one rupee invested in plant protection.

The efficacy of the new generation insecticides *viz*., thiodicarb 75 WP @ 750 ga.i.ha^{-1} (Das and Srivastava, 2002), novaluron @ 75 g ai ha^{-1} (AICRP, 2003), chlorantraniliprole 0.009% (Haritha, 2008) against *M. vitrata* in pigeon pea had been observed earlier. Similarly, the effectiveness of spinosad 0.009% (Ashokkumar and Shivaraju, 2009) and flubendiamide 480 SC @ 48 or 36 g ai ha^{-1} (Dey *et al.*, 2012) against the pest in black gram and indoxacarb 14.5 SC @ 3.45 ml/10 lit. (Patel *et al.*, 2012) in cowpea, had been reported. The efficacy of these insecticides against the

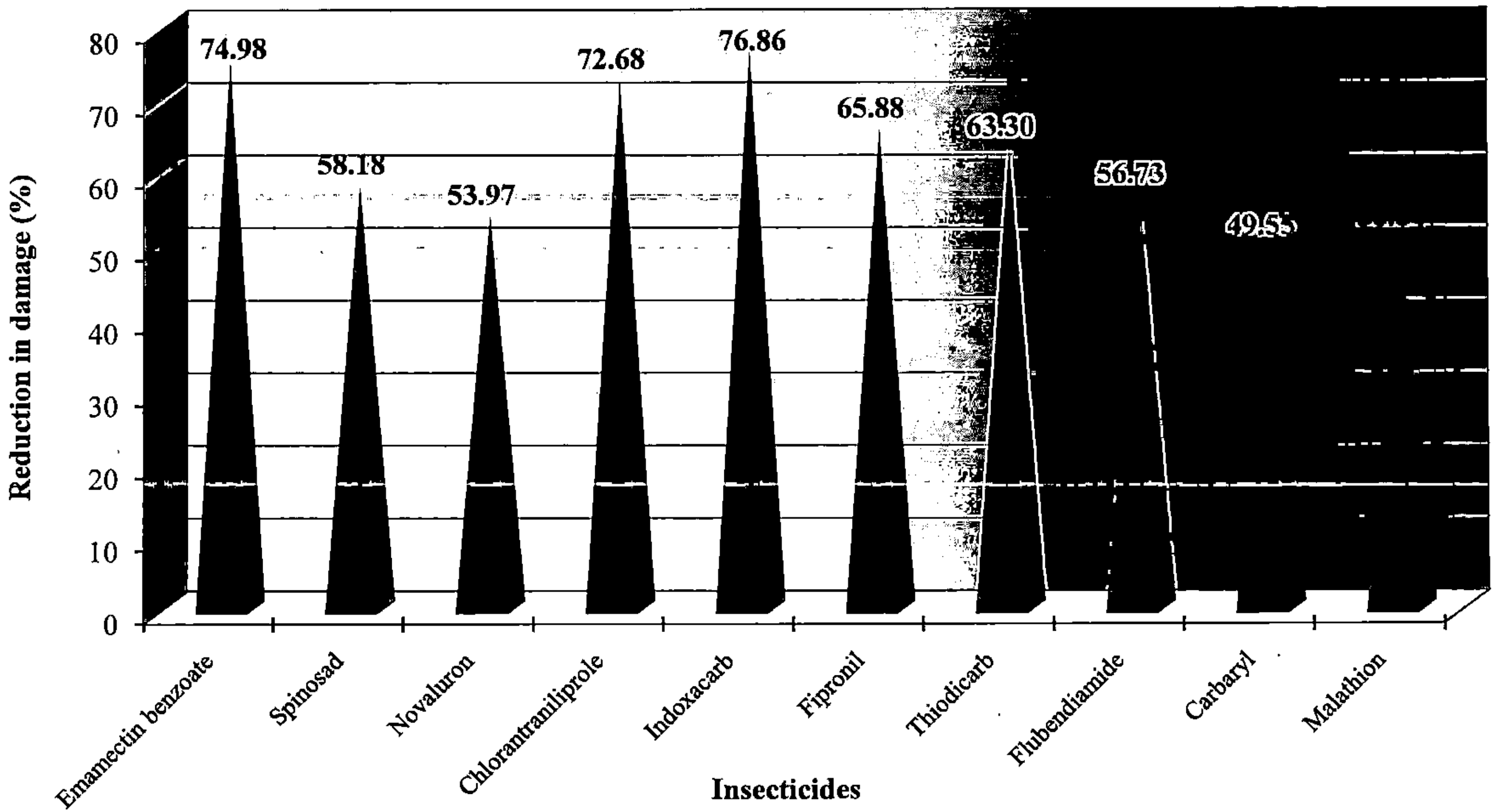


Fig. 1. Reduction in flower damage by *Maruca vitrata* in cowpea treated with new generation insecticides

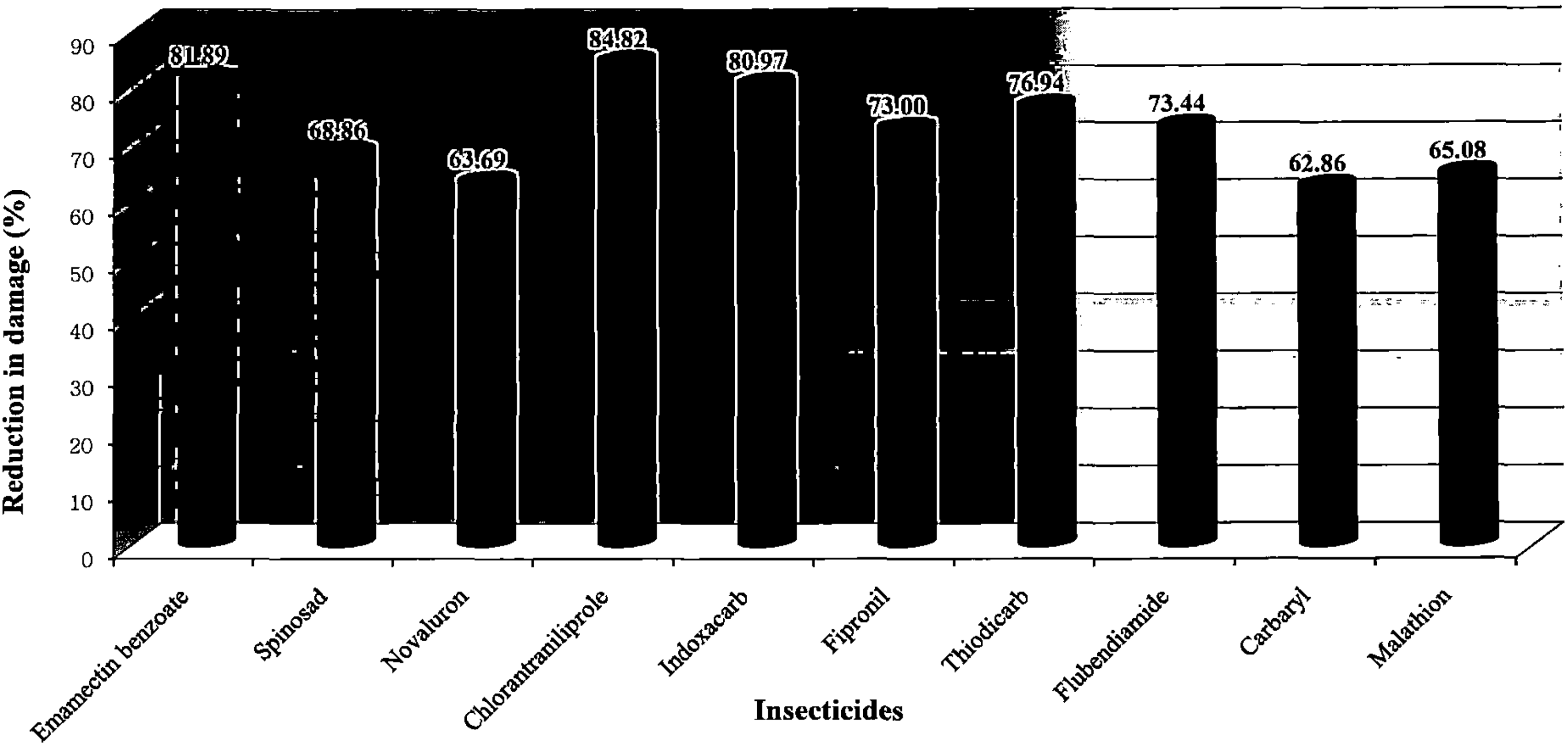


Fig. 2. Reduction in pod damage by *Maruca vitrata* in cowpea treated with new generation insecticides

pest in cowpea recorded in the present study is in conformity with these reports and indicated the possibility of utilising the newer molecules for managing the pest. Few reports are available on the efficiency of emamectin benzoate and fipronil against the pest.

The flower and pod borer, *M. vitrata* is a serious pest of cowpea damaging flowers and pods (Plate. 1). Two insecticide sprays at fortnightly intervals were required to check the pod borer infestation. The flower and pod borer usually appears in the field with the onset of flowering. Eggs are generally laid on floral buds and flowers. However, oviposition on leaves, leaf axils, terminal shoots, and pods has also been recorded. On hatching, the first instar larvae habitually bore into the two day old buds (Plate. 2). The second instars too injure the flower buds whereas the third instars damage the open flowers and the pods. The third instars display no significant difference in their preferences for flowers and pods, while the fourth and fifth instar larvae prefer to feed on the pods (Liao and Lin, 2000). As observed by Karel and Schoonhoven (1986) more larvae are seen on flowers than on pods. Hence, containing the pest at the early flowering stage is crucial to prevent the population build up and consequently decrease the infestation on the pods. Therefore, at the onset of flowering itself, management practices need to be initiated against *M. vitrata*.

A trial was done with application of NSKE 5% sprays at the onset of flowering with the above view. A second spray too was given after two weeks which prevented the population build up of the pest. Only negligible damage was noted during the flowering stage subsequent to the prophylactic sprays with the neem based insecticide. Moreover, only one spray with the insecticides was sufficient to prevent economic damage to the crop. The early neem spray would have deterred the moths from the plots thus preventing oviposition and resultant population build up. Significant reduction in flower (55.55 to 91.65 per cent) and fruit (67.01 to 90.32 per cent) damages was noted in the new generation insecticide treated plots (Fig. 3 and

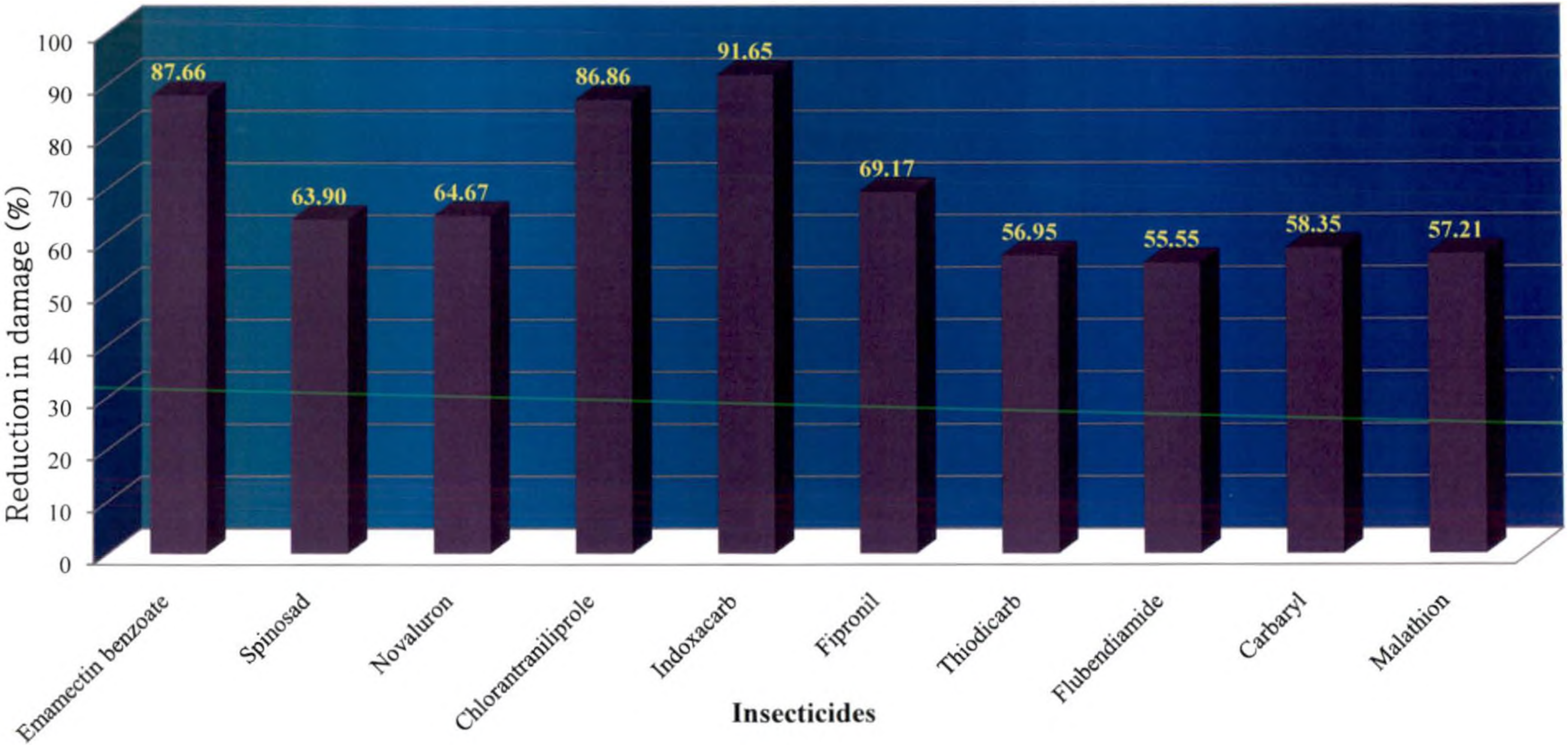


Fig. 3. Reduction in flower damage by *Maruca vitrata* in cowpea treated with neem seed kernel extract and new generation insecticides

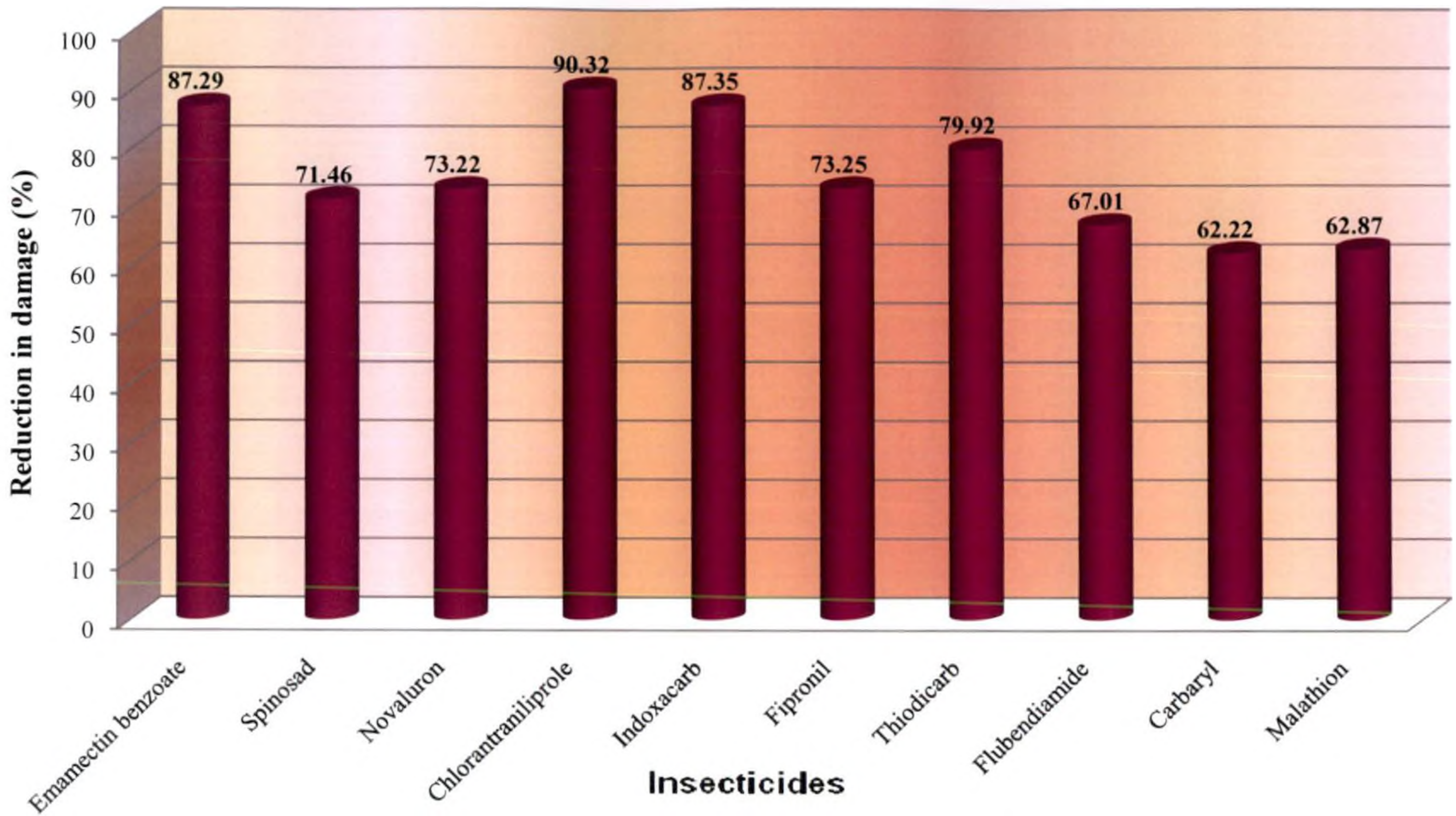
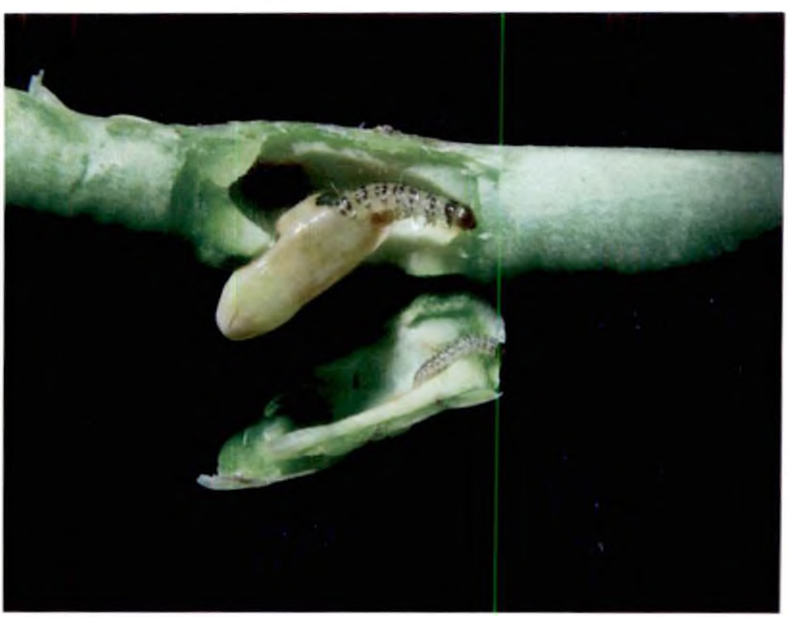


Fig. 4. Reduction in pod damage by *Maruca vitrata* in cowpea treated with neem seed kernel extract and new generation insecticides

A. Flower

B. Fruit



C. Seed

Plate 1. Infestation of *Maruca vitrata* in cowpea

Plate 2. Stages of cowpea flowers infested by different larval instars of *Maruca vitrata*

1- Emerging bud
2- One day old bud
3- Two day old bud- 1st instar larva
4- Three day old bud- 2 nd instar larva
5- Four day old bud-2 nd instar larva
6- Flower-3 rd ,4th and 5th instar larva
7- Flower- 3rd, 4 th and 5 th instar larva
8- Fruit- 3rd,4th and 5 th instar larva

4). The damage to flowers and pods was reduced to the extent of 57.21 to 58.35 and 62.22 to 62.87 per cent, respectively in the conventional insecticide treated plots. Comparatively, indoxacarb, emamectin benzoate and chlorantraniliprole gave better control of the pest. Aqueous neem extract reduced *M. vitrata* population in the field (Jackai and Oyediran, 1991). Similarly, the study by Egho, 2011 showed that at 5 % neem concentration, *M. vitrata* could be controlled. The Kerala Agricultural University also recommends need based application of neem kernel suspension (NKS) 5 % at 45 DAS in the case of moderate incidence of pod borers (KAU, 2011). From the results of the study prophylactic sprays of NSKE 5 % from the initiation of flowering coupled with need based application of chlorantraniliprole, indoxacarb or emamectin benzoate would be a suitable option for protecting cowpea from the onslaught of the borer.

Treatment of brinjal with the new generation insecticides reduced the damage of shoots by *L. orbonalis* by 62.53 to 84.00 per cent. The reduction in damage in carbaryl and malathion sprayed plots was only 64.72 and 66.36 per cent, respectively. Among the newer molecules, chlorantraniliprole (84.00 per cent), indoxacarb (76.28 per cent), spinosad (75.24 per cent) and flubendiamide (71.64 per cent) registered higher reduction in infestation of shoots (Fig.5). Infestation of fruits was also significantly lower in the insecticide treated plots, the reduction in damage ranging from 45.96 to 72.21 per cent in new generation insecticide treated plots and 31.87 to 33.09 per cent in carbaryl and malathion treatments, respectively. Chlorantraniliprole (72.21 per cent), indoxacarb (70.51 per cent), emamectin benzoate (66.70 per cent) and flubendiamide (71.64 per cent) treated plots recorded higher reduction in the fruit damage (Fig. 6). Commensurate with the reduced pest incidence, significantly higher yield was obtained from these plots, being 17.82 (flubendiamide), 17.63 (indoxacarb), 17.52 (chlorantraniliprole) and 16.51 (emamectin benzoate) kg per 9 sq. m plot. For every one rupee invested in plant protection, the returns from the treatments were Rs 5.55 (chlorantraniliprole), 5.33 (flubendiamide), 5.28

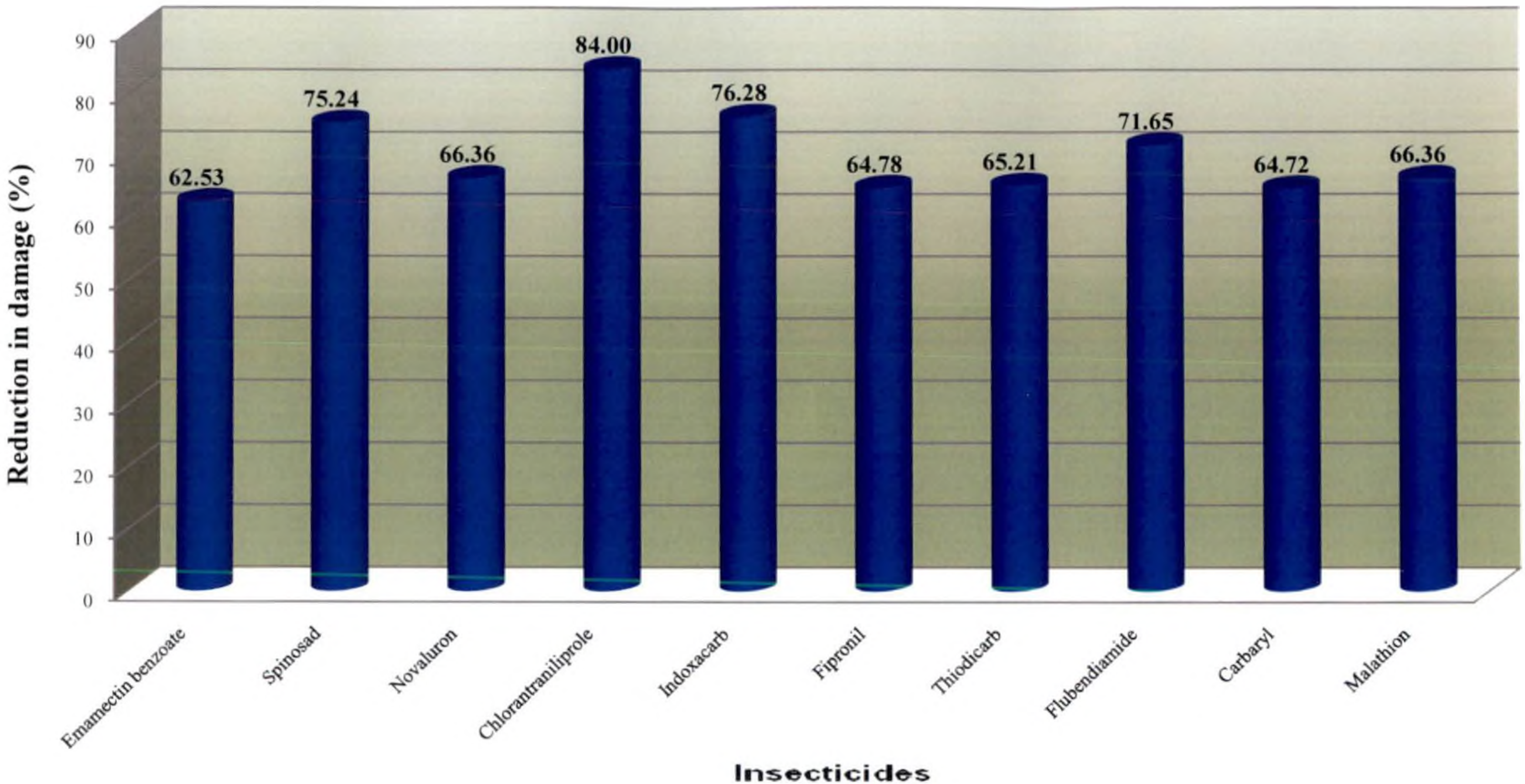


Fig. 5. Reduction in shoot damage by *Leucinodes orbonalis* in brinjal treated with new generation insecticides

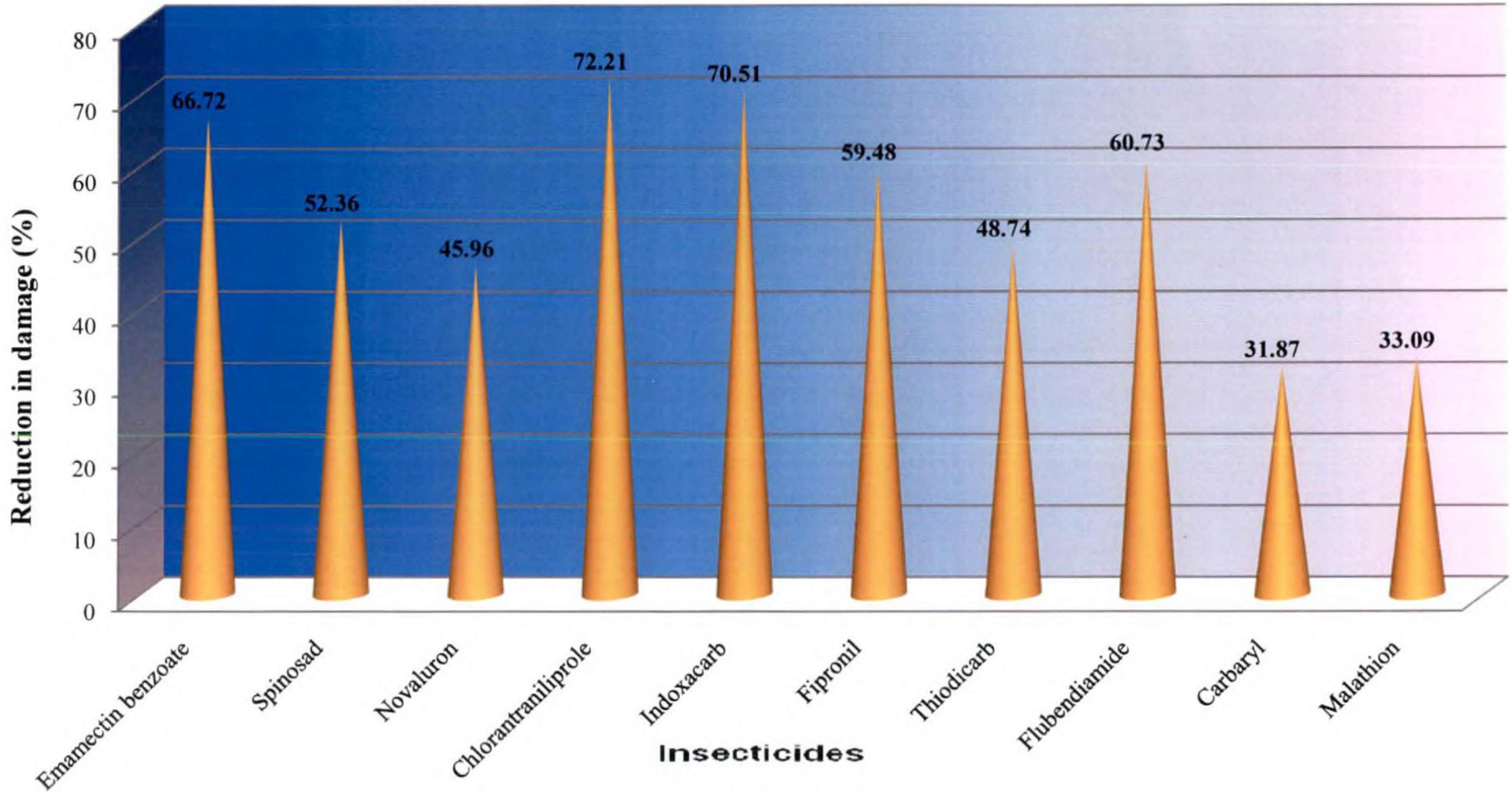


Fig. 6. Reduction in fruit damage by *Leucinodes orbonalis* in brinjal treated with new generation insecticides

(indoxacarb) and 2.32 (emamectin benzoate). The effectiveness of novaluron 0.01 % against *L. orbonalis* recorded earlier (Chatterjee and Roy, 2004 ; Sawant *et al.,* 2004) , is contrary to the results of the present study. The efficacy of different formulations of flubendiamide against *L. orbonalis* was also documented earlier (Lateef *et al.,* 2009; Jagginavar, *et al*, 2009). Similarly, emamectin benzoate 5 SG @ 20 g a.i. ha^{-1} was found effective in reducing fruit damage by *L. orbonalis* in brinjal (Kumar and Devappa, 2006; Anil and Sharma, 2010). The lowest shoot and fruit infestations (7.47 and 9.88 per cent) and highest marketable fruit yield of 143.50 q ha^{-1} were recorded in the plots treated with spinosad 2.5 SC (50 g ai ha^{-1}) followed by indoxacarb 14.5 SC 50 g ai ha^{-1} (8.89 and 13.13 per cent), emamectin benzoate 5 SG 15 g ai ha^{-1} (10.95 and 16.66 per cent), respectively (Patra *et al.,* 2009).

The fruit borer moth usually begins laying eggs during the vegetative stage and when the crop starts to flower. Within one hour after hatching, young caterpillars search for and bore into tender shoots, flower buds or fruits. Mostly, the first instars prefer flower buds and flowers, second instars all susceptible plant parts, third and fourth instars shoots and fruits, and fifth instars mostly fruits. In young plants, caterpillars are reported to bore inside petioles and midribs of large leaves. Damage to flowers reduces the fruit set and lowers the fruit yield (Plate 3). However, when fruits are available, caterpillars prefer the fruits than other plant parts. As in the case of cowpea, targeting the pest at the onset of its susceptible stage itself assumes importance in the management of *L. orbonalis* too. Prophylactic sprays with NSKE 5 % in the early vegetative stage to repel the moths may be practiced here also.

All the new generation insecticides were equally effective in reducing the shoot infestation by *E. vitella* in okra, the reduction in damage ranging from 68.09 to 80.82 per cent in the newer molecules and 67.89 and 67.73 in carbaryl and malathion treated plots respectively (Fig. 7). Chlorantraniliprole (80.82 per cent), flubendiamide (80.34 per cent), indoxacarb (78.53 per cent) and emamectin benzoate (74.95 per cent) were comparatively more effective in preventing shoot damage. The reduction

A. Shoot

B. Flower

C. Emerging fruits

D. Mature fruits

Plate 3. Infestation of *Leucinodes orbonalis* in brinjal

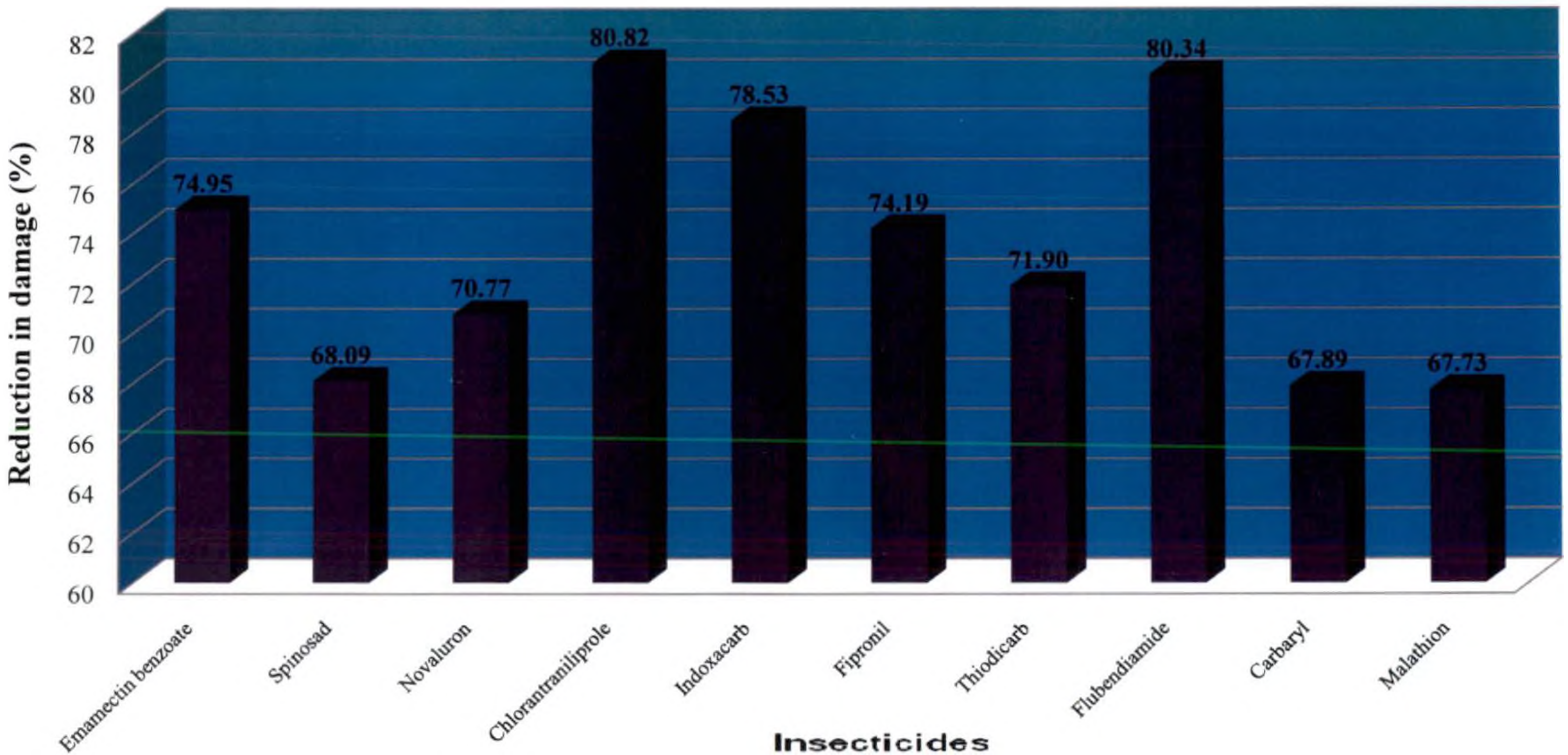


Fig. 7. Reduction in shoot damage by *Earias vitella* in okra treated with new generation insecticides

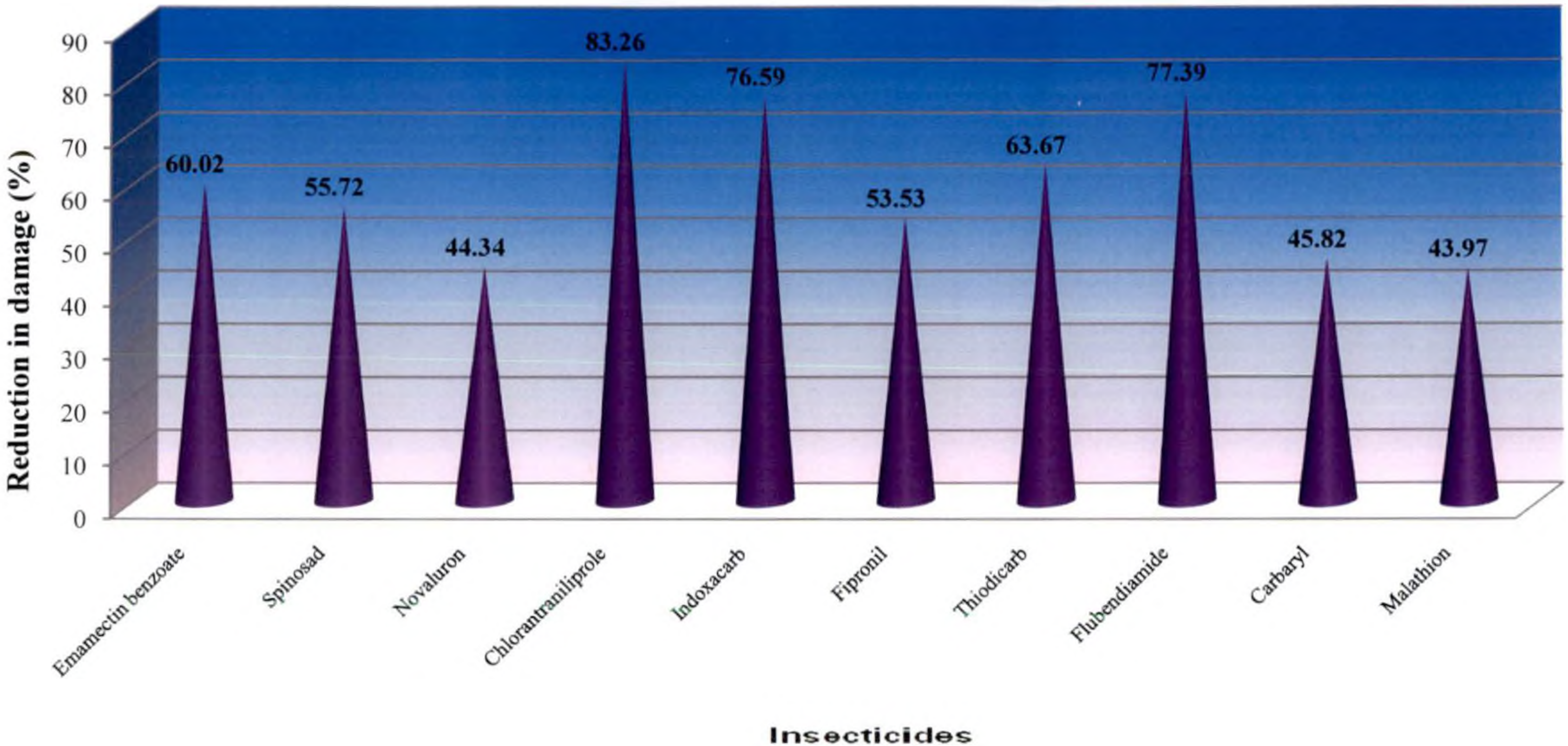


Fig. 8. Reduction in fruit damage by *Earias vitella* in okra treated with new generation insecticides

in damage of fruits ranged from 53.53 to 83.26 per cent in the novel insecticide treatments as against 45.82 and 43.97 per cent in carbaryl and malathion treatments, respectively (Fig. 8). Among the insecticides, chlorantraniliprole, flubendiamide and indoxacarb with 83.26, 77.39 and 76.59 per cent reduction in damage, respectively were superior. The associative yield obtained from these plots were significantly higher, being 5.80 kg (chlorantraniliprole), 5.61 kg (flubendiamide) and 5.50 kg per six sq. m plot compared to the untreated plot (3.51 kg). The benefit cost ratio indicated that Rs. 6.96 (indoxacarb), Rs.6.93 (flubendiamide) and Rs.6.23 (chlorantraniliprole) could be incurred in return for every one rupee spent to control the pest. The results of the study conform to the reports of other workers. Superiority of flubendiamide 480 SC @ 48 and 60 g ai ha^{-1} against spotted boll worm was reported by Udikeri *et al.* (2008). Emamectin benzoate 5 SG @ 11 g a.i ha^{-1} reduced the larval population of *E. vitella* in okra (Kuttalam *et al.*, 2008). Significantly low fruit infestation was noticed with the application of spinosad 45 SC @ 30 g ai ha^{-1} followed by abamectin 1.9 EC @30 g ai ha^{-1}. Indoxacarb 0.015 % and fipronil 0.005 % were highly effective in preventing borer damage (Sinha *et al.*, 2009; Gupta *et al.*, 2009). Rynaxypyr 20 SC @ 30 g ai ha^{-1} and @ 20 g ai ha^{-1} were superior in recording less larval populations, lower fruit damage and higher fruit yield in okra, followed by spinosad @ 56 g ai ha^{-1}, emamectin benzoate @ 15 g ai ha^{-1} and flubendiamide @ 45 g ai ha^{-1} (Chowdhary *et al.*, 2010).

The adult female lays eggs individually on leaves, floral buds and on tender fruits. The caterpillars of *E. vitella* bore inside the shoots, developing buds, flowers, fruits and feed on inner tissues (Plate 4). Damaged buds and flowers fall while affected shoots and fruits are distorted (Sardana *et al.*, 2006). Prophylactic sprays with NSKE 5 % in the early vegetative stage against the pest could reduce the intensity of damage.

It is evident from the field evaluations that chlorantraniliprole, indoxacarb, emamectin benzoate and flubendiamide are very effective in reducing the fruit borers.

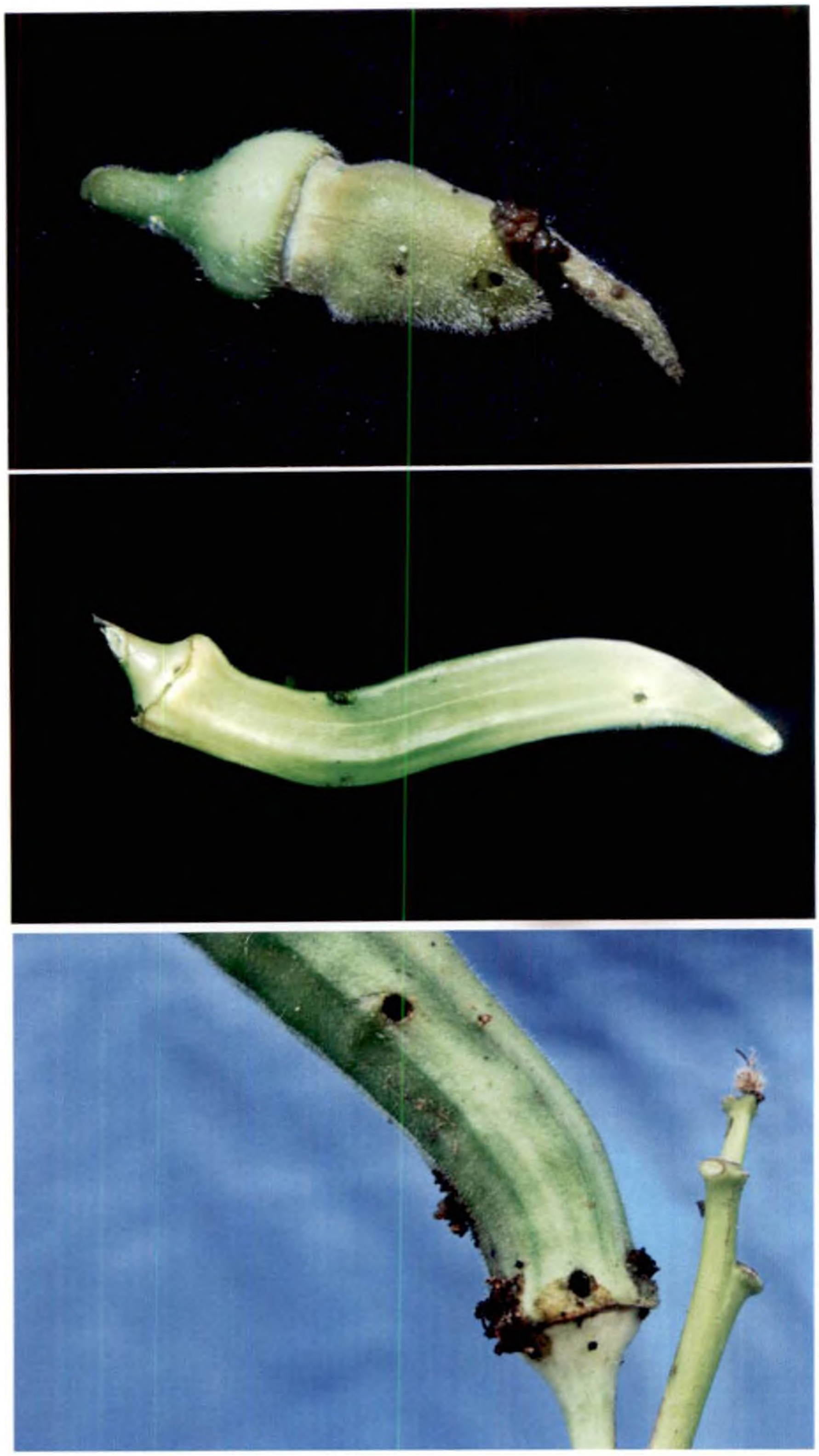


Plate 4. Infestation of *Earias vitella* in okra fruits

The supremacy of these insecticides in managing the pests is also obvious from the results of related research work. Interestingly, these insecticides belong to different classes with varied modes of action.

Chlorantraniliprole is an anthranilic diamide insecticide which activates insect ryanodine receptors, causing rapid muscle dysfunction and paralysis. Its translaminar activity, rain fastness, insecticidal potency and resistance to photo-degradation are the bases for the long-lasting crop protection observed. The insecticide is particularly potent against neonates as they hatch from the eggs. Ovicidal effects are enhanced when eggs are laid on treated surfaces. The long-lasting activity combined with its effects on eggs and larvae prevents the establishment and growth of pest populations at low use rates (Dupont, 2007). It is effective against several lepidopteran as well as coleopteran, dipteran, and hemipteran pests.

Indoxacarb belongs to the oxadiazine chemical family and is registered for the control of lepidopterous pests in the larval stages. Insecticidal activity occurs via blockage of the sodium channels in the insect nervous system resulting in impaired nerve function, feeding cessation, paralysis, and death. The mode of entry is via the stomach and contact routes. Once absorbed or ingested, feeding cessation generally occurs within two to eight hours. Indoxacarb possesses both larvicidal and ovicidal activity. It is designated as a "reduced-risk" pesticide by Environment Protection Agency and is considered an organophosphate (OP) replacement. It has low mammalian toxicity and a benign profile for avian and aquatic toxicity (USEPA, 2000).

Emamectin benzoate, an avermectin class insecticide is a chloride channel activator developed for the control of lepidopteran insects. It kills insects by disrupting neurotransmitters, causing irreversible paralysis. This naturally derived product is a highly potent new generation insecticide for use against caterpillars effective at very low dose. It has a unique mode of action that inhibits caterpillars from feeding and is highly effective in controlling resistant insect streams, while its prolonged activity ensures growers powerful crop protection. It rapidly degrades within hours on the surface of foliage by photo-oxidative processes and is an ideal partner for the food chain, fulfilling the highest demand for low residues in fresh produce. Short pre-harvest intervals and re-entry intervals offer high flexibility with respect to application timing and harvest fast-acting product, making it a sound economic choice (Syngenta, 2013).

Flubendiamide is the representative of a class of chemicals, benzenedicarboxamides or phthalic and diamides. It acts by disrupting proper muscle function by acting on ryanodine receptors (intracellular Ca2+ channels). This receptor is specialized for the rapid and massive release of Ca2+ from intracellular stores, which is an essential step in the muscle contraction. It disrupts the calcium balance in the muscles of the insects by acting on the ryanodine receptor, affecting the muscle contraction (Hall *et al.*, 1995).

Alternations of different classes of insecticides with differing modes of action being desirable in IPM strategies, identification of such promising molecules is imperative for effective pest management. Moreover, in the event of a control failure with a particular insecticide, use of a promising one in a different class with different mode of action and to which there is no known cross-resistance can be advocated. As the insecticides identified as potential ones for the borer pests of cowpea, brinjal and okra have different modes of action, their rotation will definitely provide an effective management strategy for the pests.

5.2. SAFETY OF NEW GENERATION INSECTICIDES AGAINST ENTOMOPATHOGENIC FUNGI

Knowledge on the compatibility of insecticides with other components of IPM is imperative for their successful adoption. One of the major techniques utilized for pest management in vegetable ecosystem is biological control. This approach is an environmentally sound and effective means of mitigating pests and pest effects through the use of natural enemies. Both macrobes and microbes are exploited in biological control. Among the microbes, the mycopathogens play a crucial role in pest management in vegetable fields. In this context, the safety of the new generation insecticides to the bioagents needs to be determined prior to their recommendation. A laboratory experiment was carried out to assess the safety of new generation insecticides to *B. bassiana, L. lecanii* and *M. anisopliae*, the three entomopathogens extensively used for vegetable pest management. All the insecticides were compatible with the white muscardine fungus, *B. bassiana* and in particular profuse growth of the fungus was seen in indoxacarb, emamectin benzoate and chlorantraniliprole indicating a probable synergistic effect on the fungus (Plate 5). Similarly, the various insecticides were safe to *M. anisopliae*, though comparatively lower growth of the green muscardine was noted in media poisoned with emamectin benzoate (24 per cent) and thiodicarb (26 per cent). All the treatments were found compatible with *L. lecanii* except flubendiamide and carbaryl which recorded 61 and 68 per cent reduction in the growth of the fungus, respectively (Plate 6). Presumably, the fungus was incompatible with these insecticides. Synergistic, antagonistic, or additive effects of insecticides to entomopathogens have been observed earlier (Kaakeh *et al.,* 1997; Ying *et al.*, 2003). Contrary to the results of the present study, malathion was reported to prevent the development of *B. bassiana* (Dirimanov and Angelova, 1962), *M. anisopliae* and *L. lecanii* (Talwar, 2005). However, indoxacarb and spinosad were found safe to *M. anisopliae* (Rachappa *et al*., 2007; Asi *et al.,* 2010). Fipronil were less toxic to *M. anisopliae* and *B. bassiana* (Moino and Alves, 1998). Indoxacarb and emamectin benzoate were comparatively less toxic to mycelial growth (36.78-48.67 per cent inhibition) and conidial germination (40.32-49.97 per cent inhibition) of the fungal pathogens which is in agreement with the results of the present study. Few reports are available on the compatibility of the other insecticides to the fungi.

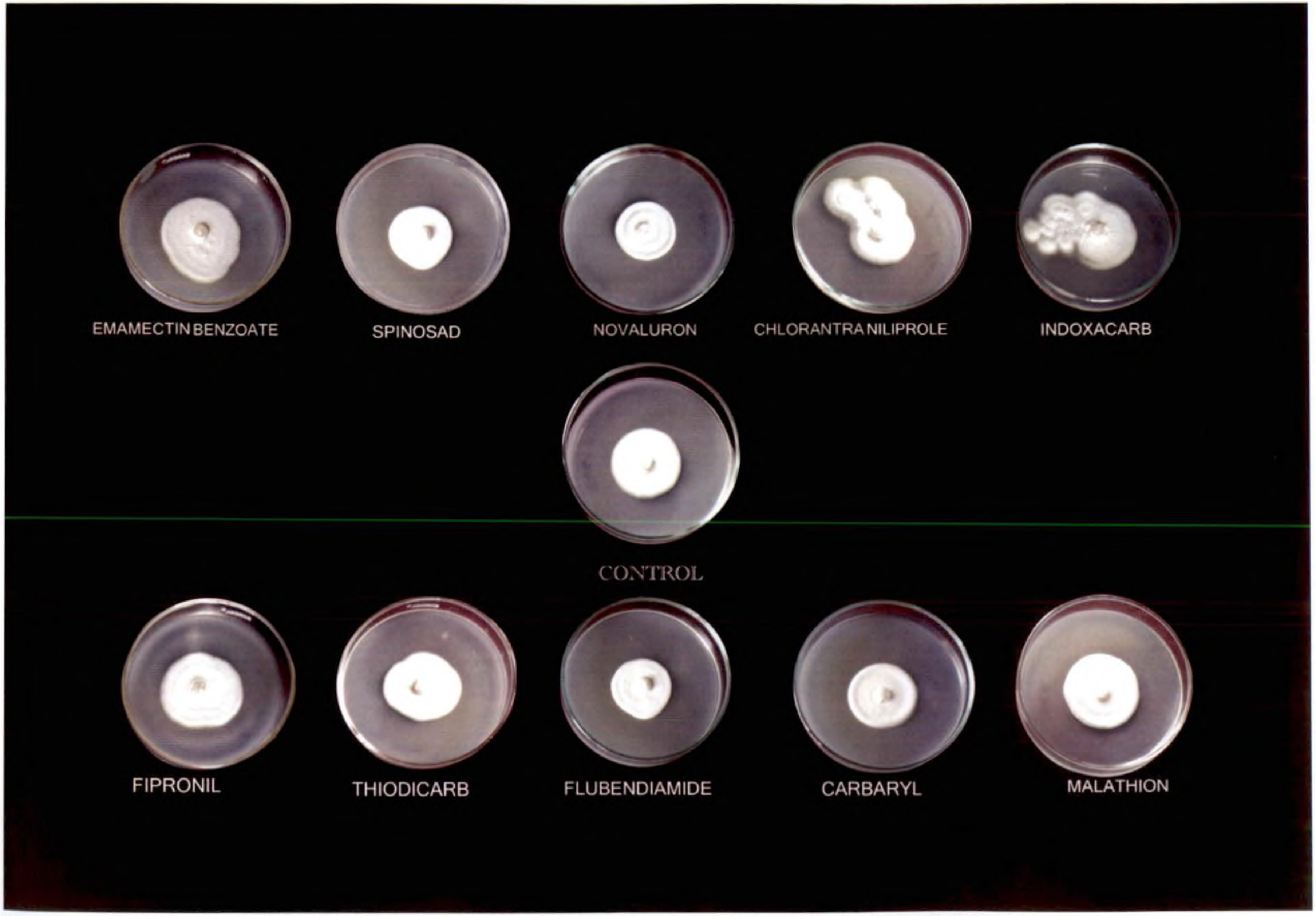


Plate 5. Effect of different insecticides on the mycelial growth of *Beauveria bassiana*

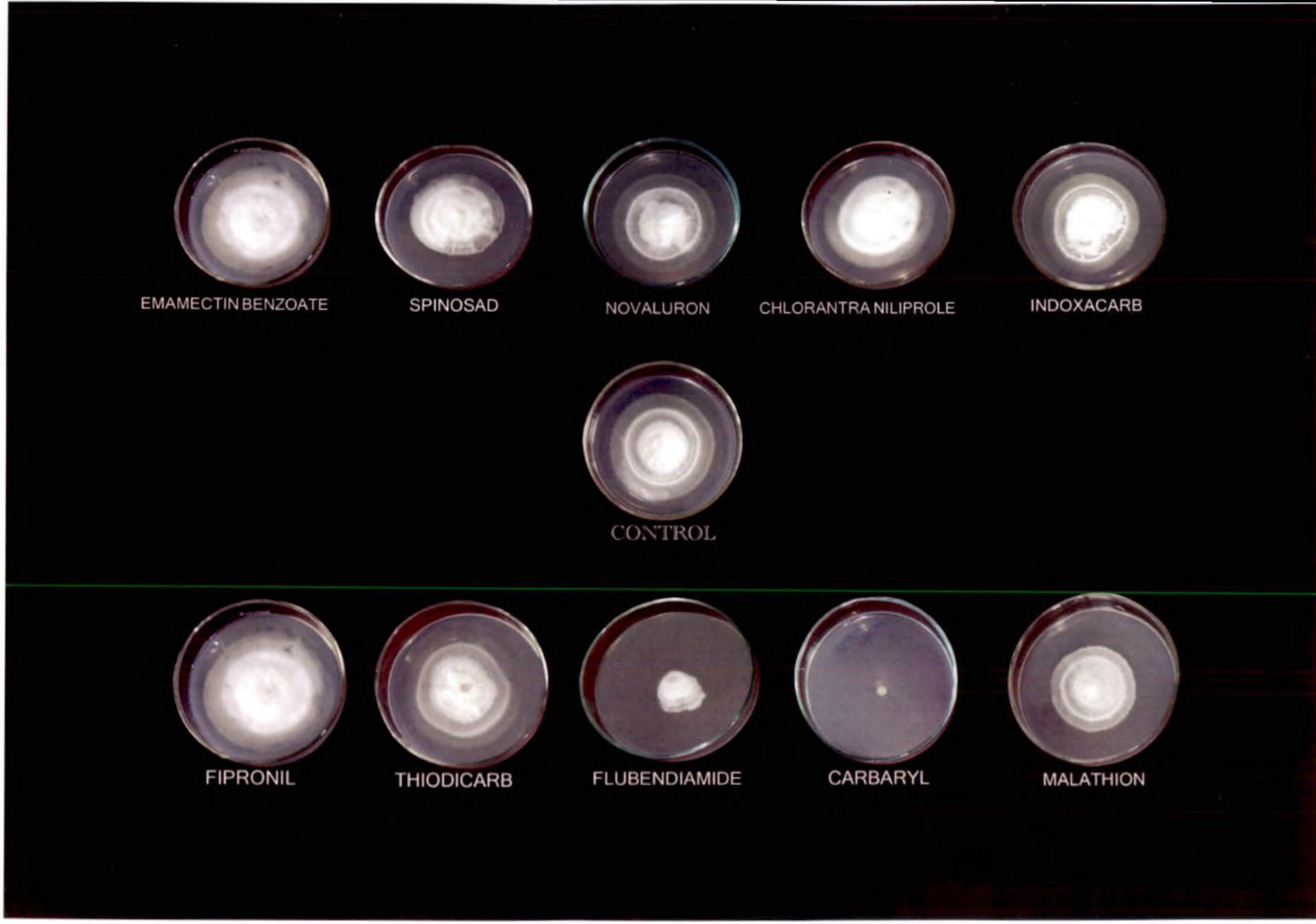


Plate 6 . Effect of different insecticides on the mycelial growth of *Lecanicillium lecanii*

Fungal biological control agents and selective insecticides may act synergistically increasing the efficiency of pest control, allowing the use of lower doses of insecticides, preservation of natural enemies, minimizing environmental pollution and decreasing the likelihood of development of resistance to either agent (Boman, 1980; Moino & Alves, 1998; Ambethgar, 2009). By contrast, use of incompatible insecticides may inhibit growth and reproduction of the pathogens and adversely affect integrated pest management (Duarte *et al.,* 1992; Malo, 1993). Since with the exception of flubendiamide which proved incompatible with *L. lecanii,* all the other new generation molecules were compatible with the three fungal pathogens commonly exploited for pest control in vegetable ecosystem, they could safely be integrated with the bioagents for pest management. *B. bassiana* is a registered biopesticide with a broad host range of approximately 700 insect species used for management of several crop insect pests. Being a broad spectrum fungus infecting various pests of vegetables, the synergism observed between the fungus and the new generation insecticides *viz,.* indoxacarb, emamectin benzoate and chlorantraniliprole augurs well for their utilization for pest management in vegetables.

5.3. PERSISTENCE AND DEGRADATION OF INSECTICIDES

Vegetable cowpea, brinjal and okra are exported to different countries around the world. Stringent food safety standards maintained by developed countries pose major challenges for a developing country's success in international markets. India's drive to increase food exports is often impeded by pesticide residues prevailing in the produce, unacceptable to the importing countries. Okra consignments from India were rejected in European countries due to the presence of residues of organophosphorus and synthetic pyrethroid insecticides (Anonymous, 2010). Due to such repeated detection of exceeding levels of residues of agrochemicals in okra exported from India to European countries, recently the European Commission has issued Regulation No. 91/2013 dated 31.01.2013 imposing requirement of Health Certificate conforming that all consignments of okra from India to Europe comply with the maximum residue levels of agrochemicals. Evidently, the exports of vegetables can be further improved, provided the strict quality demands of the international market are satisfied. Apart from this, the consumer clamour for pesticide free safe food is escalating globally. Pesticide residual levels exceeding the MRL reflect improper use of pesticides and rectification at source is required. Hence, it is imperative to fix the waiting periods for the insecticides used in these crops. With this view, the dissipation pattern of the tested insecticides was studied and is depicted in Fig 9 A and B. As the MRL of the new generation insecticides for these vegetables has not been fixed in India by FSSA (Food Safety and Standards Act) , the MRL values prescribed by the European Union (EU) was used for calculating the waiting periods.

When emamectin benzoate was sprayed @ 10 g a.i ha^{-1} on cowpea, brinjal and okra , 0.07 mg kg^{-1}, 0.10 mg kg^{-1} and 0.13 mg kg^{-1} residues were deposited on the fruits of the respective crops, two hours after spraying. However, no residues were detected in all the three fruits on the fifth day of spraying. The half life of the insecticide was 1.25, 1.28 and 1.34 days for cowpea, brinjal and okra, respectively and the waiting periods 2.99, 4.40 and 4.89 days, respectively. Though half life and waiting period of the insecticide has been worked out in crops like paddy (Li *et al.*, 2011) and apple (Wang *et al.*, 2012), work on vegetables is comparatively meagre. The dissipation experiments by Liu *et al.*, 2012 showed the half-life ($T_{1/2}$) of emamectin benzoate was around 1 day in cabbage at 18 g.a.i ha^{-1}.

A deposit of 0.94 mg kg^{-1} and 0.58 mg kg^{-1} spinosad residues was recorded in cowpea and brinjal fruits, respectively two hours after spraying @ 75 g ai ha^{-1}. The residues went below non detectable from the seventh day in cowpea and tenth day in brinjal. A higher deposit was noted in okra (1.73 mg kg^{-1}) which went below detectable level on the tenth day. The half life of the insecticide was 0.92, 1.35 and 1.03 days for cowpea, brinjal and okra respectively. A waiting period of 1 day was calculated for spinosad on cowpea and brinjal and 7.93 days for okra. The short

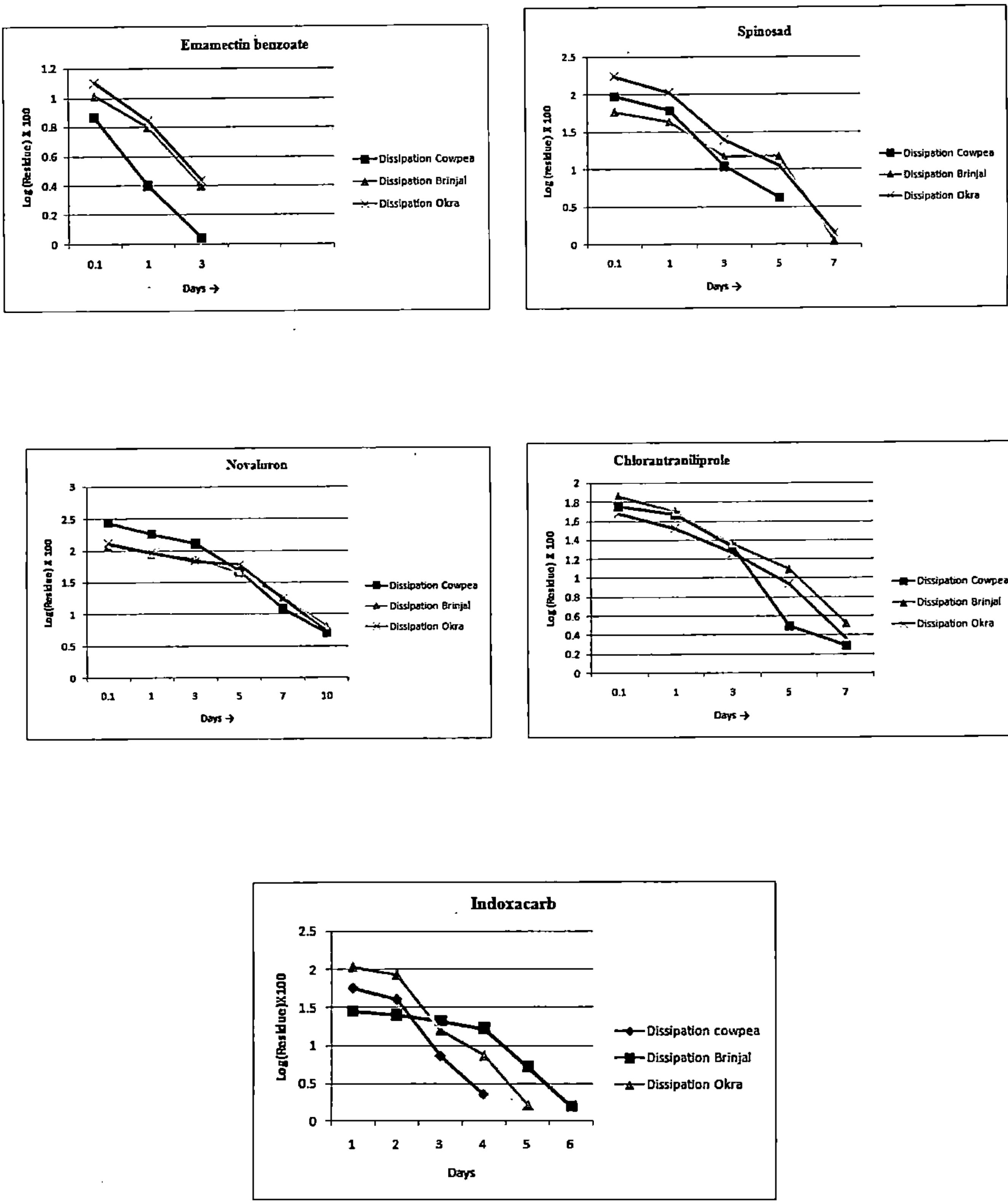


Fig. 9A. Dissipation pattern of insecticides on fruits of cowpea, brinjal and okra

waiting period in cowpea and brinjal indicated the safety of the insecticide in the vegetables which could be consumed even one day after application of the insecticide. Literature scan revealed that the concentration of spinosyn A and D in eggplant were below 0.2 mg/kg 1 day after the treatment when applied at 6000 mL/hm^2 (Zhao *et al.,* 2007). Spinosad residues at 35.0 g a.i. ha^{-1}, persisted up to 10 days in cabbage and cauliflower (Sharma *et al.*, 2008a). According to Mandal *et al.*, 2009 following three application of spinosad 2.5 SC at 15 and 30 g a.i. ha^{-1}, the average initial deposits were 0.57 and 1.34 mg kg^{-1}, respectively in cauliflower which dissipated below the limit of quantification after 10 days at both the dosages. A waiting period of six days was suggested for the safe consumption of spinosad treated cauliflower (Mandal *et al.,* 2009).

On the fifteenth day of spraying, the initial residues of novaluron at the time of spraying were at the level of 2.72, 1.21 and 1.30 mg kg^{-1} for cowpea, brinjal and okra, respectively which reached below detectable level. The half life of the insecticide was 1.66, 2.39 and 2.24 days for cowpea, brinjal and okra, respectively. Among the different insecticide molecules studied in the present investigation, novaluron had the longest waiting period of 13.76, 17.10 and 16.03 days in cowpea, brinjal and okra respectively. Novaluron when applied at 0.073-0.077 and 0.148-0.152 mg kg^{-1} and 0.075-0.078 and 0.149-0.156 mg kg^{-1}dissipated in chilli and brinjal with half-lives of 1.80-1.95 days for chilli and 1.80-2.08 days for brinjal and the residue was found to be below detectable limit on the tenth day (Das *et al.*, 2007).

The fruits of cowpea, brinjal and okra collected two hours after spraying chlorantraniliprole had 0.56, 0.72 and 0.48 mg kg^{-1} residues of the insecticide respectively which declined below detectable level from the tenth day of spraying. The half -lifves were 1.31 and 1.63 days for cowpea and brinjal and 2.21 days for okra. Of the various insecticides studied in the present investigation, chlorantraniliprole was noted to have the shortest waiting period of 0.62, 0.61 and zero day for cowpea, brinjal and okra indicating its safety to the vegetables. Similar results were obtained by other workers too. Based on their studies, Kar *et al.* (2013) suggested a waiting period of one day to reduce the risk before consumption of cauliflower curds. However, in tomato the pre-harvest interval (PHI) of chlorantraniliprole was recorded to be 8-days after the treatment at 60 mL per 4,200 m^2 (Malhat *et al.,* 2012). Therefore, application of chlorantraniliprole at the dose tested in the study is quite safe from crop protection and environmental contamination point of view and hence can be a useful component in the IPM of the different borers.

The initial residues of indoxacarb were recorded in cowpea, okra and brinjal at the rate of 0.56, 0.28 and 1.08 mg kg^{-1} on respectively two hours after spraying. The residues reached below detectable level on the seventh day in cowpea, fifteenth day in brinjal and tenth day in okra. The half life was 1.08, 2.42 and 1.13 days and the waiting periods 5.33, 0 and 1.53 days respectively. The short waiting periods in brinjal and okra indicated the relative safety of the insecticide in the crops, posing minimum risk to the consumers. The results obtained on okra agreed with the findings of Gupta *et al.* (2009) who observed that initial deposits of 0.26 and 0.67 mg kg^{-1} indoxacarb when was applied at 70 and 140 g a.i. ha^{-1} respectively dissipated to below detectable level 10 days after application. Studies on the dissipation behavior of indoxacarb (Avaunt 14.5 SC) on brinjal indicated that the initial deposits of 0.11 and 0.209 μ g^{-1} following three applications at the rate of 70 and 140 g a.i. ha^{-1} dissipated with half-life of 1.6–2.3 days (Sinha *et al.,* 2010).

The initial deposits of fipronil were recorded in cowpea, okra and brinjal at the rate of 1.12, 0.57 and 0.78 mg kg^{-1} on respectively two hours after spraying. After third day, the dissipation of fipronil was faster and on the tenth day of spraying the residue was below detectable level in cowpea and brinjal whereas for okra on seventh day itself no residues were detected. The half lives of fipronil were 1.08, 1.83 and 1.07 days in cowpea, brinjal and okra while the waiting periods were 8.09 and 8.08 days for cowpea and okra respectively and 13.19 days for brinjal. Fipronil residues

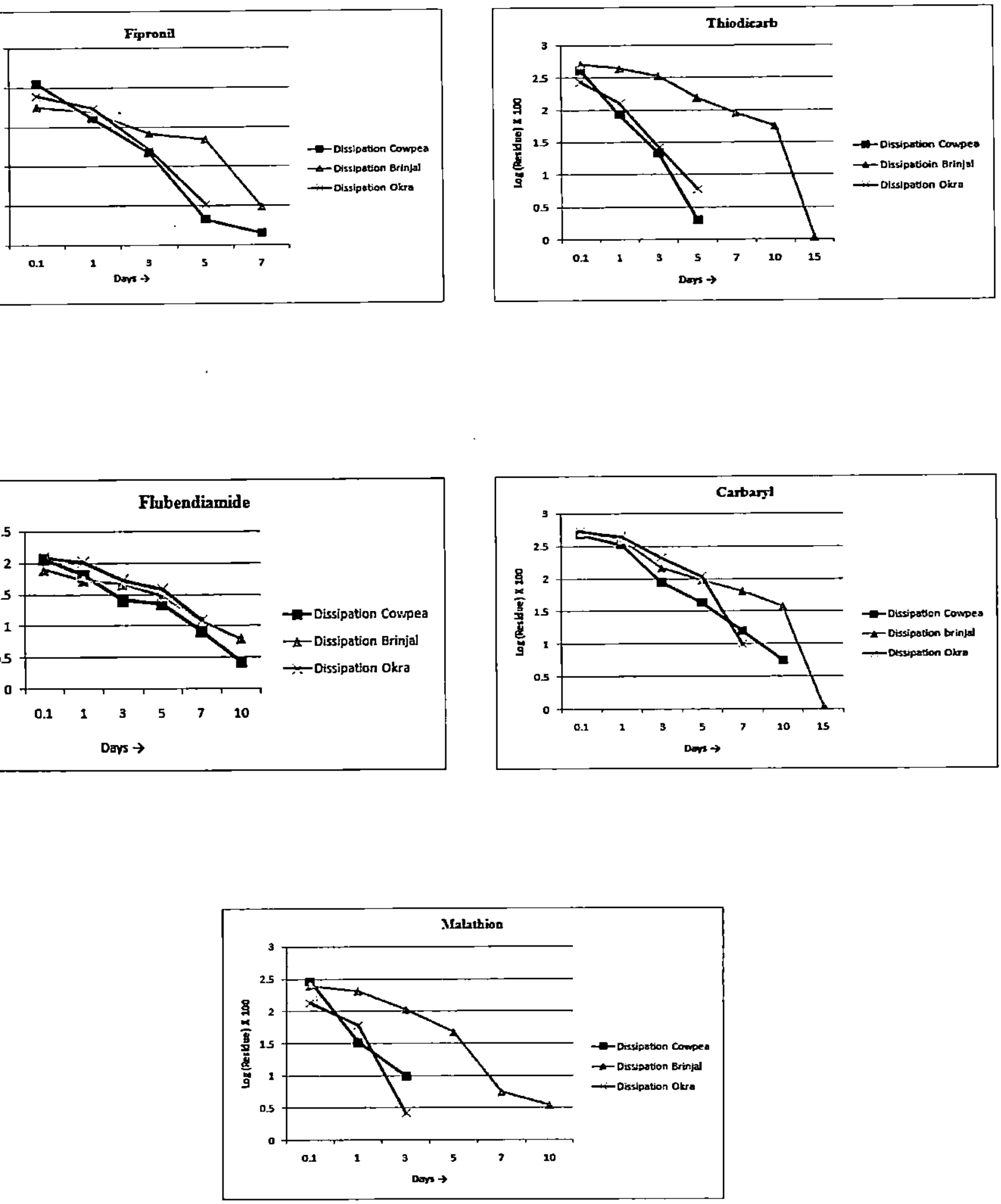


Fig. 9 B. Dissipation pattern of insecticides on fruits of cowpea, brinjal and okra

applied @ 50 and 100 g a.i.ha^{-1} persisted beyond 7 and 13 days at low dose and high dose with half-lives of 1.08 and 2.88 days in gram. Similarly, in okra, 98–100 per cent dissipation was recorded in 7 days with half life varying from 0.65 to 1.12 days. On brinjal, the residues persisted beyond 10 days at both the doses and half life varied from 1.84 to 2.31 days (Gupta *et al.*, 2008).

Compared to the other insecticides, a higher deposit of thiodicarb residues was detected on cowpea (4.13 mg kg^{-1}), brinjal (5.07 mg kg^{-1}) and okra (2.71 mg kg^{-1}) fruits, two hours after spraying. The residues were below detectable level on fifth and seventh day of spraying in cowpea and okra, respectively whereas in brinjal the residues remained up to fifteenth day (Fig. 16). The half life of the insecticide was 0.50, 1.81 and 0.89 days in cowpea, brinjal and okra, respectively. While a waiting period of 5.10 and 2.24 days was seen for cowpea and okra, respectively, a longer waiting period of 9.88 days was registered for brinjal. Few reports are available on the dissipation of thiodicarb residues in vegetables. Squash and tomatoes were sprayed with the insecticide thiodicarb 80% DF (dry flowable) at 0.5 kg/feddan, and fruit and leaf samples were collected at intervals for up to 50 days after treatment. Initial deposits of the insecticide were higher on squash fruits than on tomato fruits when thiodicarb 80% DF was sprayed. The residues were detected at 21 and 30 days after spraying, respectively and the half lives were 7.51 and 4.67 days, respectively (Antonious *et al.*, 1988).

An initial deposit of 1.14, 0.79 and 1.21 mg kg^{-1} of flubendiamide was recorded on cowpea, brinjal and okra fruits respectively on the day of spraying,. The dissipation of flubendiamide was at a slower pace and on the fifteenth day of spraying the residue was below detectable level for cowpea and brinjal whereas for okra residues remained up to tenth day only. The half life of flubendiamide was around 1.95, 2.72 and 2.18 days in cowpea, brinjal and okra, respectively. Short waiting periods of 2.55 and 5.58 days were calculated for cowpea and brinjal. Contrarily, the waiting period was 12.48 days in okra. The half-life of flubendiamide was in the range of 4.77–5.28 days in pigeon pea (Kale *et al.*, 2012). The residues of flubendiamide were reported as parent compound, and no desiodo metabolite was detected on brinjal. The initial deposits of 0.17 and 0.42 μg g^{-1} in/on brinjal fruits reached below determination level of 0.05 μg g^{-1} on the fifth and tenth day at standard and double doses, respectively. The half life ranged from 2.68 to 2.55 days (Chawla *et al.*, 2011). A waiting period of 1.63 days was suggested for the safe consumption of flubendiamide treated cabbage (Paramasivam and Banerjee, 2013). The initial deposits of 0.28 and 0.53 μg g^{-1} in/on okra fruits reached below determination level of 0.01 μg g^{-1} on the seventh and tenth day at 24 and 48 g a.i. ha^{-1}, respectively. The half life ranged from 4.7 to 5.1 days at standard and double dose, respectively (Das *et al.*, 2012).

The initial residue deposits of the conventional insecticide carbaryl on fruits of cowpea, okra and brinjal were high when estimated two hours after spraying; the quantity detected being 4.69, 5.21 and 5.32 mg kg^{-1} for respectively. The residues dissipated below detectable level on fifteenth, twentieth and tenth day of spraying in cowpea, brinjal and okra respectively. The half lives on cowpea, okra and brinjal fruits were 1.53, 1.84 and 1.29 days respectively and the waiting periods 2.83, 9.40 and 12.87 days for cowpea, brinjal and okra respectively. The dissipation of carbaryl residues to BDL on the twentieth day observed in the present study disagrees with the observation of Sudharma (1981) who reported that in brinjal fruits, the residues of carbaryl 0.15 % reached below detectable level four days after treatment. This may be due to the more sophisticated methods used in the present study for residue analysis which could detect the residues with higher precision. Rao *et al.*, (1985) opined that use of carbaryl in brinjal may not pose any appreciable residue hazard as dissipation of carbaryl residues in brinjal leaves and fruits indicated that the half lives were 1.076 and 1.370 days in leaves and fruits respectively. The initial deposit of 11.47 ppm from 0.2 % carbaryl spray on brinjal crop dissipated to 9.93 ppm within one day after treatment. Four, six , eight, ten and 15 days after treatment, the residues observed were 6.09 ppm, 5.14 ppm, 3.93 ppm, 1.87 ppm and 0.95 ppm, respectively. After 25th day the residues were not detectable (Dhas and Srivastava, 2010).

In cowpea, brinjal and okra spraying of malathion on fruits deposited an initial average deposit of 2.91, 2.45 and 1.34 mg kg^{-1}, respectively. From the fifth day of spraying no residues were detected in cowpea and okra whereas residues persisted in brinjal up to the tenth day. The half life on cowpea was 0.54 days and waiting period 6.65 days. The half life of the insecticide was 1.46 and 0.50 days for brinjal and okra, respectively and the waiting periods 10.70 and 3.25 days, respectively. The dissipation experiments by Liu *et al.* (2012) showed that the half-life ($T_{1/2}$) of malathion was around 1 day in cabbage at 18 g.a.i ha^{-1}. Initial residues of malathion on brinjal treated with dosage of 2.24 lha^{-1} dissipated from 0.8 to 0.05 mg kg^{-1} within 5 days (Islam *et al.*, 2009).

5.4 DECONTAMINATION OF INSECTICIDE RESIDUES

Insecticides on raw commodities are presumed to dissipate to some extent during storage, commercial processing, cooking, roasting, steaming etc. Traditional methods of washing vegetables to remove debris and dirt prior to consumption too reduce loosely held pesticide residues (Satpathy *et al.*, 2011). Since vegetables are the prime targets of insecticide applications, their decontamination before consumption would reduce the pesticide load. Simple and reliable techniques need necessarily be identified for eliminating the pesticide contaminants. Although extensive literature review demonstrates that in most cases, processing leads to large reductions in residue levels of the conventional insecticides, particularly through washing, peeling and cooking operations (Soliman, 2001; Zohair, 2001) the literature related to the decontamination of new classes of insecticides from vegetables are meagre. Hence, the effects of simple processing techniques *viz.*, dipping in common salt 2%, tamarind 2%, vinegar 2%, slaked lime 2%, baking soda 2%, or turmeric 1% solutions followed by washing for 20 minutes, steaming, scrubbing and plain washing in removing the residues of the eight newer classes of insecticides *viz.*, emamectin benzoate, spinosad, novaluron, chlorantraniliprole, indoxacarb, fipronil, thiodicarb and flubendiamide from cowpea, brinjal and okra fruits two hours and three days after spraying were evaluated.

The results (expressed as processing factor - PF) indicated that simple household practices removed the residues of the new generation insecticides to varying extent (Fig. 10 A to 11 C). While the removal of the residues on/ in cowpea pods, brinjal and okra harvested two hours after spraying the insecticides ranged from 34.49 to 100 (PF 0.66 to 0), 8.66 to 100 (PF 0.91 to 0), and 18.65 to 98.36 per cent (PF 0.81 to 0), respectively, the dislodging of the residues on fruits harvested on the third day ranged from 10.33 to 100 (PF 0.90 to 0), 61.87 to 100 (PF 0.38 to 0), and 19.91 to 100 per cent (PF 0.80 to 0), respectively. The degree of elimination of the conventional insecticides *viz.*, carbaryl and malathion ranged from 17.35 to 90.69 (PF 0.84 to 0.09), 38.45 to 96.55(PF 0.62 to 0.03) and 21.30 to 81.62 per cent (PF 0.79 to 0.18), in the respective crops collected two hours after spraying and from18.89 to 97.85(PF 0.89 to 0.02), 66.09 to 100 (PF 0.34 to 0), and 39.79 to 100 per cent (PF 0.60 to 0), respectively on the third day. Evidently, noticeable differences could not be discerned in the extent of removal of the insecticide residues seen two hours and three days after application. This may probably be due to the prevalence of the residues on the surface and lesser penetration into deeper layers since most of the newer classes of insecticides are nonsystemic.

With regard to the efficacy of the various decontaminating techniques in removing the insecticide residues from each of the vegetable, dipping in common salt 2%, slaked lime 2% and turmeric 1% solutions removed more than 50 per cent of the residues of the new generation and conventional insecticides from cowpea pods harvested two hours after spraying. Similarly, common salt 2%, vinegar 2%, slaked lime 2%, baking soda 2% and scrubbing dislodged more than 50 per cent of the residues of all the insecticides tested on brinjal fruits while vinegar 2%, slaked lime 2% and scrubbing were the effective treatments for okra fruits. Turmeric 1%, vinegar

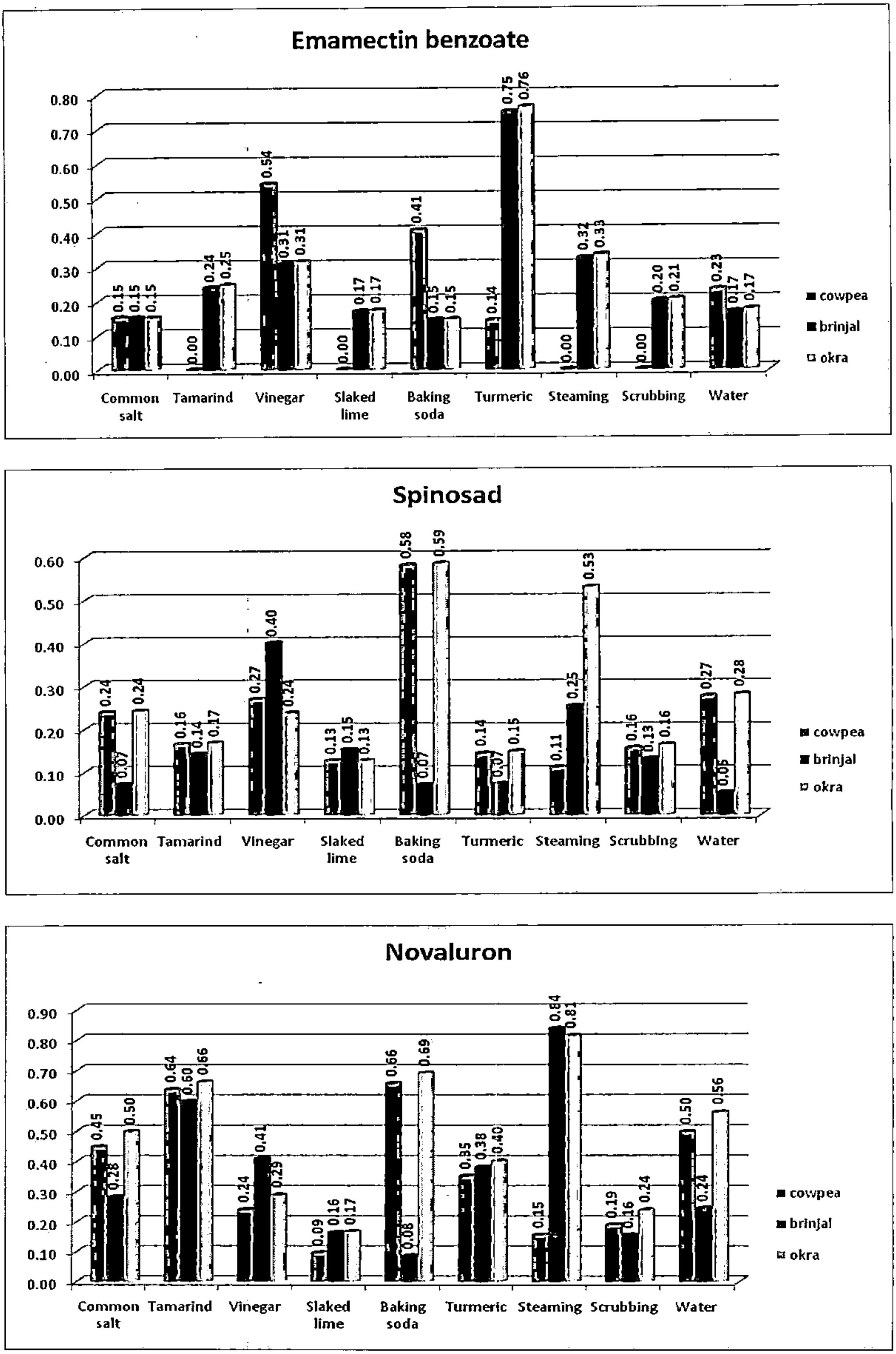
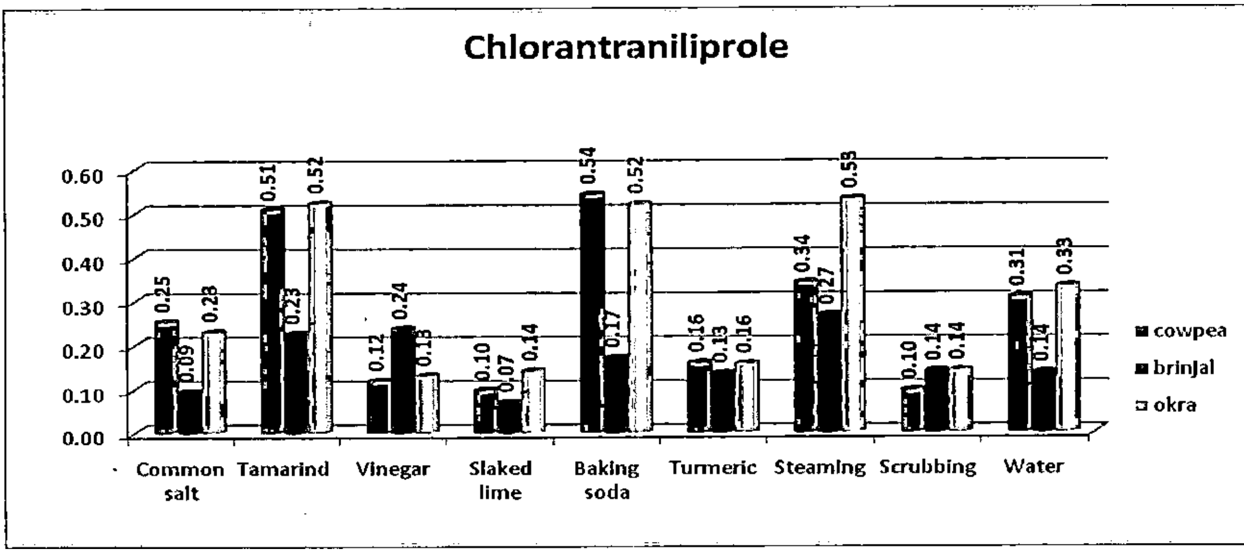
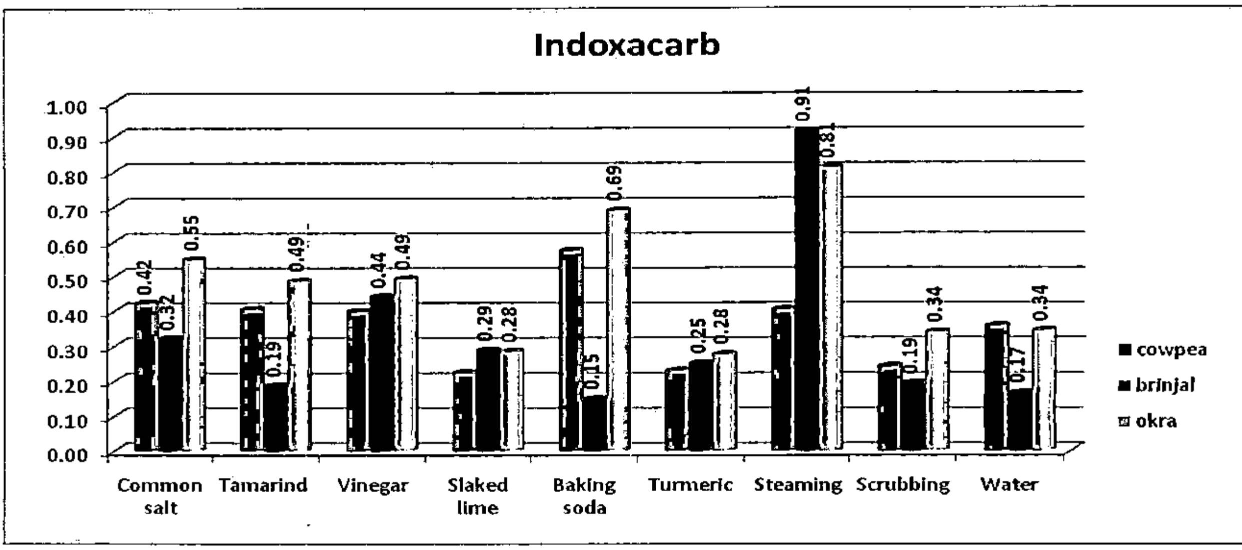


Fig.10. A. Extent of removal of insecticide residues from cowpea, brinjal and okra fruits subjected to different treatments two hours after spraying X axis-Treatments, Y axis- Processing factor

2% and scrubbing reduced more than 40 per cent of the insecticide residues from cowpea pods harvested three days after spraying whereas all the decontamination techniques degraded more than 50 per cent of the residues of all the insecticides from brinjal. Only scrubbing removed all the insecticides on okra fruits.

Washing in plain water is a common practice adopted for cleaning vegetables prior to their usage. This cleansing process has been noted to remove residues of pesticides too. In the present investigation, when the insecticide applied fruits were processed in plain water, two hours after spraying, the removal of residues was very high in the case of thiodicarb from cowpea (97.31%) followed by emamectin benzoate, spinosad, chlorantraniliprole and indoxacarb. In brinjal and okra also, removal of residues of thiodicarb was high. Substantial removal of residues of other insecticides like emamectin benzoate, spinosad, chlorantraniliprole, novaluron and indoxacarb too was recorded. After three days of spraying, residues of emamectin benzoate in the three vegetables were reduced to BDL when washed with plain water. This was followed by indoxacarb, thiodicarb and chlorantraniliprole for vegetable cowpea, spinosad, malathion and indoxacarb for okra and spinosad, malathion and thiodicarb for brinjal. The extent of removal of residues from these vegetables while dipping in water can be attributed to the difference in solubility of these insecticides in water and the types of insecticide formulations. Polar, water soluble pesticides are more readily removed than low polarity materials. Most of the new generation insecticides are highly water soluble (Krol *et al.*, 2000). The efficacy of washing in removing pesticide residues had been noted earlier too, though most of the literature pertains to the conventional insecticides. Washing of okra with tap water removed cypermethrin residues to the extent of 41.2-48.3 per cent in 0 day samples and 37.1 to 46.0 per cent in fifth day samples. Maximum (77 per cent) reduction of organophosphate insecticides was observed in brinjal, followed by 74 per cent in cauliflower and 50 per cent in okra by washing (Kumari, 2008). Aktar *et al.* (2010) reported that washing under running tap water removed 27.72–32.48 per cent of





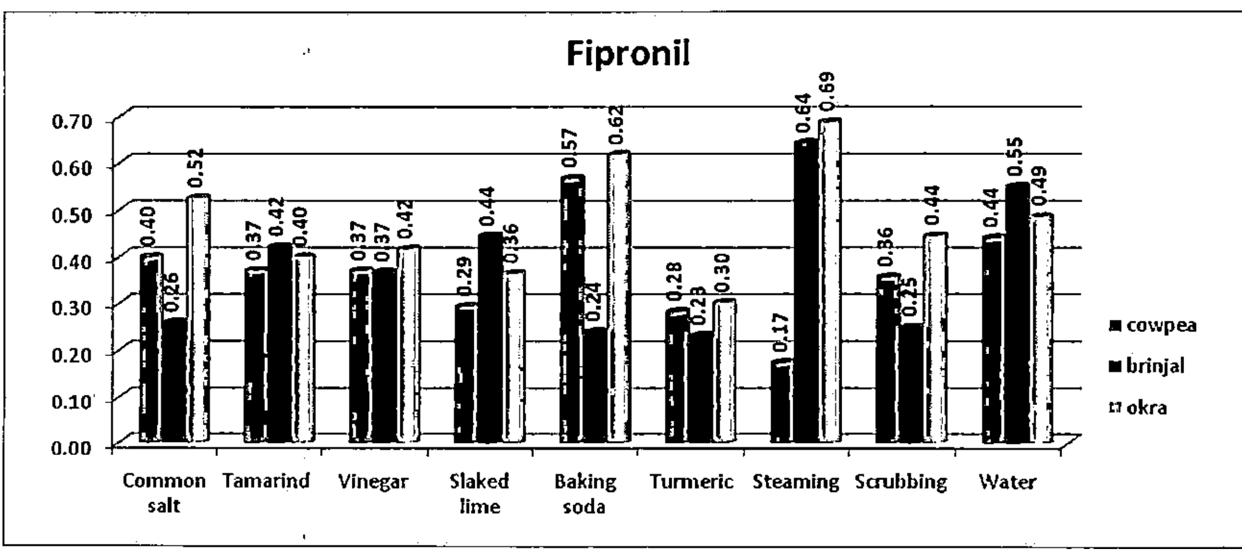


Fig.10. B. Extent of removal of insecticide residues from cowpea, brinjal and okra fruits subjected to different treatments two hours after spraying X axis-Treatments, Y axis- Processing factor

quinalphos residues from cabbage head. Water soluble contact new generation insecticides such as emamectin benzoate can be successfully removed from okra by plain washing (Sheikh *et al.*, 2012). Few reports are available on the efficacy of washing in removing the residues of the other new classes of insecticides studied in the present investigation.

Scrubbing, another common household practice too could dislodge insecticides residues, particularly the loosely held ones. Two hours after spraying, scrubbing of cowpea pods removed 100 per cent of emamectin benzoate residues and more than 70 per cent of thiodicarb, chlorantraniliprole, flubendiamide, spinosad, novaluron, and indoxacarb residues. More than 75 per cent of the residues of the new generation insecticides were removed through scrubbing from brinjal. In okra more than 75 per cent of the residues of chlorantraniliprole, spinosad, emamectin benzoate, and novaluron were removed. On the third day also, residues of emamectin benzoate, novaluron, chlorantraniliprole, flubendiamide, thiodicarb, fipronil and indoxacarb were removed substantially from cowpea. The extent of removal of residues was high for all the treatments in brinjal and okra. As the vegetable peels retain majority of the contact insecticide residues, scrubbing could eliminate the residues substantially. Barooah and Yein (1996) also reported that washing coupled with gentle rubbing by hand of brinjal fruits under tap water for one minute dislodged pesticide residues significantly. Perusal of literature indicated that the efficacy of scrubbing in removing pesticide residues has not been explored widely. The effectiveness of this method in reducing the residues of some of the new generation insecticides recorded in the present study needs to be investigated further.

On steaming of cowpea, brinjal and okra harvested two hours after spraying, residues of thiodicarb were eliminated completely. With the exception of indoxacarb and flubendiamide, residues of all other newer insecticides were removed remarkably from cowpea. In brinjal, residues of emamectin benzoate, spinosad and chlorantraniliprole were reduced significantly while in okra only residues of

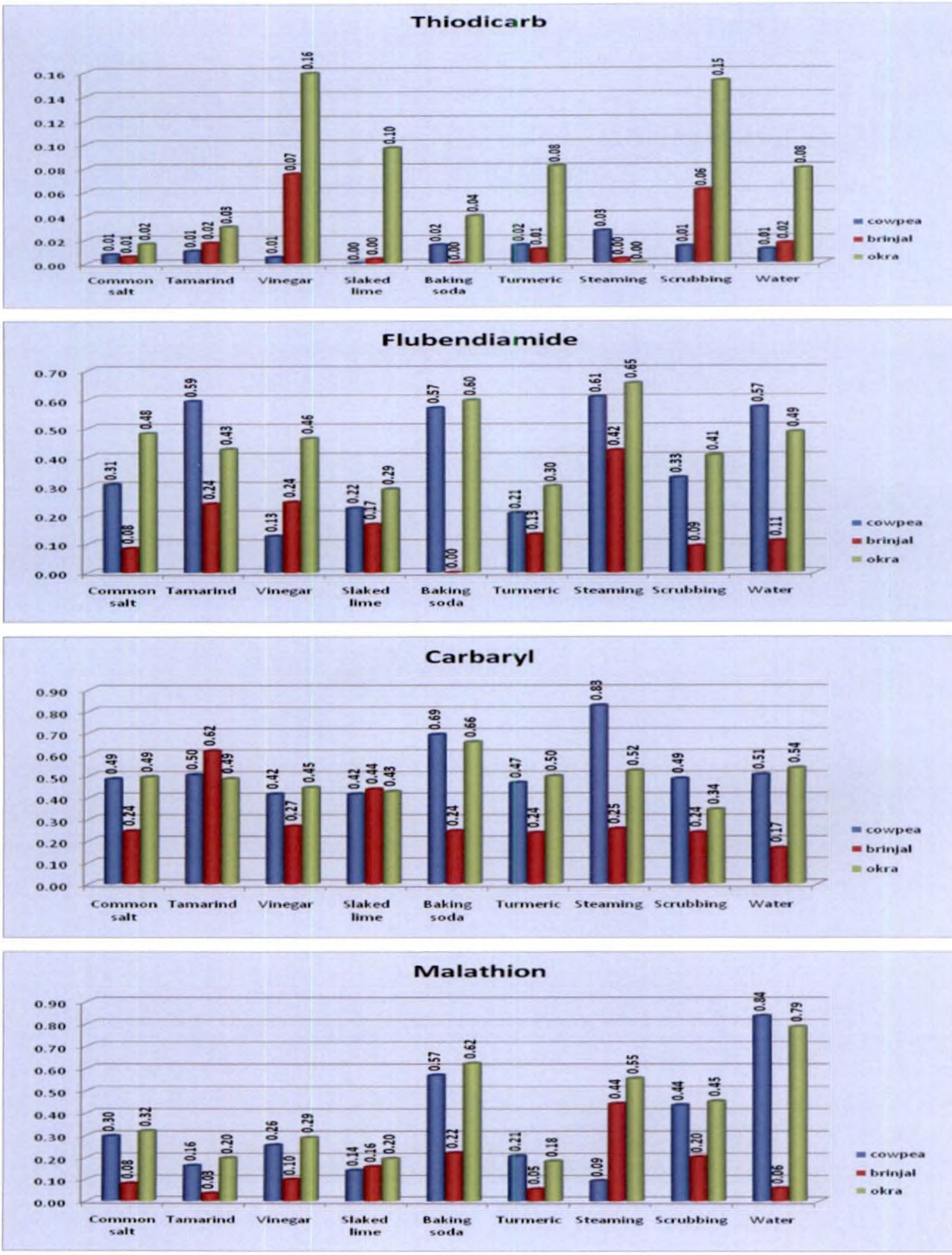


Fig.10. C. Extent of removal of insecticide residues from cowpea, brinjal and okra fruits subjected to different treatments two hours after spraying X axis-Treatments, Y axis- Processing factor

emamectin benzoate residues were reduced. On the third day after spraying, with the exception of flubendiamide, residues of all the other new generation insecticides were removed effectively from cowpea and brinjal. In okra, only residues of emamectin benzoate, thiodicarb and fipronil were removed through steaming. Rates of degradation and volatilisation of residues are increased by the heat involved in cooking or pasteurisation. However, for compounds that are of low volatility and relatively stable to hydrolysis, losses of residues through cooking may be low and concentrations may actually increase due to moisture loss. Efficacy of steaming in removing residues of insecticides had been documented earlier. Cooking after washing mitigated 5 days old residues of endosulfan, fenvalerate and monocrotophos, by 94.49, 37.97 and 11.64 per cent, respectively from the recommended rates of application (Dinabandhoo and Sharma 1994). Naseemabeevi *et al.,* 2003 studied the effect of washing and cooking in removing residues of various vegetables and noted substantial reduction of pesticide residues in washed and cooked vegetables. Similarly, washing + boiling reduced 60 to 61 per cent of residues of fenazaquin in okra and boiling/cooking 38 to 40 per cent (Duhan, 2010). On the other hand, boiling removed 100 per cent of chlorantraniliprole residues on cabbage and cauliflower (Kar *et al.*, 2012).

When the insecticide treated cowpea pods (two hours after spraying) were dipped in salt solution 2% for twenty minutes followed by washing in water, high removal of residues of thiodicarb (99.24%), emamectin benzoate (84.70%), spinosad (76.09. %) and chlorantraniliprole (74.77%) were recorded. Residues of most of the insecticides were removed from brinjal through the treatment, the maximum being for thiodicarb. In okra, only residues of thiodicarb, emamectin benzoate, spinosad and chlorantraniliprole were removed substantially. Three days after spraying, only residues of emamectin benzoate were removed from cowpea and emamectin benzoate, spinosad and thiodicarb from okra. However, residues of most of the insecticides were removed through the treatment from brinjal. Krol *et al.* (2000)

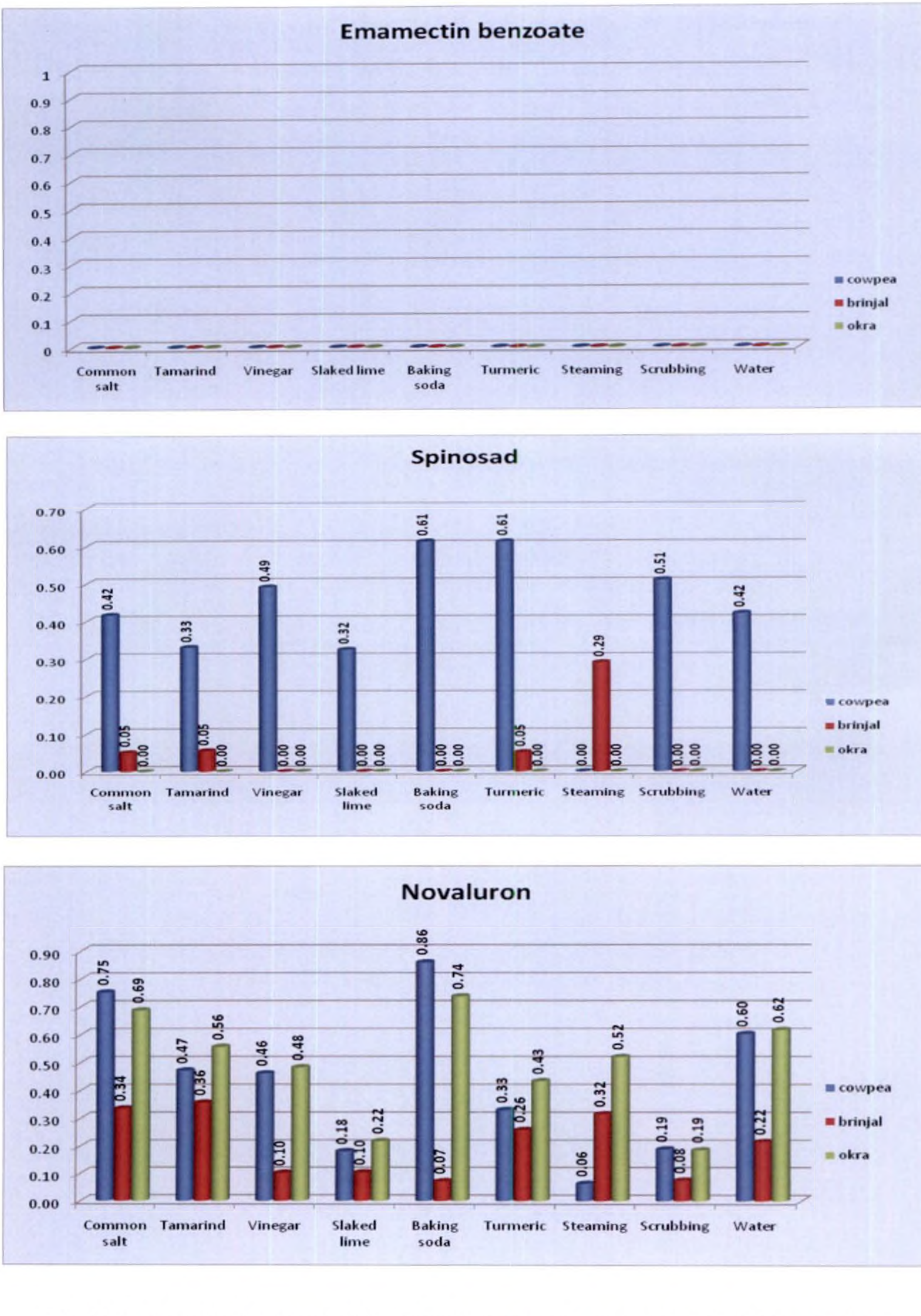
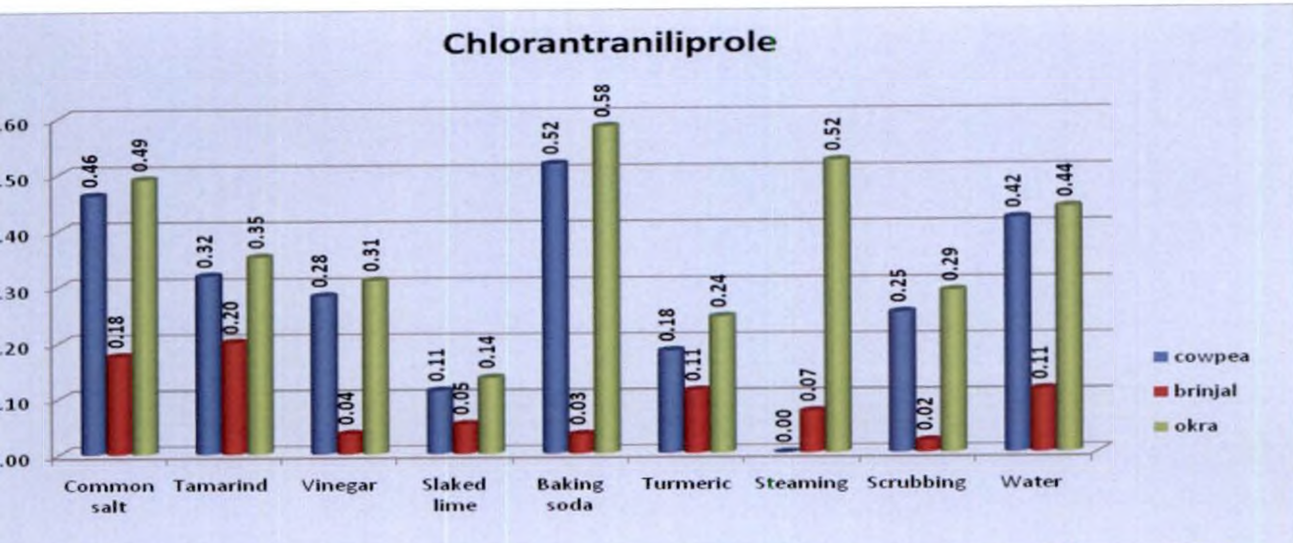
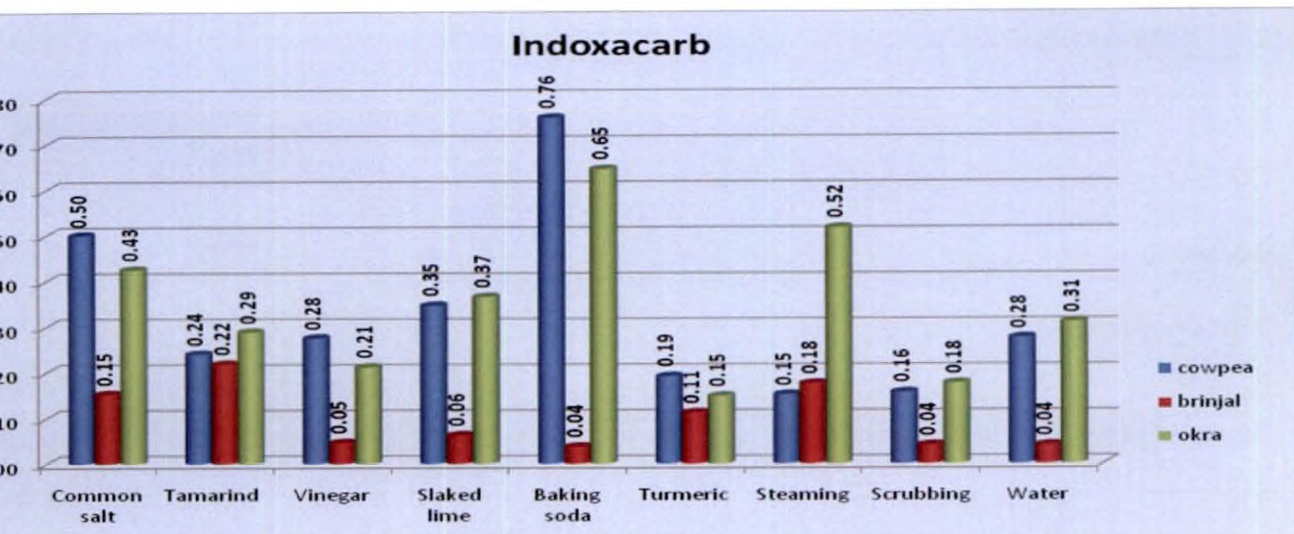


Fig.11. A. Extent of removal of insecticide residues from cowpea, brinjal and okra fruits subjected to different treatments two hours after spraying
X axis-Treatments, Y axis- Processing factor

observed that solutions formulated from chemicals like salt, baking soda, distilled vinegar, potassium permanganate readily available in market can decontaminate insecticides that are highly water soluble. This may be the reason why some of the newer molecules tested in the study were easily dislodged when immersed in 2% salt solution. Dipping of okra fruits in 2 % common salt (processing factor: 0.22-0.41) was found to be effective in the removal of residues of malathion, methyl parathion, profenophos, cypermethrin, fenvalerate, chlorpyriphos and quinalphos (Nair *et al*, 2013) while dipping chilli fruits in 2 % salt solution reduced spiromesifen residues by 62 per cent (Varghese, 2011).

Dipping cowpea pods in 2% tamarind solution followed by washing in water removed residues of emamectin benzoate (100 per cent), thiodicarb (98.95 per cent) and spinosad (83.56 per cent) two hours after spraying. In brinjal, removal of residues was high for thiodicarb, spinosad, indoxacarb, chlorantraniliprole, emamectin benzoate and flubendiamide while in okra it was for thiodicarb, spinosad and emamectin benzoate. A similar trend was seen three days after spraying also. The efficacy of tamarind solution in removing pesticide residues had been documented earlier. Dipping insecticide treated chilli fruits in 2 % tamarind solution for twenty minutes followed by washing in water removed high amount of residues of spiromesifen, imidacloprid, propargite and dimethoate. In the case of ethion also, tamarind treatment removed fairly good amount of residues. Owing to this majority, dipping in tamarind solution (2 %) was recommended as a good option for removing insecticide residues from fruits and vegetables (Varghese, 2011). Washing of brinjal, bhendi, cabbage and cauliflower in tamarind solution 2% for 30 seconds reduced insecticide deposits to nearly 50 per cent (Suresh *et al*., 2012). Dipping of curry leaves and okra in 2 % tamarind solution for 15 minutes followed by washing in tap water was found to be the most effective treatment in removing the residues of malathion, methyl parathion, profenophos, cypermethrin, fenvalerate, chlorpyriphos and quinalphos (Nair *et al*., 2013).





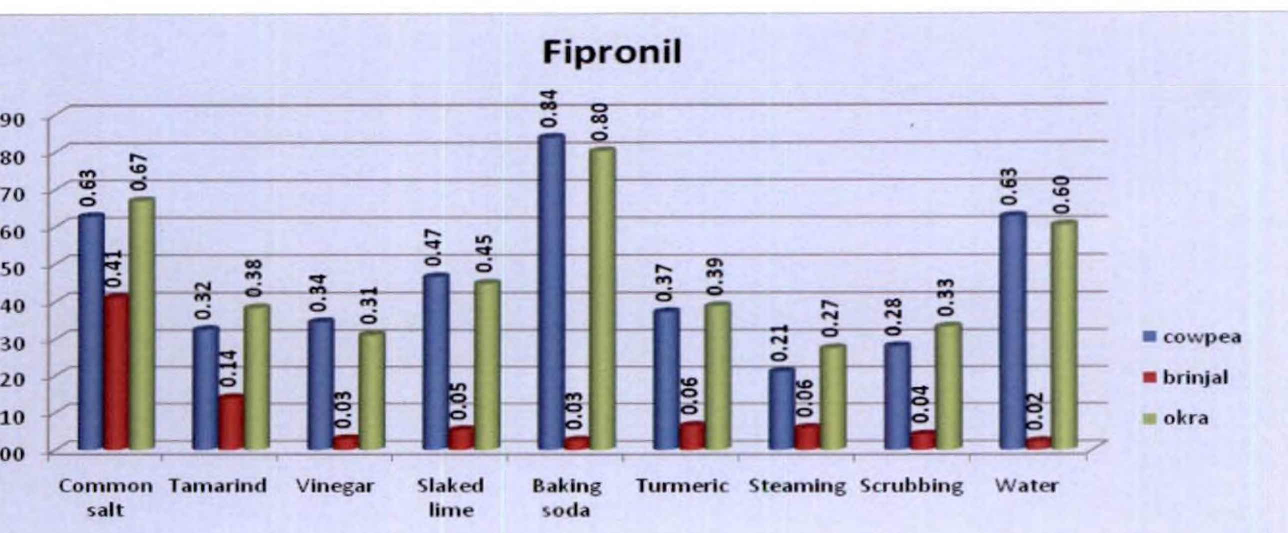


Fig.11. B. Extent of removal of insecticide residues from cowpea, brinjal and okra fruits subjected to different treatments two hours after spraying X axis-Treatments, Y axis- Processing factor

Dipping cowpea pods two hours after spraying in 2% vinegar solution for twenty minutes followed by washing in water removed thiodicarb residues (99.47 per cent) to a greater extent followed by chlorantraniliprole, flubendiamide, novaluron and spinosad. The removal of residues was in the order of thiodicarb, chlorantraniliprole, and emamectin benzoate in brinjal and chlorantraniliprole thiodicarb, spinosad, and novaluron in okra. At three days after spraying, residues of emamectin benzoate were completely removed (100 per cent) from cowpea and brinjal and spinosad from okra. Dipping okra in 2 % vinegar solution was also found to be effective in removing residues of malathion, methyl parathion, profenophos, cypermethrin, fenvalerate, chlorpyriphos and quinalphos (Nair *et al*, 2012).

Processing in 1% turmeric solution caused high reduction of residues of thiodicarb, spinosad, malathion, chlorantraniliprole and flubendiamide in cowpea, okra and brinjal. The residues of emamectin benzoate were removed entirely from cowpea and brinjal on the third day whereas spinosad residues were the most removed from okra fruits by turmeric treatment. The results of the study agree with the observations of Nair *et al*. (2012) who reported that dipping okra in 1 % turmeric effectively removed residues of malathion, methyl parathion, profenophos, cypermethrin, fenvalerate, chlorpyriphos and quinalphos.

The two alkaline substrates used in the present investigations were baking soda and slaked lime. Between the two, 2% slaked lime solution was better than 2% baking soda solution in removing residues of new generation insecticides from the vegetables. Dipping cowpea fruits in 2% slaked lime solution for twenty minutes followed by washing in water removed 100, 100, 90.55, 90.26, 87..44, 85.75, 77.71,77.70, 70.66 and 58.41 per cent residues of emamectin benzoate, thiodicarb, novaluron, chlorantraniliprole, spinosad, malathion, flubendiamide, indoxacarb, and fipronil, respectively two hours after spraying. More than 70 per cent residues of thiodicarb, chlorantraniliprole spinosad, malathion, novaluron, flubendiamide, emamectin benzoate and indoxacarb were removed from brinjal. A similar efficacy in

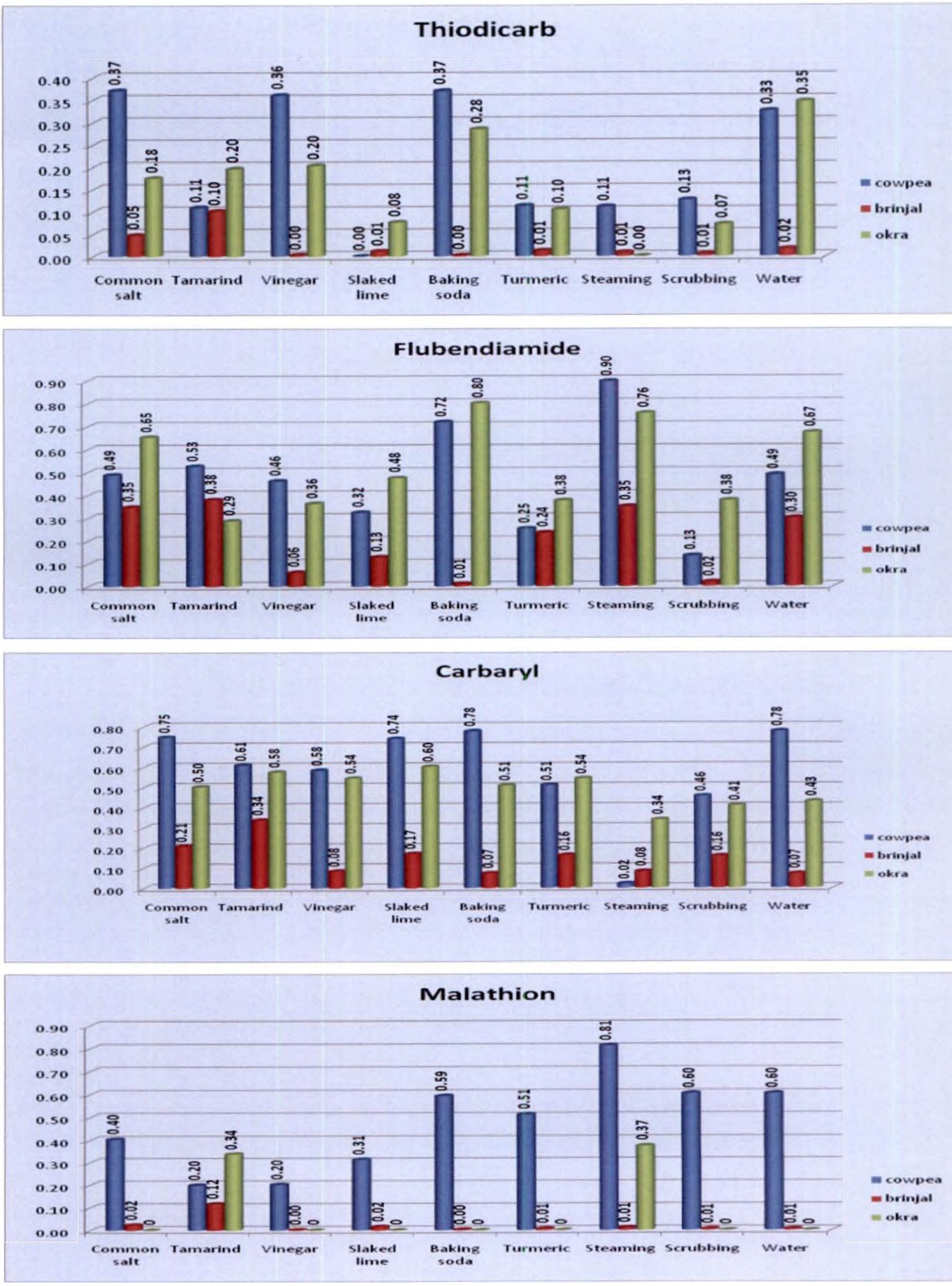


Fig.11. C. Extent of removal of insecticide residues from cowpea, brinjal and okra fruits subjected to different treatments two hours after spraying
X axis-Treatments, Y axis- Processing factor

the removal of residues of insecticides was also recorded in okra. In the baking soda treatment, only residues of thiodicarb from cowpea and emamectin benzoate and thiodicarb from okra were removed substantially. On the other hand, the extent of removal of residues of all the insecticides was very high in brinjal (75.53 to100 per cent). At three days after spraying, 100 per cent removal of residues of emamectin benzoate was observed in all the three vegetables when dipped in 2% baking soda and 2% slaked lime solutions. Removal of residues of other insecticides was also high in slaked lime treatment in cowpea and okra while it was comparatively low in baking soda. Removal of residues of all insecticides was high in brinjal when processed in baking soda 2 % solution. The efficacy of alkaline solutions in removing residues of conventional insecticides had been observed earlier. $NaHCO_3$ 0.05% was very effective in reducing residues of quinalphos and endosulfan in cauliflower (Senapathi *et al.*, 1999). Washing in 10% sodium carbonate resulted in 92, 88, and 95 per cent removal of residues of organophosphorus and organochlorine pesticides from potatoes (Zohair, 2001). Baking soda 2 % was ineffective in removing residues of acetamiprid, in chilli (Varghese, 2011).

The results of the decontamination studies revealed that the efficacies of the treatments varied with respect to different insecticidal chemistries. The effect of processing depends on many factors like characteristics of the commodity, location of the residues, age of the chemical, octanol-water partition coefficients, water solubility, vapour pressure and heat stability (Holland *et al.*, 1994). In general, the newer classes of insecticides being highly polar, their residues from the vegetables could be removed suitably by immersing the insecticide treated fruits in 2% slaked lime, 1 % turmeric, 2% vinegar or 2% tamarind solution for twenty minutes followed by washing in water and through scrubbing.

A succinct analysis of the results indicated the efficacy of all the newer classes of insecticides against the fruit borers of cowpea, brinjal and okra with chlorantranilipole, indoxacarb and emamectin benzoate being the choice insecticides for cowpea; chlorantraniliprole, indoxacarb, emamectin benzoate and flubendiamide for brinjal and chlorantraniliprole, flubendiamide and indoxacarb for okra. Although biological and other bio rational methods could play important roles in managing the fruit borers, normally it is difficult to produce fresh marketable vegetables with the necessary cosmetic quality and low cull rate without the use of insecticides to control the pests. In this context, the safer and environment friendly new classes of insecticides could provide vegetable growers with alternatives to the currently used noxious insecticides.

All the insecticides were relatively compatible with *B. bassiana* and *M. anisopliae* and so could be used concomitantly with the entomopathogens in pest management. Applications of synthetic insecticides with microbial insecticides are desirable since the stress exerted by the toxicants on the insect population would enhance their susceptibility to diseases. Inhibitory effect of flubendiamide on *L. lecanii* highlights the necessity of examining the compatibility of insecticides with other components of IPM prior to their recommendation. A precise time lag between the application of the microbial and chemical insecticides may be advocated for the incompatible ones.

Contamination of food with pesticides is gaining importance day by day. Information on the fate of the pesticides applied on crops is needed to assess the impact of the contaminants on human and the environment. Pesticide free commodity could be accomplished by observing sufficient pre harvest intervals of the concerned chemicals. In view of the waiting periods calculated for the different insecticides in the present investigation, chlorantraniliprole with the shortest waiting period of one day in all the three vegetables was noted to be the safest. Besides, spinosad (1 day), emamectin benzoate (3 days) and flubendiamide (3 days) also had waiting periods within the harvest interval of cowpea, ensuring their safety to the crop. Similarly, indoxacarb (1day), spinosad (1 day) and emamectin benzoate (4 days) had waiting periods below 5 days which is within the harvest interval of brinjal. Indoxacarb (2 days) and thiodicarb (2 days) with waiting periods below 3 days were the safer ones for okra. Such information on the pre harvest intervals could provide proper guidance for the selection and safe use of the insecticides on these vegetables.

Apart from observing the pre harvest intervals, the consumers can reduce the risk of residues in the vegetables through processing with effortless suitable decontamination techniques as revealed by the decontamination studies. Though almost all the treatments tested were highly effective in removing residues of one or the other of the newer molecules, immersing insecticide treated fruits in slaked lime 2%, turmeric 1 %, vinegar 2% or tamarind 2% solution for twenty minutes followed by washing in water and scrubbing which removed residues of most the insecticides were the better options for the new generation chemistries.

Thus, the overall results of the study indicated that, apart from the efficacy of the insecticides against pests, the associated yield increase, benefit cost ratio of the insecticide treatments, waiting period and compatibility with other IPM approaches should also be considered while recommending insecticides for the control of pests. In this perspective, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1} and emamectin benzoate 5SG @10 g a.i. ha^{-1} were adjudged as the promising insecticides for the fruit borers of cowpea, brinjal and okra in integrated crop management, the basis of sustainable agriculture.

SUMMARY

6. SUMMARY

The lepidopteran fruit borers, *M. vitrata, L. orbonalis* and *E. vitella* are the most devastating pests of cowpea, brinjal and okra, respectively. As the destructive stages lodge within the crop, management of the pests is tedious, often instigating the unilateral use of synthetic insecticides. The illogical application of the toxic conventional molecules and the consequent repercussions are well known. The present investigation was taken up to evaluate the efficacy of the relatively safer new generation insecticides recommended for tissue borers *viz.,* emamectin benzoate 5SG @10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, novaluron 10 EC @ 100 g a.i. ha^{-1}, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1}, fipronil 80 WG @ 50 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1} and flubendiamide 480 SC @ 100 g a.i. ha^{-1}in comparison with carbaryl 50 WP @ 750 g a.i. ha^{-1} and malathion 50 EC @ 500 g a.i. ha^{-1} the conventional insecticides as chemical checks against the fruit borers. The insecticides were tested both in the laboratory and field. Their compatibility with the popular entomopathogens of vegetable pests too was assessed. The dissipation patterns of the insecticides and the possibility of exploiting various simple household processing practices in reducing the residues were also studied. The results are summarized here under.

- Laboratory screening of the insecticides against *M. vitrata, L. orbonalis* and *E. vitella* indicated high mortality of the pests one and three days after treatment with a subsequent decline in the mortality. The insecticides were on par in their efficacy.

- All the new generation insecticides reduced the infestation of *M. vitrata* on cowpea flowers and fruits significantly in the field. The reduction in flower and pod damages ranged from 53.97 to 76.86 and 63.69 to 84.82 per cent, respectively. Among the newer molecules, chlorantraniliprole, indoxacarb and emamectin benzoate which recorded more than 70 and 80 per cent reduction in

flower and fruit damages respectively, were the potent insecticides in checking the pest. Higher yield was also obtained from these plots, being 14.50(indoxacarb), 13.88(chlorantraniliprole) and 13.20(emamectin benzoate) kg per 18 m^2 plot. The returns from the treatments were Rs.8.13, 6.48 and 5.27, respectively for every one rupee invested for plant protection.

- Prophylactic sprays with neem seed kernel extract 5 % at flower bud initiation stage followed by another spray after a fortnight, diminished the population of the pest remarkably. Subsequently, one spray of the insecticides sufficed to check the pest. The reduction in the flower and fruit damages in cowpea ranged from 55.55 to 91.65 and 67.01 to 90.32 per cent, respectively.Chlorantraniliprole, indoxacarb and emamectin benzoate recorded lower damage by the pest too.
- Significant reduction in the damage by *L. orbonalis* to shoots and fruits was recorded in brinjal plots treated with the newer molecules too. The extent of reduction in damage to shoots and fruits ranged from 62.53 to 84.00 and 45.96 to 72.21 per cent, respectively. Chlorantraniliprole, indoxacarb, emamectin benzoate and flubendiamide which recorded more than 60 per cent reduction in the fruit damage, proved superior to other treatments. The yield from these new generation insecticide treated plots too were significantly high, being 17.82 (flubendiamide), 17.63 (indoxacarb), 17.52 (chlorantraniliprole) and 16.51 (emamectin benzoate) kg per six sq. m plot. Benefit cost ratio worked out showed that chlorantraniliprole, flubendiamide and indoxacarb gave Rs.5.55, 5.35and 5.28, respectively in return for every one rupee invested in plant protection, while emamectin benzoate gave only Rs. 2.32.
- All the new generation insecticides were equally effective in reducing the shoot and fruit infestation by *E. vitella* in okra, the reduction in damage ranging from 68.09 to 80.82 in shoots and 53.53 to 83.26 per cent in fruits in the plots treated with the newer molecules. Chlorantraniliprole, flubendiamide and indoxacarb treatments showed more than 70 per cent reduction in fruit damage. They were comparatively more effective in preventing the pest infestation. The reduction in damage was reflected in the yield also. The yield obtained from these plots were

significantly higher, being 5.80 kg (chlorantraniliprole), 5.61 kg (flubendiamide) and 5.50 kg (indoxacarb) per six sq. m plot .The benefit cost ratio indicated that Rs.6.96 (indoxacarb), 6.93(flubendiamide) and 6.23(chlorantraniliprole)could be obtained in return for everyone rupee spent the insecticide treatments.

- Studies on the compatibility of the selected insecticides to entomopathogenic fungi revealed that none of the insecticides affected *B. bassiana* adversely indicating their safety to the fungus. Moreover, synergistic effect was noted in indoxacarb, emamectin benzoate and chlorantraniliprole treatments.
- All the insecticides were compatible with *M. anisopliae.* While chlorantraniliprole, indoxacarb spinosad and malathion recorded equal growth of the fungus, emamectin benzoate and thiodicarb showed slightly lower growth. Chlorantraniliprole, fipronil, novaluron, indoxacarb, thiodicarb, emamectin benzoate, spinosad and malathion were safe to *L. lecanii.* However, flubendiamide and carbaryl which inhibited the growth of the fungus proved incompatible.
- The analytical procedure selected/ standardized for estimation of the different insecticides gave high recovery of the insecticides, ranging from 73.20 to 116.4 per cent for cowpea, brinjal and okra fruitswhen validated. Good linearity was found within the range of 0.01-0.50 mgkg^{-1} concentration for all the insecticides selected.
- Emamectin benzoate when sprayed @ 10 g a.i ha^{-1} on cowpea, brinjal and okradeposited 0.07 mg kg^{-1},0.10 mg kg^{-1}and 0.13 mg kg^{-1}residues on the fruits of the respective crops two hours after spraying. The residues dissipated to below detectable level in all the three fruitson the fifth day of spraying. The half life of the insecticide was 1.25, 1.28 and 1.34 days for cowpea, brinjal and okra, respectively and the waiting periods 2.99, 4.40 and 4.89 days, respectively.
- In cowpea and brinjal, deposits of 0.94 mg kg $^{-1}$ and 0.58 mg kg^{-1} spinosad respectivelywere recorded two hours after spraying of the insecticide @ 75g a.i ha^{-1}. A higher deposit was noted in okra (1.73 mgkg^{-1}). While the residues became non detectable from the seventh day on cowpea, it went below detectable

level on the tenth day in brinjal and okra. On cowpea, the naturalyte had only a half life of 0.92 days and a short waiting period of 1.09 days. The half life of the insecticide was 1.35 and 1.03 days and waiting periods zero and 7.93 days in brinjal and okra, respectively.

- In the case of novaluron applied @ 100 g ai ha $^{-1}$, the initial residues detected on cowpea, brinjal and okra two hours after spraying were 2.72, 1.21 and 1.30 mg kg $^{-1}$, respectively. The residues reached below detectable level on the fifteenth day of spraying in cowpea and brinjal. However, in okra the residues went below detectable level on the tenth day. The half life of the insecticide was 1.66, 2.39 and 2.24 days for cowpea, brinjal and okra, respectively. Among the different insecticide molecules studied in the present investigation, novaluron had the longest waiting period,being 13.76, 17.10 and 16.03 days in cowpea, brinjal and okra respectively.

- The fruits of cowpea, brinjal and okra collected two hours after spraying chlorantraniliprole @ 30 g ai ha $^{-1}$had 0.56, 0.72 and 0.48 mg kg $^{-1}$ residues of the insecticide respectively which declined below detectable level from the tenth day. A half life of 1.31 and 1.63 day was calculated for cowpea and brinjal, respectively and 2.21 days for okra. Chlorantraniliprole was noted to have the shortest waiting period of 0.62, 0.61 and zero day for cowpea, brinjal and okra respectively indicating its safety to the vegetables.

- Initial deposits of 0.56, 0.28 and 1.08 mg kg $^{-1}$of indoxacarb residues were recorded on cowpea, okra and brinjal, respectively,two hours after spraying. The residues reached below detectable level on the seventh day in cowpea, fifteenth day in brinjal and tenth day in okra. The half life was 1.08, 2.42 and 1.13 days and the waiting periods 5.33, 0and 1.53days, respectively.

- Initial deposits of 1.12, 0.78 and 0.57 mg kg $^{-1}$ of fipronil residues were recorded on cowpea, okra and brinjal fruits, respectively on the day of spraying. On the tenth day, the residues were below detectable level in cowpea and brinjal whereas in okra no residues were detected on the seventh day itself. The half-life of fipronil was 1.08, 1.83 and 1.07 day in cowpea, brinjal and okra respectivelywhile the waiting periods were 8.09 and 8.08 days for cowpea and okra respectively and 13.19 days for brinjal.

- Higher deposits of thiodicarb residues were detected on cowpea (4.13 mgkg $^{-1}$), brinjal (5.07 mg kg $^{-1}$)and okra (2.71 mg kg $^{-1}$) fruits, compared to the other insecticides at two hours after spraying. The residues declined to below detectable levels on fifth and seventh day of spraying in cowpea and okra, respectively whereas in brinjal the residues remained up to the fifteenth day. The half life of the insecticide was 0.50, 1.81, and 0.89 days in cowpea, brinjal and okra, respectively. While a short waiting period of 5.10 and 2.24 days was seen in cowpea and okra, respectively, a longer waiting period of 9.88 days was registered for brinjal.
- An initial deposit of 1.14, 0.79 and 1.21 mg kg^{-1} of flubendiamide was recorded on cowpea, brinjal and okra fruits respectivelyon the day of spraying. The residues were below detectable level for cowpea and brinjal on the fifteenth day whereas for okra residues remained up to the tenth day. The half life of flubendiamide was around 1.95, 2.72 and 2.18 days in cowpea, brinjal and okra, respectively. Short waiting periods of 2.55 and 5.58 days were calculated for cowpea and brinjal, respectively. Contrarily, the waiting period was 12.48 days in okra.
- In the conventional insecticide carbaryl, the initial residue deposits were high on fruits of cowpea, brinjal and okra when estimated two hours after spraying, the quantity detected being 4.69, 5.32 and 5.21 mg kg^{-1}respectively. The residues dissipated below detectable level on the fifteenth, twentieth and tenth day of spraying in cowpea, brinjal and okra, respectively. The half-life of carbaryl on cowpea, brinjal and okra was 1.53, 1.29 and 1.84 days, respectively. The waiting periods were 2.83 and 12.87 days for cowpea and okra, respectively. For brinjal the waiting period was 9.40 days.
- In the fruits of cowpea, brinjal and okra, the deposit of malathion residues were 2.91, 2.45 and 1.34 mg kg^{-1} respectively two hours after spraying which reached below detectable levels on the fifth day in cowpea and okra and fifteenth day in

brinjal. The half life on cowpea was 0.54 days. The waiting period was calculated as 6.65 days. The half life of the insecticide was 1.46 and 0.50 days for brinjal and okra, respectively. The waiting periods were 10.70 and 3.25 days for brinjal and okra, respectively.

- The insecticide sprayed vegetables processed by either one of the decontaminating methods *viz.*, dipping in common salt 2%, tamarind 2%, vinegar 2%, slaked lime 2%, baking soda 2%, or turmeric 1% solutions, steaming, scrubbing or simple washing removed the residues of the new generation insecticides significantly. The extent of removal of the new generation insecticides from the vegetables harvested two hours after spraying ranged from 34.49 to 100, 8.66 to 100 and 18.65 to 98.36 per cent from cowpea, brinjal and okra, respectively. The dislodging of the residues on fruits harvested on the third day ranged from 10.33 to 100, 61.87 to 100 and 19.91 to 100 per cent, respectively. The degree of elimination of the conventional insecticides ranged from 17.35 to 90.69, 38.45 to 96.55 and 21.30 to 81.62 per cent in the respective crops collected two hours after spraying and from18.89 to 97.85, 66.09 to 100 and 39.79 to 100 per cent, respectively on the third day.
- The efficient decontamination techniques which could remove an appreciable load (more than 60 per cent)of the insecticides residues varied in the three vegetables. Tamarind 2% and slaked lime 2% solutions, steaming and scrubbing were the effective treatments for removing emamectin benzoate residues in cowpea two hours after spraying. Baking soda 2%, water wash, salt 2% and slaked lime 2% were the effective treatments for brinjal and okra. At three days after spraying, all the treatments were equally effective for cowpea, brinjal and okra.
- Spinosad residues could be removed very effectively from cowpea and okra two hours after spraying by steaming, slaked lime 2%, turmeric 1% and tamarind 2% solutions and scrubbing. Washing in water, dipping in baking soda 2%, common salt 2% and turmeric 1% reduced the residues on brinjal. Steaming proved better for removing residues seen three days after spraying in cowpea, whereas all the treatments were effective in eliminating spinosad residues from brinjal. With the

exception of baking soda 2% and steaming, all the other treatments were effective in okra.

- In the case of novaluron steaming, slaked lime 2 % and scrubbing were the effective treatments for removing residues in cowpea two hours after spraying whereas baking soda 2 %, scrubbing and slaked lime 2 % were more effective for brinjal and slaked lime 2 %, scrubbing and vinegar 2% for okra. The extent of removal of residues seen three days after spraying was high when cowpea pods were steamed and on treatment with slaked lime 2 % solution and scrubbing. Baking soda 2%, scrubbing, vinegar 2% and slaked lime 2 % were the desirable treatments for brinjal. Scrubbing and slaked lime 2% were the effective treatments for okra.

- As regards the chlorantraniliprole residues, scrubbing, slaked lime 2%, vinegar 2% and turmeric 1% removed appreciable quantity from cowpea two hours after spraying. Slaked lime 2% and common salt 2% were the effective treatments for brinjal and vinegar 2%, slaked lime 2%, turmeric 1% and scrubbing for okra. At three days after spraying, the extent of removal in cowpea was high on steaming and processing in slaked lime 2% and turmeric 1% solutions. All the decontamination techniques removed the residues significantly from brinjal while slaked lime 2% and turmeric 1 % solutions and scrubbing were more effective for okra.

- The extent of removal of indoxacarb residues from cowpea was high when treated with slaked lime 2%, turmeric 1% and scrubbing. Baking soda 2% , washing, tamarind 2% and scrubbing proved their efficiency in brinjal whereas slaked lime 2% and turmeric 1% were effective for okra. On the third day, the extent of removal was high when cowpea fruits were scrubbed, steamed and treated with turmeric 1% solution. Vinegar 2%, baking soda 2%, washing and scrubbing were effective for brinjal and turmeric 1 % scrubbing, vinegar 2% and tamarind 2% for okra.

- In the case of fipronil, the extent of removal of fipronil residues was more by steaming, and dipping in turmeric 1% and slaked lime 2% solutions in cowpea two hours after spraying. Processing in baking soda 2%, salt 2 %, and turmeric 1 %solutions and scrubbing were the desirable options for brinjal while turmeric 1%, slaked lime 2% and tamarind 2% solutions were better for okra. Three days after spraying, scrubbing and steaming proved their efficacy in cowpea whereasvinegar 2%, baking soda, and washing were more effective in dislodging fipronil residues from brinjal and steaming, vinegar 2% and scrubbing from okra.

- All the treatments were found effective in removing residues of thiodicarb both two hours and three days after spraying in the three vegetables.
- Flubendiamide residues were removed effectively by vinegar 2%, turmeric 1% and slaked lime 2% solutions effectively removed from cowpea two hours after spraying.Baking soda 2%, salt 2 % and scrubbing were the effective treatments for brinjal fruits and turmeric 1% and slaked lime 2% for okra.Scrubbing and turmeric 1% in cowpea, baking soda 2%, scrubbing, vinegar 2% and slaked lime 2% in brinjal and tamarind 2% ,vinegar 2%,turmeric 1% and scrubbing in okra were superior in removing flubendiamide residues after three days of spraying.
- Carbaryl residues were removed by dipping insecticide treated fruits in vinegar 2%, slaked lime 2%, and turmeric 1 % from cowpea two hours after spraying.Washing, turmeric 1 % and scrubbing were the superior processing methods for brinjal and scrubbing for okra. However, on the third day, steaming was more effective for cowpea and okra. Mere washing, baking soda 2%, steaming and vinegar 2% removed carbaryl residues in brinjal.
- Malathion residues were effectively eliminated by steaming, processing in slaked lime 2% and tamarind 2% solutions from cowpea pods two hours after spraying while tamarind 2%, turmeric1%, salt 2 % and vinegar 2% solutions and plain washing were effective for brinjal and turmeric1%, slaked lime 2% and tamarind 2%, for okra. Tamarind 2 % and vinegar 2% solutionswere effective for the removal of residues of malathion from cowpea three days after spraying while all the processing methods were effective for brinjal and okra.

- Overall analysis of the efficacy of the decontaminating techniques indicated that immersing insecticide treated fruits in slaked lime 2%, turmeric 1 %, vinegar 2% or tamarind 2% solution for twenty minutes followed by washing in water and scrubbing which removed more than 60 per cent residues of most of the new insecticides generation were the better options.

Considering the overall efficacy of the insecticides against the pests, associated yield increase, benefit cost ratio, waiting period and compatibility with bio agents, chlorantraniliprole18.5 SC@30 g a.i. ha^{-1}, indoxacarb14.5 SC @60 g a.i. ha^{-1} and emamectin benzoate 5SG@10 ga.i. ha^{-1} were adjudged as the promising insecticides against the fruit borers of cowpea, brinjal and okra.

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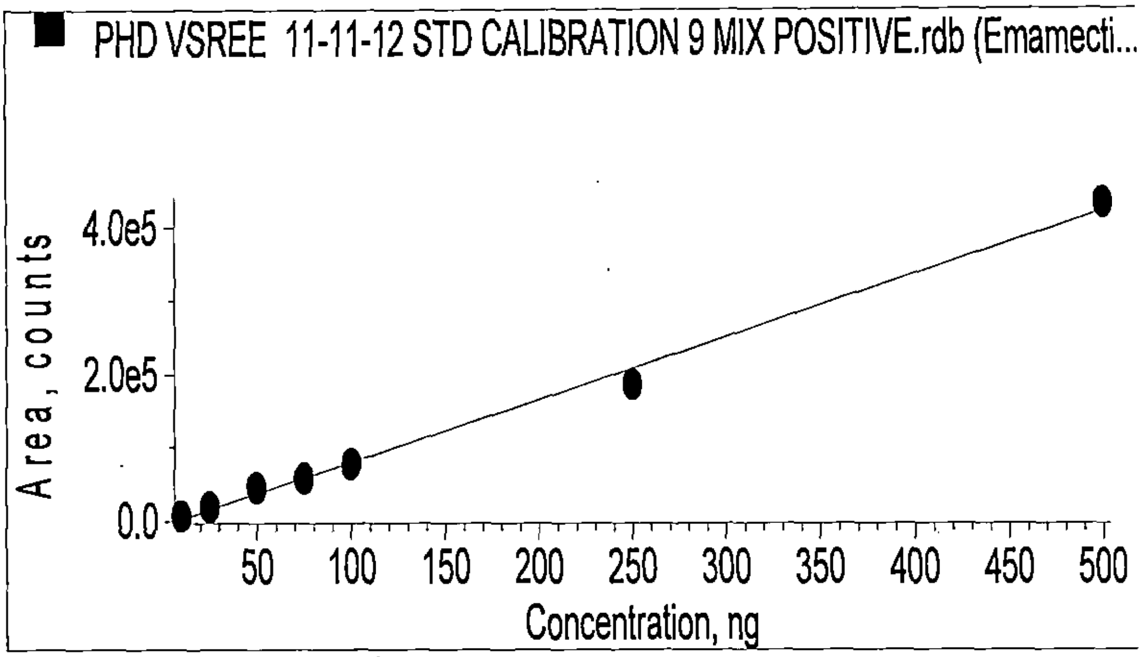
* Orginals not seen.

Appendix Ia



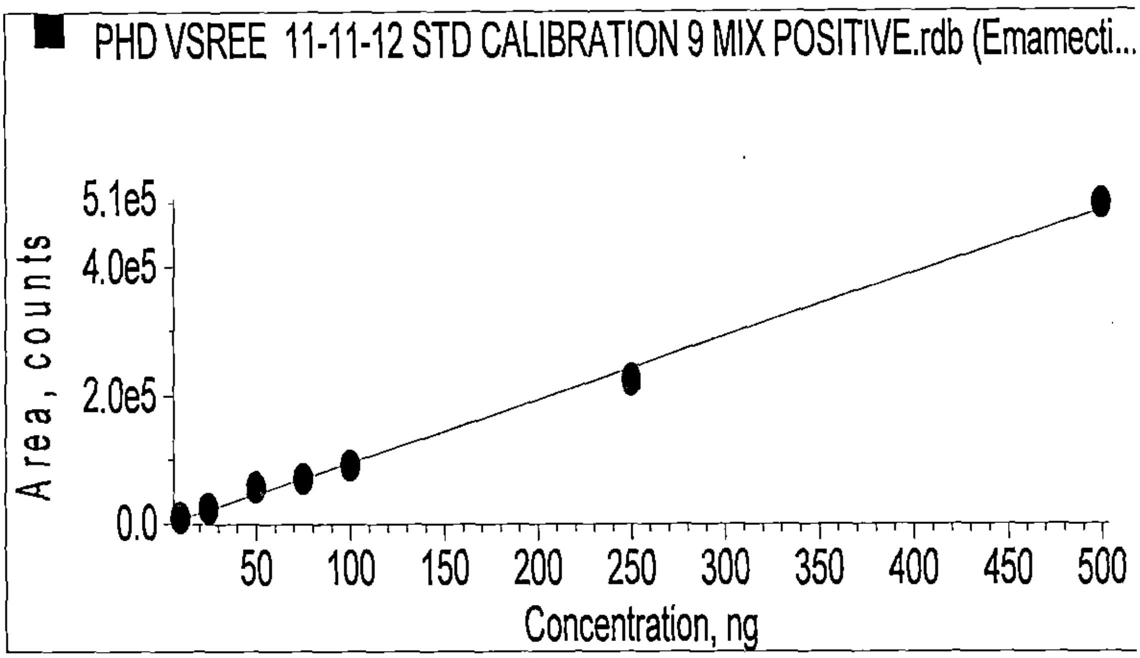
$Y = aX + b$
$a = 827$
$b = -1.46\ e^3$
$R = 0.9968$

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	6.72E+03
2	25	1.97E+04
3	50	4.55E+04
4	75	5.74E+04
5	100	7.72E+04
6	250	1.86E+05
7	500	4.33E+05

Calibration curve of Emamectin B1b1

Appendix Ib



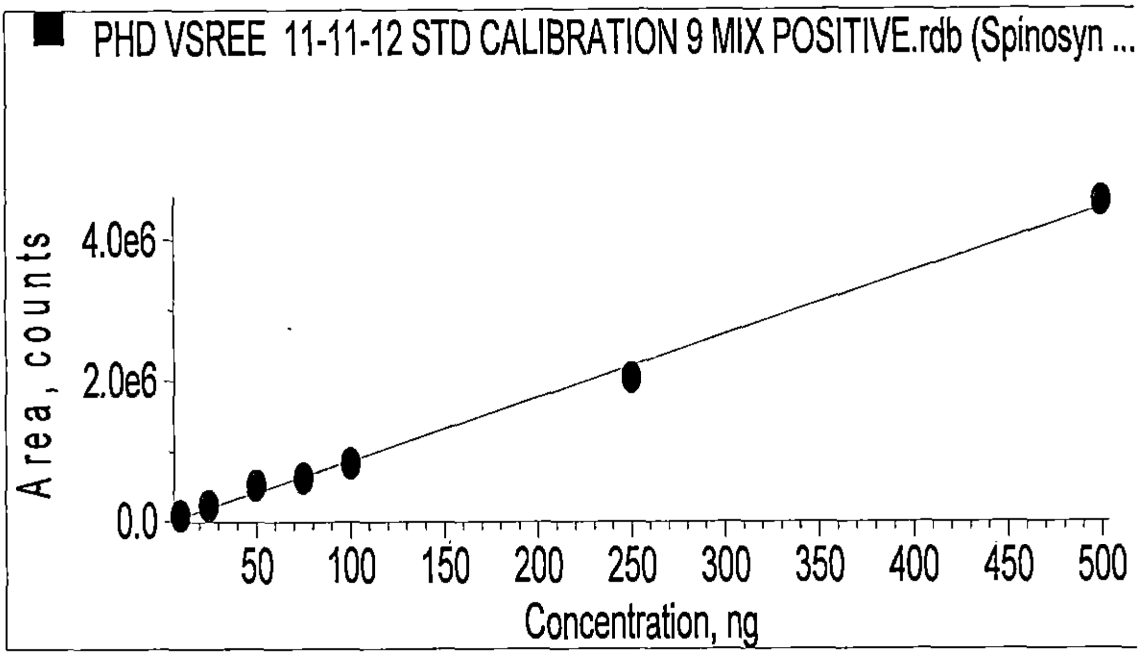
Y = aX + b
a = 959
b = -530
R = 0.9974

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	8.76E+03
2	25	2.30E+04
3	50	5.59E+04
4	75	6.90E+04
5	100	8.97E+04
6	250	2.23E+05
7	500	4.96E+05

Calibration curve of Emamectin B1A1

Appendix IIa



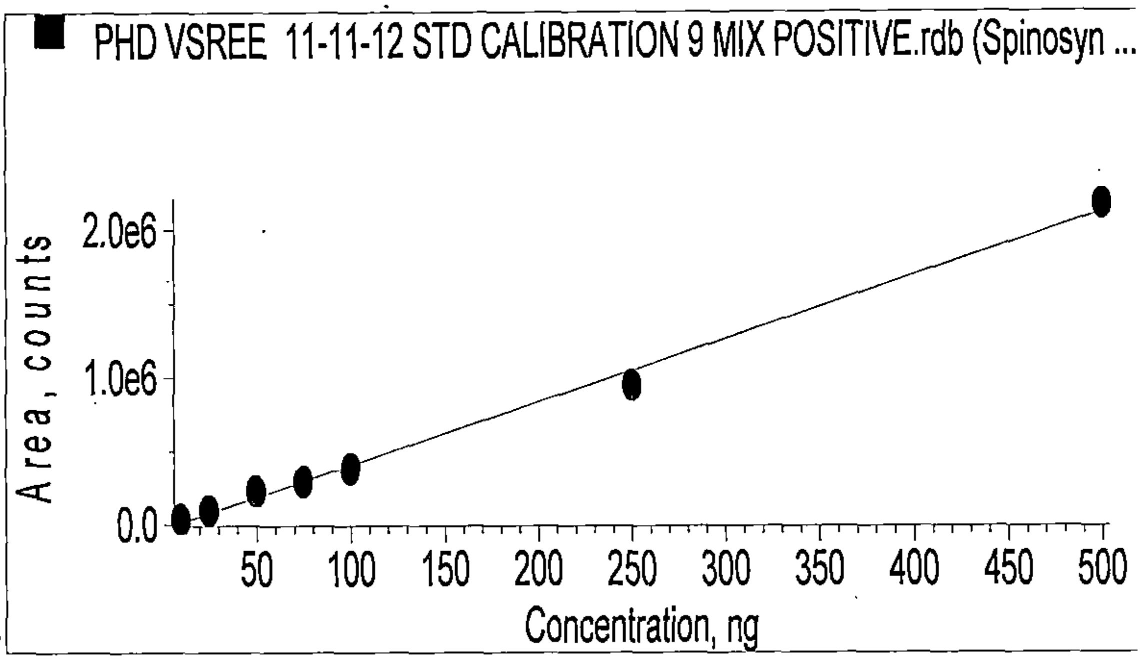
Y = aX + b
a = 4.14 e^3
b = -4.5 e^4
R = 0.9970

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	8.30E+04
2	25	2.22E+05
3	50	5.06E+05
4	75	6.08E+05
5	100	8.14E+05
6	250	2.03E+06
7	500	4.53E+06

Calibration curve of Spinosyn D

Appendix IIb



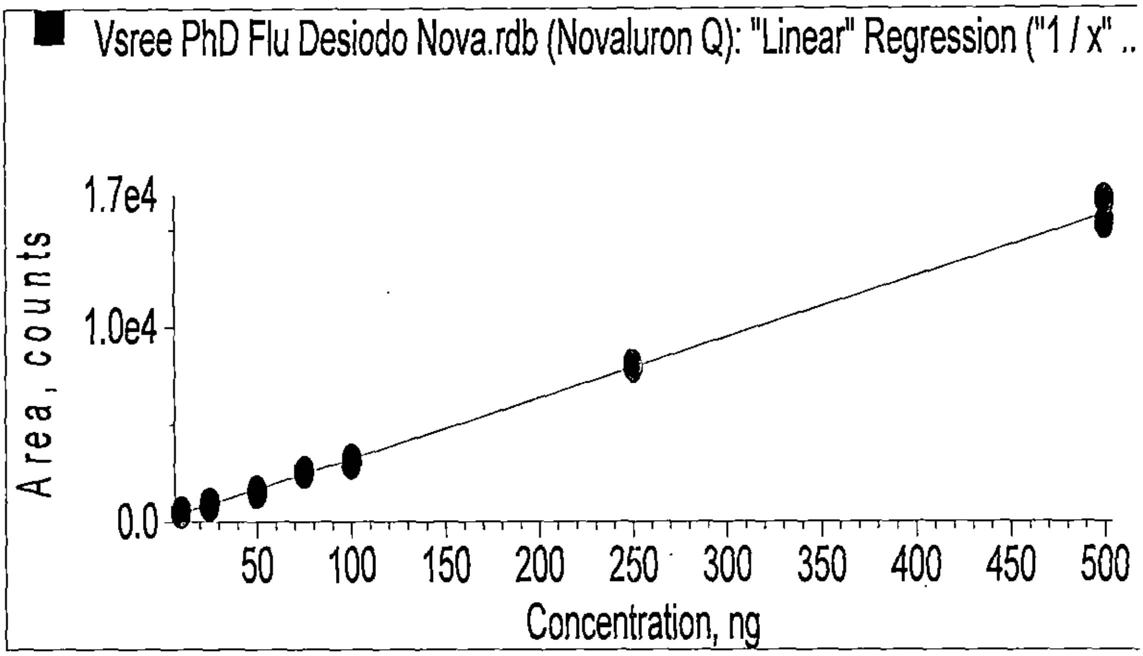
Y = aX + b
a = 8.7 e^3
b = -1.47 e^3
R = 0.9973

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	3.79E+04
2	25	9.90E+04
3	50	2.30E+05
4	75	2.92E+05
5	100	3.80E+05
6	250	9.43E+05
7	500	2.17E+06

Calibration curve of Spinosyn A

Appendix III



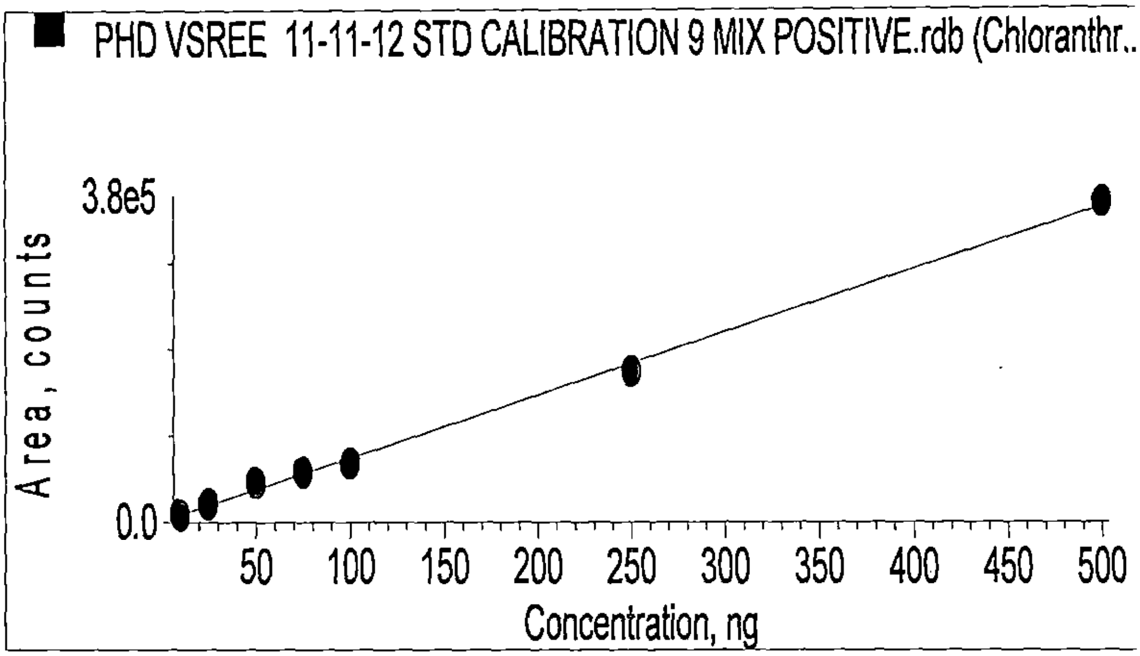
Y = aX + b
a = 31.2
b = 108
R = 0.9986

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	4.42E+01
2	25	7.93E+01
3	50	1.45E+02
4	75	2.06E+02
5	100	2.39E+02
6	250	6.39E+02
7	500	1.11E+03

Calibration curve of Novaluron

Appendix IV



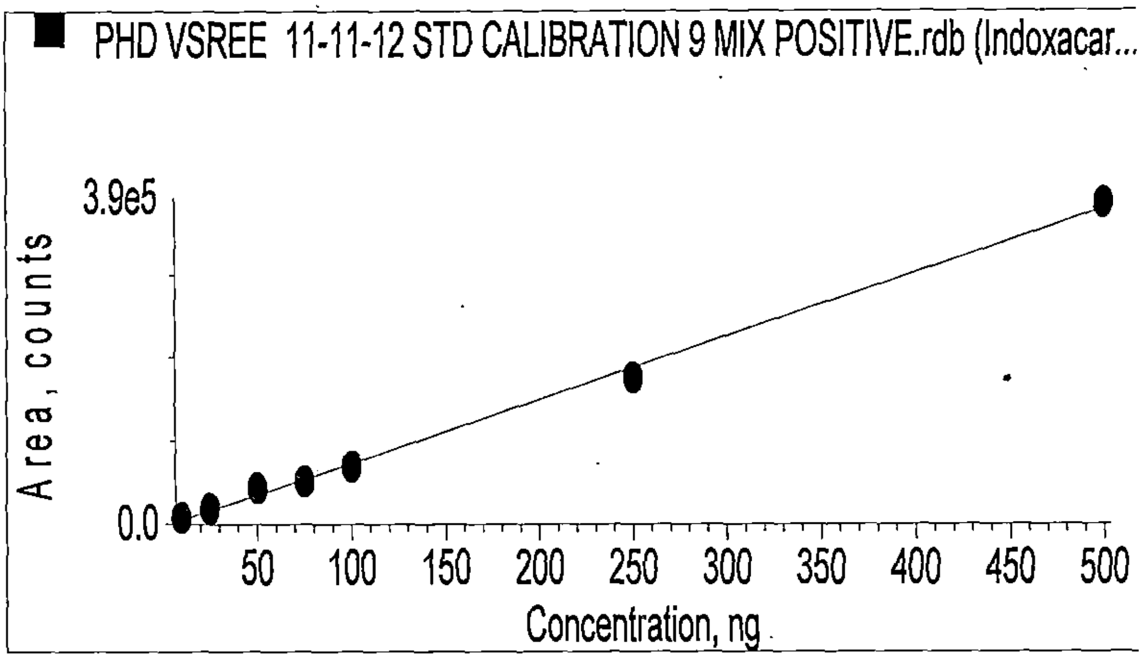
Y = aX + b
a = 667
b = 2.19 e^3
R = 0.9966

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	8.42E+03
2	25	2.06E+04
3	50	4.54E+04
4	75	5.76E+04
5	100	6.81E+04
6	250	1.74E+05
7	500	3.71E+05

Calibration curve of Chloranthranilíprole

Appendix V



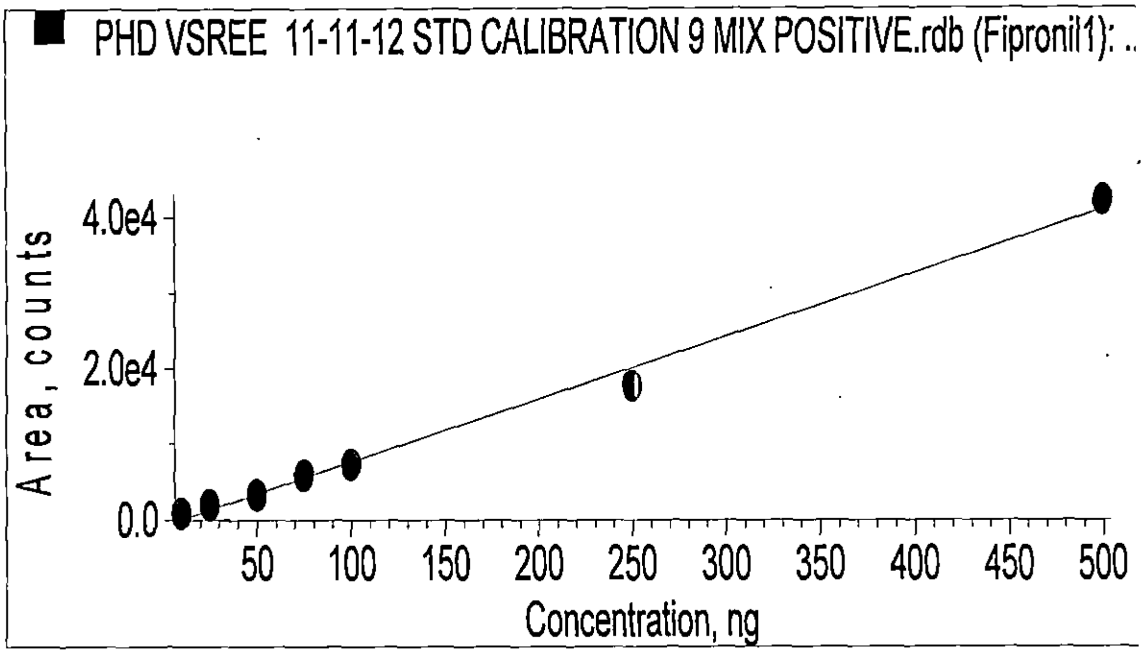
Y = aX + b
a = 743
b = -560
R = 0.9975

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	6.96E+03
2	25	1.79E+04
3	50	4.26E+04
4	75	5.07E+04
5	100	6.86E+04
6	250	1.75E+05
7	500	3.85E+05

Calibration curve of Indoxacarb

Appendix VI



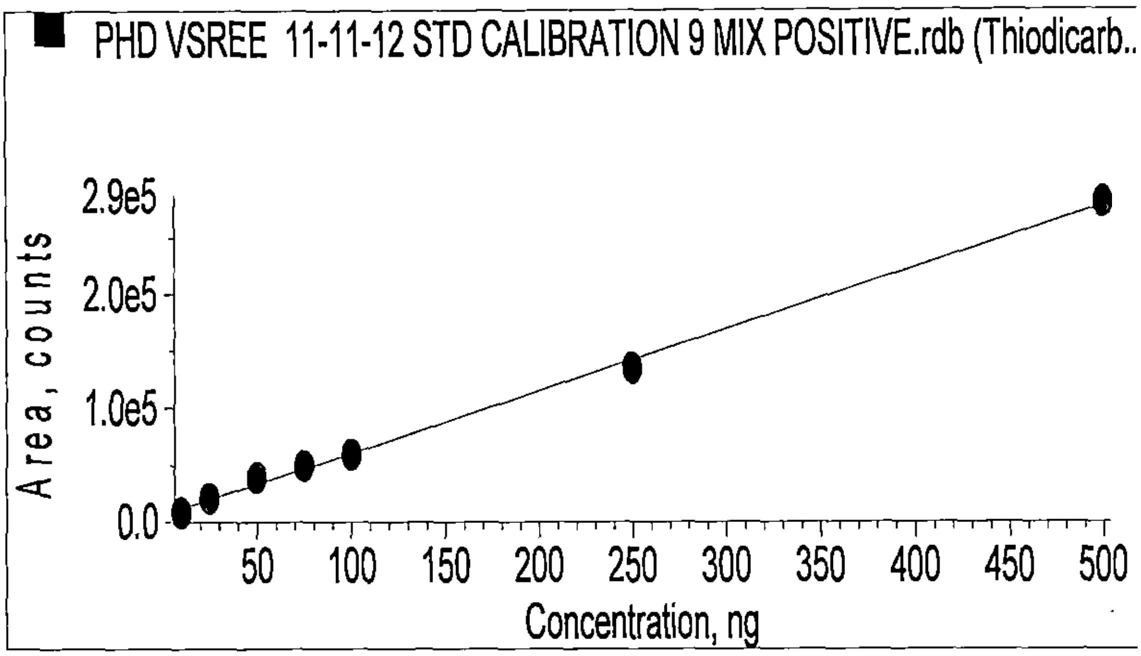
Y = aX + B
a = 78.8
b = 69.8
R = 0.9952

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	8.87E+02
2	25	1.97E+03
3	50	3.25E+03
4	75	5.84E+03
5	100	7.27E+03
6	250	1.77E+04
7	500	4.22E+04

Calibration curve of Fipronil

Appendix VII



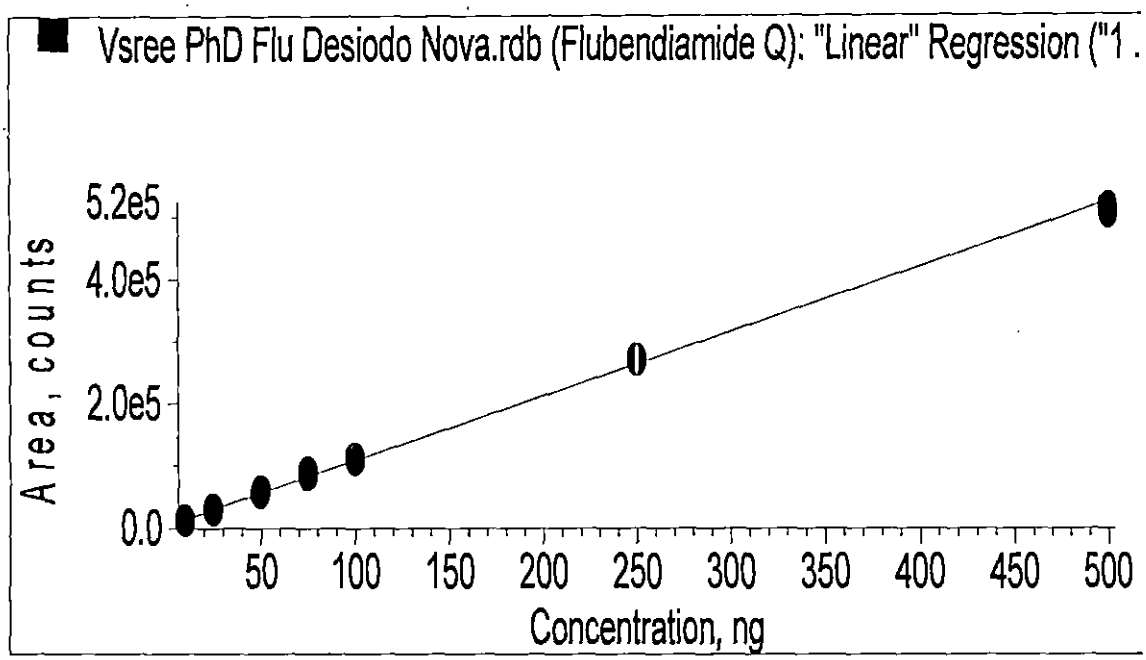
$Y = aX + b$
$a = 554$
$b = 4.9\ e^4$
$R = 0.9956$

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	8.22E+03
2	25	2.08E+04
3	50	3.93E+04
4	75	5.00E+04
5	100	5.96E+04
6	250	1.35E+05
7	500	2.81E+05

Calibration curve of Thiodicarb

Appendix VIIIa



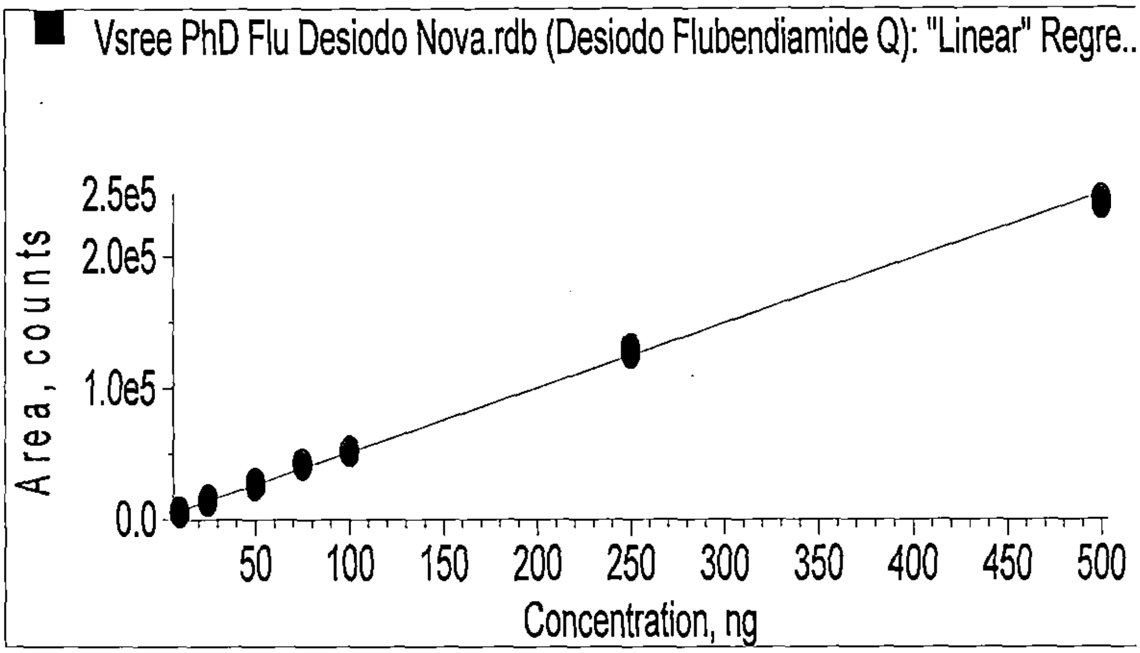
Y = aX + b
a = 1.04 e^3
b = 2.75 e^4
R = 0.9990

External Standard
Curve fit type : Linear
Origin : Not Forced
Weighing : 1/x

Level	Conc. (ppb)	Area
1	10	1.11E+03
2	25	2.67E+03
3	50	5.21E+03
4	75	7.44E+03
5	100	9.52E+03
6	250	2.13E+04
7	500	3.74E+04

Calibration curve of Flubediamide

Appendix VIIIb



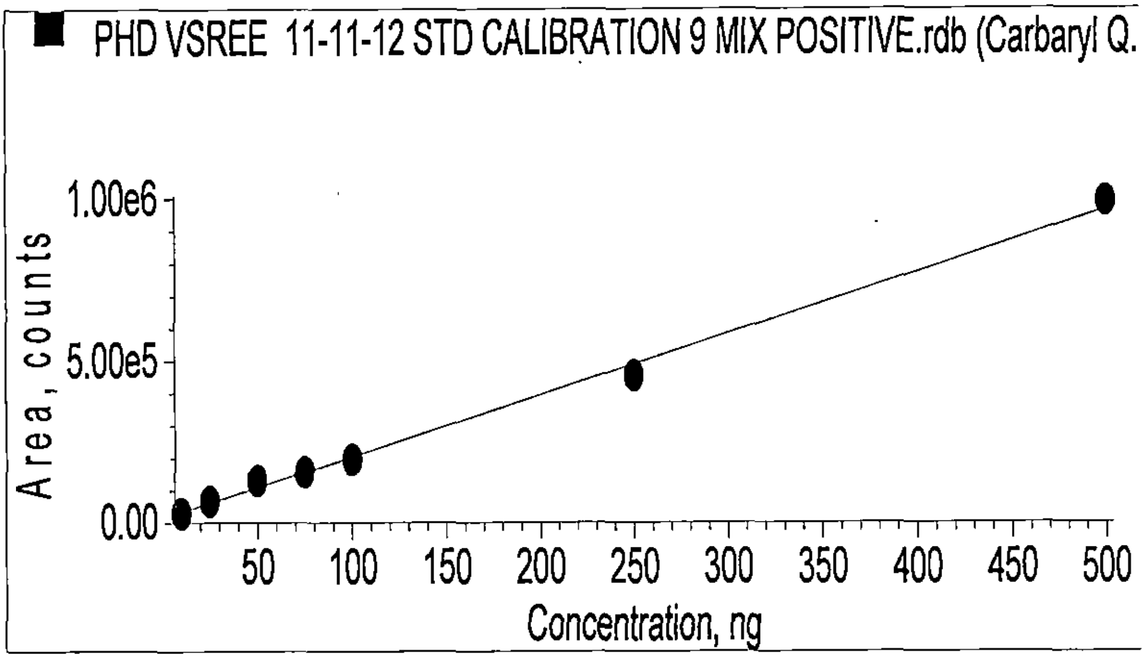
Y = aX + b
a = 493
b = 1.9 e^3
R = 0.9988

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	5.13E+02
2	25	1.29E+03
3	50	2.49E+03
4	75	3.73E+03
5	100	4.32E+03
6	250	1.04E+04
7	500	1.82E+04

Calibration curve of Desido flibendiamide

Appendix -IX



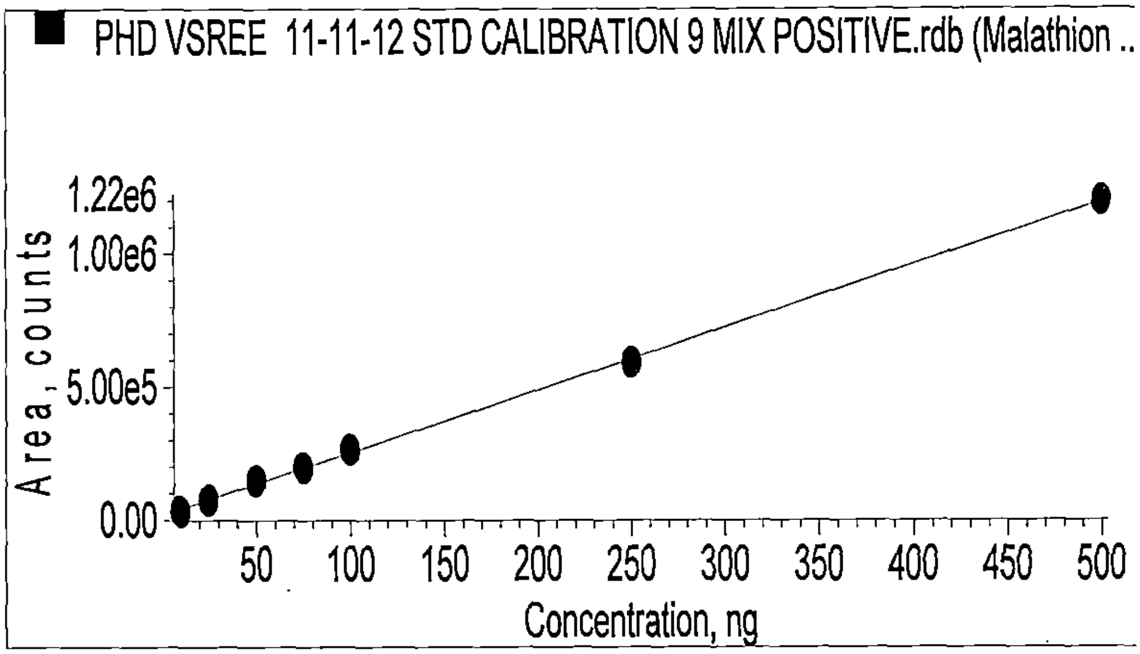
Y = aX + b
a = 1.9 e^3
b = 1.37 e^4
R = 0.9966

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area (Counts)
1	10	2.87E+04
2	25	6.59E+04
3	50	1.29E+05
4	75	1.56E+05
5	100	1.95E+05
6	250	4.52E+05
7	500	9.90E+05

Calibration curve of Carbaryl

Appendix Xa



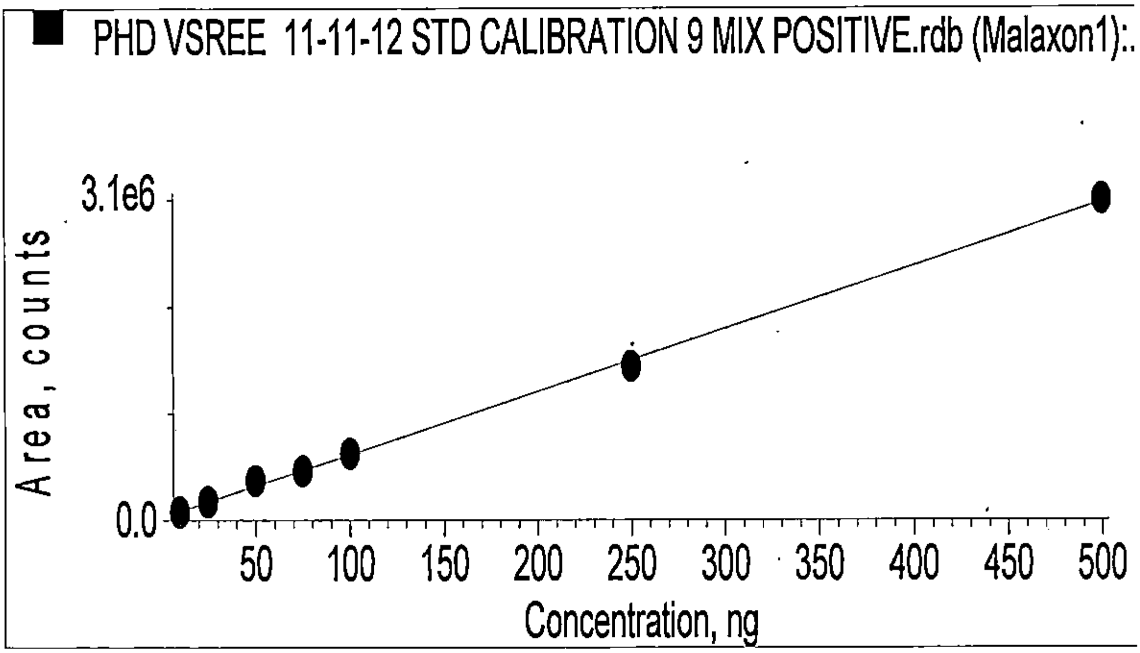
Y = aX + b
a = 2.39 e^3
b = 1.32 e^4
R = 0.9989

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

Level	Conc. (ppb)	Area
1	10	3.28E+04
2	25	7.46E+04
3	50	1.47E+05
4	75	1.97E+05
5	100	2.64E+05
6	250	5.93E+05
7	500	1.20E+06

Calibration curve of Malathion

Appendix –Xb



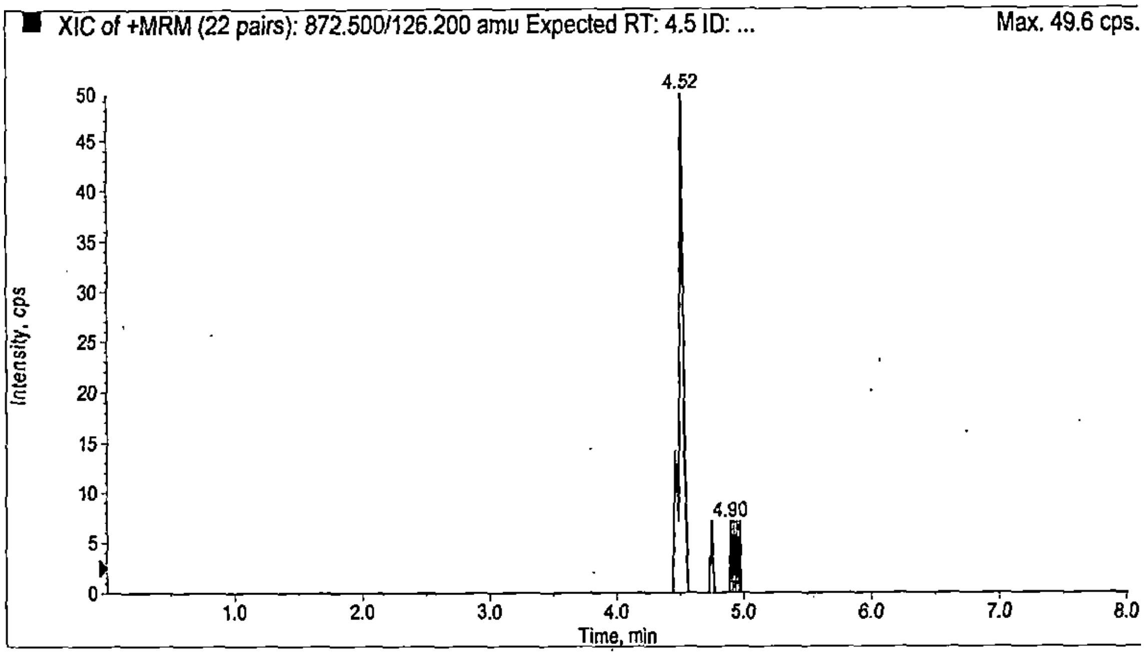
Y = aX + b
a = 5.92 e^3
b = 2.19 e^4
R = 0.9985

External Standard
Curve fit type: Linear
Origin: Not Forced
Weighing: 1/x

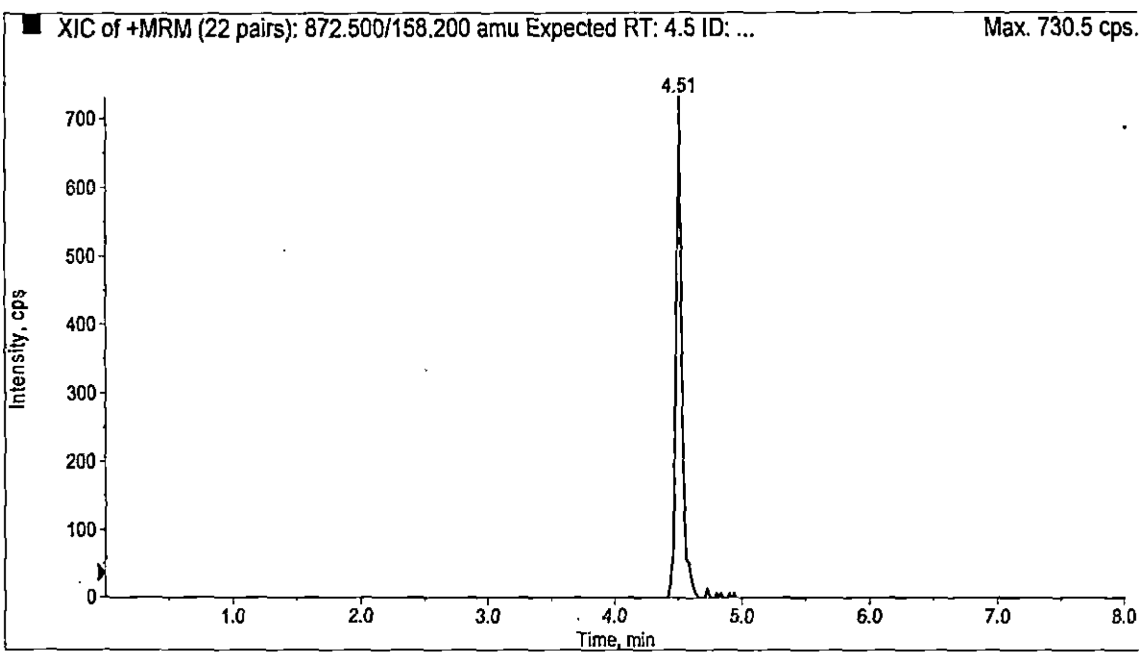
Level	Conc. (ppb)	Area
1	10	7.34E+04
2	25	1.69E+05
3	50	3.69E+05
4	75	4.59E+05
5	100	6.24E+05
6	250	1.44E+06
7	500	3.00E+06

Calibration curve of Malaoxon

Appendix XIa

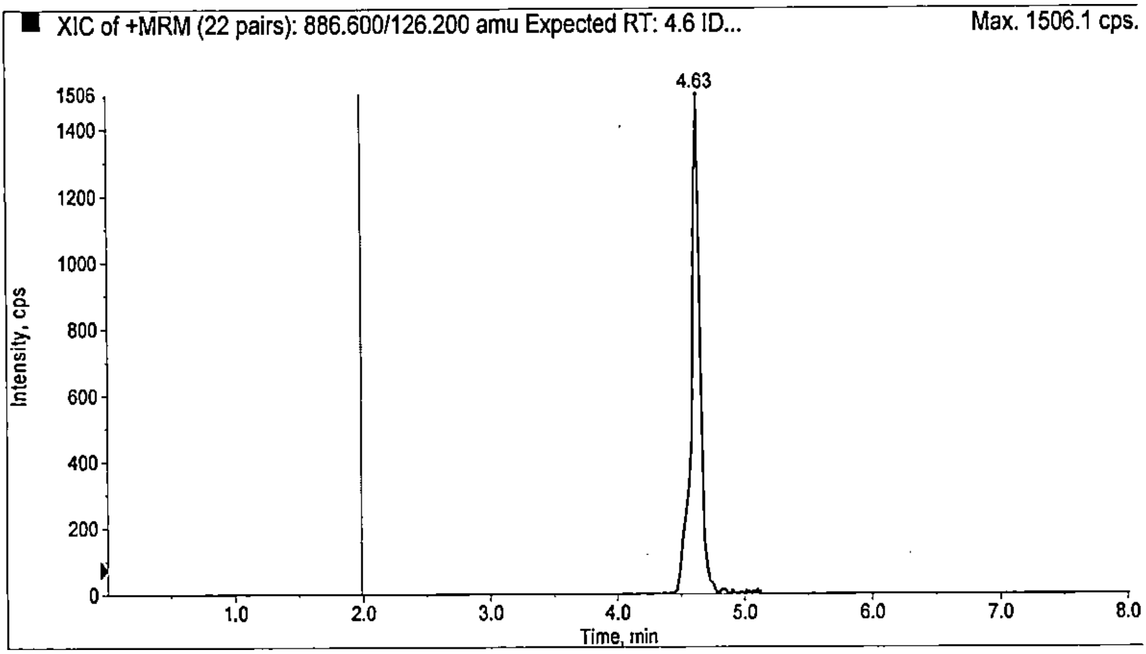


Chromatogram. 11aa. LC-MS/MS Chromatogram of emamectinB1b1 0.01ppm (Quantitative ion)

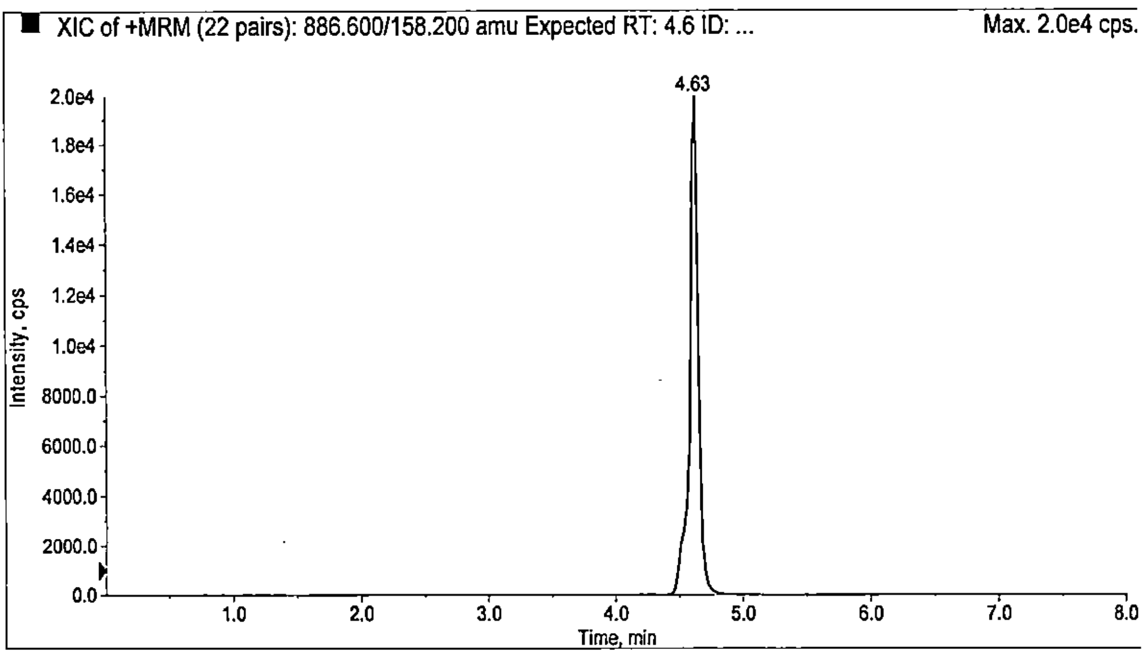


Chromatogram. 11ab. LC-MS/MS Chromatogram of emamectinB1b1 0.01ppm (Qualitative ion)

Appendix XIb

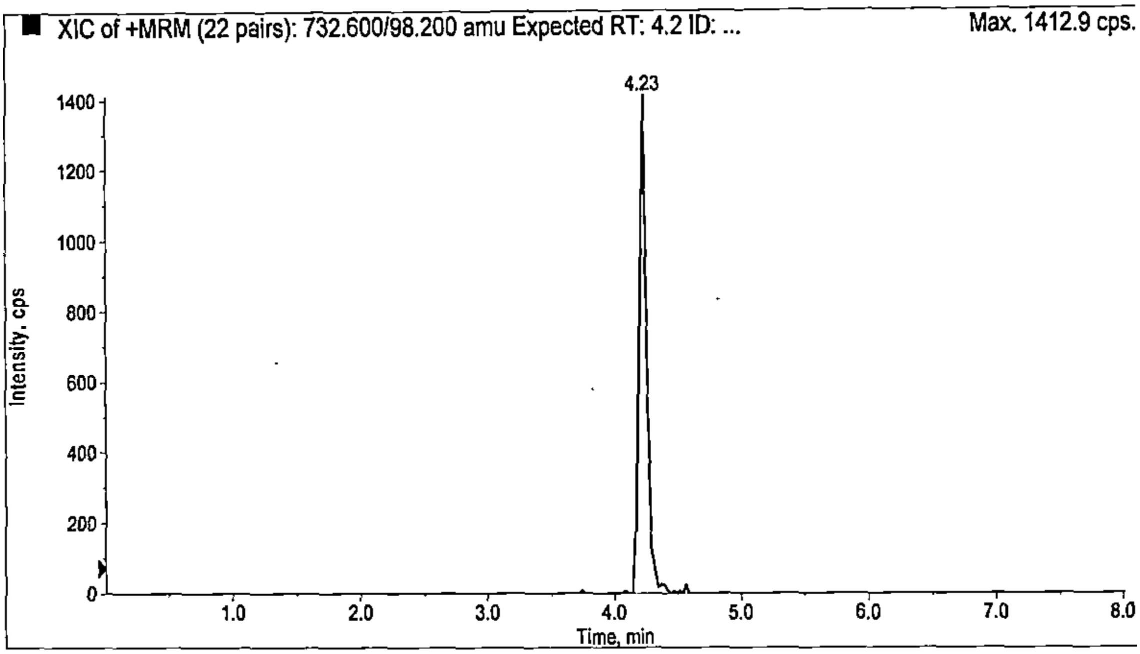


Chromatogram. 11ba. LC-MS/MS Chromatogram of emamectinB1a1 0.01ppm (Quantitative ion)

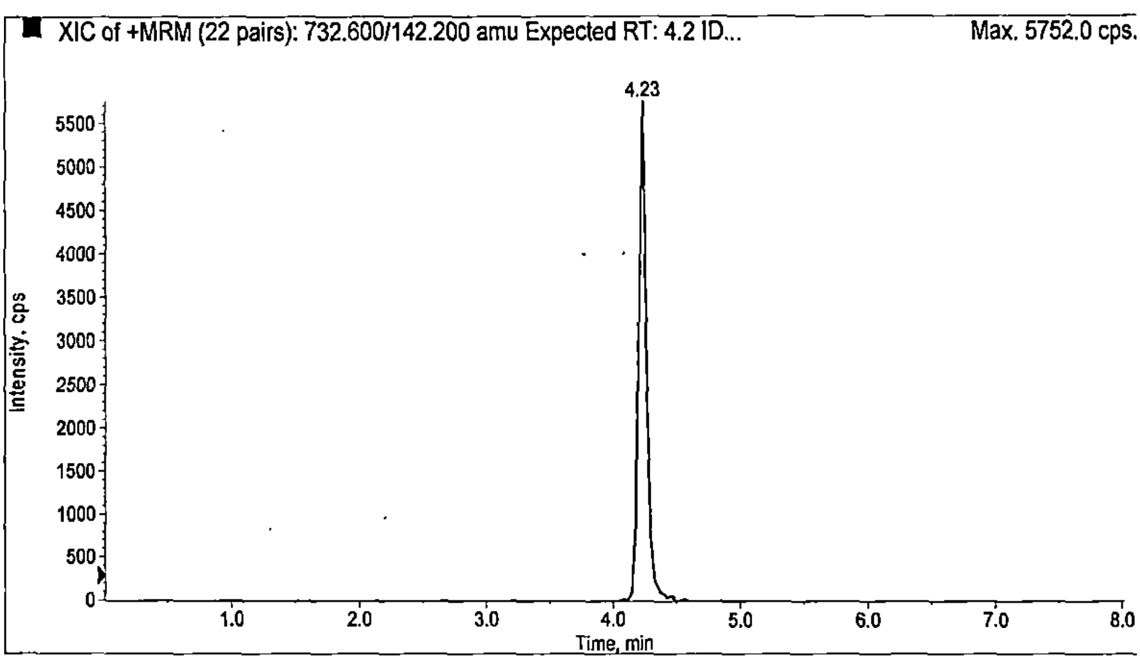


Chromatogram. 11bb. LC-MS/MS Chromatogram of emamectinB1a1 0.01ppm (Qualitative ion)

Appendix XIIa

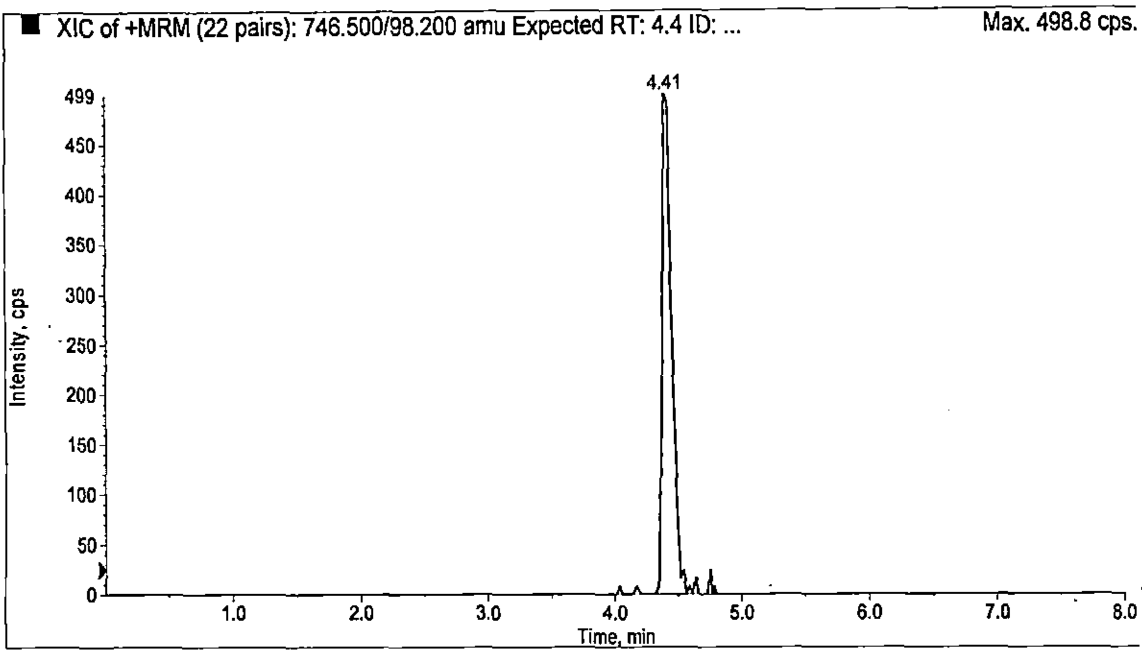


Chromatogram. 12aa. LC-MS/MS Chromatogram of spinosyn A 0.01ppm (Quantitative ion)

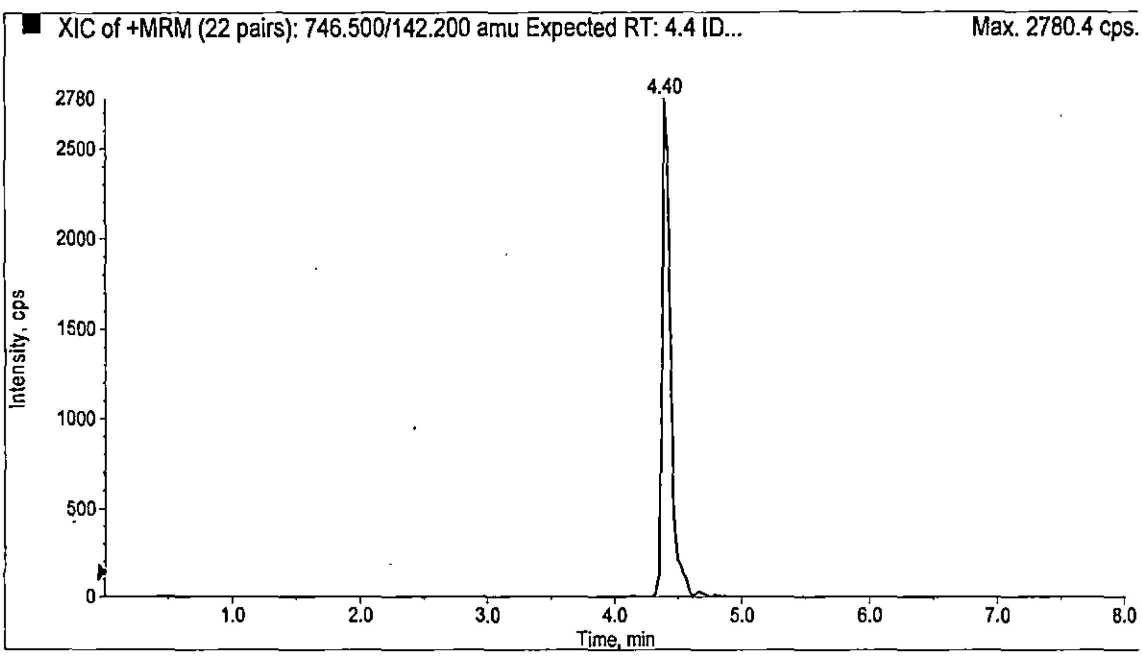


Chromatogram. 12ab. LC-MS/MS Chromatogram of spinosyn A 0.01ppm (Qualitative ion)

Appendix XIIb

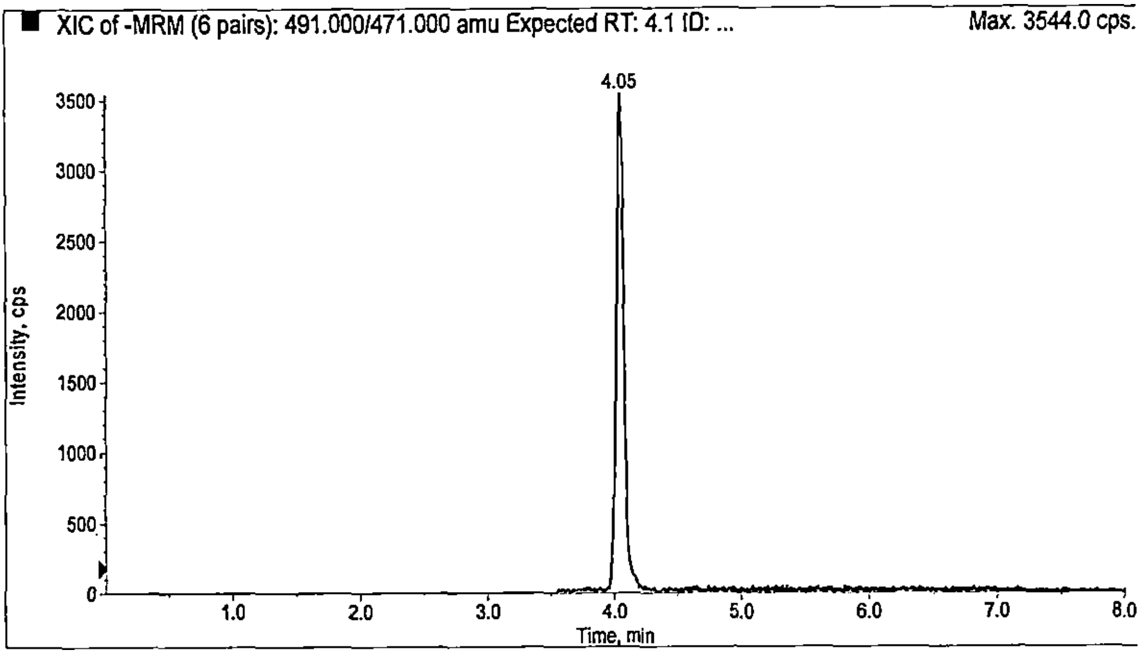


Chromatogram. 12ba. LC-MS/MS Chromatogram of spinosyn D 0.01ppm (Quantitative ion)

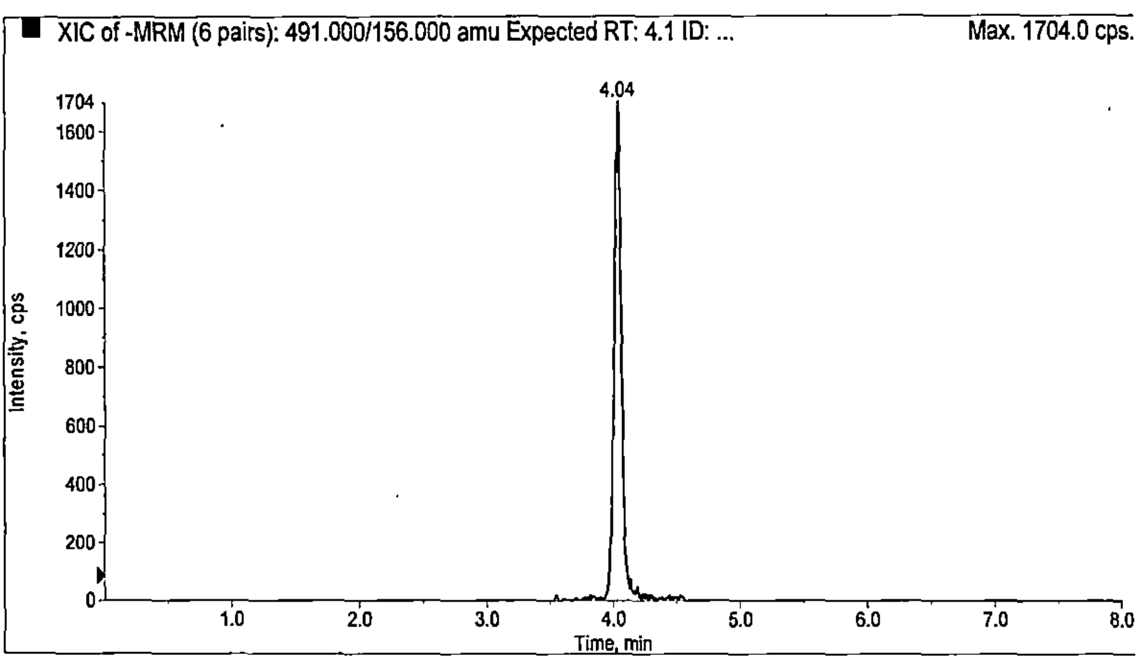


Chromatogram. 12bsb. LC-MS/MS Chromatogram of spinosyn D 0.01ppm (Qualitative ion)

Appendix XIII

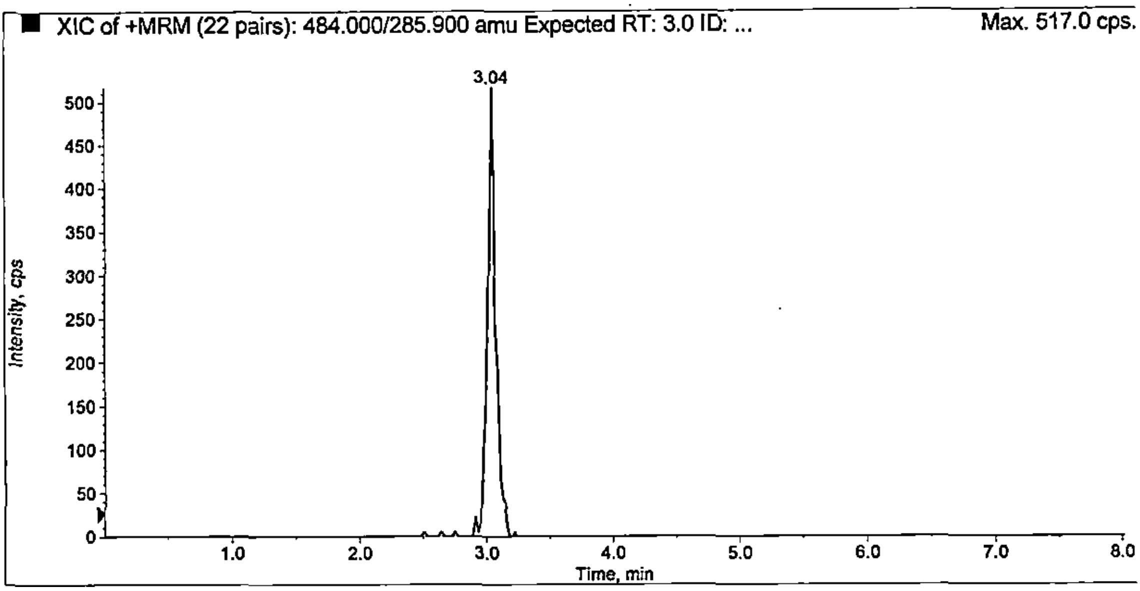


Chromatogram. 13a. LC-MS/MS Chromatogram of novaluron 0.01ppm (Quantitative ion)

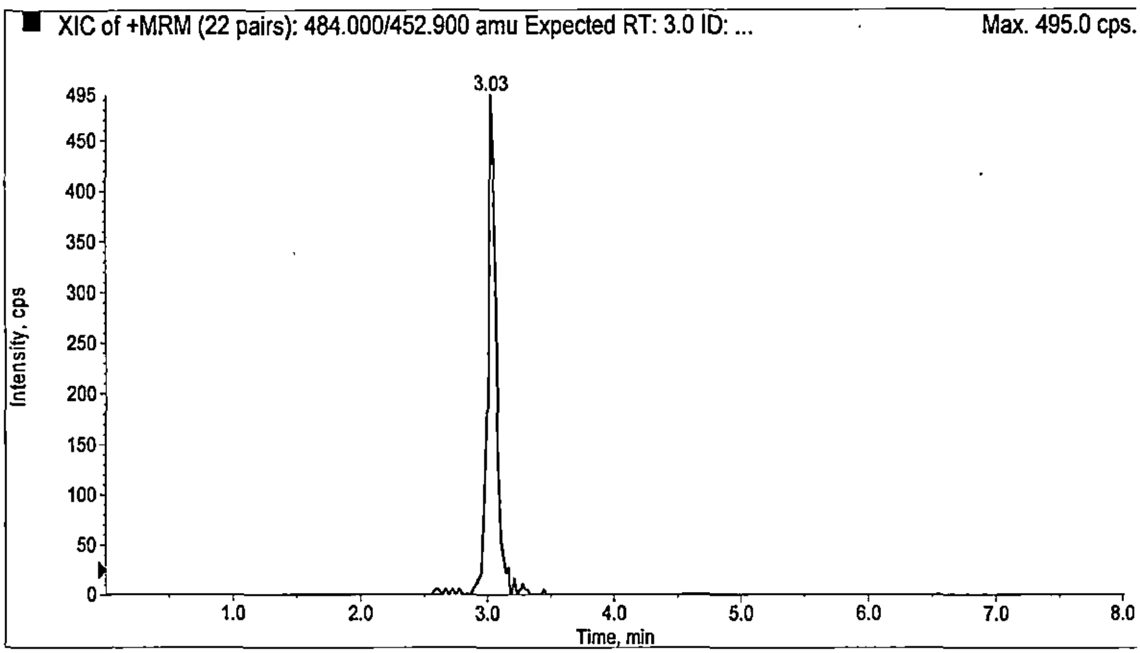


Chromatogram. 13b. LC-MS/MS Chromatogram of novaluron 0.01ppm (Qualitative ion)

Appendix XIV

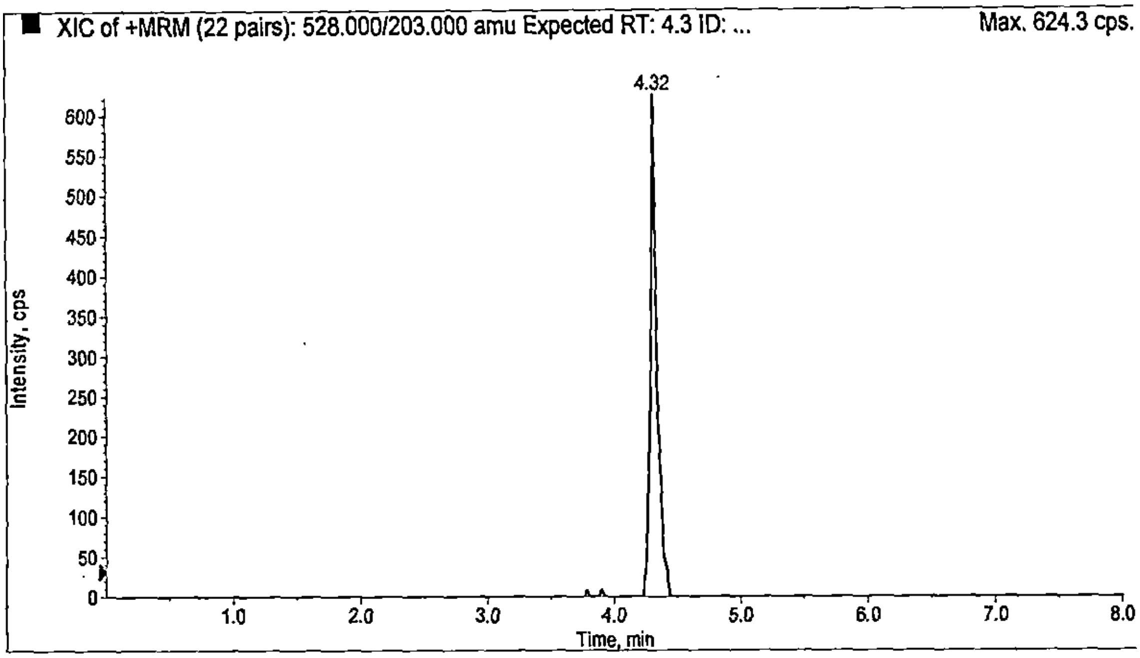


Chromatogram. 14a. LC-MS/MS Chromatogram of chloranthraniliprole 0.01ppm (Quantitative ion)

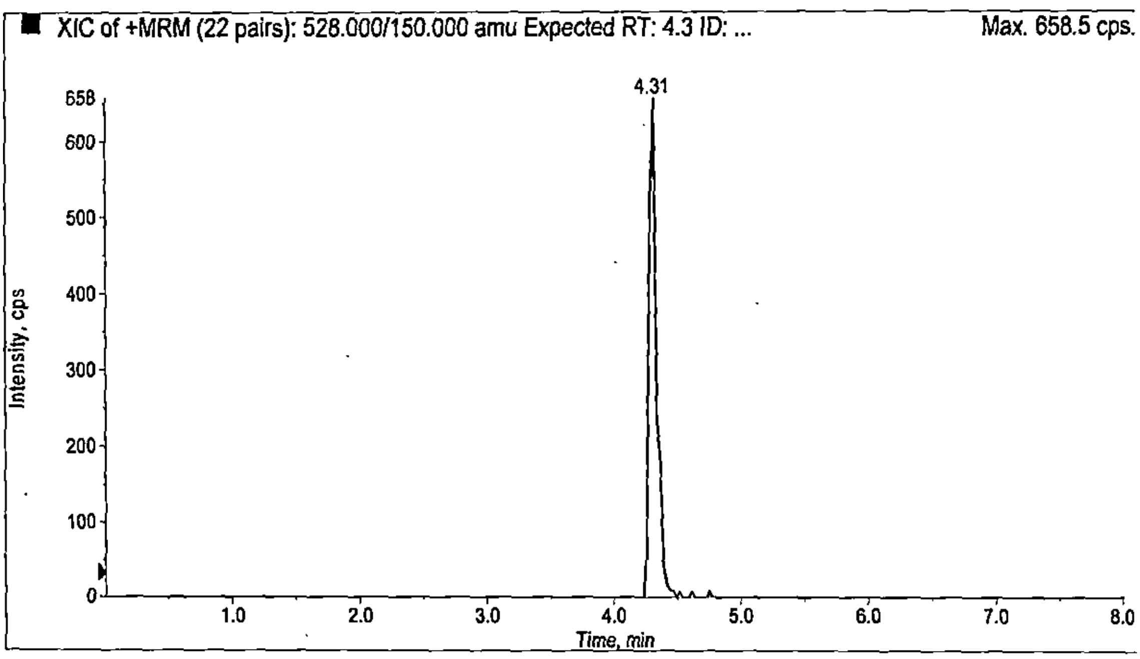


Chromatogram. 14b. LC-MS/MS Chromatogram of chloranthraniliprole 0.01ppm (Qualitative ion)

Appendix XV

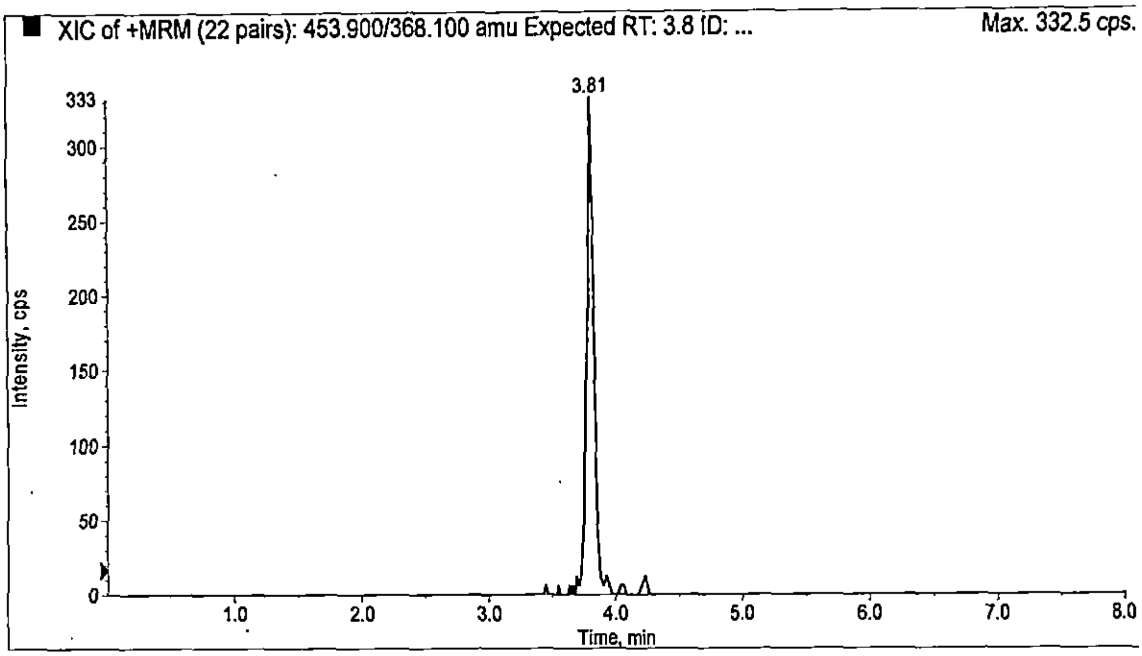


Chromatogram. 15a. LC-MS/MS Chromatogram of indoxacarb 0.01ppm (Quantitative ion)

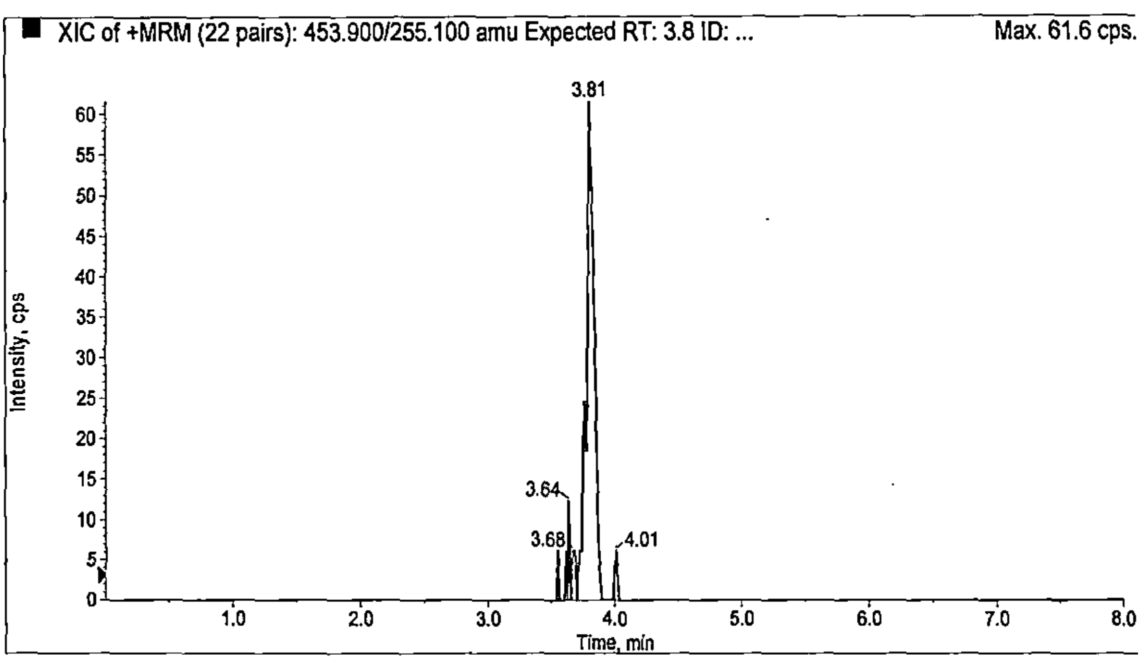


Chromatogram. 15b. LC-MS/MS Chromatogram of indoxacarb 0.01ppm (Qualitative ion)

Appendix XVI

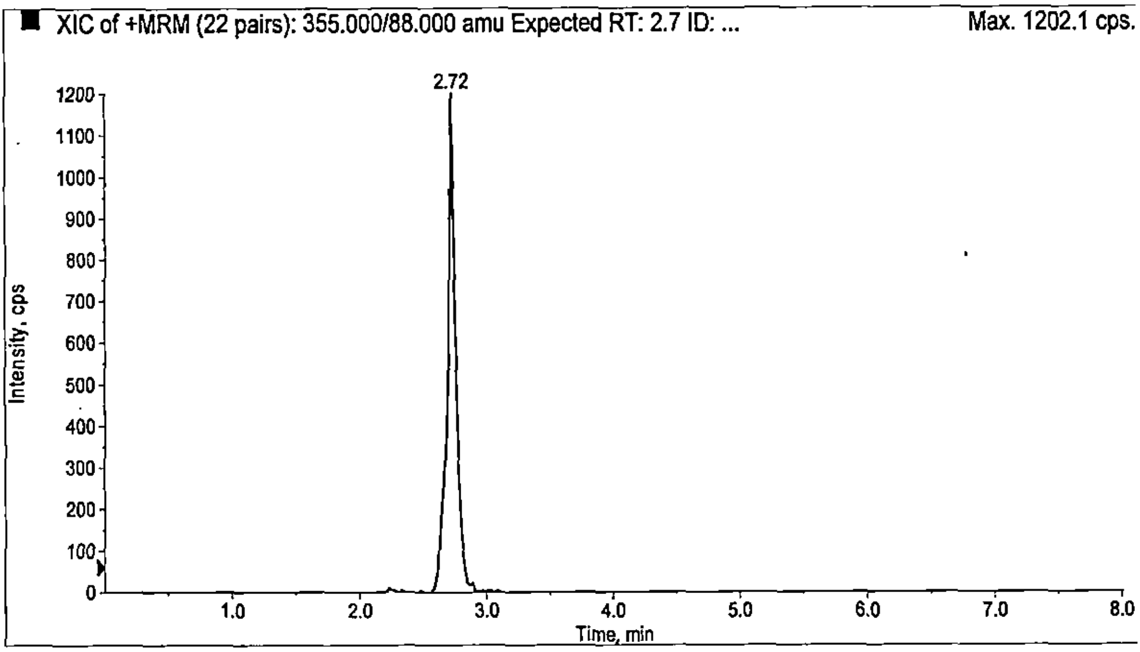


Chromatogram. 16a. LC-MS/MS Chromatogram of fipronil 0.01ppm (Quantitative ion)

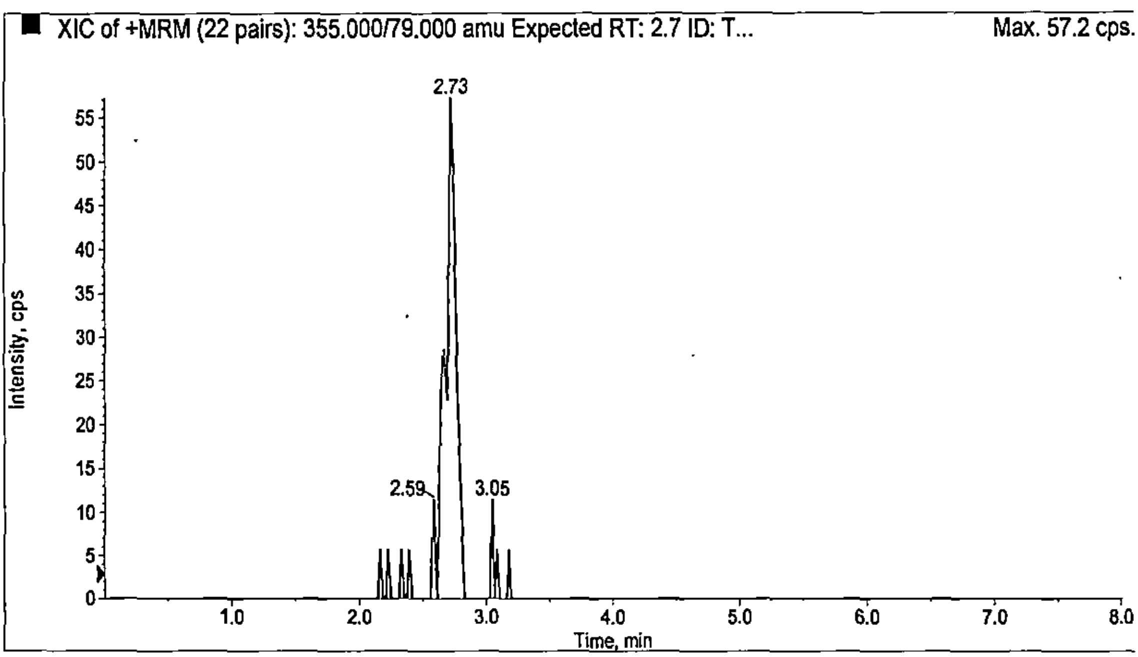


Chromatogram. 16b. LC-MS/MS Chromatogram of fipronil 0.01ppm (Qualitative ion)

Appendix XVII

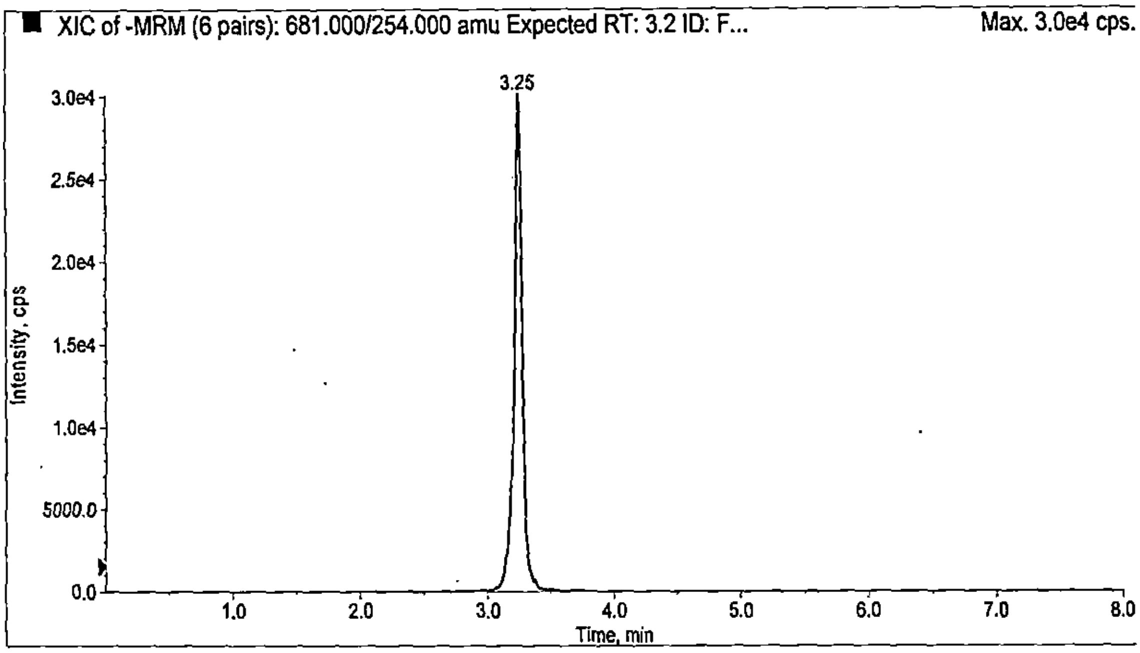


Chromatogram. 17a. LC-MS/MS Chromatogram of thiodicarb 0.01ppm (Quantitative ion)

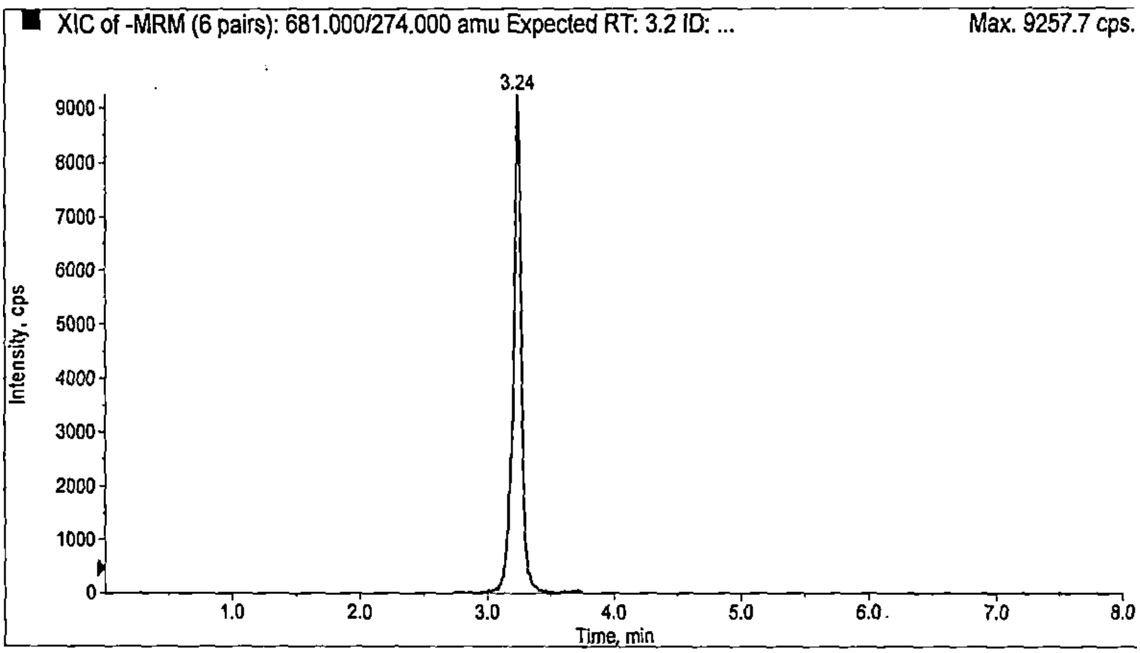


Chromatogram. 17b. LC-MS/MS Chromatogram of thiodicarb 0.01ppm (Qualitative ion)

Appendix XVIIIa

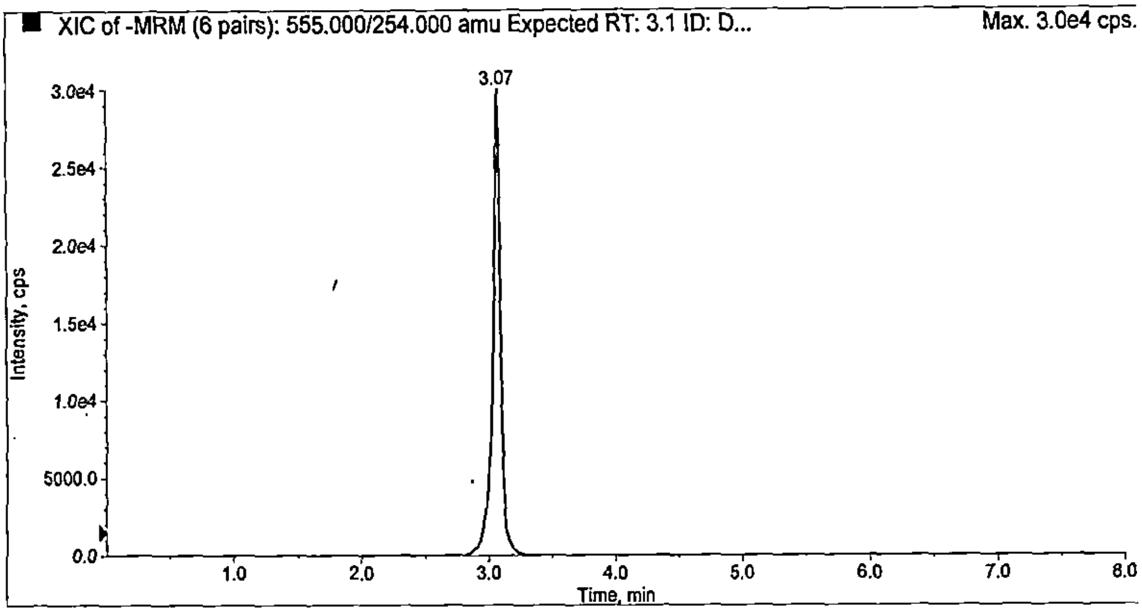


Chromatogram. 18aa. LC-MS/MS Chromatogram of flubendiamide 0.01ppm (Quantitative ion)

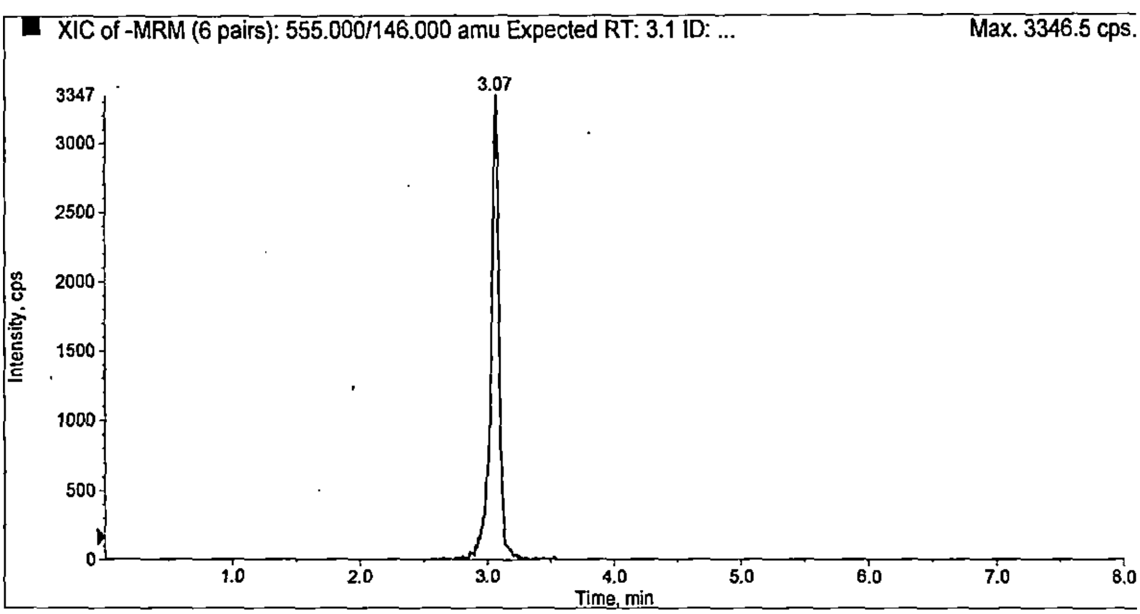


Chromatogram. 18ab. LC-MS/MS Chromatogram of flubendiamide 0.01ppm (Qualitative ion)

Appendix XVIIIb

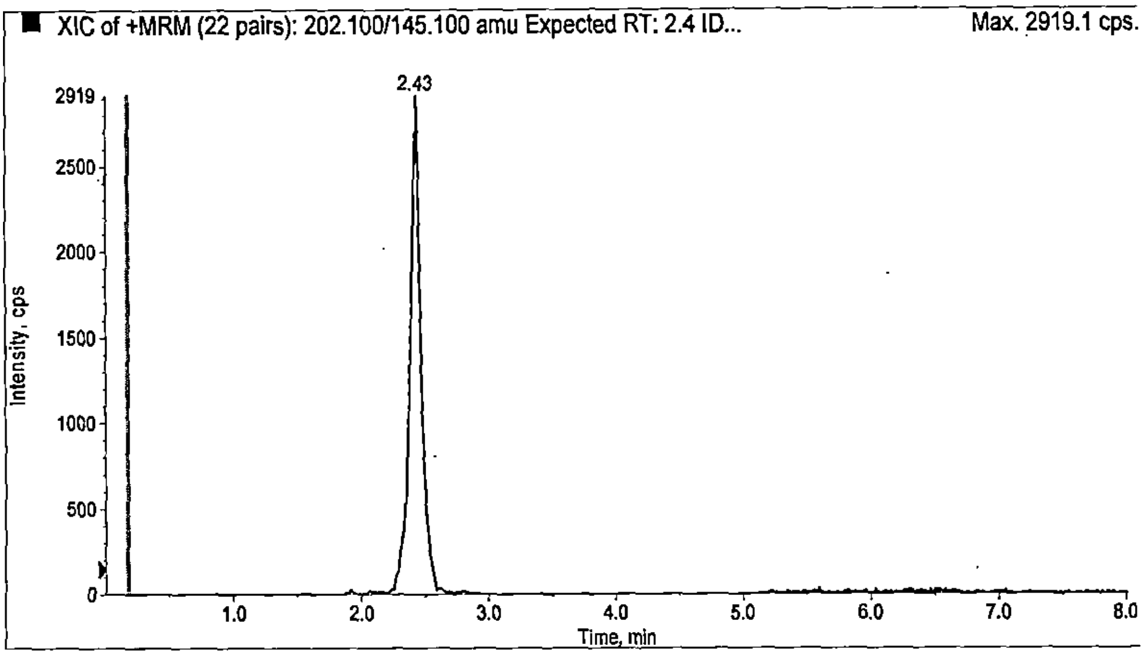


Chromatogram. 18ba. LC-MS/MS Chromatogram of desiodoflubendiamide 0.01ppm (Quantitative ion)

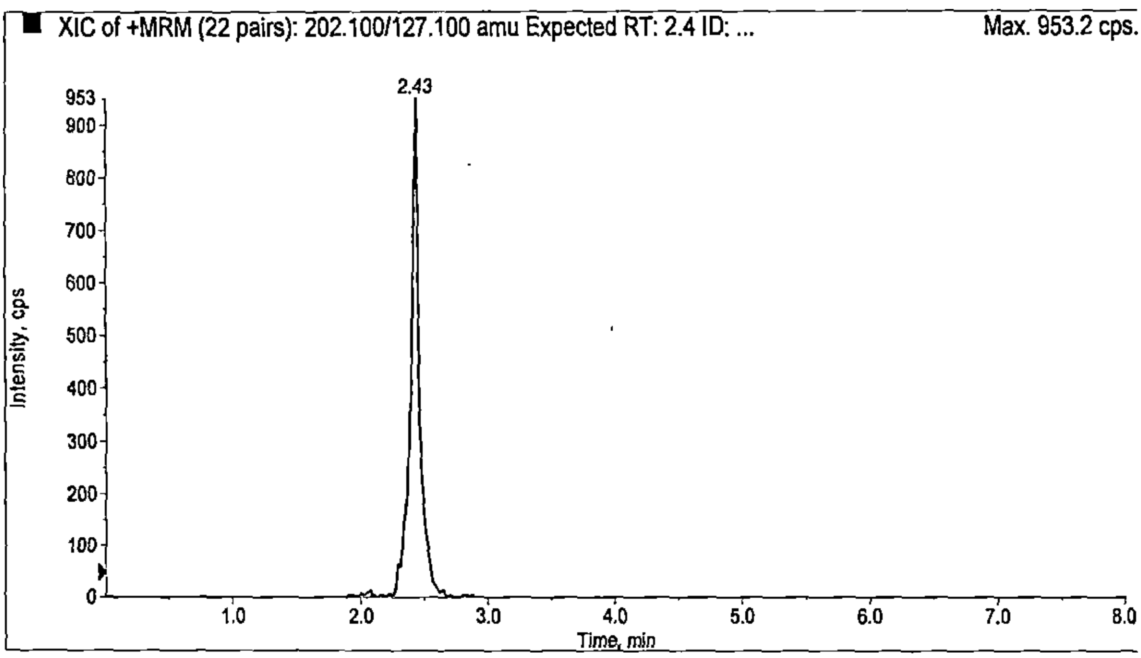


Chromatogram. 18bb. LC-MS/MS Chromatogram of desiodoflubendiamide 0.01ppm (Qualitative ion)

Appendix XIX

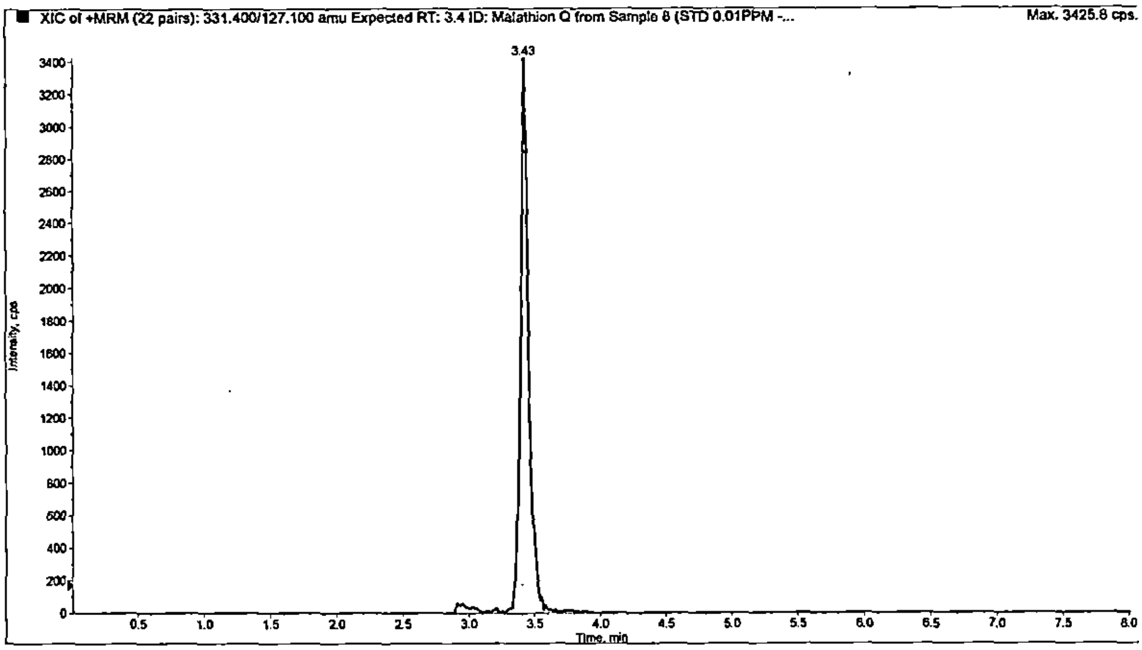


Chromatogram. 19a. LC-MS/MS Chromatogram of carbaryl 0.01ppm (Quantitative ion)

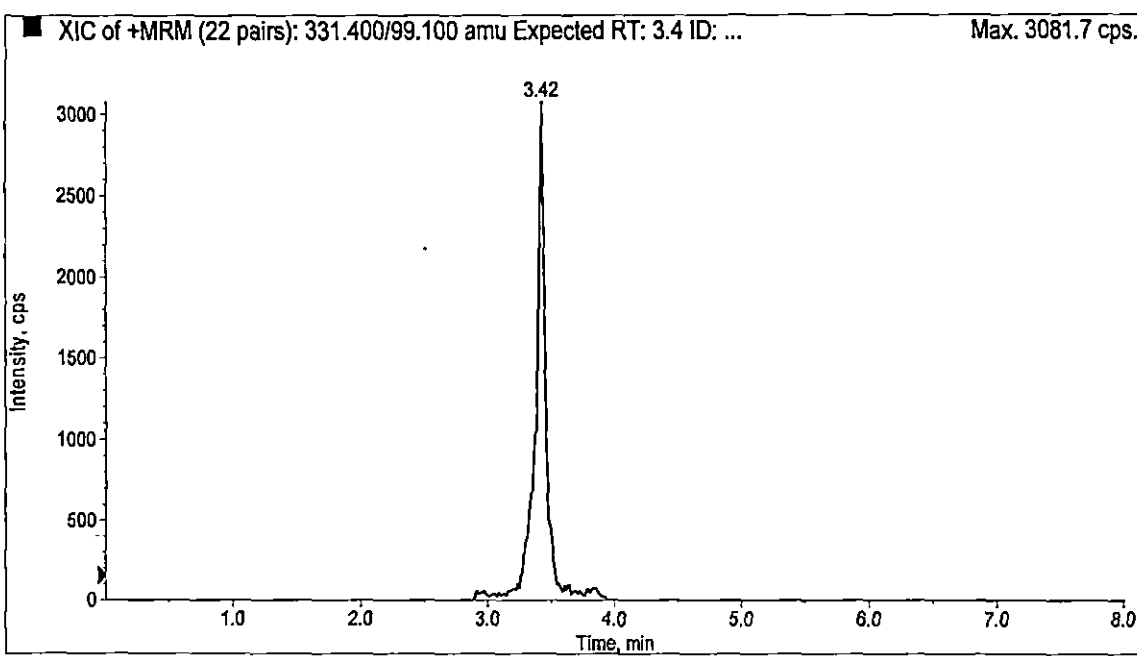


Chromatogram. 19b. LC-MS/MS Chromatogram of carbaryl 0.01ppm (Qualitative ion)

Appendix XXa

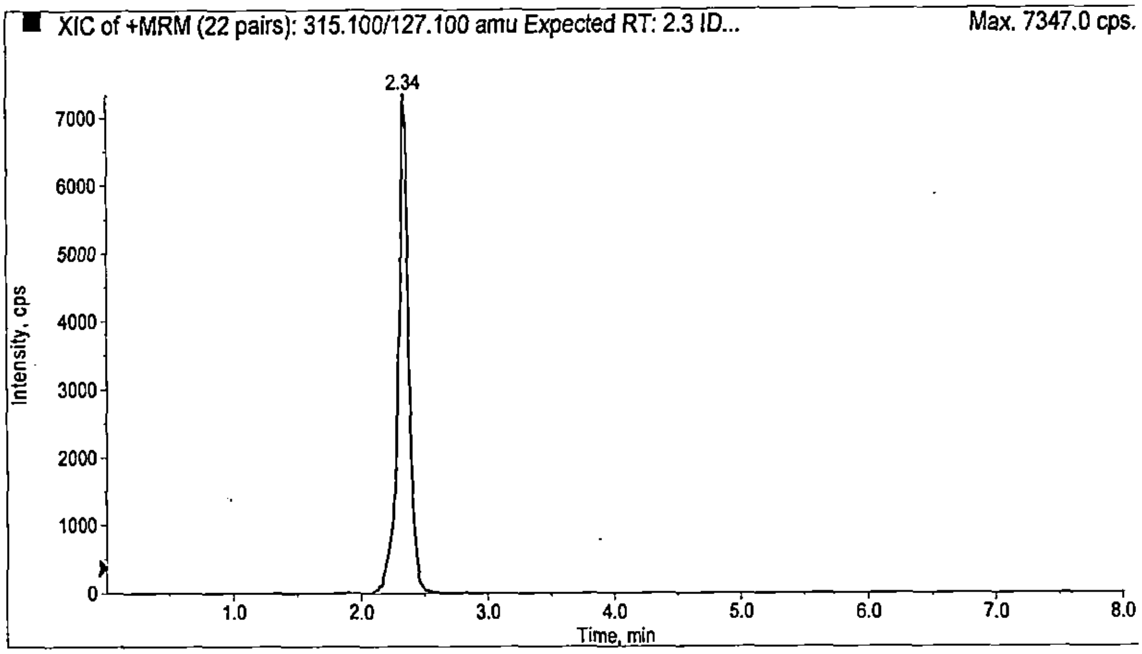


Chromatogram. 20aa. LC-MS/MS Chromatogram of malathion 0.01ppm (Quantitative ion)

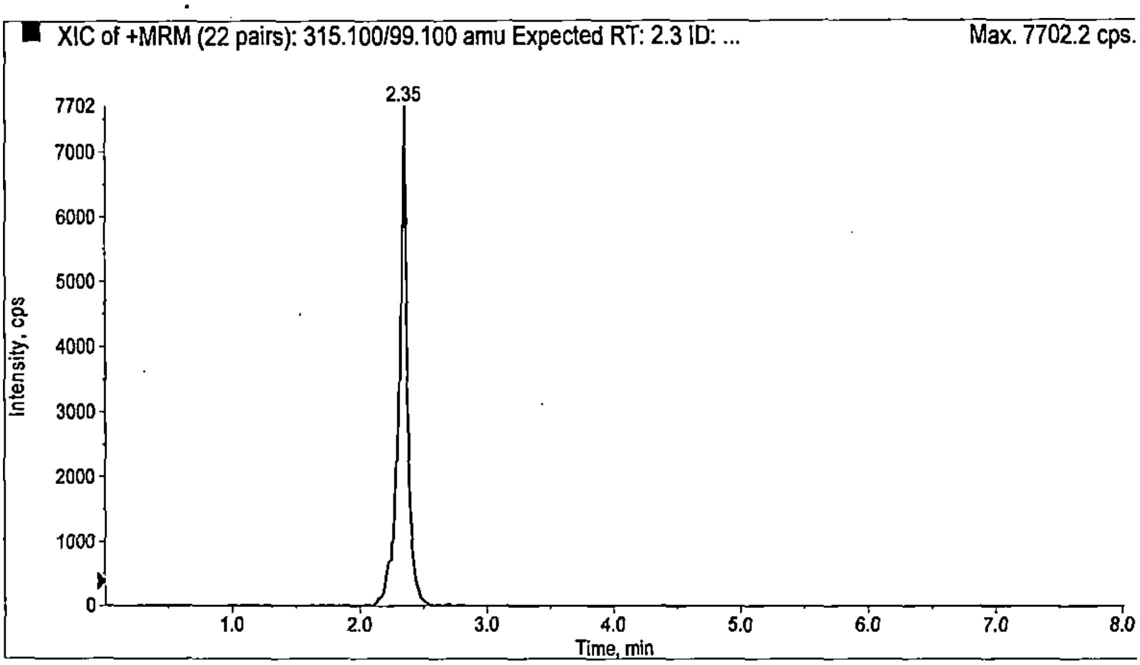


Chromatogram. 20ab. LC-MS/MS Chromatogram of malathion 0.01ppm (Qualitative ion)

Appendix XXb



Chromatogram. 20ba. LC-MS/MS Chromatogram of malaoxon 0.01ppm (Quantitative ion)



Chromatogram. 20bb. LC-MS/MS Chromatogram of malaoxon 0.01ppm (Qualitative ion)

EFFICACY AND BIOSAFETY OF NEW GENERATION INSECTICIDES FOR THE MANAGEMENT OF FRUIT BORERS OF COWPEA, BRINJAL AND OKRA

VIJAYASREE, V

(2010-21-104)

Abstract of the thesis submitted in partial fulfillment of the requirement for the degree of

DOCTOR OF PHILOSOPHY IN AGRICULTURE

Faculty of Agriculture

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THIRUVANATHAPURAM - 695 522
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2013

ABSTRACT

The investigation on the "Efficacy and biosafety of new generation insecticides for the management of fruit borers of cowpea, brinjal and okra" was conducted at the College of Agriculture, Vellayani, during 2010-2013. The objectives were to evaluate the efficacy of new generation insecticides against the fruit borers of cowpea, brinjal and okra, assess their safety to entomopathogenic fungi, determine their persistence and degradation and standardize methods to decontaminate the residues on the fruits. The studies were conducted with eight new generation insecticides *viz.,* emamectin benzoate 5SG @10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, novaluron 10 EC @ 100 g a.i. ha^{-1}, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1}, fipronil 80 WG @ 50 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1} and flubendiamide 480 SC @ 100 g a.i. ha^{-1} . Two conventional insecticides (carbaryl 50 WP @ 750 g a.i. ha^{-1} and malathion 50 EC @ 500 g a.i. $ha^{-1)}$ and an untreated control were maintained as check.

Laboratory screening of the insecticides against *Maruca vitrata, Leucinodes orbonalis* and *Earias vitella,* indicated high mortality of the pests one and three days after treatment with a subsequent decline in the mortality. The insecticides were on par in their efficacy.

All the new generation insecticides reduced the pest infestation on the vegetables significantly in the field. The reduction in the flower and pod damages in cowpea ranged from 53.97 to 76.86 and 63.69 to 84.82 per cent, respectively. Damages to brinjal and okra fruits were reduced by 45.96 to 72.21 per cent and 44.34 to 83.26 per cent, respectively. Chlorantraniliprole, indoxacarb and emamectin benzoate which recorded more than 70 and 80 per cent reduction in flower and pod damages in cowpea, chlorantraniliprole, indoxacarb, emamectin benzoate and flubendiamide with more than 60 per cent reduction in fruit damage in brinjal, and chlorantraniliprole, flubendiamide and indoxacarb with more than

70 per cent reduction in fruit damage in okra were superior. The yield was also significantly high in these treatments in the three crops. Prophylactic sprays with neem seed kernel extract 5 % at flower bud initiation and after a fortnight, decreased the population of the pod borer of cowpea remarkably. Subsequently, one spray of the insecticides sufficed to check the pest.

All the insecticides were compatible with *Beauveria bassiana* and *Metarrhizium anisopliae.* Flubendiamide and carbaryl inhibited the growth of *Lecanicillium lecanii.*

Chlorantraniliprole with a waiting period of one day in all the three vegetables was the safest insecticide. The other insecticides with waiting periods within the harvest intervals of the crops were spinosad (1day), emamectin benzoate (3 days) and flubendiamide (3 days) in cowpea, indoxacarb (1day), spinosad (1day) and emamectin benzoate (4 days) in brinjal and indoxacarb (2 days) and thiodicarb (2 days) in okra.

Immersing insecticide treated fruits in slaked lime 2%, turmeric 1 %, vinegar 2% or tamarind 2% solution for twenty minutes followed by washing in water and scrubbing which removed more than 60 per cent residues of most of the insecticides were the effective decontaminating methods for the new generation insecticides.

Considering the efficacy of the insecticides against the pests, associated yield increase, benefit cost ratio of the insecticide treatments, waiting period and compatibility with bio agents, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i. ha^{-1} and emamectin benzoate 5SG @10 g a.i. ha^{-1} were adjudged as the potential insecticides against the fruit borers of cowpea, brinjal and okra.