MANAGEMENT OF PESTS OF COWPEA AND SALAD CUCUMBER IN POLYHOUSE

by

THAMILARASI N

(2014-11-241)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2016

DECLARATION

I, hereby declare that this thesis entitled **“MANAGEMENT OF PESTS OF COWPEA AND SALAD CUCUMBER IN POLYHOUSE”** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,

04-10-2016

Thamilarasi N

(2014-11-241)

CERTIFICATE

Certified that this thesis entitled **"MANAGEMENT OF PESTS OF COWPEA AND SALAD CUCUMBER IN POLYHOUSE"** is a record of research work done independently by Ms. Pattapu Sreelakshmi under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
04-10-2016

Dr. Ambily Paul
(Major advisor, Advisory Committee)
Assistant Professor
AINP on Pesticide Residues
Dept. of Agricultural Entomology,
College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Thamilarasi N, a candidate for the degree of **Master of Science in Agriculture** with major in Agricultural Entomology, agree that this thesis entitled **"MANAGEMENT OF PESTS OF COWPEA AND SALAD CUCUMBER IN POLYHOUSE"** may be submitted by Ms. Thamilarasi N, in partial fulfilment of the requirement for the degree.

Dr. Ambily Paul
(Chairman, Advisory Committee)
Assistant professor
AINP on Pesticide Residues
Department of Agricultural Entomology
College of Agriculture, Vellayani.

Dr. K. Sudharma
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Entomology
College of Agriculture, Vellayani.

Dr. Thomas Biju Mathew
(Member, Advisory Committee)
Professor and Head
AINP on Pesticide Residues
Department of Agricultural Entomology
College of Agriculture, Vellayani.

Dr. Thomas George
(Member, Advisory Committee)
Associate Professor and PI,
Department of Soil Science and
Agricultural Chemistry
AINP on Pesticide Residues
College of Agriculture, Vellayani.

EXTERNAL EXAMINER
(Name and Address)

ACKNOWLEDGEMENT

"A gift is pure when it is given from the heart to the right person at the right time and at the right place, and when we expect nothing in return" – Bhagavad Gita.

First and foremost, I bow my head before and would like to thank my loving creator for making me a curious being who loves to explore his creation and for giving me the opportunity to travel my life journey in the field of agriculture and without him I can do nothing.

I cannot fully express in words my sincere gratitude for the friendship and guidance of my chairperson ***Dr. Ambily Paul****, Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Vellayani has extended throughout my post graduate life. Her concern for my growth as a professional and as an individual has always transcended the boundaries of the workplace. Her approach to mentioning provided for me the freedom to explore. She had tremendous faith in my ability to overcome what seemed to be a log in my journey.*

I would like to express my sincere gratefulness to ***Dr. Sudharma K,*** *Professor and Head, Department of Agricultural Entomology, for her insightful, timely and valuable advice during the course of my PG programme. I express my heartfelt gratitude to my co-advisor* ***Dr. Thomas Biju Mathew****, Professor and Head, PRRAL, College of Agriculture, Vellayani for his ever ending support and guidance. His doors were always open for me and he always provided kind and insightful advice throughout the PG programme.*

I wish to express my genuine thanks to, ***Dr. Thomas George****, Professor and PI, AINP on Pesticide Residues, Department of Soil Science and Agricultural Chemistry, member of my advisory committee for his crucial suggestions and help during the investigation of the work.*

A word of gratitude will not be sufficient to ***Dr. Sheela M. S., Dr. Hebsy Bai*** *and* ***Dr. Naseema Beevi*** *for their help rendered during the research work and manuscript preparation.*

It must be mentioned here that without the passionate and enthusiastic support and invaluable help rendered to me at most crucial time by ***Dr. Sheela K. R.*** *Professor & Head, Department of Agronomy, CoA, Vellayani, without her "this" would not have happened and this work would have been a vain exercise.*

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

I would like to express my kindhearted thanks to all Scientists who help me in identifying the specimens during their busy times.

My compassionate thanks to all friends in Pesticide residue lab, Visal chetan, Pratheesh chetan, Pradeep chetan, George chetan, Rejith chetan, Binoy chetan, Salmon chetan, Reshmi chechi, Deepa chechi, Surya chechi, Prathiba chechi, Mithra chechi, Priya chechi, Emily chechi, Sreekutty chechi, Preetha chechi, Sabari, Vishnu, Sreelal, Anil chetan and Shaju chetan who helped me at all stages of my research work.

I like to thank my classmates **shivu, sunii, jithin, mridhul, aaru, pravi, anu, jasmy and sherin** and all my juniors and batchmates for their timely help during the course work and research work.

Special credit to my friends **Nithya** who encouraged me during my falls and good companion during my PG life. No words to explain my gratitude to Siva, Sakthi and Satheesh for their help and encouragement during my study and in my life.

Words cannot express my indebtedness to my family especially **grandparents, appa, amma and mama, mohana, sruthi and sowmi.** My gratitude towards you never ends…..Thank you for being so sportive and supportive. I can't express my thankfulness towards my appa and amma for letting me to complete my post-graduation and believing in me.

I am gratefully acknowledge all the **polyhouse farmers** and **Mrs. Ancy**, SHM for their co-operation without which my study would perhaps have been incomplete.

(Thamilarasi, N)

CONTENTS

LIST OF TABLES

	condition	
19	Population of pea aphid, *Aphis craccivora* in cowpea treated with insecticides	
20	Population of pod bug, *Riptortus pedestris* in cowpea treated with insecticides	
21	Population of mites, *Tetranychus truncatus* in cowpea treated with insecticides	
22	Population of green peach aphid, *Myzus persicae* in salad cucumber treated with insecticides	
23	Population of mites, *Tetranychus* sp. in salad cucumber treated with insecticides	
24	Population of American serpentine leaf miner, *Liriomyza trifolii* in cowpea treated with insecticides	
25	Population of pumpkin caterpillar, *Diaphania indica* in salad cucumber treated with insecticides	
26	Population of American serpentine leaf miner, *Liriomyza trifolii* in salad cucumber treated with insecticides	
27	Recovery of insecticides in cowpea fruits fortified at different levels	
28	Recovery of insecticides in salad cucumber fruits fortified at different levels	
29	Residues of insecticides in cowpea fruits	
30	Residues of acaricides in cowpea fruits	
31	Residues of insecticides in cowpea fruits	
32	Residues of insecticides in salad cucumber fruits	
33	Residues of acaricides in salad cucumber fruits	
34	Residues of insecticides in salad cucumber fruits	

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
a.i.	Active ingredient
BQL	Below quantification level
C.D.	Critical Difference
DAS	Days after sowing
DAS	Days after spraying
EC	Emulsifiable concentrate
et al	And others
g	Gram
ha-1	per hectare
kg	Kilogram
L	Litre
mL	Millilitre
ppm	Parts per million
RSD	Relative standard deviation
SC	Suspension concentrate
SL	Soluble Liquid
SP	Soluble Powder
SD	Standard deviation
sp	Species
viz.,	Namely
WG	Wettable granules

INTRODUCTION

1. INTRODUCTION

Protected cultivation is the most promising method in agriculture involving hi-tech and intensive practices of crop production. It is considered to be the best alternative for efficient use of land and other resources in peri-urban areas for the perpetual production of vegetables for domestic and export purposes and it provides protection to crop plants from adverse environmental conditions. Generally, this method of cultivation is considered to be free from pests and diseases, as the polyhouses acts as a physical barrier for the spread of these organisms. Various constructional flaws and the use of infested planting materials facilitate the entry of pests into the protected structures. The congenial micro-climate is favourable for the multiplication of pests which in turn become the limiting factors for the successful crop production under protected environment (Kaur *et al.*, 2010).

In India, about twenty insect and mite species have been recorded to be associated with the crops under protected cultivation (Sood *et al*., 2006). In Kerala, hemipteran bugs, lepidopteran caterpillars and mites were reported to cause serious damage to the plants grown under the polyhouses (GOK, 2013). Cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.) and salad cucumber (*Cucumis sativus* L.) are the two important vegetables grown widely under polyhouses in Kerala. Documentation of the pests infesting these crops under polyhouses in the state is meagre. As each pest species display differential susceptibility to chemicals and other management measures, documentation of the pests attacking the crops under polyhouses would help in selecting appropriate management tactics. Now the area under polyhouses has expanded in the State due to the encouragement by the State Horticulture Mission, Government of Kerala. As such, problems of pests also amplified. These conditions lead to the increased use of noxious chemicals that in turn increased the concerns on the toxic residues in the produce especially on vegetables those are harvested frequently at close intervals and that of vegetables used for salad purposes. Hence, it is imperative to study the pests, their population dynamics and to evaluate the pesticides under polyhouses for evolving effective management practices against the pests. Knowledge on the efficacy of new generation insecticides with benign eco - toxicological profiles under protected cultivation is also lacking. Fixation of pre-harvest intervals based on the dissipation studies is also essential. Hence, project entitled “Management of pests of cowpea and salad cucumber in polyhouse” was undertaken with the following objectives,

- To conduct a preliminary survey in polyhouse to document the pest and their extent of damage in cowpea and salad cucumber and the natural enemies associated with the pests
- To evaluate the efficacy of new generation insecticides against the major pests of cowpea and salad cucumber under polyhouse and
- To determine the persistence and dissipation rate of new generation insecticides in cowpea and salad cucumber under polyhouse.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Vegetables are recognized as healthy food and they play an important role in overcoming micronutrient deficiencies and provide security of high farm returns. The major constraints in horticultural crop production are lack of sunlight in hilly ranges, varying temperature, nutrient deficient soil, pest problems and other environmental factors. These are relieved by protected cultivation and it is a drudgery-less approach for using land and other resources more efficiently (Sirohi and Bahera, 2000; Nair and Barche, 2014). The literature on the importance of protected cultivation, important crops, insect-pests, their population dynamics and the management of pests under protected cultivation are reviewed and presented under the following headings.

2.1 PROTECTED CULTIVATION

Cultivation of vegetables under protected structures is gaining importance in India especially in hilly regions of Himalaya due to the extreme low temperatures (-5 to -30 ºC) (Singh, 2000) and in plains due to the attack of pest and diseases (Rai, 2014). Protected cultivation refers to creation of favourable environmental conditions around plants, offsetting or minimizing the detrimental effects of prevailing or expected to prevail abiotic and biotic factors and to maximize the yield and resource saving (Singh, 2014). The area under protected cultivation in India is approximately 30, 000 ha and it is contributed by states *viz.*, Himachal Pradesh, Karnataka, Maharashtra, North Eastern states, Punjab, Tamil Nadu and Uttarakhand (Wani *et al.*, 2011; Shweta *et al.*, 2014). In Kerala, increase in population with shrinking land holding and increased labour charges, protected cultivation is deliberated to be the paramount for vegetable production and to improve economic conditions of the farmers (Kutty *et al.*, 2014; Nair, 2014). Pests are the major limiting factors in polyhouse cultivation and these are introduced into protected structures mainly through vents or various constructional flaws or along with infested planting materials or by adhering to the clothing of labourers. Initially polyhouses had a lower number of pest population but it increase rapidly due to the congenial climate, continuous food supply, their phytophagous nature or monocropping and lack of natural enemies inside the protected environment (Gavkare *et al.*, 2014).

Based on the structural type, material availability and geographical conditions the structures of protected cultivation can be classified as mulches, low tunnels, walk-in-tunnels, shade nets, rain shelters, glass house, green house and polyhouse. Among these, vegetable cultivation under greenhouse constituted major area of production (Nagarajan *et al.*, 2002). Due to high rainfall and humidity, rain shelters and naturally ventilated polyhouses were reported suitable for Kerala conditions (Kutty *et al.*, 2014).

Greater productivity, year around production, enhanced harvest period and early harvest, better utilization of land, water, fertilizer and less manpower are the advantages of protected cultivation (Kumar *et al.*, 2007; Prabhu *et al.*, 2009). Solar greenhouses with glass and polyethylene are gaining more importance in temperate and tropical regions (Singh, 2000).

2.1.2 Crops under Protected Cultivation

Cultivation of high value crops under protected structures is essential to get fresh vegetables year around in cold arid and urban areas (Akbar *et al.*, 2013). In India vegetables *viz.*, tomato, capsicum, cucumber, melons and ornamental crops *viz.*, rose, gerbera, carnation and chrysanthemum are mainly grown under protected cultivation in India (Chandra *et al*., 2000; Shweta *et al*., 2014). Tomato, capsicum, cucumber, cauliflower, cabbage, leafy vegetables, okra and yard long bean are the vegetables mainly grown under polyhouse conditions in Kerala (Kutty *et al*., 2014). The important crops grown under various protected structures are given in the Table 1.

Table 1. Major crops cultivated under various protected structures in India

Sl. No	Protected structures	Crops	References
1.	Polyhouse	*Abelmoschus esculentus* (L.) Moench., *Capsicum annum* L., *Chrysanthemum indicum* L., *Cucumis sativus* L., *Lycopersicon esculentum* L., *Momordica charantia* L., *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.	Jeevansab, 2000; Basavaraja *et al*., 2003;Hazarika and Phookan, 2005;Kamaruddin *et al.*, 2006; Kumar *et al.*, 2008; Gantait and Pal, 2011; Singh *et al.*, 2011; Varughese *et al.*, 2014; Kumar *et al.*, 2015; Sanjeev *et al.*, 2015; Varghese and Celine, 2015; Lekshmi and Celine, 2015; Vattakunnel *et al*., 2015.
2.	Shade net	*Brassica oleracea* var. *botrytis* L., *Capsicum annum* L., *Coriandrum sativum* L., *Lycopersicon esculentum* L., *Raphanus sativus* L., *Solanum melongena* L.	Srichandran *et al*., 2006; Thangam and Thamburaj, 2008; Venthamoni and Natarajan, 2008; Kavitha *et al.*, 2009; Sreedhara *et al.*, 2013; Rajasekar *et al.*, 2014; Swamy *et al.*, 2014.
3.	Greenhouse	*Amaranthus tricolor* L., *Capsicum annum* L., *Coriandrum sativum* L., *Cucumis sativus* L., *Lycopersicon esculentum* L., *Spinacia oleracea* L., *Trigonella foenum-graecum* L.	Ganesan, 2002; Singh *et al.*, 2003; Mahajan and Singh, 2006; Singh and Kumar, 2006; Dixit, 2007; Prabhu *et al.*, 2009.
4.	Net house	*Abelmoschus esculentus* (L.) Moench., *Capsicum annum* L., *Coriandrum sativum* L., *Cucumis sativus* L., *Cucurbita pepo* Gentry, *Lycopersicon esculentum* L.	Cheema *et al.*, 2004; Singh *et al.*, 2004; Singh *et al.*, 2005.
5.	Low tunnels	*Capsicum annum* L., *Cucumis melo* L., *Cucumis sativus* L., *Cucurbita pepo* Gentry	Sari *et al.*, 1994; Singh *et al*., 2005; Singh *et al*., 2013.
6.	Rain shelter	*Cucumis sativus* L., *Lagenaria siceraria* Ser., *Luffa aegyptiaca* L., *Lycopersicon esculentum* L., *Momordica charantia* L.	Siddeque *et al.*, 1993; Prabhu *et al.*, 2009.

2.2 PESTS UNDER PROTECTED CULTIVATION

The literature on important insect-pests under protected cultivation is presented in Table 2.

2.2.1 Population Dynamics of Pests under Polyhouse Condition

Most of the pests identified under protected cultivation survived throughout the year due to their polyphagous nature and they multiplied rapidly and showed no diapause due to continuous cropping or monocropping (Yadav and Kaushik, 2014). Favourable temperature, relative humidity and stage of the crop and type of the cover sheets used for construction were identified as important factors for their population build-up (Maklad *et al.,* 2014).

Wang and Shipp (2001) conducted an experiment in cucumber to monitor the population on *Frankliniella occidentalis* (Pergande) under greenhouse condition and they stated that thrips density was high during the temperature range of 18.20 to 26.80 ºC.

The use of polyethylene as a cover sheet increased temperature and relative humidity under greenhouse when compared to white and black nets. Maklad *et al.* (2012) stated that the population of aphids, whitefly, spider mites and thrips in cucumber were maximum under polythene sheet when related to white and black nets and that the population was positively correlated with temperature and relative humidity. Ellaithy *et al.* (2015) reported that the population of sucking pests was minimum in sweet pepper under plastic house with white shade net when compared to polythene cover house.

Yadav and Singh (2013) studied the pest incidence with relation to the environmental factors in mung bean variety HUM – 12 and stated that jassids (5.8 jassids/cage), thrips (2.4/ ten flowers), epilachna beetle (2.8/ plant) and spotted pod

Table 2. Pests of crops under protected cultivation in India

Pest	Scientific name	Host	References
Aphids	*Aphis gossypi* Glover	Capsicum, tomato	Singh *et al.*, 2004; Kaur *et al.*, 2010
	Macrosiphum sanborni Gillette	Chrysanthemum	Sabir *et al.*, 2012
	Myzus persicae Sulzer	Capsicum, cucumber, carnation, sweet pepper	Vashisth *et al.*, 2013; Gavkare *et al.*, 2014
Thrips	*Scirtothrips dorsalis* Hood	Capsicum, rose, sweet pepper	Reddy and Kumar, 2006; Kaur *et al.*, 2010; Hegde *et al.*, 2011; Sood, 2012
	Thrips tabaci Lindeman	Rose	Vashisth *et al.*, 2013
	Frankliniella sp.	Rose	Vashisth *et al.*, 2013
Whiteflies	*Bemisia tabaci* Gennadius	Cucumber	Kaur *et al.*, 2010
	Trialeurodes vaporariorum Westwood	Capsicum, tomato, cucumber	Vashisth *et al.*, 2013
Mealybug	*Drosicha mangifera* Green	Tomato, bhindi	Arora and Singh, 2012
	Phenacoccus solenopsis Tinsley	Tomato, capsicum	Singh *et al.*, 2016

Table 2. Pests of crops under protected cultivation in India (Continued)

Mites	*Polyphagotarsonemus latus* Banks	Sweet pepper	Reddy and Kumar, 2006; Kaur *et al.*, 2010
	Tetranychus urticae Koch	Tomato, Rose, Cucumber	Reddy and Kumar, 2006; Singh *et al.*, 2006; Kaur *et al.*,2010
	Tetranychus ludeni Zacher	Tomato	Kashyap, 2013
	Aculops lycopersici Massee	Tomato	Kashyap, 2013
Caterpillars	*Helicoverpa armigera* Hubner	Carnation, rose, capsicum	Vashisth *et al.*, 2013
	Spodoptera litura Fabricius	Cucumber, tomato, capsicum, eggplant, rose, sweet pepper	Cheema *et al.*, 2004; Kaur *et al.*, 2010; Vashisth *et al.*, 2013
	Plutella xylostella L.	Cabbage, cauliflower	Vashisth *et al.*, 2013
Leaf miner	*Liriomyza trifolii* Burgess	Tomato, cucumber, sweet pepper	Kaur *et al.*, 2010; Vashisth *et al.*, 2013
Nematode	*Meloidogyne incognita* (Kofoid& White) Chitwood	Cucumber, sweet pepper, tomato	Kaur *et al.*, 2010

borer (2.4 larvae/plant) had positive correlation with sunshine and evaporation while, whitefly (7.4 whiteflies/cage) had positive significance with maximum temperature. The incidence of blister beetle (2.8 adult/ plant) and pod bugs (4.8 adult/ plant) had no significance with weather but positive significance with stage and age of the crop was reported.

Kanika *et al.* (2013) studied the periodic occurrence of *T. urticae* in cucumber in relation to environmental factors and reported that the population harboured was more in grown up leaves, followed by tender and older leaves. They further observed that maximum and minimum temperature, wind speed and rainfall had significant positive correlation on population build-up while, relative humidity showed a significant negative correlation.

In 2015, Kharbade and coworkers studied the incidence of *P. latus* in capsicum during summer months in Pune and found that the population was positively correlated with maximum and minimum temperature and it was negatively correlated with relative humidity.

Shalaby *et al.* (2013) conducted an experiment on the relation between pest infestation and the time of planting of cucumber crops under plastic greenhouses and reported that the infestation by *B. tabaci* started in early crop stage and that the infestation of *A. gossypii* and *T. urticae* were observed in later stage of the crop.

2.3 MANAGEMENT OF PESTS UNDER PROTECTED CULTIVATION

The management of pests under protected cultivation required attention due to the peculiar conditions that prevailed inside the polyhouse *viz.*, short harvest interval and the presence of pesticides in the produce when compared with open field conditions (Sood, 2012; Yadav and Kaushik, 2014). The different management techniques adopted are reviewed.

2.3.1 Cultural and Mechanical Methods

Guncan *et al.* (2006) studied the cultural and mechanical methods of pest management in organic cultivation of cucumber and they reported that leaf miner infestation was reduced by removal of the damaged leaves.

2.3.2 Physical Methods

Hanafi *et al.* (2007) conducted a study to evaluate various insect nets to exclude the sucking pests under protected cultivation and found that the insect nets 10 × 20 and 10 × 22 thread lines per inch gave adequate exclusion of whiteflies without impending natural enemy movement through these insect nets. Use of electric field screens were used to prevent the entry of whiteflies in the pre-entrance act as a mechanical method of pest management (Nonomura *et al.*, 2014). The UV - absorbing sheets and photoselecting nets, reduced the flight and dispersal of sucking pests under protected environment due to an alteration of their visual behaviour and the efficacy of parasitization of natural enemy on pests (Antignus *et al.*, 2001; Mutwiwa *et al.*, 2005; Chiel *et al.*, 2006; Diaz and Fereres, 2007; Gulidov and Poehling, 2013; Shimoda and Honda, 2013).

2.3.3 Biological Control

Sarwar *et* al. (2011) examined the efficacy of mite predators against *T. urticae* in sweet pepper under greenhouse and revealed that the mite population was reduced due to the presence of predatory mites. The establishment of predators *viz.*, *Neoseiulus pseudolongispinosus* (X.) and *Euseius utilis* (L.) were maximum compared to other predators, *Euseius castaneae* (W.) and *Euseius finlandicus* (O.).

Sreenivas *et al.* (2005) studied the efficacy of entomopathogenic fungi against *T. neocaledonicus* and reported the pathogenicity under glass house conditions and found that *M. anisopliae* @ 1.2 × 108 CFU/mL showed higher per cent mycosis on mites and also on par with *B. bassiana* and *V. lecanii* treatments.

Sharma *et al.* (2015) tested the efficacy of biopesticides against *B. tabaci* on tomato and stated that the various doses of *B. bassiana*, *M. anisopliae* and *V. lecanii* were effective in reducing the population after third spray under polyhouse conditions.

2.3.4 Botanicals

The use of plant-derived botanicals against crop pests is one of the important means to be used in crop protection under an integrated pest management and these botanicals acts as a deterrent, antifeedant or possessing anti-ovipositional effects helps in the management of pest. The literature pertaining the pest management using various plant extracts and botanical pesticides are presented in Table 3.

2.3.1 Chemical Management

The studies on the management of pests under protected cultivation using various insecticides are presented in Table 4.

2.4 PESTICIDE RESIDUAL TOXICITY AND THEIR PERSISTENCE IN THE PRODUCE

Increase in the production of vegetables under protected cultivation favours an extravagant pest development which leads to the indiscriminate use of pesticides for their control. There is high concern on the persistence and degradation of pesticide residue in the produce and their waiting intervals before harvest, because some of the produce are consumed as raw. The literature related to the persistence and degradation of various pesticides under protected cultivation are presented in table 5.

Table 3. Management of pest using non-chemicals under protected cultivation

Sl. No.	Treatment	Concentration	Pest	Crop	Result	Reference
1.	Essential oils from *Satureja hortensis* L., *Ocimum basilicum* L. and *Thymus vulgaris* L.	1.56, 3.125, 6.25, 12.5µL, respectively	*T. urticae*, *B. tabaci*	Bean plants	*S. hortensis* was found to be effective	Aslan *et al.*, 2004
2.	Azadirachtin	5 and 10 mL L^{-1}	Leaf miner	Tomato	High mortality of immature larvae in two doses applied as a soil treatment	Hossain, 2005
3.	Rosemary oil and Ecotrol (Rosemary oil-based pesticide)	5% and 10%	*T. urticae*	Tomato	Ecotrol reduced the population by 52% and did not affect the eggs of *P. persimilis*.	Miresmailli and Isman, 2006
4.	Aqueous extracts of *A. indica*, *Chenopodium ambrosioides* (leaves + stem + inflorescence), *Mansoa alliacea* (leaves), *Mentha pulegium* (leaves), *Piper aduncum* (leaves), *Piper callosum* (leaves), *Pelargonium graveolens* (leaves), *Plectranthus neochilus* (leaves), *Ruta graveolens* (leaves), *Trichilia casaretti* (leaves), *Trichilia pallida* (leaves), *Toona ciliate*	3 %	*B. tabaci*	Tomato	Leaf extract of *Toona ciliata* reduced thenumber of adults and eggs in tomato leaflets where, leaf extract of *Piper aduncum* had the highest ovicidal effect. However, the leaf extracts of *Trichilia pallida*, *Trichilia casaretti*, and *Toona ciliata* showed the highest mortality of both nymphs and adults of *B. tabaci* biotype B.	Baldin *et al.*, 2007

Table 3. Management of pest using non-chemicals under protected cultivation (Continued)

5.	Neem Azal 1% EC	5, 10 and 15 mL L^{-1}	*B. tabaci*	Tomato	Deterred the adult settlement and reduced egg deposition and the toxicity of the residue declined 5 days after treatment.	Kumar and Poehling, 2007
6.	Agricultural spray oil Azadirachtin Agricultural spray oil + Azadirachtin	0.1 and 0.5 % 0.1 and 0.5 % 0.1 and 0.5 %	*T. urticae*	Cucumber	Highest mortality was observed in the combination spray of agricultural spray oil and azadirachtin @ 0.5 per cent and agricultural spray oil (0.5 %) alone.	Deka *et al.*, 2011
7.	Essential oils and aqueous extracts of *Thymus vulgaris* L., *Achillea millefolium* L., *Foeniculum vulgare* L., and *Cuminum cyminum* L. and *Citrus sinensis* L.	40µL mL^{-1}	*T. vaporariorum*	Cucumber	Anti-oviposition effect was observed from essential oil of *A. millefolium* and the highest repellence effect were observed from aqueous extracts of *C. cyminum* and *T. vulgaris.*	Dehghani and Ahmadi, 2013

Table 4. Management of pests under protected cultivation using chemical insecticides

Sl. No.	Treatment	Concentration	Pest	Crop	Result	Reference
1.	Abamectin 1.9 EC Spinosad 12 SC	2 and 4 mL L^{-1}	Leaf miner and its parasitoids	Tomato	As a foliar spray spinosad affected the oviposition and egg hatching capacity and abamectin reduced egg deposition and embryonic development. However, both insecticides reduced the emergence of *Neochrysocharis formosa* and *Opius chromatomyiae.*	Hossain, 2005
2.	Dicofol 18.5 EC Wettable sulphur 80 WP Abamectin 1.9 EC Fenazaquin 10 EC	0.037 % 0.24 % 0.00095 % 0.01 %	*T. urticae*	Tomato	The combine spray module of abamectin-wettable sulphur-abamectin was effective in population reduction (1.23-2.08 mites per leaf) followed by dicofol-wettable sulphur-dicofol (4.05-4.23 mites per leaf).	Reddy and Kumar, 2006
3.	Dicofol 18.5 EC Imidacloprid 200 SL Propargite 57 EC Oxydemeton methyl 25 EC Dimethoate 30 EC	0.04 % 0.04 % 0.1 % 0.05 % 0.06 %	*T. urticae*	Rose	The maximum reduction of egg hatching was observed in dimethoate (63.69 %) treated plot followed by oxydemeton methyl (54.6 %) whereas, all the active stages of *T. urticae* were reduced in all treatments except in imidacloprid.	Singh *et al.*, 2006

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

4.	Abamectin 1.9 EC Spinosad 12 SC	2, 4 and 6mL L^{-1}	*B. tabaci*	Tomato	Abamectin deterred the adult settlement and reduced egg deposition and it was persist upto 15 days. Spinosad and abamectin recorded cent per cent mortality at all stages with 6-9 days after application where, the residual toxicity of the spinosad persisted upto 5 days after treatment.	Kumar and Poehling, 2007
5.	Spinetoram 12 EC Vertimec 1.8 EC	1mL L^{-1}	*T. urticae*	Eggplant	Spinetoram showed cent per cent mortality on all stages whereas, vertimec showed only 76 per cent mortality under greenhouse conditions.	El-Kady *et al.*, 2007
6.	Abamectin 1.9 EC Chlorpyriphos 40.8EC Cyromazine 75 WP Indoxacarb 150 SC Spinosad 240 SC	1.2 mL L^{-1} 3.0 mL L^{-1} 0.1 g L^{-1} 1.0 mL L^{-1} 0.3mL L^{-1}	*L. trifolii*	Bean plants	Abamectin and spinosad were found to be toxic and affected egg hatching, adult emergence and their feeding behaviour however, cyromazine severely hampered their pupation and adult eclosion.	Saryazdi *et al.*, 2012
7.	Imidacloprid 35 EC Thiacloprid 48 EC Thiomethoxam 25WG Etofenprox 10 SC Dinotefuran 20 SG	300 mL 120 mL 80 mL 178.5 mL 200 g/ feddan	*B. tabaci* *M. persicae*	Tomato	Thiacloprid showed high reduction of *B. tabaci* (1.33 nymph/leaf) where, Dinotefuran reduced *M. persicae* (1.3 nymph/leaf) population. However, imidacloprid gave a good reduction in the mean number of *B. tabaci* and *M. persicae* (0.97 and 1.22, respectively).	El-Sayed, 2013

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

8.	Thiacloprid 36 WG	7.5, 15 and 30 kg ha^{-1}	*B. tabaci*	Cucumber	Thiacloprid @ 15 kg/ha caused 37.2 – 95.3% mortality of *B. tabaci* within 21 days after treatment.	Dong *et al.*, 2014
9.	Etofenprox 10 SC Imidacloprid 35 SC Spirotetramat 10 SC	2 mL L^{-1} 2 mL L^{-1} 2 mL L^{-1}	*B. tabaci* *L. trifolii*	Cucumber	After three sprayings it would found to be etofenprox and imidacloprid is more superior in controlling the nymphs and adults of whitefly upto 95.7 – 98.4%, where in leaf miner imidacloprid reduced population to 78.7% and decreased 77% mines followed by etofenprox upto 57.1% and 54.5%.	Sabry *et al.*, 2015
10.	Spinosad 24 SC Abamectin 1.9 EC	240 g a.i. ha^{-1} 18 g a.i. ha^{-1}	*T. urticae*	Sweet potato	The mixture of spinosad and abamectin caused 74 per cent female fecundity reduction and egg hatching rate when compared to their individual application.	Ismail *et al.*, 2007
11.	Indoxacarb 15 SC Indoxacarb 15 SC Indoxacarb 15 SC Indoxacarb 15 SC Indoxacarb 15 SC Chlorpyriphos 20 EC	30 g a.i. ha^{-1} 40 g a.i. ha^{-1} 50 g a.i. ha^{-1} 55 g a.i. ha^{-1} 60 g a.i. ha^{-1} 500 g a.i. ha^{-1}	*H. armigera* *S. exigua*	Chilli	Indoxacarb with 55 g ai ha^{-1} found to be optimum which shows larval mortality of 97.05% in *S. exigua* and 92.38% in *H. armigera* with 1.73% mean fruit damage.	Ahmed and Prasad, 2010

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

12.	Acephate 76 SL Acephate 76 SL Deltamethrin 2.8 EC Deltamethrin 2.8 EC Imidacloprid 17.8 SL Imidacloprid 17.8 SL	0.05 % 0.10 % 0.025 % 0.05 % 0.025 % 0.05 %	*M. persicae,* *P. latus,* *S. dorsalis*	Capsicum	Deltamethrin 2.8 EC 0.025% and 0.05% reduces the population of mites about 0.37 - 0.72 % per plant where, imidacloprid @ 0.025% and 0.05% and acephate @ 0.05% and 0.10% gave best control over aphids and thrips by lower its population upto 0.76 – 1.05 % and 0.03 - 0.06 % per plant, respectively.	Kaur and Singh, 2013
13.	Abamectin 1.9 EC Cartap hydrochloride50SP Spinosad 45 SC Fipronil 5 SC Imidacloprid 17.8 SL Carbosulfan 25 EC Triazophos 40 EC	0.00057 % 0.05 % 0.018 % 0.0075 % 0.0071 % 0.025 % 0.08 %	*L. trifolii*	Cucumber	The highest percent maggot mortality of 70.95 % and decline in leaf damage of about 55.34 % was achieved with abamectin 1.9 EC followed by cartap hydrochloride 50 SP with 68.25 % mortality and 48.71 % reduction of leaf damage.	Pawar and Patil, 2013
14.	Cyantraniliprole 10 OD Cyantraniliprole 10 OD Cyantraniliprole 10 OD Cyantraniliprole 10 OD Cyantraniliprole 10 OD Spinosad 45 SC Imidacloprid 17.8 SL	45 g a.i. ha^{-1} 60 g a.i. ha^{-1} 75 g a.i. ha^{-1} 90 g a.i. ha^{-1} 105 g a.i. ha^{-1} 56 g a.i. ha^{-1} 25 g a.i. ha^{-1}	*A. gossypii* and *C. septempunc -tata*	Gherkins	Imidacloprid 17.8 SL @ 25 g a.i ha^{-1} recorded significantly lowest aphid population per 3 terminal leaves (1.46) followed by cyantraniliprole 10 OD @ 90 and 105 g a.i. /ha (4.87 and 7.40) with 98.79, 93.85 and 95.95 per cent reduction in aphid population over control and it did not have any significant effect of reduction on *C. septempunctata.*	Misra, 2013

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

15.	Abamectin 1.9 EC Acetamiprid 20 SP Bifenthrin 10 EC Buprofezin 25 EC Dicofol 18.5 EC Hexythiazox 5.45 EC Malathion 50 EC Propargite 57 EC Spinosad 2.5 SC Spiromesifen 240 SC	0.004 % 0.008 % 0.004 % 0.02 % 0.046 % 0.003 % 0.05 % 0.057 % 0.003 % 0.023 %	*T. vaporarior-um* *T. ludeni* *A. lycopersici*	Tomato	Highest mean per cent reduction in immature and adult stages of *T. vaporariorum* was observed in abamectin and acetamiprid (90.12 – 93.41 %) followed by bifenthrin (87.23 %). Where, abamectin and propargite (95.72 – 87.00 %) found to be effective against adults of *T. ludeni* but, bifenthrin and abamectin (99.23 – 99.37 %) was effective against *A. lycopersici*.	Kashyap, 2013
16.	Abamectin 1.9 EC Fenazaquin 10 EC Buprofezin 25 EC Fenpyroximate 5 EC Propargite 57 EC Diafenthiuron 50 WP Dimethoate 30 EC	0.0025 % 0.01 % 0.03 % 0.0025 % 0.05 % 0.055 % 0.03 %	*T. urticae*	Gerbera	Diafenthiuron 50 WP most effective in population reduction of about 68.79% followed by fenpyroximate 5 EC about 64.57% and in case of reduction in hatching of eggs diafenthiuron 50 WP is on par with fenpyroximate 5 EC of about 67.92%.	Shah and Shukla, 2014

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

17.	Spiromesifen 240 SC Chlofenapyr 10 SC Abamectin 1.9 EC Fenpyroximate 5 EC Hexythiazox 5.45 EC Bifenazate 50 WP Dicofol 18.5 EC	0.8 mL L^{-1} 1.5 mL L^{-1} 0.8 mL L^{-1} 1.0 mL L^{-1} 0.8 mL L^{-1} 0.3 mL L^{-1} 2.5 mL L^{-1}	*T. urticae*	Chrysanthemum	Chlorfenapyr, abamectin, hexythiazox and fenpyroximate shows an excellent control of *T. urticae* about 97.13 – 99.88 per cent mortality when compared with dicofol (58.37%)	Reddy *et al.*, 2014
18.	Abamectin 1.9 EC Abamectin 1.9 EC Spiromesifen 22.9 SC Fenpyroximate 5 EC Dicofol 18.5 EC Propargite 57 EC Fenazaquin 10 EC Hexythiazox 5.45 EC Hexythiazox 5.45 EC	0.50 mL L^{-1} 1.00 mL L^{-1} 0.80 mL L^{-1} 1.25 mL L^{-1} 2.70 mL L^{-1} 2.00 mL L^{-1} 1.70 mL L^{-1} 0.75 mL L^{-1} 1.25 mL L^{-1}	*T. urticae*	Cucumber	Abamectin and fenazaquin showed 94.33 – 100 per cent mortality in both seasons and the insecticide persist upto 14 days after treatment followed by spiromesifen and fenpyroximate showed 84 – 95 per cent mortality.	Reddy *et al.*, 2014

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

19.	Oxy-demeton methyl 25 EC Buprofezin 25 EC Cyantraniliprole 10 OD Diafenthiuron 50 WP Spiromesifen 240 SC Chlorfenapyr 10 SC	2.0 mL L^{-1} 2.0 mL L^{-1} 5 mL L^{-1} 0.50 g L^{-1} 2.1 mL L^{-1} 5 mL L^{-1}	*T. vaporario - rum*	Tomato	Spiromesifen found to be most toxic with LC_{50} and LC_{90} values of 2.72 and 13.48 ppm followed by cyanraniliprole with 28 – 98 per cent of first instar nymphal mortality.	Kumar and Singh, 2014
20.	Bifenazate 240 SC Fenazaquin 10 EC Thiamethoxam 25 WG Chlorfenapyr 10 SC Hexythiazox 10 EC Clothianidin 50 WG Dicofol 18.5 EC Abamectin 1.9 EC	0.24 % 0.01 % 0.0075 % 0.008 % 0.01 % 0.02 % 0.05 % 0.002 %	*P. latus*	Capsicum	Abamectin 1.9 EC was recorded lowest cumulative mean mite population of 3.21 mites/ 3 leaves and was on par with chlorfenapyr 10 SC (3.58 mites/ 3 leaves), fenazaquin 10 EC (3.91 mites/ 3 leaves) and bifenazate 240 SC (4.13 mites/ 3 leaves).	Kharbade *et al.*, 2015

Table 4. Management of pests under protected cultivation using chemical insecticides (Continued)

21.	Imidacloprid 17.8 SL Emamectin benzoate 1.9 EC Monocrotophos 36EC Thiamethoxam25WG	100 mL ha^{-1} 325 mL ha^{-1} 100 mL ha^{-1} 100 mL ha^{-1}	*S. dorsalis* *B. tabaci* *A. gossypii* *P. latus* *M. hirsutus* *S. obliqua*	Capsicum	Imidacloprid found to be an effective treatment against mite and mealy bug followed by emamactin benzoate. With respect to thrips, imidacloprid and monocrotophos were found to be significantly superior followed by thiamethoxam. Similarly, for aphids and whitefly imidacloprid was found to be the best treatment followed by thiamethoxam and the maximum yield of 21433.3 kg/ha was obtained in thiomethoxam treated plot.	Kumar and Srivastava, 2015
22.	Spiromesifen 240 SC Spiromesifen 240 SC Spiromesifen 240 SC Propargite 57 EC Dicofol 18.5 EC	96 g ai ha^{-1} 120 g ai ha^{-1} 144 g ai ha^{-1} 430 g ai ha^{-1} 250 g ai ha^{-1}	*T. urticae*	Cucumber	Spiromesifen 240 SC @ 144 g a.i. /ha application had significantly reduced mite infestation when sprayed at 21 days interval with mean mite population of 0.8 – 1.3 mite/ five leaves was most effective in reducing mite population and also resulted in highest yield per plant. Phytotoxicity observations of spiromesifen recorded upto 15 days after application revealed no phytotoxicity symptoms at evaluated doses of 120, 144, 288 and 576 g a.i./ha, respectively.	Sood *et al.*, 2015

Table.5. Dissipation and persistence of insecticides under protected structures

Sl. No	Crop	Insecticide	Dosage	Initial concentration (mg Kg^{-1})	Days taken to reach BDL	Half-life (days)	Reference
1.	Cucumber	Acetamiprid	20 g a.i. ha^{-1}	0.79	9	-	Cara *et al.*, 2011
			40 g a.i. ha^{-1}	1.02	9	-	
2.	Cucumber	Imidacloprid	30 g a.i. ha^{-1}	1.93	13	3.40	Hassanzadeh *et al.*, 2012
			60 g a.i. ha^{-1}	3.65	17	2.70	
3.	Solanaceous vegetables	Chlorpyrifos	200 g a.i. ha^{-1}	-	-	3-6	Lu *et al.*, 2014
4.	Capsicum	Acephate, Methamidophos	292 g a.i. ha^{-1}	-	21	-	Sharma *et al.*, 2012
5.	Tomato	Imidacloprid	30 g a.i. ha^{-1}	-	15	-	Reddy *et al.*, 2007
6.	Tomato	Spinosad	-	2.336	-	2.76	Kashyap, 2013
		Abamectin	-	0.720	-	1.76	
7.	Cucumber	Imidacloprid	30 g a.i. ha^{-1}	0.943	21	2.2	Abbassy *et al.*, 2014
8.	Capsicum	Flubendiamide	48 g a.i. ha^{-1}	0.977	25	-	Buddidathi *et al.*, 2016
			96 g a.i. ha^{-1}	1.834	25	-	

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Purposive survey was conducted among the farmers having polyhouses in Thiruvananthapuram district to gather information on the general conditions of poly houses and to document pests and natural enemies in cowpea and salad cucumber under polyhouse. The studies on the population dynamics and extent of infestation of the pests in cowpea and salad cucumber and the evaluation of the efficacy of new generation insecticides against the major pests of cowpea and salad cucumber were carried out in the Instructional Farm, College of Agriculture, Vellayani. The estimation of residues of these new generation insecticides in cowpea and salad cucumber was conducted at Pesticide Residue Research and Analytical Laboratory, Department of Agricultural Entomology, College of Agriculture, Vellayani. The materials used and the methods adopted are detailed here under.

3.1 DOCUMENTATION OF PESTS, NATURAL ENEMIES AND PESTICIDE USE PATTERN IN POLYHOUSES

Twenty polyhouses were selected purposively in Thiruvananthapuram district during January, 2015 – June, 2015 (Plate 1) and the farmers were interviewed twice to collect the required information as per the questionnaire (Appendix-I).

The information on general condition of the polyhouses and the details of the crops cultivated in the polyhouses were collected. The pests and natural enemies collected from different polyhouses were brought to the laboratory and identified. The stage of crop infested by each pest was recorded. The unidentified specimens were sent to respective taxonomists and identified (Table 6). The details on plant protection practices adopted, chemicals used and their dose, interval between spraying, types of sprayer used, time of application, interval between spraying and harvest and source of technical advice for adoption of plant protection operations were collected and recorded. The incidence of sucking pests and leaf feeders in cowpea and salad cucumber under


Cicil chandran, Kulathoor


Balraj, Parassala


Chakrapani, Mudakkal


Chandrakumar, Nemom


Ribia, Vamanapuram


Lal K. Laxemen, Parasala


Kurup, K. R. M. Kizhuvilam


CoA, Vellayani


Sathyadas, Poovar


Shiffa Syraj, Sasthamangalam


Muhammed Sudheer, Manical

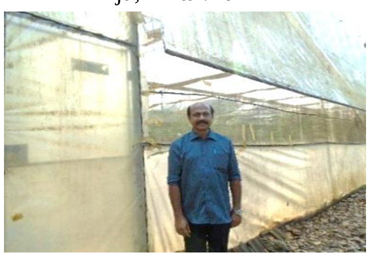

Niju, Thittivila


Shafeek, Trivandrum


CoA, Vellayani


Sudheer Kumar, Neyyatingara


Vijay Motha, Panavoor


Hariprasad, K. Pulimath


Reeja, Vamanapuram


Jayasuda, Parasala


Biju Kumar, Vamanapuram

Plate 1. Polyhouse farmers surveyed in Thiruvananthapuram district

Table 6. Details of specimens sent for identification

Sl. No	Specimen	Collected from		Identified by
		Crop	Place	
1	Girdle beetle and Leaf beetle	Cowpea	Vellayani	Dr. Prathapan, K. D. Assistant Professor, College of Agriculture, KAU, Vellayani
2	Tortrycid larvae and Leaf miner	Cowpea	Vellayani, Karrette Neyyatingara	Dr. Prakash Chand Pathania Professor, College of Agriculture, PAU, Ludhiana
3	Thrips	Cowpea and salad cucumber	Venjaramood, Vellayani	Mrs. Rachana Scientist, NBAIR, Bangalore, Karnataka
4	Mites	Cowpea and salad cucumber	Vamanapuram, Manical	Dr. Haseena Bhaskar Associate Professor, College of Horticulture, KAU, Vellanikara
5	Coccinellids	Cowpea and salad cucumber	Poovar, Vellayani	Dr. Poorani, J. Scientist, NCBR, Trichy
6	Spiders	Cowpea and salad cucumber	Venjaramood, Vellayani	Dr. Sudhikumar Professor, Calicut University, Kochi

polyhouses was compiled to find out the dominant group of pests (sucking/ leaf feeders) in polyhouses.

3.2 STUDIES ON POPULATION DYNAMICS AND INFESTATION OF PESTS IN COWPEA AND SALAD CUCUMBER

The experiment was carried out in the polyhouse located in the Instructional Farm, College of Agriculture, Vellayani during August, 2015 – November, 2015 to study the population of pests of cowpea and salad cucumber. The crops were raised according to the Good Agricultural Practices (GAP) suggested by Susheela (2015) in polyhouses.

Design – CRD

Replication – 4

3.2.1 Population Dynamics

The population of sucking and leaf feeders in cowpea and salad cucumber under polyhouse conditions were recorded at 15, 30, 45, 60, 75, 90 and 120 days after sowing. Ten plants were randomly selected from 15 plants in each replication and the mean number of pest population was calculated.

3.2.1.1 Sucking Pests

Aphids

The number of aphids from each plant was assessed from 15 cm of the terminal twig with the unopened leaves and two opened leaves and the mean number was recorded (Nithya, 2015).

Mealybug

The mean number of mealybug including nymphs was assessed from 30 cm of the growing shoot tip of each of the selected 10 plants.

Pod bugs

The pods, flowers, leaves and stem were closely examined for pod bug nymphs and adults and the mean number present in each plant was recorded (Meena, 2007).

Mites

Three leaves were randomly selected from top, middle and bottom portions of each observational plant and the mean number of mites was counted and recorded (Bindu, 1997).

3.2.1.2 Leaf Feeders

Tortrycid larvae and Pumpkin caterpillar

Observations were taken from randomly selected ten plants and the number of larvae per plant was recorded.

American serpentine leaf miner

Three leaves each from top, middle and bottom of the plant were selected and the number of larvae within the mines were counted and the mean number was recorded (Regi, 2002).

Girdle beetle

The number of adults per plant was counted and recorded.

Leaf beetle

The number of beetles per plant was counted and recorded.

3.2.2 Pest Infestation

The infestation of sucking and leaf feeders in cowpea and salad cucumber under polyhouse conditions were recorded at different time intervals of 15, 30, 45, 60, 75, 90 and 120 days after sowing. The percentage infestation was calculated by using the following formula.

$$\text{Per cent infestation} = \frac{\text{Number of plants infested}}{\text{Total number of plants}} \times 100$$

3.3 EVALUATION OF EFFICACY OF NEW GENERATION INSECTICIDES AGAINST THE MAJOR PESTS IN COWPEA AND SALAD CUCUMBER

The efficacy of new generation insecticides was evaluated against the major pests identified from 3.1. In cowpea, pea aphid, pod bugs and mites were the major sucking pest and American serpentine leaf miner was identified as important leaf feeder. Green peach aphid and mites were the major sucking pests in salad cucumber and leaf miner and pumpkin caterpillar were identified as major leaf feeders. The new generation insecticides and acaricides used against sucking pests and leaf feeders were tested at their recommended doses in both cowpea and salad cucumber under polyhouse and the details are presented in Table 7. Four experiments in both cowpea and salad cucumber were laid in polyhouse located in the Instructional Farm, Vellayani. The cowpea plants of variety Vellayani Jyothika and salad cucumber of F1 parthenocarpic hybrid Multistar were planted in rows by adopting the Good Agricultural Practices (GAP) suggested by Susheela (2015) in polyhouses and ten plants per replication were randomly selected.

3.3.1 Evaluation of Insecticides against Sucking Pests Infesting Cowpea and salad cucumber

3.3.1.1 Cowpea

Aphids and pod bugs

Design – CRD

Treatment – 6

Table 7. Details of insecticides used for the management of pests under polyhouse

Sl. No	Details of insecticides				
	Chemical name	Trade name	Chemical group	Mode of action as per IRAC, 2016	Dosage (g a.i. ha^{-1})
a) Insecticides against sucking pests					
1.	Acetamiprid 20 SP	Rapid	Neonicotinoids	Nicotinic acetylcholine receptor competitive modulators	10-20
2.	Imidacloprid 17.8 SL	Confidence 555	Neonicotinoids	Nicotinic acetylcholine receptor competitive modulators	20
3.	Thiamethoxam 25 WG	Excel	Neonicotinoids	Nicotinic acetylcholine receptor competitive modulators	7-10
4.	Thiacloprid 21.7 SC	Splendour	Neonicotinoids	Nicotinic acetylcholine receptor competitive modulators	24-30
5.	Dimethoate 30 EC (Check)	Tafgor	Organophosphates	Acetylcholinesterase (AChE) inhibitors	200-350
b) Acaricides tested against mites					
6.	Spiromesifen 22.9 SC	Oberon	Tetronic and tetramic acid derivatives	Inhibitors of acetyl CoA carboxylase	72-96
7.	Fenpyroximate 5 EC	Mite block	METI acaricides and	Mitochondrial complex I electron	15-30

			insecticides	transport inhibitors	
8.	Dimethoate 30 EC (Check)	Tafgor	Organophosphates	Acetylcholinesterase (AChE) inhibitors	200-350
c) Insecticides tested against leaf feeders					
9.	Spinosad 45 SC	Tracer	Spinosyns	Nicotinic Acetylcholine receptor (allosteric) activators	75
10.	Chlorantraniliprole 18.5 SC	Coragen	Diamides	Ryanodine receptor modulators	30
11.	Flubendiamide 39.35 SC	Fame	Diamides	Ryanodine receptor modulators	25
12.	Indoxacarb 14.5 SC	Ammate	Oxadiezenes	Voltage-dependent sodium channel blockers	50-60
13.	Quinalphos 25 EC (Check)	Ekalux	Organophosphates	Acetylcholinesterase (AChE) inhibitors	250-350

Replication – 3

The first spray was given as and when 10 per cent infestation was noticed and the second spray was given at 25 days after first spray when reoccurrence of aphid was noticed. Only one spray was given in pod bugs since there was no re occurrence of pest. The population of aphids and pod bugs were taken before treatment and 1, 3, 5, 7, 10 and 15 days after treatment as described under 3.2.1.1.

Mites

Design – CRD

Treatment – 4

Replication – 4

The first spray was given as and when 10 per cent infestation was noticed and the second spray was given at 25 days after first spraying when reoccurrence of pest was noticed. The population of mite was taken before treatment and 1, 3, 5, 7, 10 and 15 days after treatment as described under 3.2.1.1.

3.3.1.2. Salad cucumber

Green peach aphid

The details of design and schedule of spray was same as described under 3.3.1.1

Mites

The details of design and schedule of spray was same as described under 3.3.1.1

3.3.2. Evaluation of Insecticides against Leaf Feeders Infesting Cowpea and Salad Cucumber

3.3.2.1 Cowpea

Design – CRD

Treatment – 6

Replication – 3

American serpentine leaf miner

The first spray was given when 10 per cent of leaves shown leaf mining symptoms. The second spray was given 20 days after the first spray when reoccurrence of pest was noticed. Observations on the population of leaf miner were assessed before and 1, 3, 5, 7, 10 and 15 days after treatment as described under American serpentine leaf miner in 3.2.1.2.

3.3.2.2 Salad cucumber

Pumpkin caterpillar and American serpentine leaf miner

The design and schedule of spray was same as in the experiment no. 3.3.1.2. The first spray was given when 10 per cent of leaves showed infestation. The second spray was given 20 days after the first spray only against American leaf miner when reoccurrence of pest was noticed. Observations on the population of pumpkin caterpillar and leaf miner were assessed before and 1, 3, 5, 7, 10 and 15 days after treatment as described under in 3.2.1.2.

3.4 PERSISTENCE AND DEGRADATION OF RESIDUES OF PESTICIDES IN COWPEA AND SALAD CUCUMBER

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

The experiment was carried out in the polyhouse located in the Instructional Farm, College of Agriculture, Vellayani to study the persistence and degradation of residues of pesticides in cowpea and salad cucumber.

3.4.1. Method Validation

3.4.1.1 Preparation of standard insecticide mixtures

Certified reference materials of pesticides *viz.,* acetamiprid, imidacloprid, thiamethoxam, thiacloprid, spiromesifen, fenpyroximate, spinosad, chlorantraniliprole, flubendiamide and indoxacarb with 99.9, 99.9, 99.6, 99.9, 99.9, 99.4, 97.3, 99.1, 98.3 and 93.9 per cent purity, respectively were purchased from M/s Sigma Aldrich. Stock solutions (1000 μg mL^{-1}) of the insecticides were prepared by dissolving a weighed quantity of the analytical grade material in HPLC grade methanol. The stock solutions were serially diluted to prepare an intermediate stock of 100 μg mL^{-1}. The intermediate stock solutions were further diluted with HPLC grade methanol to prepare working standard mixtures (10 μg mL^{-1}) of the insecticides to be analysed by positive electro spray ionozation (acetamiprid, imidacloprid, thiamethoxam, thiacloprid, spiromesifen, fenpyroximate, spinosad, chlorantraniliprole and indoxacarb) and by negative electro spray ionization (flubendiamide). 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 μg mL^{-1} concentrations of analytical grade insecticides.

3.4.1.2 Fortification and Recovery Experiment

Cowpea and salad cucumber (500 g) harvested from control plots were chopped and ground to a fine paste. Five replicates of 25 g representative samples of the fruits were taken in 50 mL centrifuge tubes and spiked with 0.05, 0.25 and 0.50 mL of 10 μg mL^{-1} working standard mixtures of the insecticides. The extraction and clean-up 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 70-120 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.

3.4.2 Dissipation of the Insecticides

3.4.2.1 Sampling

Insecticides sprayed harvestable fruits of cowpea and salad cucumber (2 kg each) were collected from each plot two hours, one, three, five, seven, ten and fifteen days after spraying, brought to the laboratory in polythene bags and processed immediately for residue analysis.

3.4.2.2 Residue Extraction

The multiresidue estimation procedure recommended for vegetables as per QuEChERS method with suitable modifications was adopted for residue extraction and clean up in cowpea and salad cucumber. The harvested fruits were macerated as such in a high-speed blender (BLIXER 6 vv Robot Coupe) for three times and a representative sample of 25g of ground vegetable was taken in a 250 mL centrifuge tube. HPLC grade acetonitrile (50 mL) was added to the samples and homogenised with a high speed tissue homogenizer (Heidolph Silent Crusher-M) at 14000 rpm for three minutes. This was followed by the addition of 10 g activated sodium chloride (NaCl) and vortexing for two minutes for separation of the acetonitrile layer. The samples were then centrifuged for five minutes at 2500 rpm and 12 mL of the clear upper layer was transferred into 50 mL centrifuge tubes containing six g pre-activated sodium sulphate and vortexed for two minutes. The acetonitrile extracts were subjected to clean up by dispersive solid phase extraction (DSPE). For this, 8 mL of the upper layer was transferred into centrifuge tubes (15 mL) containing 0.20 g PSA and 1.20 g magnesium sulphate. The mixtures were then shaken in vortex for two minutes and again centrifuged for five minutes at 2500 rpm. The supernatant liquids (5 mL each) were transferred to turbovap tube and evaporated to dryness under a gentle steam of nitrogen using a Turbovap set at 40 ºC 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.

3.4.2.3 Residue Estimation

The chromatographic separation was achieved using Waters Acquity UPLC system equipped with a reversed phase Atlantis d C-18 (2.1 × 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 - 0.4 min linear from 20 % to 90 % B, 4.0 - 5 min linear from 90 % to 95 % B, and 5 - 9 min linear from 95 % to 100 % B, 9-10 min linear from 100 % to 20 % B, with 10-12 min maintained the same polarity of 20 % B. The flow rate remains constant at 0.8 mL min-1 and injection volume was 10 µL. The column temperature was maintained at 40 ºC. 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 ºC, ion gas (GSI) 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 acetamiprid, imidacloprid, thiamethoxam, thiacloprid, spiromesifen, fenpyroximate, chlorantraniliprole and indoxacarb were found to be 1.41, 1.17, 0.87, 1.68, 4.71, 4.95, 3.00 and 4.24 minutes respectively. The retention time for spinosyn A and spinosyn D were 4.15 and 4.34 minutes, 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 remains constant at 0.75 mL min-1 and injection volume was 10 μL. The column temperature was kept at 40 ºC. 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 ºC, ion gas (GSI) 50 psi, ion gas (GS2) 60 psi, ion spray voltage 4,500 V, curtain gas 13 psi. Under these operating conditions the retention time of flubendiamide was found to be 3.84 minute.

3.4.2.4 Residue quantification

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

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

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

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

3.5 STATISTICAL ANALYSIS

Data on each experiment were analysed, applying suitable methods of analysis (Panse and Sukhatme, 1967). Appropriate transformations were made and significant results were compared on the basis of critical differences.

MATERIALS AND METHODS

4. RESULTS

4.1 DOCUMENTATION OF PESTS, NATURAL ENEMIES AND PESTICIDE USE PATTERN IN POLYHOUSES

Results on the survey of general conditions of polyhouses, cropping pattern, important pests and their management measures adopted in cowpea and salad cucumber in polyhouses of Thiruvananthapuram districts are presented in Table 8-12.

4.1.1 General Conditions of Polyhouses

Among the polyhouses surveyed, 25 per cent of polyhouses were in good construction without slits in anteroom and cladding materials, 30 per cent of polyhouses with slits in anteroom and 25 per cent had low quality cladding materials. Whereas, 20 per cent polyhouses were not maintained well with slits in anteroom (Table 8).

4.1.2 Major Crops and Cropping Pattern

The major crops cultivated were cowpea and salad cucumber which accounts 30 and 25 per cent of total polyhouse surveyed. However, 25 per cent of polyhouses were cultivating both cowpea and salad cucumber. Whereas, 20 per cent of polyhouses had multiple crops like cowpea, salad cucumber, snake gourd, bhindi, brinjal, amaranthus, cabbage, cauliflower, palak and broccoli (Figure 1).

4.1.3 Pests and Natural Enemies of Cowpea and Salad Cucumber

The data on the details of pest and natural enemies in cowpea and salad cucumber under polyhouses in Thiruvananthapuram district are depicted in Table 9 and 10, respectively.

Table 8. Categories of polyhouses in Thiruvananthapuram district

Sl. No	Particulars	Polyhouses (%)
1	Polyhouses with good construction (no slits in ante room and cladding materials)	25
2	Polyhouses with slits in ante room	30
3	Polyhouses with low quality cladding material	25
4	Polyhouses with slits and without proper construction	20

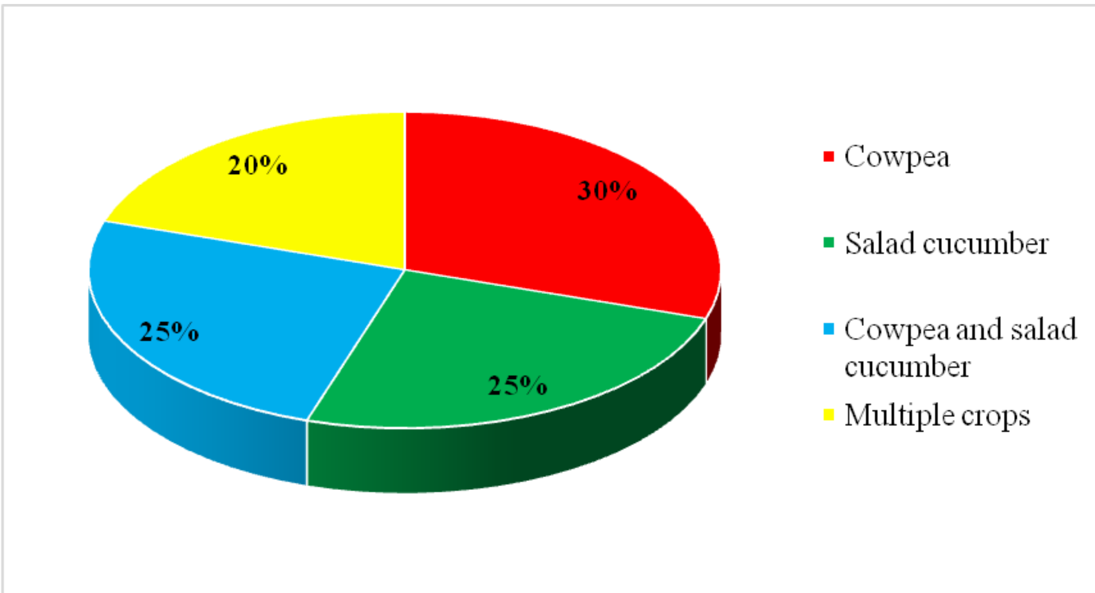


Figure 1. Major crops under polyhouse in Thiruvananthapuram district

From the survey, it was clear that both sucking and leaf feeders were dominant group of pests infesting cowpea and salad cucumber. In cowpea sucking pests recorded were aphids, *Aphis craccivora* Koch (Aphididae: Hemiptera), mealybug, *Ferrisia virgata* Cockerell (Pseudococcidae: Hemiptera), pod bugs, *Riptortus pedestris* Fabricius (Alydidae: Hemiptera), fulgorid bug, *Eurybrachys tomentosa* Fabricius (Eurybrachidae: Hemiptera), thrips, *Ayyaria chaetophora* Karny (Thripidae : Thysanoptera), mites, *Tetranychus truncatus* Ehara (Tetranychidae: Acarina) and in salad cucumber *viz.*, green peach aphid, *Myzus persicae* Sulzer (Aphididae: Hemiptera), mealybug, *Ferrisia virgata* Cockerell (Pseudococcidae: Hemiptera), three thrips, *Astrothrips tumiceps* Karny, *Thrips hawaiiensi* (Morgan), *Frankliniella schultzei* (Trybom) (Thripidae: Thysanoptera) and mites, *Tetranychus* sp. (Tetranychidae: Acarina) were the sucking pests (Table 9) (Plate 2 and 3).

The leaf feeders observed in cowpea were tobacco caterpillar, *Spodoptera litura* Fabricius (Noctuidae: Lepidoptera), pod borer, *Lampides boeticus* Linnaeus (Lycaenidae: Lepidoptera), tortrycid moth (Tortricidae: Lepidoptera), leaf miner (Gelechidae: Lepidoptera), leaf beetle, *Pagria flavopustulata* Baly (Chrysomelidae: Coleoptera), stem girdler, *Oberiopsis brevis* Gahan (Cerambycidae: Coloeoptera), American serpentine leaf miner, *Liriomyza trifolii* Burgess (Agromyzidae: Diptera) (Plate 4).

Pumpkin caterpillar, *Diaphania indica* Saunders (Crambidae: Lepidoptera) and American serpentine leaf miner, *Liriomyza trifolii* Burgess (Agromyzidae: Diptera) were the leaf feeders recorded from salad cucumber (Plate 5). The reports of the infestation of the pests *viz.,* tortrycid larvae, leaf miner and girdle beetle, *O. brevis* in cowpea were the first record of these pests infesting cowpea in polyhouses (Plate 6 - 9).

Table 9. Pest infesting cowpea and salad cucumber in polyhouses of Thiruvananthapuram district

Particulars					Stage of crop
Types of pest A. Sucking pest	Common name	Scientific name	Family: Order	Polyhouses (%)	
i) Cowpea	Mites	*Tetranychus truncatus* Ehara	Tetranychidae: Acarina	40	Vegetative, Flowering, Fruiting
	Aphids	*Aphis craccivora* Koch	Aphididae: Hemiptera	27	Flowering, Fruiting
	Thrips	*Ayyaria chaetophora* Karny	Thripidae: Thysanoptera	27	Flowering, Fruiting
	Pod bugs	*Riptortus pedestris* Fabricius	Alydidae: Hemiptera	13	Fruiting
	Fulgorid bug	*Eurybrachys tomentosa* Fabricius	Eurybrachidae: Hemiptera	7	Flowering, Fruiting
	Mealybug	*Ferrisia virgata* Cockerell	Pseudococcidae: Hemiptera	7	Fruiting
ii) Salad cucumber	Mites	*Tetranychus* sp.	Tetranychidae: Acarina	33	Fruiting
	Aphids	*Myzus persicae* Sulzer	Aphididae: Hemiptera	20	Vegetative, Fruiting
	Thrips	*Astrothrips timiceps* Karny *Thrips hawaiiensis* Morgan *Frankliniella schultzei* Trybom	Thripidae: Thysanoptera	13	Flowering, Fruiting
	Mealybug	*Ferrisia virgata* Cockerell	Pseudococcidae: Hemiptera	7	Fruiting

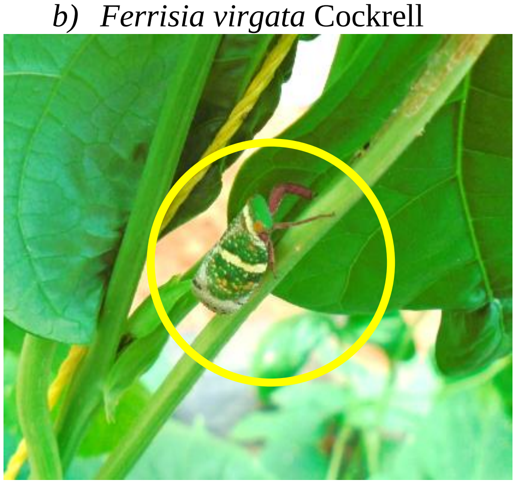
Table 9. Pest infesting cowpea and salad cucumber in polyhouses of Thiruvananthapuram district (Continued)

B. Leaf feeders i) Cowpea	American serpentine leaf miner	*Liriomyza trifolii* Burgess	Agromyzidae: Diptera	47	Vegetative, Flowering
	Tobacco caterpillar	*Spodoptera litura* Fabricius	Noctuidae: Lepidoptera	27	Flowering, Fruiting
	Pod borer	*Lampides boeticus* Linnaeus	Lycaenidae: Lepidoptera	13	Flowering, Fruiting
	Tortrycid moth	Unidentified	Tortricidae: Lepidoptera	13	Vegetative, Flowering, Fruiting
	Leaf miner	Unidentified	Gelechidae: Lepidoptera	13	Flowering, Fruiting
	Leaf beetle	*Pagria flavopustulata* Baly	Chrysomelidae: Coleoptera	7	Vegetative
	Stem girdler	*Oberyopsis brevis* Gahan	Cerambycidae: Coloeoptera	7	Vegetative, Flowering, Fruiting
ii) Salad cucumber	American serpentine leaf miner	*Liriomyza trifolii* Burgess	Agromyzidae: Diptera	40	Vegetative, Fruiting
	Pumpkin caterpillar	*Diaphania indica* Saunders	Crambidae: Lepidoptera	7	Vegetative

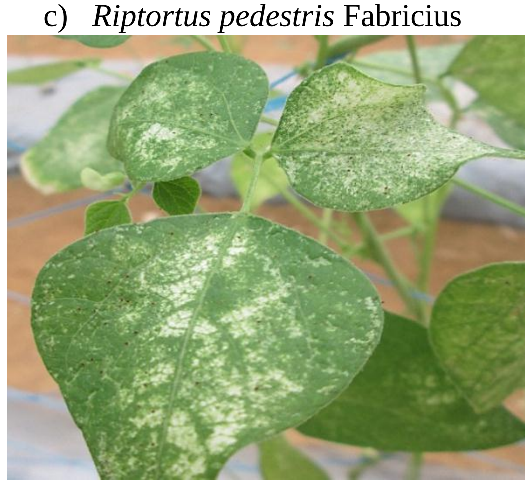
a) Aphis craccivora Koch

b) Ferrisia virgata Cockrell

c) *Riptortus pedestris* Fabricius



d) Eurybrachys tomentosa Fabricius



e) Tetranychus truncatus Ehara

Plate 2. Infestation of sucking pests in cowpea

a) Myzus persicae Sulzer

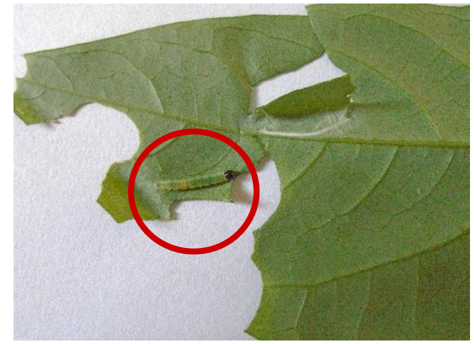
b) *Ferrisia virgata* Cockrell

c) *Tetranychus* sp.

Plate 3. Infestation of sucking pests in salad cucumber

a) *Spodoptera litura* Fabricius

b) *Lampides boeticus* Linnaeus



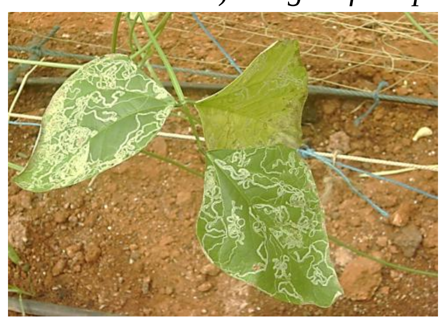
c) Tortrycid larvae

d) Tortrycid larvae

e) Leaf miner

f) *Pagria flavopustulata* Baly

e) *Oberyopsis brevis* Gahan



g) *Liriomyza trifolii* Burgess

Plate 4. Infestation of leaf feeders in cowpea

a) *Diaphania indica* Saunders

b) *Liriomyza trifolii* Burgess

Plate 5. Infestation of leaf feeders in salad cucumber

a) Grub

b) Adult

c. Damage

Plate 6. Life stages and feeding symptoms of stem girdler

a) Early instar larvae

b) Late instar larvae

c) Pupae

d) Adult

e) Damage

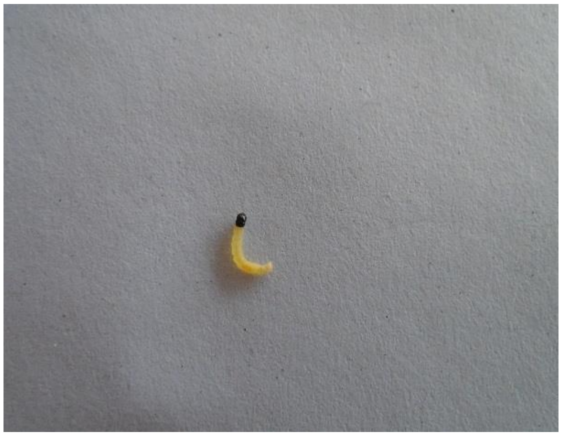
Plate 7. Life stages and feeding symptoms of stem girdler

a) Larvae

b) Adult

c) Damage

Plate 8. Life stages and feeding symptoms of tortrycid larvae



a) Early instar larvae

b) Late instar larvae

c) Pupae

d) Adult

e) Damage

Plate 9. Life stages and feeding symptoms of tortrycid larvae

The data on the details of infestation of sucking pests in cowpea showed that mites were the dominating pest infesting 40 per cent of the polyhouses and its infestation was seen in vegetative, flowering and fruiting stages. 27 per cent each of polyhouses were affected by aphids and thrips at flowering and fruiting stages followed by pod bug (13 %) at fruiting stage and seven per cent each of polyhouses were attacked by mealybug and fulgorid bug.

Similarly, mite was the dominant pest in salad cucumber seen in 33 per cent of polyhouses at fruiting stage followed by aphids (20 %) at vegetative and fruiting stage. Infestation of thrips found in 13 per cent polyhouses at flowering and fruiting stage. Whereas, less number of polyhouses (7 %) had mealybug infestation at fruiting stage.

American serpentine leaf miner was recorded from 47 per cent of the polyhouses in vegetative and flowering stages of cowpea followed by tobacco caterpillar (27 %) at flowering and fruiting stage. However, pod borer, tortricid moth and leaf miner were seen in 13 per cent each of polyhouses. Whereas, infestation of leaf beetle and stem girdler noticed in 7 per cent each of polyhouses in vegetative, flowering and fruiting stage of crop. In salad cucumber 40 per cent of the polyhouses were infested with American serpentine leaf miner at vegetative and fruiting stage and only 7 per cent polyhouses affected with pumpkin caterpillar during its vegetative stage.

The various predatory fauna associated with cowpea and salad cucumber under polyhouse are presented in Table 10 and Plate 10.

Coccinellids, *Coccinella* sp. (Coccinellidae: Coleoptera), Syrphids (Syrphidae: Diptera), and three spiders *viz.*, Lynx spider, *Oxyopes javanus* Thorell (Oxyopidae: Araneae), Garden spider, *Argiope pulchella* Thorell (Araneidae:

Table 10. Natural enemies in cowpea and salad cucumber under polyhouse

Sl. No	Common name	Scientific name	Family: Order	Polyhouses (%)	Stage of crop
1.	Coccinellids	*Coccinella* sp.	Coccinellidae: Coleoptera	15	Flowering, Fruiting
2.	Syrphids	Unidentified	Syrphidae: Diptera	10	Vegetative, Flowering
3.	Lynx spider	*Oxyopes javanus* Thorell	Oxyopidae: Araneae	20	Vegetative, Flowering, Fruiting
4.	Orange lynx spider	*Oxyopes sunandae* Tikader	Oxyopidae: Araneae	5	Vegetative, Flowering, Fruiting
5.	Garden spider	*Argiope pulchella* Thorell	Araneidae: Araneae	10	Vegetative, Flowering, Fruiting

a) Coccinella sp.

b) *Cocinella* sp.

c) Syrphids

d) *Oxyopes javanus* Thorell

e) *Oxyopes sunandae* Tikader

f) *Argiope pulchella* Thorell

Plate 10. Natural enemies in polyhouse

Araneae), Orange lynx spider, *Oxyopes sunandae* Tikader (Oxyopidae: Araneae) were the natural enemies in cowpea and salad cucumber under polyhouse.

The coccinellids were observed in 15 per cent and syrphids in 10 per cent of the polyhouses in vegetative, flowering and fruiting stage of the crops. Whereas, 20 per cent of the polyhouses with *O. javanus*, 10 per cent with *A. pulchella* and only 5 per cent with *O. sunandae* were seen during vegetative, flowering and fruiting stage.

4.1.4 Pest Incidence in Cowpea and Salad Cucumber under Polyhouse

Survey revealed that both sucking pests and leaf feeders caused significant damage in cowpea and salad cucumber under polyhouses. The pest incidence in cowpea under polyhouse revealed that infestation of sucking pests and leaf feeders were 71 per cent each (Table 11). However, in salad cucumber 67 per cent of polyhouses had the infestation of sucking pests and 50 per cent had infestation of leaf feeders.

4.1.5 Pesticide Use Pattern

The data on the adoption of plant protection measures stated that 35 per cent of the polyhouse growers used chemical insecticides alone, 25 per cent using botanicals and 20 per cent were applying both botanicals and chemical insecticides for the management of pests. However, 5 per cent each of polyhouse farmers were using biocontrol agents alone and botanicals and biocontrol agents. While 10 per cent of polyhouses were using biocontrol agents with chemical insecticides (Table 12).

In case of insecticides used, 73 per cent of polyhouses were sprayed with new generation insecticides, 18 per cent with organophosphorous insecticides and 9 per cent with synthetic pyretheroids. Whereas, in no polyhouses organochlorine and carbamate pesticides were used.

Table 11. Pest incidence in cowpea and salad cucumber under polyhouse

Crop	Polyhouses having pest infestation (%)	
	Sucking pest	Leaf feeders
Cowpea	71	71
Salad cucumber	67	50

Table 12. Pesticide use pattern of polyhouses in Thiruvananthapuram district

Particulars		Polyhouses (%)
1. Protection practices adopted	a) Botanicals	25
	b) Biocontrol agents	5
	c) Chemical insecticides	35
	d) Botanicals and biocontrol agents	5
	e) Botanicals and chemical insecticides	20
	f) Biocontrol agents and chemical insecticides	10
2. Insecticides used	a) Organochlorine	0
	b) Organophosphates	18
	c) Carbamates	0
	d) Synthetic pyretheroids	9
	e) New generation insecticides	73
a) Dose	a) Recommended dose	40
	b) Approximate dose	60
b) Mode of mixing	a) Manual mixing	10
	b) No manual mixing	90
c) Attention towards labels	a) Reading labels before use	60
	b) No attention towards labels	40
d) Mode of application	a) Prophylactic application	40
	b) Need based application	60
e) Interval between sprayings	a) 7 days	15
	b) 10 days	25
	c) 15 days	15
	d) Need based spray	45
f) Type of sprayer used	a) Hand sprayer	65
	b) Knapsack sprayer	35
g) Time of application of pesticides	a) Morning	65
	b) Afternoon	Nil
	c) Evening	35

h) Interval between pesticide application and harvest	a) 5 days	25
	b) 1 week	60
	c) After 1 week	15
i) Source of technical advice on plant protection operations	a) KrishiBhavan only	15
	b) State Horticulture Mission only	10
	c) Kerala Agricultural University only	25
	d) KrishiBhavan and State Horticulture Mission	15
	e) State Horticulture Mission and Other progressive farmers	10
	f) Kerala Agricultural University and KrishiBhavan	5
	g) Kerala Agricultural University and Progressive farmer	10
	h) State Horticulture Mission, Kerala Agricultural University and Other progressive farmers	10

Regarding the dose of chemicals, 40 per cent of polyhouses followed recommended dose of chemicals on spraying while, 60 per cent followed approximate dose only. In case of manual mixing of pesticides, 90 per cent of polyhouse farmers did not follow the practice of manual mixing while, 10 per cent followed the manual mixing of chemicals before spraying.

Majority of the polyhouse farmers paid their attention towards labels on pesticide bottle (60 %) while spraying, 40 per cent were not concerned on labels before use. Considering the application of pesticides, 40 per cent were applied as a prophylactic where 60 per cent sprayed as need based.

Regarding the interval between sprayings 45 per cent of polyhouse farmers gave more than 15 days interval, 25 per cent sprayed at 15 days interval and 15 per cent each given 7 and 15 days interval. The pesticide application was done by using different types of sprayers. Most of the farmers (65 %) were using hand sprayers and less number of farmers (35 %) using knapsack sprayers. The farmers used to spray insecticides at different times 65 per cent of polyhouse farmers sprayed chemicals in the morning while, 35 per cent done spraying only at evening. However, no farmers were spraying chemicals in afternoon time. 60 per cent of polyhouses followed a harvest interval of one week between spraying and harvest while, 25 per cent gave five days interval. Whereas, 15 per cent of polyhouse farmers done harvest after 1 week interval only.

The polyhouse farmers collected the technical advice for the adoption of plant protection measures from different sources, 25 per cent farmers collected information from Kerala Agricultural University whereas, 15 per cent of each gathered information from nearby Krishi bhavan, Krishi bhavan and State Horticulture Mission. However, 10 per cent each of polyhouse farmers gathered information from State Horticulture Mission, State Horticulture Mission and progressive farmers, Kerala Agricultural University and progressive farmers and from Kerala Agricultural

University, State Horticulture Mission and progressive farmers respectively. While, 5 per cent of them collected the information from both Kerala Agricultural University and Krishi bhavan.

4.2 STUDIES ON THE POPULATION DYNAMICS AND INFESTATION OF PESTS OF COWPEA AND SALAD CUCUMBER

The studies on the population dynamics and infestation of sucking pests and leaf feeders of cowpea and salad cucumber under polyhouses in Thiruvananthapuram district were depicted in Table 13 - 18.

4.2.1. Cowpea

4.2.1.1. Sucking Pests

Aphids

Population of aphids started after 30 days of sowing. Significantly highest population of aphid (369.38) was observed in cowpea plants on 60 days after sowing followed by the population after 75 days of sowing (288.16) and the population of aphid after 90 days of sowing was 252.90 and decreased to 197.95 after 120 days of sowing. The population started to increase after 45 days of sowing was 131.62 with the lowest population was observed after 30 days of sowing (4.52) where, no aphid population was found out in cowpea plants after 15 days of sowing (Table 13).

The infestation started 30 days after sowing (13.23 %) and it was significantly different from the infestation after 45 days of sowing (68.87 %). Cent percent infestation was noticed from 75 to 120 days and found to be on par with infestation after 60 days of sowing (92.65 %) (Table 14).

Table 13. Population dynamics of sucking pests in cowpea under polyhouse condition

Days after sowing	Mean number of population of sucking pests in cowpea			
	Aphids *	Pod bugs**	Mealy bug***	Mites****
15	-	-	-	-
30	4.52	-	-	6.25
45	131.62	-	-	33.83
60	369.38	1.99	41.22	69.15
75	288.16	2.76	79.8	111.29
90	252.90	2.76	129.99	120.13
120	197.95	1.59	163.98	35.69
CD (0.05%)	18.656	0.458	22.720	7.140

*Number of aphids per 15 cm shoot length, **Number of mealybug per 30 cm shoot length, ***Number of bugs per plant, ****Number of mites per top, middle and bottom three leaves

Table 14. Infestation of sucking pests in cowpea under polyhouse condition

Days after sowing	Infestation of sucking pests in cowpea (%)			
	Aphids	Mealy bug	Pod bugs	Mites
15	-	-	-	-
30	13.23	-	-	4.41
45	69.12	-	-	33.82
60	92.65	54.41	48.53	57.35
75	100	67.65	75.01	77.94
90	100	86.77	77.94	88.23
120	100	100	82.36	100
CD (0.05%)	10.432	11.188	16.086	7.891

Mealybug

Mealybug population noticed after 60 days of sowing under polyhouse condition (Table 13). The highest population of mealybug (163.98) was observed 120 days after sowing followed by 90, 75 and 60 after sowing (129.99, 79.80 and 41.22, respectively) and the values were significantly different.

Mealybug infestation started 60 days after sowing in cowpea under polyhouse condition. The highest infestation of mealybug was noticed in 120 days after sowing (100 %) followed by 90, 75 and 60 days after sowing (86.77, 67.65 and 54.41 %, respectively) and they were significantly different from each other (Table 14).

Pod bugs

The population of pod bugs was found after 60 days of sowing in cowpea under polyhouse condition (Table 13). Significantly highest population of pod bugs (2.76) was observed after 75 and 90 days of sowing followed by 60 days after sowing (1.99) and is significantly different. The lowest number of pod bugs population was observed after 120 days of sowing (1.59).

Infestation started after 60 days of sowing with an infestation of 48.53 per cent (Table 14). The highest infestation of pod bugs was observed after 120 days of sowing (82.36 %) and the infestation after 90 and 75 days after sowing was 77.94 and 75.01 per cent and it was significantly on par with each other.

Mites

Significantly highest population of mites (120.13) was observed in cowpea after 90 days of sowing followed by 75 and 60 days after sowing (111.29 and 69.15, respectively) and significantly different. The population of mites after 120 days of sowing was observed as 35.69 and found to be on par with 45 days after sowing

(33.83). The lowest population (6.25) was observed after 30 days of sowing (Table 13).

The highest infestation by mites in cowpea under polyhouse was noticed after 120 days of sowing (100 %) followed by 90, 75 and 60 days after sowing (88.23, 77.94 and 57.35 %, respectively) and the values were significantly different from each other. The lowest infestation (4.41 %) was observed after 30 days of sowing and the infestation after 45 days of sowing was 33.82 per cent whereas, no mite infestation was observed 15 days after sowing (Table 14).

4.2.1.2 Leaf Feeders

Tortrycid larvae

The population of tortrycid started (0.13) after 30 days of sowing and it was significantly different from the population observed in 45 and 60 days after sowing (0.25 each). The highest population of tortrycid was noticed in 75 days after sowing (0.33) and it was significantly different from the population of tortrycid after 90 days of sowing (0.15). The population of tortrycid became zero 120 days after sowing (Table 15).

Infestation of tortrycid was 12.50 per cent after 30 days of sowing. The higher infestation was noticed (27.50 %) 75 days after sowing and was found to be on par with the infestation on 45 (22.50 %) and 60 days after sowing (17.50 %). However, the per cent infestation of tortrycid larvae on 90 days after sowing was 12.50. No infestation was found in cowpea after 120 days of sowing (Table 16).

Girdle beetle

The population started early after 15 days of planting. Maximum population (0.33) of stem girdler was observed in cowpea after 60 days of sowing and was found to be on par with 120 and 75 days after sowing (0.28 and 0.25, respectively).

Table 15. Population of leaf feeders in cowpea under polyhouse condition

Days after sowing	Mean number of population of leaf feeders in cowpea			
	Tortrycid larvae*	Stem girdler**	Leaf beetle**	Leaf miner***
15	-	0.2	1.93	1.51
30	0.13	0.13	3.0	2.18
45	0.25	0.22	3.63	2.94
60	0.25	0.33	-	3.86
75	0.33	0.25	-	3.25
90	0.15	0.17	-	1.71
120	-	0.28	-	1.29
CD (0.05%)	0.086	0.102	1.176	0.829

*Number of larvae per plant, **Number of beetles per plant, ***Number of larvae per top, middle and bottom three leaves

Table 16. Infestation of leaf feeders in cowpea under polyhouse condition

Days after sowing	Infestation of leaf feeders in cowpea (%)				
	Tortrycid larvae	Stem girdler infestation		Leaf beetle	Leaf miner
		Leaf infestation	Stem infestation		
15	-	44.11	-	51.75	17.65
30	12.5	57.36	-	67.89	48.53
45	22.5	68.87	11.73	84.29	79.42
60	17.5	72.30	13.18	-	91.18
75	27.5	83.77	14.65	-	100
90	12.5	87.49	16.13	-	100
120	-	94.04	-	-	100
CD (0.05%)	10.790	10.790	4.922	5.936	10.952

However, the population of stem girdler after 45 days of sowing was noticed as 0.22 and was significantly on par with 15, 90 and 30 days after sowing (Table 15).

The infestation was seen both in leaf and stem. The leaf infestation started 15 days after spraying (44.11 %) and was significantly different from the infestation after 30 days of sowing (57.36 %) and stem infestation stated 45 days after spraying (11.73). The highest leaf infestation in cowpea by stem girdler was recorded on 120 days after sowing (94.04 %) and it was on par with 90 and 75 days after sowing (87.49 and 83.77 %, respectively). Whereas, the infestation in cowpea was noticed as 68.87 and 72.30 per cent on 45 and 60 days after sowing and they were found to be on par with each other (Table 16). Maximum stem infestation was observed as 16.13 per cent after 90 days of sowing and it was found to be on par with the infestation on 45, 60 and 75 days after sowing (11.73, 13.18 and 14.65 %, respectively).

Leaf beetle

Population started early, *i.e.*, 15 days after sowing (1.93). The highest population of leaf beetle in cowpea under polyhouse was seen 45 days after sowing (3.63) followed by 30 and 45 days after sowing (3.0 and 1.93) and they were found to be on par (Table 15).

The infestation of leaf beetle started 15 days after sowing and caused 51.75 per cent of infestation. The highest infestation of leaf beetle in cowpea was observed on 45 days after sowing (84.29 %) followed by 15 and 30 days after sowing (51.75 and 67.89 %) and they were found to be significantly different (Table 16).

American serpentine leaf miner

The population started 15 days after sowing (Table 15). Significantly highest population of leaf miner (3.86) was seen after 60 days of sowing and it was found to be on par with 75 days after spraying (3.25) followed by 45 and 30 days after sowing (2.94 and 2.18, respectively) and the values were significantly different. Whereas, the population observed after 90 days of sowing was 1.71 and were significantly on par with 15 and 120 days after sowing (1.51 and 1.29, respectively).

The infestation of leaf miner started 15 days after sowing (17.65 %) and it was significantly different from others. The infestation increased to 48.53 per cent after 30 days of sowing. The per cent infestation of leaf miner 45 and 60 days after sowing in cowpea was 79.42 and 91.18, respectively and they were significantly different. Cent per cent infestation was noticed in cowpea after 75 days of sowing (Table 16).

4.2.2 Salad Cucumber

The data on the population dynamics and infestation of pests in salad cucumber under polyhouse conditions are depicted in Table 17 and 18.

4.2.2.1 Sucking Pests

Aphids

The highest population of green peach aphid was observed 45 days after sowing (133.5) and it was found to be on par with the population on 30 days after sowing (124.5). The population of green peach aphid decreased and reached 72 after 60 days of sowing. Significantly lower population of aphid was noticed in 90 days after spraying (21) and it was on par with the population in salad cucumber 75 days after sowing (28.5) (Table 17).

Infestation started 30 days after sowing (84.87). The highest aphid infestation in salad cucumber was observed after 45 days of sowing (96.98 %) followed by 60 days after sowing (52.28 %) and it was significantly different from each other. However, the infestation after 75 and 90 days after sowing was noticed as 32.19 per cent and 10.38 per cent, respectively (Table 18).

Table 17. Population dynamics of pests in salad cucumber under polyhouse condition

Days after sowing	Mean number of populationof pests in salad cucumber			
	Aphids*	Mites**	American serpentine leaf miner***	Pumpkin caterpillar****
15	-	-	-	-
30	124.5	1.54	0.98	0.88
45	133.5	10.66	2.79	1.15
60	72	46.34	1.97	2.0
75	28.5	72.02	1.43	4.1
90	21	87.07	0.67	3.6
CD (0.05%)	44.213	5.061	0.658	0.365

*Number of aphids per 15 cm shoot length, **Number of mites per top, middle and bottom three leaves, ***Number of larvae per top, middle and bottom three leaves, ****Number of larvae per plant

Table 14. Infestation of pests in salad cucumber under polyhouse condition

Days after sowing	Infestation of pests in salad cucumber (%)			
	Aphids	Mites	Leaf miner	Pumpkin caterpillar
15	-	-	-	-
30	84.87	4.41	34.25	48.75
45	96.98	23.53	98.53	32.25
60	52.28	63.42	86.76	62.5
75	32.19	89.51	72.79	100
90	10.38	98.53	32.35	100
CD (0.05%)	9.782	5.198	17.775	3.803

Mites

Population started 30 days after sowing (1.54) and significantly higher population (87.07) of mite was noticed after 90 days of sowing followed by 75 and 60 after sowing (72.02 and 46.34, respectively) and the values were significantly different. Similarly, the population seen after 45 days of sowing was 10.66 and significantly differred from the population after 30 days of sowing (1.54). However, no mite population was observed after 15 days of sowing (Table 17).

The infestation of mite was observed only after 30 days of sowing (4.41 %). Significantly highest infestation of mite was noticed after 90 days of sowing (98.53 %) followed by the infestation after 60 and 75 days of sowing (63.52 and 89.51 %, respectively) and these were significantly different. The per cent infestation observed 45 days after sowing was 23.53 (Table 18).

4.2.2.2 Leaf Feeders

Pumpkin caterpillar

The population started and reached 0.88 after 30 days of sowing and it was on par with the population on 45 days after sowing (1.15) and also it reached 2.0 after 60 days of sowing. The highest population was noticed in 75 days after sowing (4.1) followed by the population on 90 days after sowing was 3.6 and the values were significantly different (Table 17).

The per cent infestation of pumpkin caterpillar after 30 days of sowing was 48.75. Similarly, the infestation after 45 and 60 days of sowing was 32.25 and 62.50 per cent, respectively. Whereas, cent per cent infestation was observed at 75 and 90 days after sowing (Table 18).

American serpentine leaf miner

The population of leaf miner started with 0.98 after 30 days of sowing and was significantly on par with the population at 90 days after sowing (0.67). The highest population was noticed 45 days after sowing (2.79) and it was significantly different from the population of leaf miner after 60 and 75 days of sowing (1.97 and 1.43, respectively) (Table 17).

The highest infestation of leaf miner in salad cucumber was observed after 45 days of sowing (98.53 %) and no significant difference was seen 60 days after sowing (86.76 %) followed by 72.79 per cent infestation after 75 days of sowing and they were significantly different. The per cent infestation after 30 days of sowing was 34.25 per cent and it was on par with the infestation after 90 days of sowing (32.35 %) (Table 18).

4.3 EVALUATION OF EFFICACY OF NEW GENERATION INSECTICIDES AGAINST THE MAJOR PESTS IN COWPEA AND SALAD CUCUMBER UNDER POLYHOUSE

The results on the study of the efficacy of new generation insecticides on different pests of cowpea and salad cucumber under polyhouse conditions are presented below.

4.3.1 Evaluation of Insecticides against Sucking Pests Infesting Cowpea and Salad Cucumber

4.3.1.1 Cowpea

Aphids

The results on the efficacy of new generation insecticides against the cowpea aphids, *A. craccivora* under polyhouse conditions after first and second spray are given in Table 19. In first spray, no significant difference was observed in mortality

Table 19. Population of pea aphid, *Aphis craccivora* in cowpea treated with insecticides

Insecticide	Dosage (g or mL L^{-1})	*Number of aphids per 30 cm shoot (DAT)											
		I spray						II spray					
		1	3	5	7	10	15	1	3	5	7	10	15
Acetamiprid 20 % SP	0.10	46.33 (6.80)	0 (1)	0 (1)	0 (1)	11.67 (3.54)	24.67 (5.05)	39.00 (6.28)	0 (1)	0 (1)	0 (1)	8.33 (3.03)	17.67 (4.27)
Imidacloprid 17.5 % SL	0.20	23.67 (4.91)	0 (1)	0 (1)	0 (1)	1.67 (1.58)	12.67 (3.60)	26.67 (5.23)	0 (1)	0 (1)	0 (1)	1.67 (1.48)	6.33 (2.64)
Thiomethoxam 25 % WG	0.30	14.67 (3.94)	0 (1)	0 (1)	0 (1)	0 (1)	7.33 (2.86)	19.00 (3.95)	0 (1)	0 (1)	0 (1)	0 (1)	3.67 (2)
Thiacloprid 21.7 % SC	0.25	75.00 (8.70)	31.67 (5.69)	12.33 (3.60)	12.33 (3.60)	17.33 (4.26)	32.33 (5.75)	54.33 (7.36)	29.33 (5.43)	0 (1)	2.33 (1.61)	20.33 (4.58)	40.33 (6.42)
Dimethoate 30 % EC (Check)	1.50	95.00 (9.79)	41.33 (6.49)	19.00 (4.45)	30.00 (5.53)	47.33 (6.91)	73.33 (8.60)	83.33 (9.13)	35.67 (6.03)	13.67 (3.70)	14.67 (3.88)	18.33 (4.35)	44.33 (6.69)
Control		128.33 (11.36)	115.67 (10.79)	115.00 (10.76)	115.00 (10.76)	134.00 (11.62)	144.00 (12.04)	146.33 (12.10)	135.67 (11.62)	136.00 (11.63)	136.67 (11.66)	149.33 (12.21)	167.67 (12.96)
CD (0.05)		(1.268)	(0.493)	(0.607)	(0.696)	(0.824)	(1.057)	(2.262)	(1.055)	(1.084)	(1.236)	(1.093)	(1.336)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

of aphids in all treatments before spraying. Significantly lower population of aphid was recorded in thiamethoxam 25 WG @ 0.30 g L^{-1} (14.67) which was on par with the mortality observed in population of aphid treated with imidacloprid 17.8 SL @ 0.20 mL L^{-1} (23.67) after one day of treatment. The population observed in acetamiprid 20 SP @ 0.10 g L^{-1} treated plants was 46.33. The plot treated with thiacloprid 21.7 SC @ 0.25 mL L^{-1} recorded higher population of 75.00 and was on par with dimethoate 30 EC @ 1.50 mL L-1 (95.00).

No population of aphid was recorded in thiamethoxam 25 WG @ 0.30 g L^{-1}, imidacloprid 17.8 % SL @ 0.20 mL L^{-1} and acetamiprid 20 SP @ 0.10 g L^{-1} treated plants after three days of treatment. However, thiacloprid 21.7 SC @ 0.25 mL L^{-1} treated plants showed 31.67 population of aphids followed by dimethoate 30 EC @ 1.50 mL L^{-1} (41.33) and they were significantly different.

More or less comparable results was obtained on fifth day after treatment. No population was observed in the plants treated with acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG @ 0.30 g L^{-1} while, plants treated with thiacloprid 21.7 SC @ 0.25 mL L^{-1} showed population of 12.33 followed by dimethoate 30 EC @ 1.50 mL L^{-1} (19.00) and they were significantly different. Similar results were seen in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1}, thiamethoxam 25 WG @ 0.30 g L^{-1} and thiacloprid 21.7 SC @ 0.25 mL L^{-1} treated plots after seven days of treatment but, the population started raising in dimethoate 30 EC @ 1.50 mL L^{-1} (30.00) and it was significantly different from other treatment.

No population of aphid was observed in thiamethoxam 25 WG @ 0.30 g L^{-1} treated plant after tenth day of treatment. However, lower population of aphid was recorded in imidacloprid 17.8 SL @ 0.20 mL L^{-1} (1.67) followed by acetamiprid 20 SP @ 0.10 g L^{-1} (11.67) and thiacloprid 21.7 SC @ 0.25 mL L^{-1} (17.33) treated plants and they were significantly different from dimethoate 30 EC @ 1.50 mL L^{-1} (47.33) which was treated as check. After fifteen days of treatment, lower population of aphid was observed in thiamethoxam 25 WG @ 0.30 g L^{-1} (7.33) which was on par with imidacloprid 17.8 SL @ 0.20 mL L^{-1} (12.67) and significantly different from acetamiprid 20 SP @ 0.10 g L^{-1} (24.67) and thiacloprid 21.7 SC @ 0.25 mL L^{-1} (32.33) whereas, 73.33 aphids was noticed in dimethoate 30 EC @ 1.50 mL L^{-1} treated plants.

More or less similar results were obtained in second spray and there was no significant difference in pre count. There was a significant difference in population of aphids in cowpea after one day of spraying and the treatment thiamethoxam 25 WG @ 0.30 g L^{-1} (19.00) and imidacloprid 17.8 SL @ 0.20 mL L^{-1} (26.67) showed lower population of aphids followed by acetamiprid 20 SP @ 0.10 g L^{-1} (39.00). Thiacloprid 21.7 SC @ 0.25 mL L^{-1} and dimethoate 30 EC @ 1.50 mL L^{-1} recorded 54.33 and 83.33 aphids, respectively and it was significantly on par.

Accordingly, no aphid was found in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG@ 0.30 g L^{-1} treated plants after three days of treatment and the populations were significantly different from thiacloprid 21.7 SC @ 0.25 mL L^{-1} (29.33) and dimethoate 30 EC @ 1.50 mL L^{-1} (35.67). Similarly no population of aphid was observed in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1}, thiamethoxam 25 WG @ 0.30 g L^{-1} and thiacloprid 21.7 SC @ 0.25 mL L^{-1} treated plants after fifth day of treatment and the population were significantly different from dimethoate 30 EC @ 1.50 mL L^{-1} (13.67) used as a check.

More or less similar results was obtained seven days after treatment. No aphid was seen in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG @ 0.30 g L^{-1} treated plants followed by thiacloprid 21.7 SC @ 0.25 mL L^{-1} (2.33) and dimethoate 30 EC @ 1.50 mL L^{-1} (14.67) and they were significantly different. After ten days of treatment, no population of aphid was observed in thiamethoxam 25 WG @ 0.30 g L^{-1} treated plants. Population of aphid was recorded from imidacloprid 17.8 SL @ 0.20 mL L^{-1} and acetamiprid 20 SP @ 0.10 g L^{-1} were 1.67 and 8.33, respectively. Significantly similar population of aphid was recorded in dimethoate 30 EC @ 1.50 mL L^{-1} (18.33) and thiacloprid 21.7 SC @ 0.25 mL L^{-1} (20.33) treated plants.

On fifteen days after treatment, the plants treated with thiamethoxam 25 WG @ 0.30 g L^{-1} (3.67) and imidacloprid 17.8 SL @ 0.20 mL L^{-1} (6.33) recorded the lower population of aphids and were significantly on par followed by acetamiprid 20 SP @ 0.10 g L^{-1} (17.67). While, thiacloprid 21.7 SC @ 0.25 mL L^{-1} (40.33) and dimethoate 30 EC @ 1.50 mL L^{-1} (44.33) showed the presence of higher number of aphid compared to other treatments.

Pod bugs

The results on the population of pod bugs in cowpea treated with insecticides under polyhouse conditions were presented in Table 20. No significant difference was observed in the population of pod bugs in cowpea after one day of treatment.

Significantly lower population was recorded in imidacloprid 17.8 SL @ 0.20 mL L^{-1} (3.33) and thiamethoxam 25 WG @ 0.30 g L^{-1} (3.50) and acetamiprid 20 SP @ 0.10 g L^{-1} (4.50) treated plants, which were significantly on par after three days of treatment. The plot treated with thiacloprid 21.7 SC @ 0.25 mL L^{-1} recorded higher population of 5.33 bugs and has no significant difference with check dimethoate 30 EC @ 1.50 mL L^{-1} (5.00). Thiamethoxam 25 WG@ 0.30 g L^{-1} (2.17) and imidacloprid 17.8 % SL @ 0.20 mL L^{-1} (2.83) recorded the lowest population and it was on par followed by acetamiprid 20 SP @ 0.10 g L^{-1} (3.50) after five days of treatment. However, thiacloprid 21.7 SC @ 0.25 mL L^{-1} and dimethoate 30 EC @ 1.50 mL L^{-1} treated plants recorded higher population (5.33 and 4.67 bugs, respectively) and they were significantly on par.

Table 20. Population of pod bug, *Riptortus pedestris* (Fabricius) in cowpea treated with insecticides

Insecticide	Dosage (g or mL L^{-1})	*Number of bugs per plant (DAT)					
		1	3	5	7	10	15
Acetamiprid 20 % SP	0.10	5.83 (2.59)	4.50 (2.34)	3.50 (2.11)	4.00 (2.23)	3.00 (1.98)	2.00 (1.73)
Imidacloprid 17.5 % SL	0.20	5.17 (2.48)	3.33 (2.08)	2.83 (1.95)	2.33 (1.82)	1.67 (1.61)	0.20 (1.11)
Thiamethoxam 25 % WG	0.30	5.67 (2.58)	3.50 (2.09)	2.17 (1.77)	2.50 (1.87)	1.33 (1.52)	0.20 (1.11)
Thiacloprid 21.7 % SC	0.25	6.17 (2.67)	5.33 (2.52)	5.33 (2.52)	5.00 (2.45)	5.67 (2.58)	6.00 (2.64)
Dimethoate 30 % EC (Check)	1.50	6.00 (2.64)	5.00 (2.44)	4.67 (2.37)	5.33 (2.52)	5.83 (2.61)	7.00 (2.83)
Control		5.33 (2.51)	5.83 (2.61)	6.33 (2.70)	6.83 (2.80)	7.50 (2.91)	7.50 (2.91)
CD (0.05)		(NS)	(0.337)	(0.310)	(0.181)	(0.366)	(0.192)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

More or less comparable result was obtained on seventh day after treatment and lower population was observed in the treatment plants of imidacloprid 17.8 SL @ 0.20 mL L^{-1} (2.33) and thiamethoxam 25 WG @ 0.30 g L^{-1} (2.50) while, acetamiprid 20 SP @ 0.10 g L^{-1} (4.00), thiacloprid 21.7 SC @ 0.25 mL L^{-1} (5.00) and dimethoate 30 EC @ 1.50 mL L^{-1} (5.33) recorded highest population and they were significantly different.

After ten days of treatment thiamethoxam 25 WG @ 0.30 g L^{-1} (1.33) and imidacloprid 17.8 SL @ 0.20 mL L^{-1} (1.67) recorded lower population of pod bugs followed by acetamiprid 20 SP @ 0.10 g L^{-1}, thiacloprid 21.7 SC @ 0.25 mL L^{-1} and dimethoate 30 EC @ 1.50 mL L^{-1} (3.00, 5.67 and 5.83, respectively). Whereas, 0.20 bugs were observed in thiamethoxam 25 WG @ 0.30 g L^{-1} and imidacloprid 17.8 SL @ 0.20 mL L^{-1} treated plants after fifteen days of treatment and significantly different from acetamiprid 20 SP @ 0.10 g L^{-1} (2.00), thiacloprid 21.7 SC @ 0.25 mL L^{-1} (6.00) and dimethoate 30 EC @ 1.50 mL L^{-1} (7.00).

Mites

The results on the population of mites in cowpea treated with acaricides sprayed two times under polyhouse were depicted in Table 21. No significant difference was observed in the population of mite in cowpea before treatment and one day after treatment.

Significantly lower population of mite was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} (21.75) followed by fenpyroximate 5 EC 0.60 mL L^{-1} (43.50) treated plants which was significantly different from each other. The population of mite in dimethoate 30 EC @ 1.50 mL L^{-1} treated plants was 100.25 after three days of treatment. Whereas, no mite was seen in spiromesifen 22.9 SC @ 0.80 mL L^{-1} after five days of treatment and it was significantly different from fenpyroximate 5 EC @ 0.60 mL L^{-1} (10.75) and dimethoate 30 EC @ 1.50 mL L^{-1} (69.00) treated plants.

Table 21. Population of mites, *Tetranychus truncatus* in cowpea treated with insecticides

Insecticide	Dosage ($mL\ L^{-1}$)	*Number of mites (DAT)											
		I spray						II spray					
		1	3	5	7	10	15	1	3	5	7	10	15
Spiromesifen 22.9 % SC	0.80	122.50 (11.10)	21.75 (4.76)	0 (1)	0 (1)	1.75 (1.55)	10.50 (3.37)	129.00 (11.40)	27.25 (5.31)	0 (1)	0 (1)	0 (1)	4.50 (2.32)
Fenpyroximate 5 % EC	0.60	123.75 (11.15)	43.50 (6.66)	10.75 (3.12)	9.25 (2.95)	11.75 (3.48)	22.25 (4.80)	135.75 (11.69)	30.50 (5.61)	0 (1)	0 (1)	3.25 (1.92)	10.50 (3.37)
Dimethoate 30 % EC (Check)	1.50	139.75 (11.86)	100.25 (10.05)	69.00 (8.35)	69.00 (8.35)	80.50 (9.02)	99.50 (10.02)	138.75 (11.79)	97.00 (9.89)	76.00 (8.77)	78.50 (8.91)	97.00 (9.89)	117.25 (10.87)
Control		138.00 (11.78)	138.25 (11.79)	138.50 (11.80)	142.00 (11.95)	143.50 (12.01)	143.50 (12.01)	152.25 (12.36)	151.25 (12.32)	151.25 (12.32)	152.50 (12.37)	157.50 (12.57)	164.25 (12.83)
CD (0.05)		(NS)	(0.629)	(1.247)	(1.111)	(0.895)	(0.620)	(NS)	(0.893)	(0.462)	(0.478)	(0.930)	(0.799)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

No population of mite was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants after seven days of treatment. However, 9.25 mites were seen in fenpyroximate 5 EC @ 0.60 mL L^{-1} and it was significantly different from dimethoate 30 EC @ 1.50 mL L^{-1} (69.00) treated plants. After 10 days of treatment, significantly lower population of mite was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants (1.75) followed by the population in fenpyroximate 5 EC @ 0.60 mL L^{-1} (11.75) and dimethoate 30 EC @ 1.50 mL L^{-1} (80.50) and they were significantly different of treatments. The mean number of mites were increased in all treatments after fifteen days *viz.*, spiromesifen 22.9 SC @ 0.80 mL L^{-1} (10.50), fenpyroximate 5 EC @ 0.60 mL L^{-1} (22.25) and dimethoate 30 EC @ 1.50 mL L^{-1} (99.50) and they were significantly different from each other.

More or less similar trend was observed in second spraying also. No significant difference was observed in the mean population of mite before second spraying and one day after spraying. Significantly lower population of mite was observed in plants treated with spiromesifen 22.9 SC @ 0.80 mL L^{-1} (27.25) and fenpyroximate 5 EC @ 0.60 mL L^{-1} (30.50) and they were on par. The population of mite in dimethoate 30 EC @ 1.50 mL L^{-1} treated plant was 97.00.

After, five days of spraying, no population of mite was recorded in spiromesifen 22.9 SC @ 0.80 mL L^{-1} and fenpyroximate 5 EC @ 0.60 mL L^{-1} treated plants. However, the population observed in dimethoate 30 EC @ 1.50 mL L^{-1} treated plants was 76.00. Similar results were observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} and fenpyroximate 5 EC @ 0.60 mL L^{-1} treated plots after seven days of spraying. The mean population of mite observed in dimethoate 30 EC @ 1.50 mL L^{-1} treated plant was 78.50. The population of mite started raising after ten days of treatment, whereas no mite was noticed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} and it was on par with fenpyroximate 5 EC @ 0.60 mL L^{-1} (3.25) and significantly different from dimethoate 30 EC @ 1.50 mL L^{-1} (97.00).

The population of mite in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants was increased to 4.50 after fifteen days of treatment followed by fenpyroximate 5 EC @ 0.60 mL L^{-1} (10.50) and dimethoate 30 EC @ 1.50 mL L^{-1} (117.25) and they were significantly different.

4.3.1.2. Salad cucumber

Aphids

The results of the study on the population of green peach aphid, *M. persicae* in salad cucumber sprayed with insecticides two times under polyhouse conditions are depicted in Table 22. No significant difference was observed in the population of *M. persicae* in all treatments before spraying.

No significant difference was obtained in pre count population aphids during the first spray. There was a significant difference between the treatments after one day of treatment and lower population was seen in the treatment thiamethoxam 25 WG @ 0.30 g L^{-1} (17.33) followed by imidacloprid 17.8 SL @ 0.20 mL L^{-1} (36.67) and acetamiprid 20 SP @ 0.10 g L^{-1} (39.00) and they were significantly different. However, thiacloprid 21.7 SC @ 0.25 mL L^{-1} and dimethoate 30 EC @ 1.50 mL L^{-1} recorded 52.67 and 60.00 aphids, respectively and it was significantly on par.

Similarly, no aphid was found in imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG @ 0.30 g L^{-1} treated crops after three days of treatment and they were significantly different from acetamiprid 20 SP @ 0.10 g L^{-1} (8.67), thiacloprid 21.7 SC @ 0.25 mL L^{-1} (29.00) and dimethoate 30 EC @ 1.50 mL L^{-1} (48.33). Five days after treatment no aphid was seen in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG @ 0.30 g L^{-1} treatment plots followed by thiacloprid 21.7 SC @ 0.25 mL L^{-1} (16.00) and dimethoate 30 EC @ 1.50 mL L^{-1} (52.33) and they were significantly different.

Table 22. Population of green peach aphid, *Myzus persicae* in salad cucumber treated with insecticides

Insecticide	Dosage (g or mL L[-1])	*Number of aphids per 30 cm shoot length (DAT)											
		I Spray						II Spray					
		1	3	5	7	10	15	1	3	5	7	10	15
Acetamiprid 20 % SP	0.10	58.33 (7.64)	8.67 (2.91)	0 (1)	0 (1)	5.67 (2.38)	20.67 (4.57)	55.33 (7.47)	1.67 (1.48)	0 (1)	0 (1)	8.33 (3.05)	20.33 (4.58)
Imidacloprid 17.5 % SL	0.20	36.67 (6.09)	0 (1)	0 (1)	0 (1)	3.67 (2.02)	11.67 (3.52)	40.33 (6.39)	0 (1)	0 (1)	0 (1)	2.33 (1.61)	7.33 (2.61)
Thiomethoxam 25 % WG	0.30	17.33 (4.13)	0 (1)	0 (1)	0 (1)	1.33 (1.41)	10.00 (3.26)	39.33 (6.34)	0 (1)	0 (1)	0 (1)	0 (1)	4.67 (2.32)
Thiacloprid 21.7 % SC	0.25	52.67 (7.30)	29.00 (5.45)	16.00 (4.06)	18.33 (4.38)	28.67 (5.43)	45.00 (6.76)	74.67 (8.68)	17.67 (4.31)	12.67 (3.68)	11.67 (3.55)	41.67 (6.46)	60.00 (7.78)
Dimethoate 30 % EC (Check)	1.50	60.00 (7.75)	48.33 (6.99)	52.33 (7.29)	53.67 (7.39)	62.67 (7.97)	84.00 (9.21)	155.00 (12.46)	101.00 (10.09)	77.67 (8.86)	77.00 (8.83)	88.33 (9.45)	107.33 (10.41)
Control		158.33 (12.59)	146.67 (12.10)	146.67 (12.11)	158.33 (12.59)	171.67 (13.09)	190.00 (13.77)	178.33 (13.38)	152.67 (12.36)	151.67 (12.32)	151.67 (12.32)	165.00 (12.85)	186.67 (13.69)
CD (0.05)		(1.703)	(1.441)	(1.008)	(0.786)	(1.462)	(1.368)	(0.792)	(0.982)	(0.781)	(0.722)	(1.200)	(0.948)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

Similar trend was observed seven days after treatment. No aphid was seen in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG @ 0.30 g L^{-1} treated plots. However, the population of aphid in thiacloprid 21.7 SC @ 0.25 mL L^{-1} (18.33) and dimethoate 30 EC @ 1.50 mL L^{-1} (53.67) treated plants were significantly different from each other. However, after ten days of treatment the lower number of aphid population was observed in thiamethoxam 25 WG @ 0.30 g L^{-1} (1.33), imidacloprid 17.8 SL @ 0.20 mL L^{-1} and acetamiprid 20 SP @ 0.10 g L^{-1} (5.67) and the treatments were significantly on par followed by thiacloprid 21.7 SC @ 0.25 mL L^{-1} (28.67) and dimethoate 30 EC @ 1.50 mL L^{-1} (62.67) and they were significantly different.

On fifteen days after treatment, the plants treated with thiamethoxam 25 % WG@ 0.30 g L^{-1} (10.00), imidacloprid 17.8 SL @ 0.20 mL L^{-1} (11.67) and acetamiprid 20 SP @ 0.10 g L^{-1} (20.67) recorded the lowest population of aphids and were significantly on par. While, thiacloprid 21.7 SC @ 0.25 mL L^{-1} (45.00) and dimethoate 30 EC @ 1.50 mL L^{-1} (84.00) recorded the maximum aphid population compared to other treatments. During second spray significantly lower number of aphids was observed in the thiamethoxam 25 WG @ 0.30 g L^{-1} (39.33) and imidacloprid 17.8 SL @ 0.20 mL L^{-1} (40.33) treated plants and they were on par also. The population of aphid in plants treated with acetamiprid 20 SP @ 0.10 g L^{-1} (55.33), thiacloprid 22.7 SC @ 0.25 mL L^{-1} (74.67) and dimethoate 30 EC @ 1.50 mL L^{-1} (155.00) were significantly different one day after treatment. However, no aphid population was noticed in imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG @ 0.30 g L^{-1} treated plants and was found to be on par with acetamiprid 20 SP @ 0.10 g L^{-1} (1.67). Significantly different population of aphid was observed in thiacloprid 21.7 SC @ 0.25 mL L^{-1} (17.67) and dimethoate 30 EC @ 1.50 mL L^{-1} (101.00) after three days of treatment.

On fifth day after treatment, no aphid population was found in acetamiprid 20 SP @ 0.10 g L^{-1}, imidacloprid 17.8 SL @ 0.20 mL L^{-1} and thiamethoxam 25 WG@ 0.30 g L^{-1} treated plots and were significantly different from thiacloprid 21.7 SC @ 0.25 mL L^{-1} (12.67) and dimethoate 30 EC @ 1.50 mL L^{-1} (77.67). Similar trend of results were observed on seventh day after treatment and the population of aphid in thiacloprid 21.7 SC @ 0.25 mL L^{-1} and dimethoate 30 EC @ 1.50 mL L^{-1} treated plants were 11.67 and 77.00, respectively.

Whereas, the population of aphid started raising in all treatments ten days after spraying. The population of aphid was zero in thiamethoxam 25 WG @ 0.30 g L^{-1} and it was on par with imidacloprid 17.8 % SL @ 0.20 mL L^{-1} (2.33) followed by acetamiprid 20 SP @ 0.10 g L^{-1} (8.33), thiacloprid 21.7 SC @ 0.25 mL L^{-1} (41.67) and dimethoate 30 EC @ 1.50 mL L^{-1} (88.33) and the treatments were significantly different.

Similarly, fifteen days after treatment the lowest number of aphid population was noticed in thiamethoxam 25 WG @ 0.30 g L^{-1} (4.67) which is on par with imidacloprid 17.8 SL @ 0.20 mL L^{-1} and significantly different from acetamiprid 20 SP @ 0.10 g L^{-1} (20.33), thiacloprid 21.7 SL @ 0.25 mL L^{-1} (60.00) and dimethoate 30 EC @ 1.50 mL L^{-1} (107.33) treated plants.

Mites

The results on the population of mite in salad cucumber treated with insecticides in two sprays under polyhouse conditions were given in Table 23. No significant difference was observed in the mite population in salad cucumber before treatment and one day after treatment.

In the first spray, significantly lower mean mite population was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} (31.25) and fenpyroximate 5 EC @ 0.60 mL L^{-1}

Table 23. Population of mites, *Tetranychus* sp. in salad cucumber treated with insecticides

Insecticide	Dosage ($mL\ L^{-1}$)	*Number of mites survived (DAT)											
		I Spray						II Spray					
		1	3	5	7	10	15	1	3	5	7	10	15
Spiromesifen 22.9 % SC	0.80	90.25 (9.52)	31.25 (5.09)	0 (1)	0 (1)	0 (1)	16.25 (3.75)	71.25 (8.46)	7.50 (2.47)	0 (1)	0 (1)	2.00 (1.66)	6.25 (2.67)
Fenpyroximate 5 % EC	0.60	99.25 (9.99)	36.25 (6.07)	15.50 (4.04)	15.50 (4.04)	18.25 (4.38)	23.50 (4.94)	95.50 (9.81)	22.25 (4.78)	10.75 (3.41)	12.25 (3.63)	16.5 (4.17)	22.75 (4.87)
Dimethoate 30 % EC (Check)	1.50	108.50 (10.44)	86.50 (9.33)	73.50 (8.60)	91.25 (9.60)	97.50 (9.92)	101.00 (10.10)	126.75 (11.29)	102.50 (10.17)	95.25 (9.81)	95.25 (9.81)	105.5 (10.32)	114.00 (10.72)
Control		127.50 (11.30)	127.50 (11.30)	128.75 (11.36)	130.50 (11.44)	132.50 (11.53)	138.50 (11.78)	130.75 (11.47)	131.75 (11.52)	132.25 (11.54)	134.00 (11.61)	140.75 (11.90)	143.00 (11.99)
CD (0.05)		(NS)	(2.187)	(1.032)	(0.698)	(0.632)	(1.259)	(0.750)	(1.366)	(0.447)	(0.357)	(0.603)	(0.442)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

(36.25) sprayed plants after three days of treatment and they were significantly different from dimethoate 30 EC @ 1.50 mL L^{-1} (86.50).

No mite population was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} after five days of treatment and it was significantly different from fenpyroximate 5 EC @ 0.60 mL L^{-1} (15.50) and dimethoate 30 EC @ 1.50 mL L^{-1} (73.50). Even after seven days of spraying no mite was seen in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants. The population of mite in fenpyroximate 5 EC @ 0.60 mL L^{-1} (15.50) sprayed plants was significantly different from that of dimethoate 30 EC @ 1.50 mL L^{-1} (91.25). Similarly, after tenth day of spraying no mite was seen in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants. 18.25 mites were seen in fenpyroximate 5 EC @ 0.60 mL L^{-1}treated plants followed by dimethoate 30 EC @ 1.50 mL L^{-1} (97.50) treated plants and they were significantly different.

However, the population of mite in spiromesifen 22.9 SC @ 0.80 mL L^{-1} and fenpyroximate 5 EC @ 0.60 mL L^{-1} treated plants were 16.25 and 23.50 respectively after fifteen days of treatment and they were significantly on par. The population in dimethoate 30 EC @ 1.50 mL L^{-1} was 101.00 and it was significantly different from others.

More or less similar trend was observed in the population of mite after second spray. No significant difference was observed in the mean mite population before treatment. Significantly, lower population of mite was recorded in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants (71.25) followed by fenpyroximate 5 EC @ 0.60 mL L^{-1} (95.50) which were significantly different one day after treatment. The population of mite observed in dimethoate 30 EC @ 1.50 mL L^{-1} treated plant was 126.75. Similarly, after third day of spraying significant lower mite population was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} (7.50) and it was significantly different from fenpyroximate 5 EC @ 0.60 mL L^{-1} (22.25) and dimethoate 30 EC @ 1.50 mL L^{-1} (102.50).

No mite was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants after five days of treatment followed by fenpyroximate 5 EC @ 0.60 mL L^{-1} (10.75) and dimethoate 30 EC @ 1.50 mL L^{-1} (95.25) and they were significantly different. Similar, results were observed in seven days of treatment. No mite was observed in spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants followed by fenpyroximate 5 EC @ 0.60 mL L^{-1} (12.25) which were significantly different from population in dimethoate 30 EC @ 1.50 mL L^{-1} treated plants (95.25). The population of mite started raising after ten days of treatment, where spiromesifen 22.9 SC @ 0.80 mL L^{-1} treated plants recorded lower number of mites (2.00) and it was significantly different from fenpyroximate 5 EC @ 0.60 mL L^{-1} (16.50) and dimethoate 30 EC @ 1.50 mL L^{-1} (105.50) treated plants.

However, fifteen days after spraying the population of mites in spiromesifen 22.9 SC @ 0.80 mL L^{-1} was 6.25 followed by fenpyroximate 5 EC @ 0.60 mL L^{-1} (22.75) and dimethoate 30 EC @ 1.50 mL L^{-1} (114.00) and they were significantly different from each other.

4.3.2 Evaluation of Insecticides against Leaf Feeders Infesting Cowpea and Salad Cucumber

4.3.2.1 Cowpea

American serpentine leaf miner

The results of the study on the population of leaf miner, *L. trifolii* in cowpea treated with insecticides under polyhouse during first and second spray are presented in Table 24. In first spray no significant difference was observed in the population of leaf miner in cowpea treated with insecticides after one day of treatment.

Significantly lower population was observed in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (2.83) and spinosad 45 SC @ 0.30 mL L^{-1} (3.33) and the treatments were on par followed by quinalphos 25 EC @ 3.00 mL L^{-1} (4.33). The highest population

Table 24. Population of American serpentine leaf miner, *Liriomyza trifolii* in cowpea treated with insecticides

Insecticide	Dosage ($mL\ L^{-1}$)	*Number of larvae (DAT)											
		I Spray						II Spray					
		1	3	5	7	10	15	1	3	5	7	10	15
Spinosad 45 % SC	0.30	9.67 (3.26)	3.33 (2.08)	0.17 (1.07)	0 (1)	0 (1)	0.20 (1.09)	6.33 (2.70)	1.17 (1.43)	0 (1)	0 (1)	0.33 (1.15)	1.00 (1.41)
Chlorantraniliprole 18.5 % SC	0.30	6.67 (2.75)	2.83 (1.95)	0 (1)	0 (1)	0.33 (1.14)	0.60 (1.28)	7.83 (2.97)	0.83 (1.34)	0 (1)	0 (1)	0.17 (1.07)	0.83 (1.35)
Flubendiamide 39.35 % SC	0.10	8.33 (3.04)	6.83 (2.79)	6.50 (2.72)	5.33 (2.50)	6.33 (2.70)	8.17 (3.02)	10.50 (3.38)	8.17 (3.03)	7.17 (2.85)	6.83 (2.79)	7.33 (2.88)	8.83 (3.13)
Indoxacarb 14.5 % SC	1.0	9.33 (3.20)	8.00 (2.98)	6.33 (2.69)	4.67 (2.38)	5.50 (2.53)	7.00 (2.83)	7.50 (2.90)	5.17 (2.47)	4.33 (2.31)	5.00 (2.45)	5.50 (2.54)	6.00 (2.64)
Quinalphos 25 % EC (Check)	3.0	6.50 (2.73)	4.33 (2.98)	4.17 (2.23)	5.17 (2.47)	6.83 (2.78)	8.00 (2.99)	9.67 (3.26)	7.50 (2.90)	5.67 (2.57)	6.00 (2.63)	6.83 (2.78)	7.50 (2.89)
Control		9.17 (3.16)	9.17 (3.16)	8.17 (3.00)	8.67 (3.10)	8.67 (3.09)	9.83 (3.28)	9.83 (3.29)	10.17 (3.34)	9.50 (3.24)	9.50 (3.24)	9.83 (3.29)	10.67 (3.41)
CD (0.05)		(NS)	(0.470)	(0.565)	(0.362)	(0.089)	(0.324)	(NS)	(0.395)	(0.208)	(0.255)	(0.321)	(0.366

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, * Mean of ten plants of leaf miner was recorded in flubendiamide 39.35 SC @ 0.10 mL L^{-1} (6.83) and indoxacarb 14.5 SC @ 1.00 mL L^{-1} (8.00) treated plants after three days of treatment.

More or less similar results was obtained on fifth day after treatment. No population was observed in the chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plants and it was on par with spinosad 45 SC @ 0.30 mL L^{-1} (0.17) while, flubendiamide 39.35 SC @ 0.10 mL L^{-1}, indoxacarb 14.5 SC @ 1.00 mL L^{-1} and quinalphos 25 EC @ 3.00 mL L^{-1} recorded higher population of leaf miner (6.50, 6.33 and 4.17, respectively) and they were significantly different. After seven days of treatment no population was recorded in spinosad 45 SC @ 0.30 mL L^{-1} and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plants. Flubendiamide 39.35 SC @ 0.10 mL L^{-1}, indoxacrb 14.5 SC @ 1.00 mL L^{-1} and quinalphos 25 EC @ 3.00 mL L^{-1} recorded maximum population of leaf miner (5.33, 4.67 and 5.17, respectively) and it was significantly different from other treatment.

No leaf miner population was observed in spinosad 45 SC @ 0.30 mL L^{-1} treated plant after tenth day of treatment. However, lower population of leaf miner was recorded in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.33) followed by indoxacarb 14.5 SC @ 1.00 mL L^{-1} (5.50) treated plants and they were significantly different. The population observed in flubendiamide 39.35 SC @ 0.10 mL L^{-1} and quinalphos 25 EC @ 3.00 mL L^{-1} treated plants were 6.33 and 6.83, respectively and they were significantly different.

After fifteen days of treatment, lower population of leaf miner was observed in spinosad 45 SC @ 0.30 mL L^{-1} (0.20) which was on par with chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.60) and significantly different from indoxacarb 14.5 SC @ 1.00 mL L^{-1} (7.00) and quinalphos 25 EC @ 3.00 mL L^{-1} (8.00) whereas, 8.17 leaf miner larvae was noticed in flubendiamide 39.35 SC @ 0.10 mL L^{-1} treated plot.

More or less similar results was obtained during second spray. There was no significant difference was obtained in pre count during the second spray and one day after treatment. There was a significant difference in population of leaf miner in cowpea after three day of spraying. Significantly lower population of leaf miner was observed in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.83) and spinosad 45 SC @ 0.30 mL L^{-1} (1.17) treated plants and they were on par also. The population observed in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (5.17) treated plants were significantly similar. Significantly higher population was seen in flubendiamide 39.35 SC @ 0.10 mL L^{-1} (8.17) and quinalphos 25 EC @ 3.00 mL L^{-1} (7.50) treated plants.

Accordingly, no leaf miner larvae was found in spinosad 45 SC @ 0.30 mL L^{-1} and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plants after five days of treatment. Populations of leaf miner in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (4.33), flubendiamide 39.35 SC @ 0.10 mL L^{-1} (7.17) and quinalphos 25 EC @ 3.00 mL L^{-1} (6.00) treated plants were significantly different. Whereas, seven days after treatment no population of leaf miner was observed in spinosad 45 SC @ 0.30 mL L^{-1} and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plants. The population were significantly different from flubendiamide 39.35 SC @ 0.10 mL L^{-1} (6.83), indoxacarb 14.5 SC @ 1.00 mL L^{-1} (5.00) and quinalphos 25 EC @ 3.00 mL L^{-1} (6.00).

After ten days of treatment, lower population of leaf miner was observed in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.17) and spinosad 45 SC @ 0.30 mL L^{-1} (0.33) treated plants. Significantly similar population of leaf miner was recorded in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (5.50), quinalphos 25 EC @ 3.00 mL L^{-1} (6.83) and flubendiamide 39.35 SC @ 0.10 mL L^{-1} (7.33).

On fifteen days after treatment, the plants treated with chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.83) and spinosad 45 SC @ 0.30 mL L^{-1} (1.00) recorded the lowest population of leaf miner and were significantly on par. While, indoxacarb 14.5

SC @ 1.00 mL L^{-1} (6.00), quinalphos 25 EC @ 3.00 mL L^{-1} (7.50) and flubendiamide 39.35 SC @ 0.10 mL L^{-1} (8.83) showed the presence of maximum number of leaf miner population compared to other treatments.

4.3.2.2 Salad cucumber

Pumpkin caterpillar

The results of the study on the mean population of pumpkin caterpillar, *D. indica* in salad cucumber under polyhouse condition are depicted in Table 25. No significant difference was observed in the population of pumpkin caterpillar before spraying and one day after spraying.

No larvae of pumpkin caterpillar was recorded in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} and flubendiamide 39.35 SC @ 0.10 mL L^{-1} three days after treatment followed by indoxacarb 14.5 SC @ 1.00 mL L^{-1} (0.80) and spinosad 45 SC @ 0.30 mL L^{-1} (1.00) and the treatments were significantly different and 3.40 larvae was observed in quinalphos 25 EC @ 3.00 mL L^{-1} treated plot. Similarly, no larvae of pumpkin caterpillar was recorded in plants treated with spinosad 45 SC @ 0.30 mL L^{-1}, chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1}, flubendiamide 39.35 SC @ 0.10 mL L^{-1} and indoxacarb 14.5 SC @ 1.00 mL L^{-1} after five days of treatment whereas, quinalphos 25 EC @ 3.00 mL L^{-1} recorded 2.80 larvae. More or less similar results was obtained on seventh day after treatment. No larvae was observed in the plants treated with spinosad 45 SC @ 0.30 mL L^{-1}, chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1}, flubendiamide 39.35 SC @ 0.10 mL L^{-1} and indoxacarb 14.5 SC @ 0.10 mL L^{-1}. However, 2.00 pumpkin caterpillar larvae was found in quinalphos 25 EC @ 3.00 mL L^{-1} treated plants.

After ten days of treatment no larvae was observed in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} and flubendiamide 39.35 SC @ 0.10 mL L^{-1} treatments and was significantly on par with spinosad 45 SC @ 0.30 mL L^{-1} (0.13) followed by

Table 25. Population of pumpkin caterpillar, *Diaphania indica* (Saunders) in salad cucumber treated with insecticides

Insecticide	Dosage (mL/L)	*Number of larvae per plant (DAT)						
		Pre count	1	3	5	7	10	15
Spinosad 45 % SC	0.30	3.13 (2.03)	3.13 (2.03)	1.00 (1.41)	0 (1)	0 (1)	0.13 (1.06)	0.33 (1.15)
Chlorantraniliprole 18.5 % SC	0.30	3.53 (2.13)	3.33 (2.08)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
Flubendiamide 39.35 % SC	0.10	4.67 (2.38)	4.27 (2.29)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
Indoxacarb 14.5 % SC	1.0	3.67 (2.15)	3.27 (2.05)	0.8 (1.32)	0 (1)	0 (1)	0.27 (1.12)	0.80 (1.34)
Quinalphos 25 % EC (Check)	3.0	4.13 (2.26)	4.00 (2.23)	3.40 (2.09)	2.80 (1.94)	2.00 (1.73)	2.20 (1.79)	2.80 (1.95)
Control		5.07 (2.46)	5.07 (2.46)	5.80 (2.61)	5.07 (2.46)	5.13 (2.48)	5.07 (2.46)	5.60 (2.56)
CD (0.05)		(NS)	(NS)	(0.243)	(0.181)	(0.256)	(0.149)	(0.187)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

indoxacarb 14.5 SC @ 1.00 mL L^{-1} (0.27) and significantly different from quinalphos 25 EC @ 3.00 mL L^{-1} (2.20).

Similarly, chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} and flubendiamide 39.35 SC @ 0.10 mL L^{-1} recorded no larval population after fifteen days of spraying and 0.33 larvae was noticed in spinosad 45 SC @ 0.30 mL L^{-1} followed by indoxacarb 14.5 SC @ 1.00 mL L^{-1} (0.80) and quinalphos 25 EC @ 3.00 mL L^{-1} (2.80).

American serpentine leaf miner

The results of the study on the mean population of leaf miner, *L. trifolii* in salad cucumber treated with insecticides under polyhouse condition are presented in Table 26. No significant difference was observed in the population of leaf miner treated with different insecticides after one day of spraying.

Significantly lower population of *L. trifolii* was observed i.e., spinosad 45 SC @ 0.30 mL L^{-1} (1.33) and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (1.83) on three days after treatment. The population of *L. trifolii* recorded in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (3.67), quinalphos 25 EC @ 3.00 mL L^{-1} (4.17) and flubendiamide 39.35 SC @ 0.10 mL L^{-1} (4.67) were significantly different.

However, no population of *L. trifolii* was observed in spinosad 45 SC @ 0.30 mL L^{-1} and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plots after five days of treatment. The mean population recorded in flubendiamide 39.35 SC @ 0.10 mL L^{-1}, indoxacarb 14.5 SC @ 1.00 mL L^{-1} and quinalphos 25 EC @ 3.00 mL L^{-1} were 3.50, 3.33 and 3.13, respectively and they were significantly on par.

Similar results were recorded seven days after treatment. No leaf miner population was recorded in spinosad 45 SC @ 0.30 mL L^{-1} and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plots and the treatments were significantly different

Table 26. Population of American serpentine leaf miner, *Liriomyza trifolii* in salad cucumber treated with insecticides

Insecticide	Dosage (mL L^{-1})	*Number of larvae (DAT)											
		I Spray						II Spray					
		1	3	5	7	10	15	1	3	5	7	10	15
Spinosad 45 % SC	0.30	5.00 (2.44)	1.33 (1.48)	0 (1)	0 (1)	0.17 (1.07)	0.60 (1.29)	4.17 (2.27)	1.67 (1.57)	0 (1)	0 (1)	0.33 (1.15)	0.83 (1.33)
Chlorantraniliprole 18.5 % SC	0.30	4.67 (2.38)	1.83 (1.64)	0 (1)	0 (1)	0 (1)	0.20 (1.07)	3.50 (2.11)	0.33 (1.14)	0 (1)	0 (1)	0.17 (1.07)	0.50 (1.21)
Flubendiamide 39.35 % SC	0.10	5.33 (2.51)	4.67 (2.37)	3.50 (2.10)	4.33 (2.30)	4.50 (2.34)	5.17 (2.47)	4.67 (2.37)	3.83 (2.19)	3.50 (2.10)	3.50 (2.10)	3.17 (2.04)	4.00 (2.23)
Indoxacarb 14.5 % SC	1.0	4.83 (2.41)	3.67 (2.15)	3.33 (2.08)	4.00 (2.23)	4.17 (2.27)	5.00 (2.45)	4.67 (2.38)	3.83 (2.19)	3.33 (2.08)	2.83 (1.95)	3.67 (2.15)	4.33 (2.31)
Quinalphos 25 % EC (Check)	3.0	4.67 (2.37)	4.17 (2.27)	3.13 (2.07)	3.83 (2.18)	4.50 (2.33)	5.50 (2.54)	5.17 (2.48)	4.17 (2.26)	3.33 (2.08)	3.83 (2.19)	5.00 (2.45)	5.67 (2.58)
Control		5.33 (2.50)	5.50 (2.54)	6.33 (2.70)	6.67 (2.77)	6.50 (2.74)	8.17 (3.02)	5.00 (2.44)	5.17 (2.48)	5.83 (2.61)	6.00 (2.65)	6.67 (2.77)	8.83 (3.13)
CD (0.05)		(NS)	(0.422)	(0.314)	(0.307)	(0.261)	(0.357)	(NS)	(0.477)	(0.317)	(0.225)	(0.239)	(0.347)

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT- Days after treatment, *Mean of ten plants

from flubendiamide 39.35 SC @ 0.10 mL L^{-1} (4.33), indoxacarb 14.5 SC @ 1.00 mL L^{-1} (4.00) and quinalphos 25 EC @ 3.00 mL L^{-1} (3.83).

There was no leaf miner larvae in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plants and was on par with spinosad 45 SC @ 0.30 mL L^{-1} (0.17) after ten days of treatment. The maximum population was observed in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (4.17), flubendiamide 39.35 SC @ 0.10 mL L^{-1} (4.50) and quinalphos 25 EC @ 3.00 mL L^{-1} (4.50) and they were significantly different from other treatments.

Lower population of *L. trifolii* was seen in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.20) and spinosad 45 SC @ 0.30 mL L^{-1} (0.60) after fifteen days of treatment and it was on par and the population in flubendiamide 39.35 SC @ 0.10 mL L^{-1}, indoxacarb 14.5 SC @ 1.00 mL L^{-1} and dimethoate 25 EC @ 1.50 mL L^{-1} treated plants were 5.17, 5.00 and 5.50, respectively.

No significant difference was observed in the population of *L. trifolii* before second spraying and after one day of treatment. Significantly lower population was observed in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.33) and it was found to be on par with spinosad 45 SC @ 0.30 mL L^{-1} (1.67) after three days of spraying. The higher population of leaf miner was recorded in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (3.83), flubendiamide 39.35 SC @ 0.10 mL L^{-1} (3.83) and quinalphos 25 EC @ 3.00 mL L^{-1} (4.17) treated plants.

There was no population of *L. trifolii* was noticed in spinosad 45 SC @ 0.30 mL L^{-1} and chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} treated plants after five days of treatment and it was significantly different from indoxacarb 14.5 SC @ 1.00 mL L^{-1}, quinalphos 25 EC @ 3.00 mL L^{-1} and flubendiamide 39.35 SC @ 0.10 mL L^{-1} and the population were 3.33, 3.33 and 3.50, respectively.

Similar results were obtained seven days after treatment. No leaf miner larvae was observed in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} and spinosad 45 SC @

0.30 mL L^{-1} treated plots and these were significantly different from the population in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (2.83), flubendiamide 39.35 SC @ 0.10 mL L^{-1} (3.50) and quinalphos 25 EC @ 3.00 mL L^{-1} (3.83). Whereas, ten days after treatment the lower population was recorded in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} (0.17) and spinosad 45 SC @ 0.30 mL L^{-1} (0.33) and the treatments were on par. The mean population recorded in indoxacarb 14.5 SC @ 1.00 mL L^{-1} (3.67), flubendiamide 39.35 SC @ 0.10 mL L^{-1} (3.17) and quinalphos 25 EC @ 3.00 mL L^{-1} (5.00) were significantly different.

After fifteen days of treatment the population of *L. trifolii* in chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1} and spinosad 45 SC @ 0.30 mL L^{-1} were 0.50 and 0.83 and were significantly on par. The highest population was observed in indoxacarb 14.5 SC @ 1.00 mL L^{-1}, flubendiamide 39.35 SC @ 0.10 mL L^{-1} and quinalphos 25 EC @ 3.00 mL L^{-1} (4.33, 4.00 and 5.67, respectively).

4.4 PERSISTENCE AND DEGRADATION OF RESIDUES OF PESTICIDES IN COWPEA AND SALAD CUCUMBER UNDER POLYHOUSE

4.4.1 Validation of Method for the Pesticide Residue Analysis

4.4.1.1 Cowpea

The results of the validation for the estimation of the different insecticides in cowpea pods showed satisfactory recovery for all the compounds fortified. Method validation was accomplished with good linearity and satisfactory recoveries. The mean recovery of all the insecticides under study was within the acceptance range of 70-120 per cent at three levels of fortification. The repeatability of the recovery results as indicated by the relative standard deviations, RSD < 20 per cent, confirmed that the method was sufficiently reliable for pesticide analysis and the results are presented in Table 27.

Table 27. Per cent recovery of new generation insecticides in cowpea

Insecticides	Fortification levels (mg kg^{-1})					
	0.05		0.25		0.50	
	Mean % recovery	RSD (%)	Mean % recovery	RSD (%)	Mean % recovery	RSD (%)
Acetamiprid	106.20	6.43	104.90	10.29	98.20	19.60
Imidacloprid	104.00	6.20	104.20	10.05	97.60	15.00
Thiamethoxam	102.50	6.12	98.00	10.19	93.80	10.05
Thiacloprid	107.30	6.57	109.00	10.45	98.70	18.92
Spiromesifen	104.20	5.04	113.00	10.56	107.90	6.50
Fenpyroximate	107.60	6.52	106.80	8.40	105.60	18.91
Spinosad A1	109.20	7.26	115.00	10.62	119.90	19.42
Spinosad D1	102.65	8.13	111.20	15.41	109.95	18.63
Chlorantraniliprole	102.60	7.99	107.00	13.79	108.70	11.36
Flubendiamide	79.90	8.39	95.60	6.63	99.15	7.08
Indoxacarb	102.20	7.52	112.60	12.29	114.05	19.23

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

The mean per cent recovery of acetamiprid at three different fortification levels *viz,* 0.05, 0.25 and 0.50 mg kg^{-1} were 106.20, 104.90 and 98.20, respectively with relative standard deviation 6.43, 10.29 and 19.60, per cent respectively. The mean per cent recovery of imidacloprid was 104.00, 104.20 and 97.60, respectively at three fortification levels with relative standard deviation of 6.20 to 15.00 per cent. However, in thiamethoxam the mean recoveries were 102.50, 98.00 and 93.80, per cent respectively at three fortification levels with 6.12 to 10.19 per cent relative standard deviation. In case of thiacloprid the mean per cent recoveries were 107.30, 109.00 and 98.70 at three fortification levels with acceptance range of 6.57 to 18.92 per cent relative standard deviation.

The fortification studies of spiromesifen at three fortification level of 0.05, 0.25 and 0.50 mg kg^{-1} showed that the mean per cent recoveries were 104.20, 113.00 and 107.90 with accepted relative standard deviation was in the range of 5.04 to 10.56 per cent while, the fenpyroximate had a recovery of 107.60, 106.80 and 105.60 per cent respectively for three fortification levels with 6.52 to 18.91 per cent relative standard deviation.

Satisfactory results were obtained in the fortification studies using new generation insecticides against leaf feeder pests. The mean per cent recoveries of the metabolite of spinosad, spinosad A1 was 109.20, 115.00 and 119.90 at 0.05, 0.25 and 0.50 mg kg^{-1} fortified levels, respectively with the accepted relative standard deviation of 7.26 to 25.42 per cent and for another metabolite, spinosad D1 the values were 102.65, 111.20 and 109.95 when fortified at 0.05, 0.25 and 0.50 ppm levels with relative standard deviation of 8.13 to 20.63 per cent. Similarly the mean per cent recovery of chlorantraniliprole was 102.60, 107.00 and 108.70 at three fortification levels with the relative standard deviation of 7.99 to 13.79 per cent. However, the mean recoveries of flubendiamide were 79.90, 95.60 and 99.15 per cent, respectively at three fortification levels with the relative standard deviation in the accepted range of 6.63 to 8.39 per cent. Similarly, the mean per cent recovery of indoxacarb was 102.20, 112.60 and 114.05 at 0.05, 0.25 and 0.50 mg kg^{-1} fortification levels, respectively with the relative standard deviation in the range of 7.52 to 21.23 per cent.

4.4.1.2 Salad cucumber

The results of the validation for the estimation of various insecticides in salad cucumber fruits showed satisfactory recovery with in the acceptance range of 70-120 per cent at three different levels of fortification. The repeatability of the recovery results as indicated by the relative standard deviations, RSD < 20 per cent, and the results are depicted in Table 28.

The mean per cent recovery of acetamiprid was 94.20, 102.90 and 107.20 at three different fortification levels *viz,* 0.05, 0.25 and 0.50 mg kg^{-1} with relative standard deviation in the accepted range of 7.79 to 15.32 per cent. Whereas, the mean per cent recovery of imidacloprid were 104.40, 103.60 and 112.40 at three fortification levels with acceptance range of 6.43 to 15.65 per cent relative standard deviation. In case of thiamethoxam the mean per cent recoveries were 83.60, 97.70 and 101.80 at three fortification levels with relative standard deviation of 8.00 to 12.69 per cent. Similarly, the mean per cent recovery of thiacloprid at three fortification level was 93.80, 104.80 and 110.20 per cent with accepted relative standard deviation was in the range of 7.48 to 12.50 per cent. However, in spiromesifen the mean recoveries were 85.00, 107.20 and 117.20 per cent at three fortification levels with 8.54 to 12.16 per cent relative standard deviation. While, the fenpyroximate had a recovery of about 116.20, 111.00 and 115.60 per cent at three fortification levels with 8.48 to 19.20 per cent relative standard deviation.

The mean per cent recovery of the metabolite of spinosad, spinosad A1 was 101.73, 111.33 and 95.93 per cent with the relative standard deviation in the accepted range of 6.51 to 14.84 per cent and for another metabolite, spinosad D1 the values

Table 28. Per cent recovery of new generation insecticides in salad cucumber

Insecticides	Fortification levels (mg kg^{-1})					
	0.05		0.25		0.50	
	Mean % recovery	RSD (%)	Mean % recovery	RSD (%)	Mean % recovery	RSD (%)
Acetamiprid	94.20	13.16	102.90	7.79	107.20	15.32
Imidacloprid	104.40	9.94	103.60	6.43	112.40	15.65
Thiamethoxam	83.60	12.69	97.70	8.00	101.80	12.31
Thiacloprid	93.80	9.16	104.80	7.48	110.20	12.50
Spiromesifen	85.00	11.95	107.20	8.54	117.20	12.16
Fenpyroximate	116.20	10.26	111.00	8.48	115.60	19.20
Spinosad A1	101.73	6.51	111.33	8.82	95.93	14.84
Spinosad D1	101.33	6.16	108.80	10.78	103.07	11.44
Chlorantraniliprole	100.47	10.18	101.60	13.33	96.07	14.34
Flubendiamide	114.00	4.65	92.67	8.79	105.00	9.35
Indoxacarb	101.53	7.96	103.33	13.30	96.87	15.45

Limit of quantification (LOQ) – 0.05 mg kg^{-1}, RSD – Relative Standard Deviation were 101.33, 108.80 and 103.07 at 0.05, 0.25 and 0.50 mg kg^{-1} at three fortified levels with 6.51 to 14.84 per cent accepted range of relative standard deviation. Similarly, percentage recovery of chlorantraniliprole was 100.47, 101.60 and 96.07 per cent at three fortification levels with acceptance range of 10.18 to 14.34 per cent relative standard deviation. However, the mean recovery of flubendiamide was 114.00, 92.67 and 105.00 per cent at three fortified levels and the relative standard deviation was in the range of 4.65 to 9.35 per cent. Whereas, in indoxacarb the mean per cent recovery was 101.53, 103.33 and 96.87 per cent fortified at 0.05, 0.25 and 0.50 ppm levels with the relative standard deviation ranges from 7.96 to 15.45 per cent.

4.4.2 Estimation of Persistence and Degradation of Residues of Various Pesticides and their Half-lives

The mean residue, dissipation per cent and half-lives of new generation insecticides in cowpea pods were represented in Table 29-31.

Acetamiprid

The initial deposit of acetamiprid (two hours after spraying) @ 0.10 g L^{-1}, was 0.28 mg kg^{-1}. One day after spraying, the residue degraded to 0.24 mg kg^{-1}, with a reduction of 14.28 per cent. The 66.67 per cent of the residue degraded on the third day and the concentration of residue recorded being 0.08 mg kg^{-1}. On the fifth day, the residue dissipated to 0.06 mg kg^{-1} with reduction of 79.17 per cent. However, on the seventh day, the residues reached below quantification level. The half-life recorded was 1.90 days.

Imidacloprid

Imidacloprid applied at the rate of 0.20 mL L^{-1} resulted in an initial deposit of 0.32 mg kg^{-1} on cowpea fruits after two hours of spraying. One day after spraying, the

Table 29. Residue of insecticides in cowpea fruits

Days after Spraying (DAS)	Acetamiprid		Imidacloprid		Thiamethoxam		Thiacloprid	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	0.28±0.01		0.32±0.02		0.89±0.01		0.37±0.005	
1	0.24±0.01	14.28	0.15±0.006	53.13	0.83±0.03	6.74	0.29±0.02	21.62
3	0.08±0.004	66.67	BQL		0.56±0.02	37.08	0.18±0.02	51.35
5	0.06±0.009	79.17	BQL		0.29±0.01	67.42	BQL	
7	BQL		BQL		0.13±0.01	85.39	BQL	
10	BQL		BQL		BQL		BQL	
Half-life (Days)	1.90		0.82		2.55		2.80	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg kg^{-1}, SD – Standard Deviation

Table 30. Residue of acaricides in cowpea fruits

Days after Spraying (DAS)	Spiromesifen		Fenpyroximate	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL	
0 (2 h after spraying)	1.54±0.13		0.23±0.005	
1	1.36±0.16	11.69	0.14±0.02	39.13
3	0.97±0.18	37.01	0.08±0.005	65.22
5	0.52±0.04	66.23	0.06±0.001	73.91
7	0.47±0.13	69.48	BQL	
10	BQL		BQL	
Half-life (Days)	4.65		3.71	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg kg^{-1}, SD – Standard Deviation

Table 31. Residue of insecticides in cowpea fruits

Days after Spraying (DAS)	Spinosad		Chlorantraniliprole		Flubendiamide		Indoxacarb	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	1.34 ±0.08		1.19±0.07		0.89±0.09		0.95±0.07	
1	1.13±0.05	15.67	0.67±0.01	43.70	0.48±0.04	46.07	0.51±0.04	46.32
3	0.73±0.01	45.52	0.13±0.009	89.09	0.27±0.05	69.66	0.46±0.03	51.58
5	0.71±0.05	47.01	0.08±0.05	93.28	BQL		BQL	
7	0.12±0.008	91.04	BQL		BQL		BQL	
10	BQL		BQL		BQL		BQL	
Half-life (Days)	1.17		1.20		2.71		3.19	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg kg^{-1}, SD – Standard Deviation

insecticide residue dissipated to 0.15 mg kg^{-1}, with reduction of 53.13 per cent residue from the initial residue. Residue became below quantification level on fifth day at LOQ 0.05 mg kg^{-1}. The half-life of imidacloprid observed was 0.82 days.

Thiamethoxam

The initial deposit of 0.89 mg kg^{-1} was recorded on cowpea fruits two hours after spraying and it reduced to 0.83 mg kg^{-1} with a dissipation percentage of 6.74 on the first day. On the third day, the residue dissipated to 0.56 mg kg^{-1} with a dissipation per cent of 37.08. An average residue deposit of 0.29 mg kg^{-1} was recorded on fifth day with the dissipation percentage 67.42. On the seventh day, 0.13 mg kg^{-1} of residue was recorded on the fruits with a dissipation percentage of 85.39 and the half-life was calculated as 2.55 days. By the tenth day, the residue reached below quantification.

Thiacloprid

An initial residue deposit of 0.37 mg kg^{-1} was recorded two hours after spraying. One day after spraying, the residue reduced to 0.29 mg kg^{-1}, recording a reduction of 21.62 per cent. On the third day, the residue dissipated to 0.18 mg kg^{-1} and the dissipation percentage was 51.35. The half-life of thiacloprid was 2.81 days. On fifth day, residue of thiacloprid reached below quantification level.

Spiromesifen

The initial deposit of spiromesifen after two hours of spraying was 1.54 mg kg^{-1} on cowpea. On the next day the residue dissipated to 1.36 mg kg^{-1}, indicating 11.69 per cent loss of the residues. On the third day, 37.01 per cent reduction of residue was observed and the residues being 0.97 mg kg^{-1}. An average residue deposit of 0.52 mg kg^{-1} and the dissipation percentage of 66.23 was noticed five days after spraying. On the seventh day, an average residue of 0.47 mg kg^{-1} was recorded on cowpea fruits with a dissipation percentage of 69.48 and the half-life computed for spiromesifen was 4.65 days. The residue became below quantification level on tenth day of spraying.

Fenpyroximate

Spraying of fenpyroximate resulted in an initial deposit of 0.23 mg kg^{-1} on cowpea fruits when estimated two hours after the application. The residue dissipated to 0.14 mg kg^{-1} on one day after spraying, recording 39.13 per cent reduction in the initial deposit. The residue dissipated to 0.08 mg kg^{-1}, with per cent dissipation of 65.22 on the third day. On the fifth day, only 0.06 mg kg^{-1} residue was recorded, indicating 73.91 per cent reduction of the initial residue. The half-life of fenpyroximate was 3.71 days. The residue reached below quantification level on the seventh day of spraying.

Spinosad

The initial deposit of spinosad was reported as 1.34 mg kg^{-1} on cowpea fruits two hours after spraying. On the first day after spraying the residue dissipated to 1.13 mg kg^{-1} with a dissipation percentage of 15.67. The percentage dissipation observed after third day of spraying was 45.52 and the residue recorded from the fruits being 0.73 mg kg^{-1}. The residues degraded to 0.71 mg kg^{-1} with percentage dissipation of 47.01 on the fifth day. On the seventh day the residue dissipated to 0.12 mg kg^{-1} with a dissipation percentage of 91.04. On the tenth day, the residue reached below the quantification level. The half-life of spinosad was worked out to be 1.17 days.

Chlorantraniliprole

The initial deposit of 1.19 mg kg^{-1} of chlorantraniliprole was recorded on cowpea fruits two hours after spraying and it was reduced to 0.67 mg kg^{-1} with a dissipation percentage of 43.70 on the first day after spraying. On the third day, the residue reduced to 89.09 per cent of the initial deposit and the concentration of residue detected being 0.13 mg kg^{-1}. An average residue deposit of 0.08 mg kg^{-1} was recorded on fifth day with the dissipation percentage of 93.28. The half-life of chlorantraniliprole was calculated as 1.20 days. By the seventh day, the residue reached below the quantification level.

Flubendiamide

The cowpea fruits recorded an average initial deposit of 0.89 mg kg^{-1} two hours after spraying which dissipated to 0.48 mg kg-1 on the next day, registering 46.07 per cent dissipation. The residue level was 0.27 mg kg^{-1} on the third day, the dissipation percentage being 69.66 which reached below quantification level on the fifth day of spraying with a half-life period of 2.71 days.

Indoxacarb

An initial residue of 0.95 mg kg^{-1} was recorded two hours after spraying. One day after spraying, the residue reached to 0.51 mg kg^{-1}, recording dissipation percentage of 46.32. On the third day, the residue was reduced to 0.46 mg kg^{-1} and the dissipation percentage increased to 51.58. On fifth day, residue of indoxacarb reached below quantification level. The calculated half-life period for the indoxacarb residue was 3.19 days.

4.4.2.2 Estimation of persistence and degradation of residues of various pesticides and their half-life in salad cucumber fruits

The initial deposit, percentage dissipation and half-life of new generation insecticides in cowpea pods were represented in Table 32-34.

Acetamiprid

The mean residue of acetamiprid detected at different intervals presented in Table 32 showed that the initial deposit of 0.42 mg kg^{-1}, dissipated to 0.26 mg kg^{-1},

Table 32. Residue of insecticides in salad cucumber fruits

Days after Spraying (DAS)	Acetamiprid		Imidacloprid		Thiamethoxam		Thiacloprid	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	0.42±0.03		0.18±0.03		0.16±0.007		0.13±0.009	
1	0.26±0.03	38.09	0.07±0.007	61.11	0.14±0.009	12.50	0.08±0.01	38.46
3	0.13±0.01	69.05	BQL		0.09±0.005	43.75	BQL	
5	0.09±0.01	78.57	BQL		0.06±0.005	68.75	BQL	
7	0.06±0.003	88.10	BQL		BQL		BQL	
10	BQL		BQL		BQL		BQL	
Half-life (Days)	2.55		0.66		1.39		1.28	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg kg^{-1}, SD – Standard Deviation

Table 33. Residue of acaricides in salad cucumber fruits

Days after Spraying (DAS)	Spiromesifen		Fenpyroximate	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL	
0 (2 h after spraying)	0.24±0.03		0.06±0.005	
1	0.13±0.007	45.83	BQL	-
3	0.12±0.01	50.00	BQL	-
5	0.06±0.001	75.00	BQL	-
7	BQL		BQL	-
Half-life (Days)	4.65		-	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg kg^{-1}, SD – Standard Deviation

Table 34. Residue of insecticides in salad cucumber fruits

Days after Spraying (DAS)	Spinosad		Chlorantraniliprole		Flubendiamide		Indoxacarb	
	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)	Mean residue ± SD (mg kg^{-1})	Dissipation (%)
Before application	BQL		BQL		BQL		BQL	
0 (2 h after spraying)	0.20 ±0.08		0.19±0.01		0.14±0.01		0.14±0.006	
1	0.11±0.05	45.00	0.17±0.02	10.53	0.12±0.007	14.29	0.12±0.01	14.29
3	0.09±0.01	55.00	0.07±0.004	63.16	0.11±0.01	21.43	0.10±0.003	28.57
5	BQL		BQL		0.06±0.003	64.29	0.06±0.003	57.14
7	BQL		BQL		BQL		BQL	
Half-life (Days)	2.81		1.92		3.56		6.19	

BQL – Below Quantification Level, Limit of Quantification (LOQ) - 0.05 mg kg^{-1}, SD – Standard Deviation

with a reduction of 38.09 per cent one day after spraying. On the third day, the residue reduced to 0.13 mg kg^{-1} and the dissipation percentage was 69.05. On the fifth day the percentage dissipation was 78.57 per cent and the residue level was 0.09 mg kg^{-1}. On the seventh day, a residue level was 0.06 mg kg^{-1} and the percentage dissipation was 88.10. The residue degraded to below quantification level on the tenth day of spraying. The half-life of acetamiprid was calculated as 2.55 days.

Imidacloprid

The initial deposit of imidacloprid was 0.18 mg kg^{-1}. On the first day the percentage dissipation was 61.11 per cent and the residue level was 0.07 mg kg^{-1} and had the lower half-life of 0.66 days. On the third day, residue became below quantification limit.

Thiamethoxam

The initial deposit of 0.16 mg kg^{-1} was recorded on salad cucumber fruits two hours after spraying reduced to 0.14 mg kg^{-1} with a dissipation percentage of 12.50 after one day. On the third day, the percentage dissipation was 43.75 per cent with residue was 0.09 mg kg^{-1}. The residue detected in the fruits collected on the fifth day was 0.06 mg kg^{-1} with a dissipation percentage of 68.75. Residue became below quantification level on seventh day and the half-life computed for the thiamethoxam was 1.39 days.

Thiacloprid

An initial deposit of 0.13 mg kg^{-1} of thiacloprid was detected on cucumber fruits two hours after spraying. The residue of the insecticide was found to be 0.08 mg kg^{-1} with dissipation percentage of 38.46 on one day after spraying. Residue become below quantification level of 0.05 mg kg^{-1} from the third day of spraying. The half-life was calculated as 1.28 days on salad cucumber fruits.

Spiromesifen

Two hours after spraying, an initial deposit of 0.24 mg kg^{-1} was recorded on cucumber fruits. One day after spraying per cent dissipation recorded was 45.83 and the residue was 0.13 mg kg^{-1}. On the third day the residue recorded was 0.12 mg kg^{-1} and the dissipation percentage was 50.00. On the fifth day the residue level was 0.06 mg kg^{-1} with a dissipation percentage of 75.00 with a half-life of 2.83 days. Residue was below quantification level on seventh day after spraying.

Fenpyroximate

The initial deposit of fenpyroximate on salad cucumber fruits was 0.06 mg kg^{-1} after two hours of spraying. After one day, the residue got reduced to below quantification limit.

Spinosad

The initial deposit of 0.20 mg kg^{-1} was recorded in salad cucumber two hours after spraying which dissipated to 0.11 mg kg^{-1} on the next day, registering 45.00 per cent dissipation. The residue level was 0.09 mg kg^{-1} on the third day with the dissipation percentage of 55.00 which reached below quantification level on the fifth day of spraying and had a half-life period of 2.81 days.

Chlorantraniliprole

Two hours after spraying, an initial deposit of 0.19 mg kg^{-1} of chlorantraniliprole residues was recorded on salad cucumber fruits which after one day degraded to 0.17 mg kg^{-1} with a dissipation percentage of 10.53. On the third day, the residue reduced to 63.16 per cent with a residue in the fruits being 0.07 mg kg^{-1}. From the fifth day onwards, the residue was below quantification level and the half-life was reported to be 1.92 days.

Flubendiamide

The initial deposit of flubendiamide on salad cucumber fruits was found to be 0.14 mg kg^{-1},which got dissipated to 0.12 mg kg^{-1} one day after spraying with a dissipation percentage of 14.29. On the third day, 21.43 per cent of the initial residue dissipated and the residue level became 0.11 mg kg^{-1}. The dissipation continued on the fifth day, the residue detected being, 0.06 mg kg^{-1} and dissipation percentage 64.29 and had a half-life of 3.56 days. Residue become below quantification level of 0.05 mg kg^{-1} on seventh day.

Indoxacarb

The initial deposit of 0.14mg kg^{-1} was recorded on salad cucumber fruits two hours after spraying reduced to 0.12 mg kg^{-1} on the next day with a dissipation percentage of 14.29. On the third day, 28.57 per cent of the initial deposit was dissipated and the concentration became 0.10 mg kg^{-1}. Five days after spraying, the fruits recorded 0.06 mg kg^{-1} of indoxacarb residue with a dissipation percentage of 57.14. Indoxacarb sprayed on salad cucumber fruits took 6.19 days to degrade its residue to half of the initial deposit. The residue level reached below quantification level on the seventh day.

DISCUSSION

5. DISCUSSION

Protected cultivation is one of the most promising areas of agriculture and it is an upcoming and alternative production system for horticultural and ornamental crops involving high-tech and intensive practices. Polyhouse farming provides better income in a short period of time with less labours and it reduces dependency on rainfall and makes the optimum use of land and water resources.

One of the major hypotheses on the emergence of protected cultivation is the raising of pest and diseases free crops. However, the polyhouses cultivation provides the ideal environment not only for the optimum plant growth but also for the herbivorous insects and mites due to various flaws in the construction of polyhouses that facilitate their entry. Many pests including sucking pests and leaf feeders get entry into the polyhouse through infested planting material also. Often, the natural enemies that serve to keep pests under control outside are not present inside the polyhouse (Sood, 2012). Besides these, warm, humid climate and abundant food in a polyhouse provide an excellent and stable environment for pest development (Yadav and Kaushik, 2014). For these reasons, pests situations often develop in this indoor environment more rapidly and with greater severity than outdoors.

As on date 4, 80,452.63 m^2 areas are reported to be under cultivation in polyhouses in Kerala (SHM, 2016). In these polyhouses in Kerala serious constructional flaws and pest incidence has been reported (GOK, 2013). Farmers usually rely on chemical insecticides to alleviate the losses due to pests from polyhouse and it has increased the concerns of the public about chemical residues, particularly in freshly consumed vegetables grown in polyhouses due to the sensational reports on pesticide residues through various media. However, the precise information on the pests infesting the different crops, population dynamics of the pests, efficacy of insecticides and their residual toxicity in protected environment are meagre. In this context, the study entitled "Management of pests of cowpea and salad cucumber in polyhouse” was undertaken with the objectives of documenting the pests and natural enemies on cowpea and salad cucumber in polyhouses and to evaluate the efficacy of new generation insecticides against the major pests would help in developing safe pest management strategies in two vegetables, cowpea and salad cucumber under polyhouse condition.

5.1 DOCUMENTATION OF PESTS, NATURAL ENEMIES AND PESTICIDE USE PATTERN IN POLYHOUSES

A purposive survey conducted in polyhouses of Thiruvananthapuram district revealed that only 25 per cent of the polyhouses were constructed as per the specifications prescribed while 75 per cent were having structural flaws (Figure 2) like slits in ante room, low quality cladding material with slits and without proper construction paved the way for pest and disease incidence. The concept of polyhouse is that it should be devoid of pest and diseases but this is not the actual scenario in the polyhouses of Kerala. The Karshaka Santwanam Team of the Kerala Agricultural University (GOK, 2013) visited various polyhouses in the southern districts of Kerala during 2013, and reported that 92 per cent of the polyhouses were ravaged by pests and diseases and they stated that air spaces, holes or slits in cladding materials or gaps in the door frames of the ante room envisaged the entry of pests inside the polyhouses. Ante room is an important construction requisite of any polyhouse and it is meant to provide an additional layer of safety to the main polyhouse with respect to the entry of pest. Farmers who constructed 30 per cent of polyhouses in Thiruvananthapuram district did not conceive the real idea behind the need of ante room in a polyhouse and hence small to big gaps were seen in the door frames of ante room or between ante room and polyhouse, which permitted the entry of many pests defeating the purpose of protected cultivation.

Cowpea and salad cucumber are the major crops cultivated in 80 per cent polyhouses of Kerala considering their high demand in southern Kerala. Cultivation

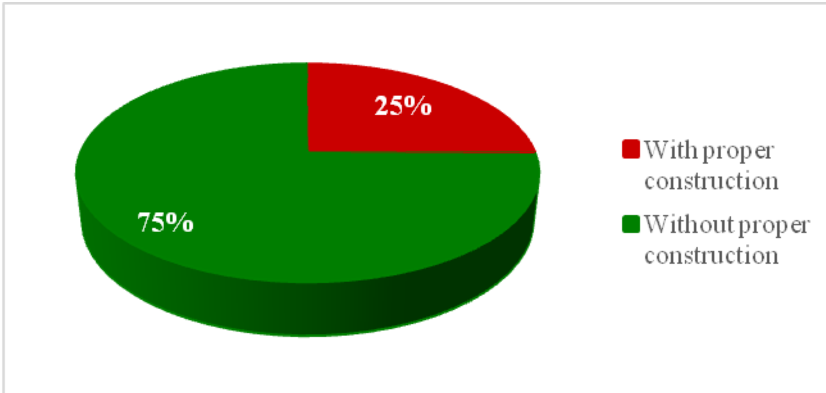


Figure 2. General conditions of polyhouses

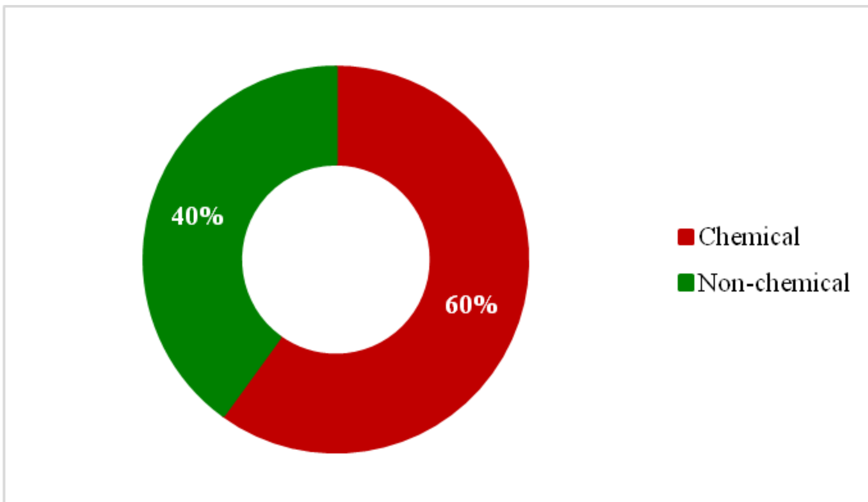


Figure 3. Extent of use of insecticides

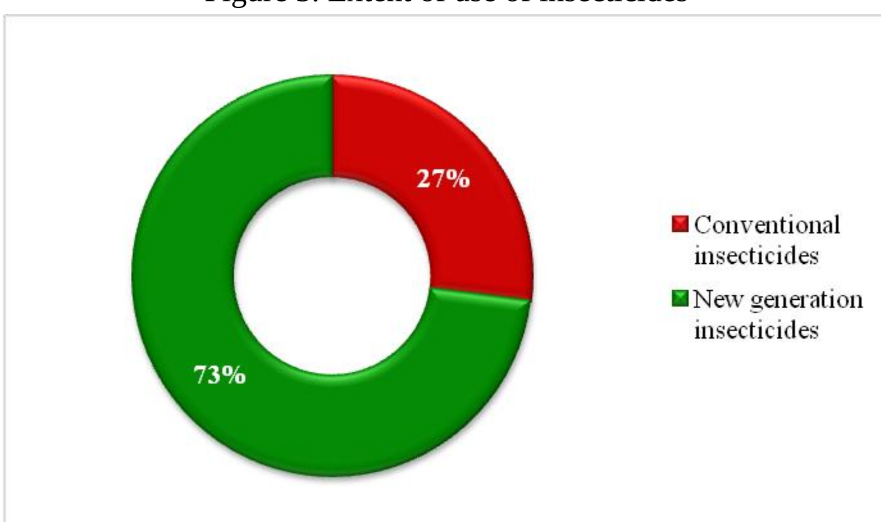


Figure 4. Extent of use of new generation insecticides

of crops as a monocrop in successive years promoted the rapid multiplication of the pests. In addition improper sanitation facilitated a hiding places for the pests.

From the survey, it was clear that both sucking pests and leaf feeders infested cowpea and salad cucumber. In cowpea, the sucking pests observed were aphid, *A. craccivora;* mealybug, *F. virgata;* pod bugs, *R. pedestris;* fulgorid bug, *E. tomentosa;* thrips, *A. chaetophora;* mites, *T. truncatus* and in salad cucumber green peach aphid, *M. persicae;* mealybug, *F. virgata;* three thrips, *A. tumiceps; T. hawaiiensi; F. schultzei* and mites, *Tetranychus* sp. were the sucking pests. The leaf feeders observed in cowpea were tobacco caterpillar, *S litura*, pod borer, *L. boeticus;* tortrycid moth, leaf miner, leaf beetle, *P. flavopustulata;* stem girdler, *O. brevis* and American serpentine leaf miner, *L. trifolii.*

Pumpkin caterpillar, *D. indica* and American serpentine leaf miner, *L. trifolii* were the leaf feeders recorded from salad cucumber. The present reports on the infestation of the pests *viz.*, tortrycid larvae, leaf miner and girdle beetle, *O. brevis* in cowpea are the first record of these pests in polyhouses. The studies conducted by Vashisth *et al.* (2013); Gavkare *et al.*(2014) at Himachal Pradesh showed that *T. vaporariorum*, *M. persicae*, *T. tabaci*, *Frankliniella* sp. were the sucking pests and *S. litura, H. armigera, P. xylostella* and *L. trifolii* were the leaf feeders infesting capsicum, tomato, cucumber, pea and cole crops under polyhouse. However, in Punjab the major sucking pests reported were *B. tabaci, A. gossypii, S. dorsalis, P. latus, T. urticae* and leaf feeders *viz., S. litura, L. trifolii* and nematode *M. incognita* infesting cucumber and tomato under net-house (Kaur *et al.,* 2010). Nandini (2010) conducted a study on pests of capsicum under protected condition and she reported *P. latus, S. dorsalis* and *S. litura* as the major pests. In Haryana, Arora and Singh (2012), reported the incidence of mealybug, *D. mangifera* in ladys' finger and tomato under protected cultivation. Sethi and Dubey (2010) reported that the temperature inside the polyhouse was 2.5-3 ºC higher when compared to open field condition and that this facilitated the rapid multiplication of pests inside the polyhouse.

The natural enemy population found inside the polyhouses were coccinellids, syrphids and spiders. The important spiders associated with cowpea and salad cucumber were lynx spider, *O. javanus*, orange lynx spider *O. sunandae* and garden spider, *A. pulchella*. The striking feature was the absence of host specific parasites and parasitoids of pests of cowpea and salad cucumber under polyhouses. The diversity of spiders is greater in undisturbed natural environments than in disturbed ecosystem (Umarani and Umamaheswari, 2013).

Regarding the pesticide use pattern chemical insecticides were used in 60 per cent of the polyhouse and non-chemicals were applied in 40 per cent of the polyhouses for pest management (Figure 3). Of this in 73 per cent of the polyhouses new generation insecticides and in 27 per cent conventional insecticides were used (Figure 4). Majority of polyhouse farmers surveyed were not true or traditional farmers. Most of them were attracted to polyhouse cultivation by the huge subsidies of government given through State Horticulture Mission (SHM). Moreover, the farmers were regularly attending training programmes conducted by SHM every month and got familiarised with new generation insecticides. The positive side of this was that majority (60 %) read the labels before using chemicals and the 60 per cent farmers applied pesticide on need basis. Beside this, 45 per cent of the farmers surveyed gave sufficient interval between application of insecticides (> 15 days). Sixty per cent polyhouse farmers were giving seven days interval between pesticide application and harvest.

5.2 POPULATION DYNAMICS AND INFESTATION OF PESTS IN COWPEA AND SALAD CUCUMBER

Pests are an integral part of agro-ecosystems and the changes in their densities in time and space and the forces effecting the variations are important. Studies on the population dynamics and infestation of sucking pests and leaf feeders in cowpea and salad cucumber revealed that the initiation of population and infestation of the different pests varied in polyhouse conditions. Population of aphids, *A. craccivora* was very low in the early phase of the crop but it increased gradually and the higher population was seen coinciding with the active vegetative stage of the crops with maximum infestation after 60 days of sowing (92.65 – 100 %). In salad cucumber, the population of green peach aphid, *M. persicae* was higher at 45 days after sowing. Aphids are known to transmit diseases to the plants which are often more serious than the feeding injury that it causes (Navas, 2014). The life cycle of aphid is very short in addition they have parthenocarpic reproduction and high fecundity (Murphy *et al.*, 2006). Hence, enormous populations build-up occur in relatively short period.

The population of pod bugs, *R. pedestris* and mealybug, *F. virgata* were maximum after 60 to 120 days of sowing (48.53 – 82.36 and 54.47 - 100). Adults and nymphs of *R. pedestris* fed gregariously on green pods and in absence it utilized dry pods (Meena, 2007).

With regard to the mite, *T. truncatus* and *Tetranychus* sp. The higher population and infestation in cowpea and salad cucumber was seen 90 days after sowing under polyhouse. *T. urticae* is an important pest feeding on wide range of host plants under polyhouse (Reddy and Kumar, 2006; Singh *et al.,* 2006; Kaur *et al.,* 2010). However, in our study *T. truncatus* was identified as a major mite in cowpea. Unlike natural conditions, the population and infestation of mite was more in polyhouses. While considering the population of natural enemies it was seen that less number of predatory mites and other predators were seen inside the polyhouses which may be the reasons for the high population build-up of mites inside the polyhouse. The mite had a developmental period of 7 days at 81 ºF and made successful survival at hot periods prevailed inside the polyhouses (Gerson and Weintraub, 2007).

The population of leaf feeders were seen throughout the crop growth period except *P. flavopustulata*, the population and infestation of which was seen upto 45 days after sowing only. The population and infestation of the newly identified pest, tortrycid larvae started 30 days after sowing and were maximum at 75 days after sowing. Another new report of pest infesting cowpea in polyhouse was *O. brevis* and its population started from the initial stage of crop and sustained throughout the crop period. Early symptoms included the drying of the edges of the leaves, wilting with dead petioles and the main stem having the two parallel girdles. The presence of two circular cuts on the branch or stem was the characteristic symptom observed. Larvae bore into the stem of the cowpea and fed from inside and made tunnels within the stem. The leaf infestation by the larvae started in the early stage itself while, stem infestation was noted 45 days after sowing. Population of the pumpkin caterpillar, *D. indica* was higher after 60 days of sowing in salad cucumber (2.00 to 3.60 larvae per plant). *D. indica* is an important pest in cucurbitaceous vegetables and was seen throughout the year. In field conditions, the population of the larvae of *D. indica* was supressed by the parasites *A. taragamae* and *Goniozus* sp. (Peter and David, 1991). The absence of these parasites noticed under polyhouse may be the reason for the population build-up of *D. indica* under polyhouse (August – November, 2015).

The most predominant leaf feeder was *L. trifolii,* its infestation was maximum at 60 days of sowing in cowpea and 45 days after sowing in salad cucumber. The temperature regime of above 25-30 ºC was observed inside polyhouse and this has been reported to be favourable for the rapid development of the larvae of *L. trifolii* (Minkenberg and Lantern, 1986) and at high temperature there was an increase in the number of eggs laid by the female per day (Zoebisch *et al.,* 1992). Leaf miner may invade into the polyhouses along with infested seedling materials or the insect proof nets having more than 34 threads per linear inch (Sood, 2012).

5.3 EFFICACY OF NEW GENERATION INSECTICIDES AGAINST MAJOR PESTS OF COWPEA AND SALAD CUCUMBER

The studies on the efficacy of new generation insecticides against sucking pests *viz.*, aphids and pod bugs in cowpea and salad cucumber revealed that the neonicotinoids *viz.*, thiamethoxam 0.30 g L^{-1} and imidacloprid 0.20 mL L^{-1} were better in managing the aphids, *A. craccivora* and pod bug, *R. pedestris* in cowpea and green peach aphid, *M. persicae* in salad cucumber (Figure 5, 6 and 7). Spiromesifen 0.80 mL L^{-1} was recorded as be the best in reducing the population of mites in cowpea and salad cucumber (Figure 8 and 9). Chlorantraniliprole 0.30 mL L^{-1} and spinosad 0.30 mL L^{-1} reduced the population of leaf miner in cowpea and salad cucumber (Figure 10 and 11). Studies on the management of *D. indica* showed that chlorantraniliprole 0.30 mL L^{-1} was found to be the best in managing the pest (Figure 12). Thamilvel (2009) reported that the foliar application of acetamiprid @ 0.002 per cent and imidacloprid @ 0.003 per cent reduced the infestation of aphids in winged bean in open condition in Kerala. Imidacloprid @ 0.05 per cent effectively reduced the population of *M. persicae* and *S. dorsalis* in capsicum grown under net-house conditions in Punjab (Kaur and Singh, 2013). Similarly, Kooner *et al.* (2015) studied the bioefficacy of neonicotinoids against *A. gossypii* on tomato in Punjab and they reported that imidacloprid 17.8 SL and thiamethoxam 25 WG were superior in reducing the aphid population in open field conditions.

The promosing insecticides, imidacloprid and thiamethoxam both belong to the group “neonicotinoids”. The neonicotinoids are systemic insecticides and are very effective for the control of sucking and chewing insect pests such as aphid, whitefly, leaf hopper and some beetles (Devee *et al.*, 2011). However, application of neonicotinoids in several crops not only kills the pest but also affects the beneficial

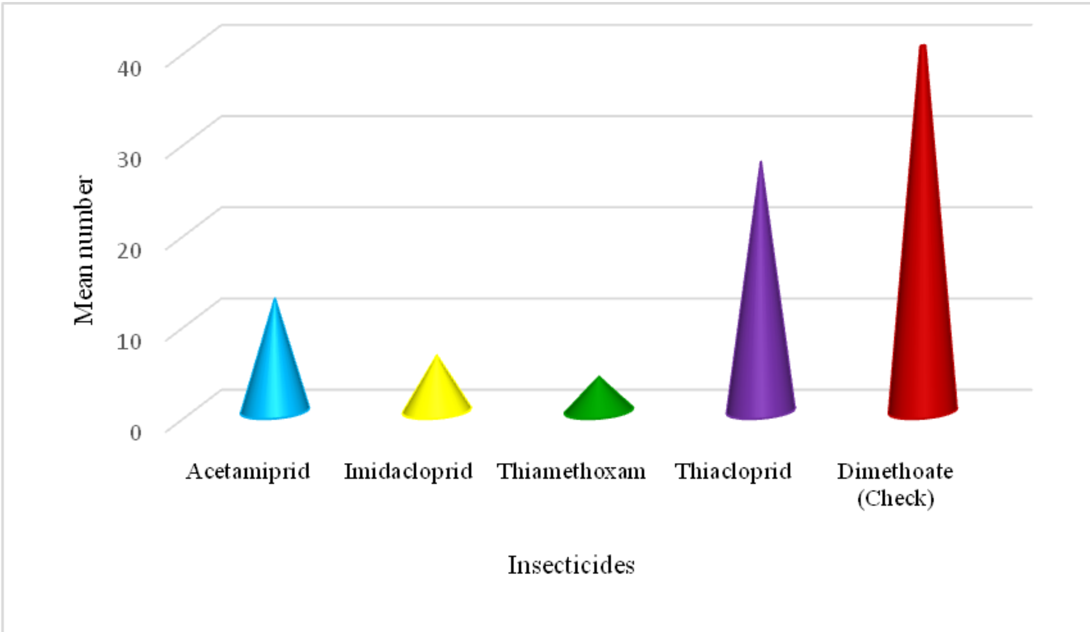


Figure 5. Population of *Aphis craccivora* Koch in cowpea treated with insecticides

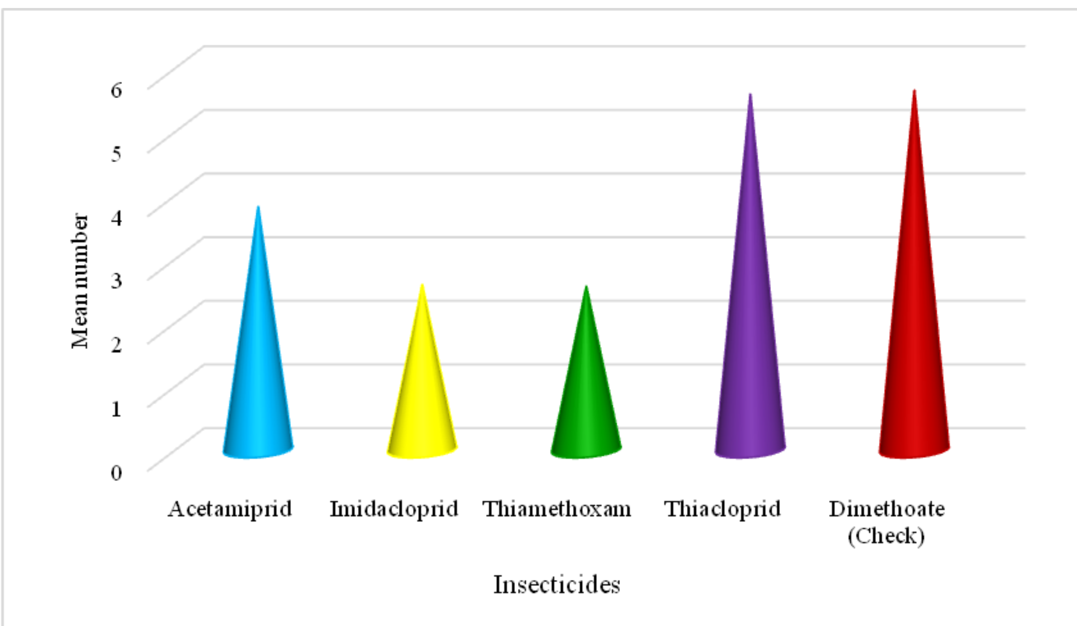


Figure 6. Population of *Riptortus pedestris* Fabricius in cowpea treated with insecticides

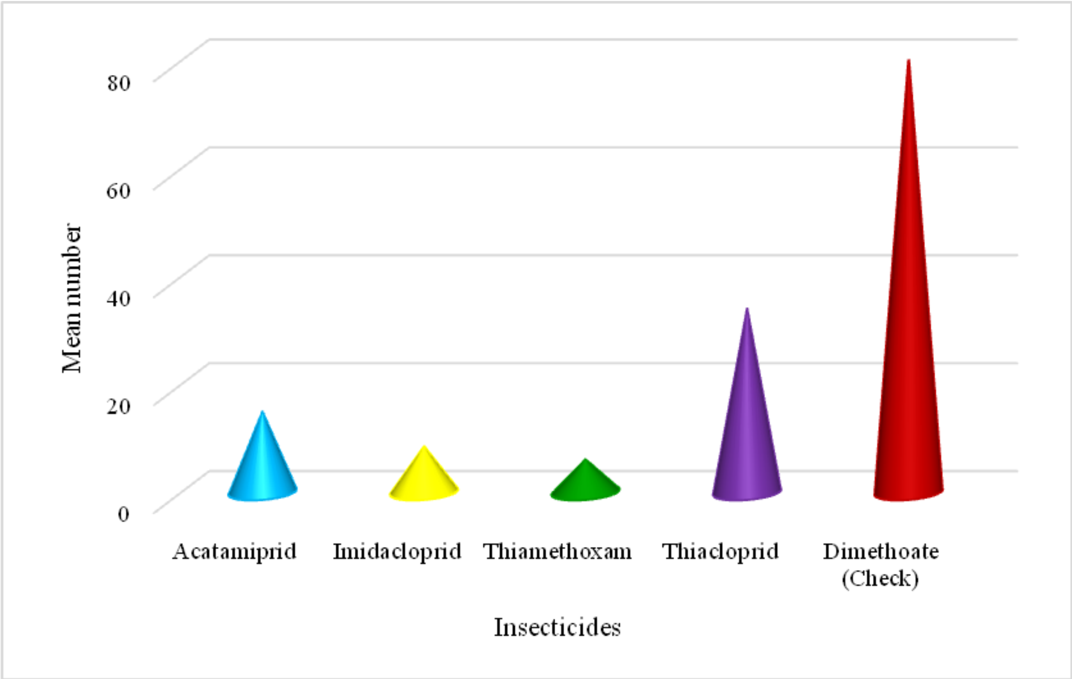


Figure 7. Population of *Myzus persicae* Sulzer in salad cucumber treated with insecticides

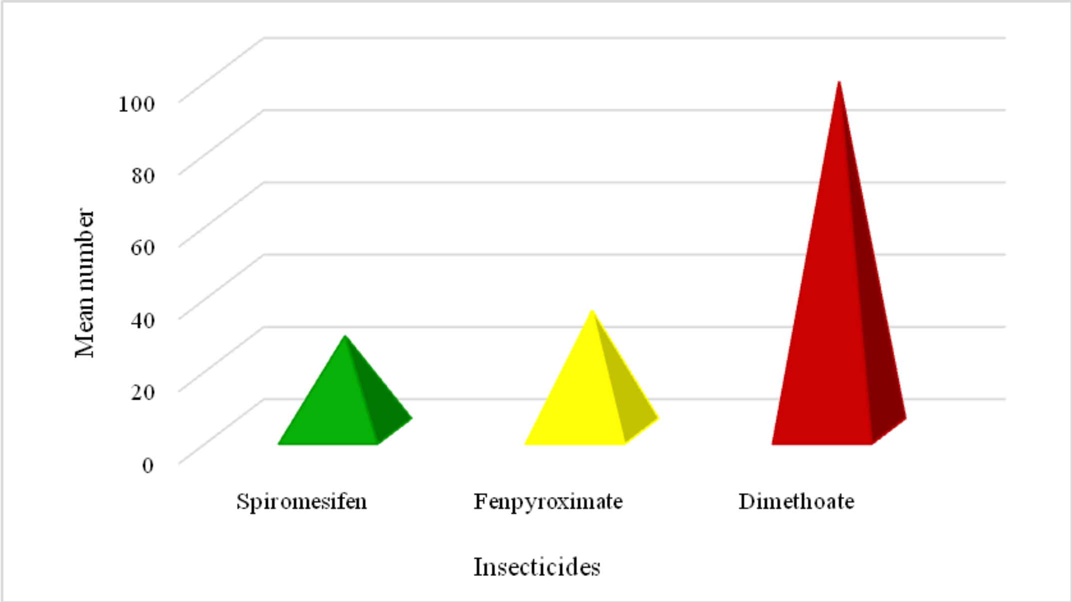


Figure 8. Population of *Tetranychus truncatus* Ehara in cowpea treated with insecticides

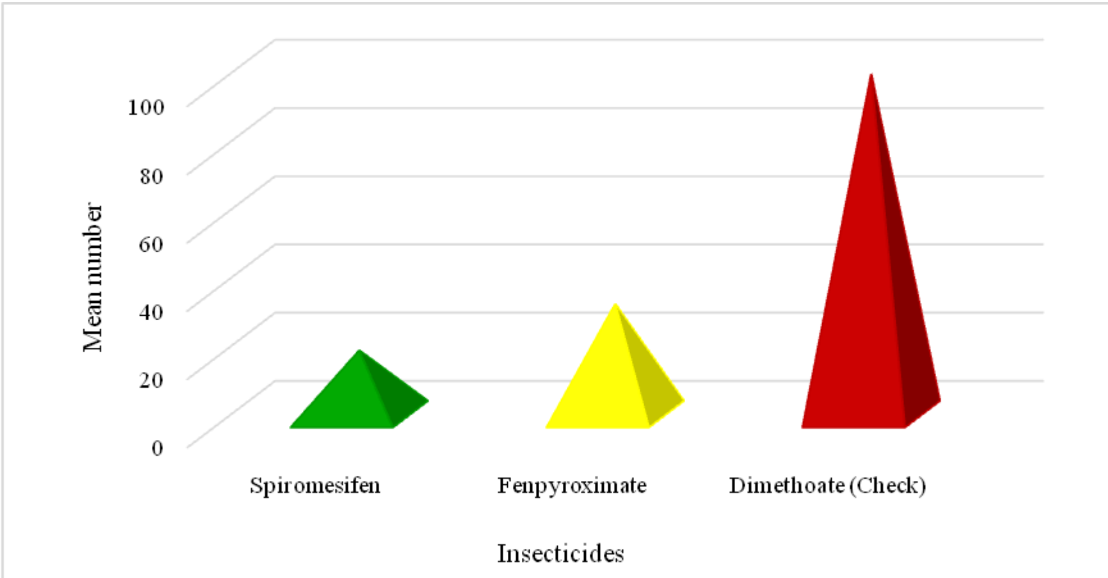


Figure 9. Population of *Tetranychus* sp. in salad cucumber treated with insecticides

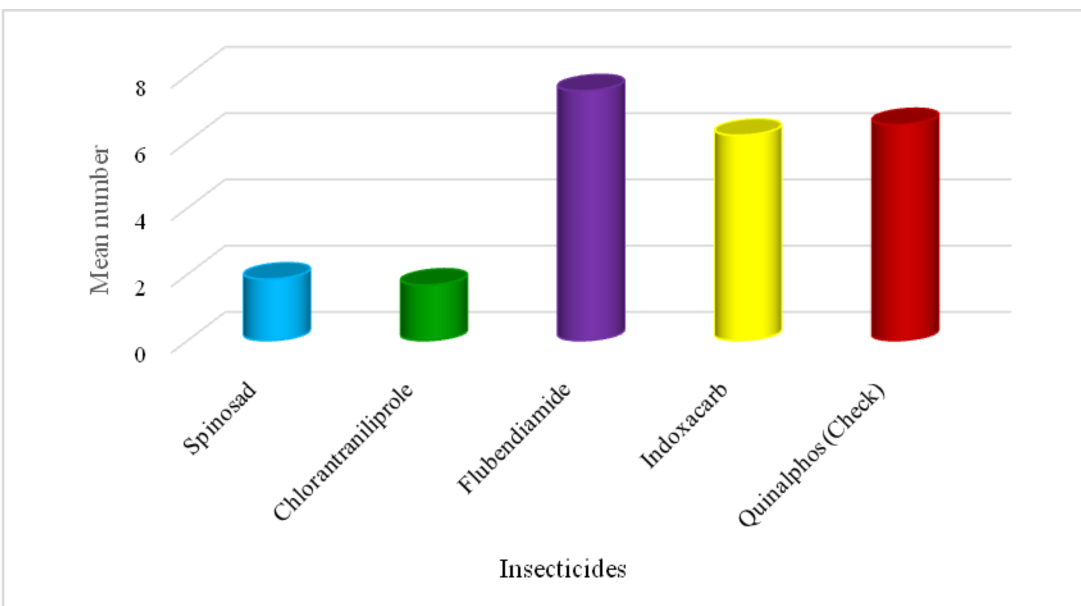


Figure 10. Population of *Liriomyza trifolii* Burgess in cowpea treated with insecticides

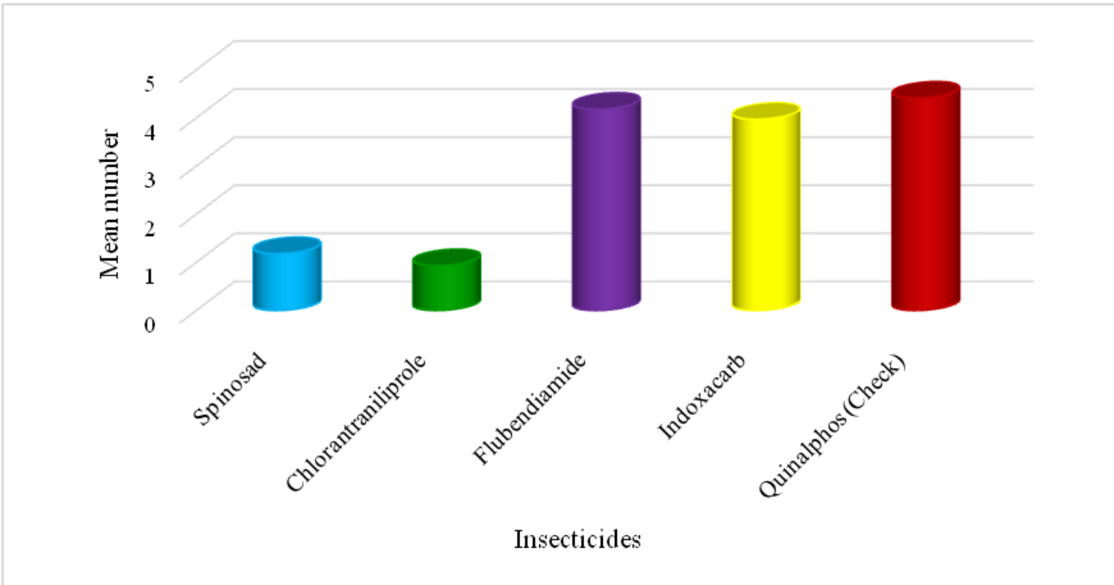


Figure 11. Population of *Liriomyza trifolii* Burgess in salad cucumber treated with insecticides

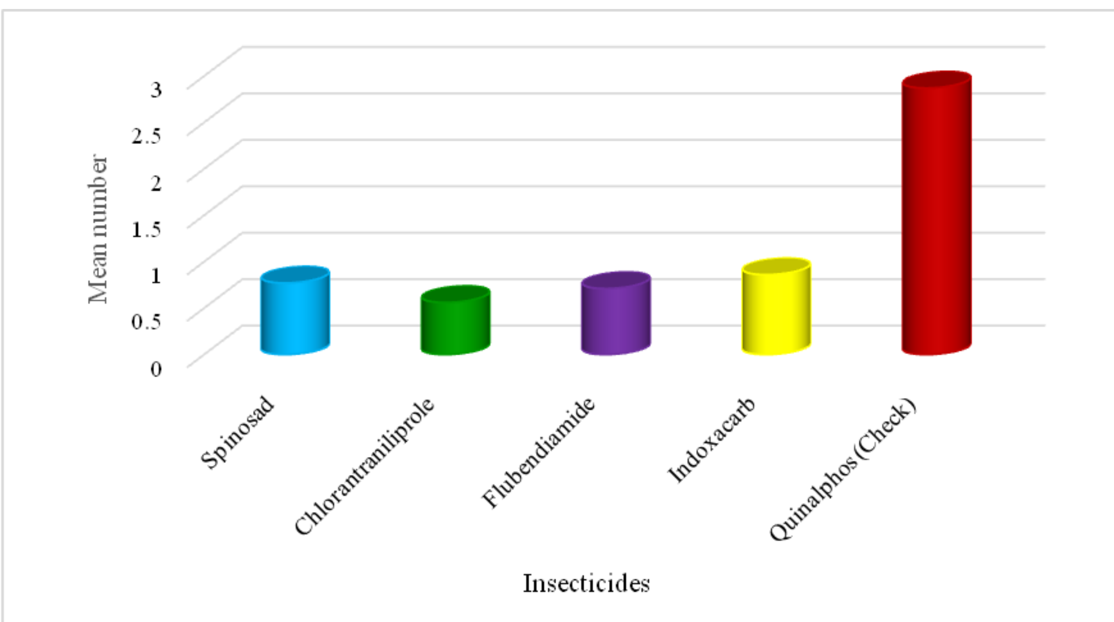


Figure 12. Population of *Diaphania indica* Saunders in salad cucumber treated with insecticides

insects like honey bees and bio agents. Honey bees are main pollinating agents in majority of crops grown in open field condition. However, the role of pollinators under protected cultivation is limited because the pollinators cannot survive inside polyhouse due to the hostile climate prevailed. Hence, it is safe to apply neonicotinoids inside the polyhouse.

Most of the conventional acaricides are generally old generic, broad spectrum, require higher dose and many of them toxic to the natural enemies. Therefore, newer molecules having acaro-insecticidal activities against mites have been evaluated and their efficacy compared with conventional insecticides (Halder *et al.,* 2015). Spiromesifen and fenpyroximate have been recently introduced in India as acaricides for mite management *viz.,* vegetables, fruit crops, plantation crops, etc. The efficacy of new generation acaricides *viz.,* spiromesifen 22.9 SC @ 0.80 mL L^{-1} and fenpyroximate 5 EC @ 0.60 mL L^{-1} with dimethoate 30 EC @ 1.50 mL L^{-1} as a check was evaluated against *Tetranychus* sp. in cowpea and salad cucumber in polyhouse. Among these, spiromesifen was found to be the best treatment that recorded 10.50 and 4.50 mites $plant^{-1}$ respectively in cowpea and 16.25 and 6.25 mites $plant^{-1}$ respectively in salad cucumber at fifteen days after treatment during first and second spray. Spiromesifen and fenpyroximate were evaluated against *T. urticae* in different crops *viz.,* cucumber, gerbera, chrysanthemum and carnation under protected cultivation and were reported effective in managing the mite population (Pathipati *et al.,* 2012; Reddy and Latha, 2013; Reddy *et al.,* 2014; Shah and Shukla, 2014; Sood *et al.,* 2015).

The new generation insecticides *viz.,* spinosad 45 SC @ 0.30 mL L^{-1}, chlorantraniliprole 18.5 SC @ 0.30 mL L^{-1}, flubendiamide 39.35 SC @ 0.10 mL L^{-1}, indoxacarb 14.5 SC @ 1.00 mL L^{-1} and quinalphos 25 EC @ 3.00 mL L^{-1} were evaluated as a check against leaf feeder and borers in cowpea and salad cucumber. Among these, spinosad and chlorantraniliprole recorded the lowest number of leaf miner larvae after 15 days of spraying in cowpea and salad cucumber. Pawar and Patil (2013) evaluated the efficacy of spinosad against *L. trifolii* in cucumber and stated that 63.00 per cent mean mortality of *D. indica* occurred in the field. Cent per cent mortality of pumpkin caterpillar, *D. indica* was observed in chlorantraniliprole @ 0.30 mL L^{-1} and flubendiamide @ 0.10 mL L^{-1} treated plants in salad cucumber. Jyothsna *et al.,* (2013) reported that flubendiamide 60 g a.i. ha^{-1} was effective in reducing the population of *D. indica* in gherkins under open field conditions. Similarly, flubendiamide @ 0.004 per cent was superior in containing the population of *D. indica* in bitter gourd (Lenin, 2011).

The diamides are the most recent addition to the limited number of insecticide classes with specific target site activity that are highly efficacious, control a wide pest spectrum, and have a favorable toxicological profile. Almost, all compounds comes under the toxicity group, green revealing its safety to mammals. Currently, available and widely used diamide insecticides include chlorantraniliprole and flubendiamide. The diamide comes under the primary group of Ryanodine receptor modulators (IRAC, 2016). Diamides activate ryanodine sensitive intra-cellular calcium release channels in insects and disrupt the proper function of muscles.

5.4. PERSISTENCE AND DEGRADATION OF RESIDUES OF PESTICIDES IN COWPEA AND SALAD CUCUMBER UNDER POLYHOUSE

A wide range of pesticides are being used indiscriminately for managing pests and diseases with least concern for their residual toxicities in most polyhouses. Specific studies on the efficacy of new generation insecticides against pests of cowpea and salad cucumber under polyhouse are lacking in the state. Hence, this research work has been undertaken to study the dissipation of new generation insecticides in cowpea and salad cucumber to ensure the safety of the products to the end users.

The residues of promising insecticides used against sucking pests *viz.*, imidacloprid 17.8 % SL and thiamethoxam 25 % WG dissipated within three and ten days in cowpea and three and five days in salad cucumber respectively when applied @ 0.20 mL L^{-1} and 0.30 g L^{-1}. Whereas, the effective acaricide, spiromesifen 22.9 % SC @ 0.80 mL L^{-1} dissipated within seven and five days in cowpea and salad cucumber respectively. The promising insecticides against leaf feeders *viz.*, chlorantraniliprole 18.5 % SC @ 0.30 mL L^{-1} and spinosad 45 % SC @ 0.30 mL L^{-1} leaf feeders dissipated five and seven days respectively in cowpea and three days each in salad cucumber. The studies on the dissipation of insecticides under protected cultivation in different parts showed that thiamethoxam dissipated within 15 days in okra (Chauhan *et al.*, 2013). Whereas, imidacloprid dissipated in 2.2 days in greenhouse cucumber (Abbassy *et al.*, 2014).

Reddy *et al.*, 2007 reported that the residues of imidacloprid was 0.20 and 0.05 mg kg^{-1} in sweet pepper and tomato after five days of spraying and it persisted upto more than 15 days in sweet pepper, it was higher in greenhouse than in open field. The dissipation behaviour of spiromesifen was studied by Varghese *et al.* (2011) in chilli, in open condition in Kerala and found out that the residue persisted upto five days of spraying applied at the rate of 96 g a.i. ha^{-1}. Vijayasree (2013) reported that the waiting period of chlorantraniliprole in cowpea was 2.99 days under field conditions. The present study showed that under polyhouse condition, the persistence of spiromesifen is more *viz.*, seven days in cowpea and five days in salad cucumber.

The studies on the dissipation of imidacloprid and spinosad in cowpea cultivated under open condition at College of Agriculture, Vellayani, Kerala Agricultural University revealed that the residue dissipated and reached below detectable level of 0.05 mg kg^{-1} with in one and ten days, respectively (KAU, 2015). However, in the present study these molecules showed different dissipation pattern and reached below detectable limit of 0.05 mg kg^{-1} within three and ten days respectively under polyhouse condition. However, spinosad and chlorantraniliprole residue assessed in cucurbitaceous vegetable showed the rapid dissipation in open condition. Atmospheric and hydrospheric agencies like sunlight, temperature, humidity, wind velocity etc. prevailing outside might have caused enhanced degradation of the pesticide molecule. In the outside environment pesticide molecule is present in combination with several natural materials which might have act as sensitizers that caused an enhanced action of the UV component of the sunlight directly on these molecules. This could be attributed as the reason for the faster degradation observed when compared to the controlled condition inside the polyhouses.

In this study, two insecticides *viz.*, thiamethoxam 25 % WG @ 0.30 g L^{-1} and imidacloprid 17.8 % SL @ 0.20 mL L^{-1} were found be effective in containing the sucking pests. However, when safety aspects was considered, eventhough thiamethoxam was under the toxicity class “blue” its residue persisted up to 7 and 5 days respectively in cowpea and salad cucumber. Even though imidacloprid was under the toxicity class “yellow”, this dissipated within 3 days each in both crops. By considering the eco-toxicological effect of these insecticides, it is suggested that application of thiamethoxam @ 0.30 g L^{-1} may be followed if the infestation of sucking pest is in the vegetative stage and application of imidacloprid @ 0.20 mL L^{-1} if it is in fruiting stage inside the polyhouse. Chlorantraniliprole 18.5 % SC @ 0.30 mL L^{-1} comes under the toxicity class “green” is recommended for managing leaf feeders *viz., L. trifolii* and *D. indica* in both cowpea and salad cucumber.

The area under polyhouses is expanding rapidly in the state due to the encouragement by the State Horticulture Mission. The polyhouse farmers should be trained and educated properly to monitor the general condition, compactness of the netting, slits in cladding materials etc. at regular intervals. Priority should be given to improve the awareness level of the growers for timely diagnosis of pest and diseases and judicious use of insecticides. Research efforts are needed for developing pest management technologies under protected environment with emphasis on avoidance and selective use of pesticides safe waiting intervals based on harvest time pesticide residue need to be established for the crops under protected environment as this information is lacking completely. Technologically feasible and sturdy structures without constructional defects suitable for the different agro-climatic and climatic conditions are urgently needed to tackle the problems of pest and diseases.

SUMMARY

6. SUMMARY

Area under protected cultivation is expanding in Kerala state, although various constructional flaws and congenial microclimate favours the occurrence of pest and diseases and it is one of the major limiting factors for the increased production of vegetables under polyhouse condition. The present study was undertaken to conduct a survey among polyhouse farmers of Thiruvananthapuram district for gathering the information on general conditions of polyhouse, major crops, pest incidence, pesticide use pattern, to evaluate the efficacy of new generation insecticides against sucking pests and leaf feeders in cowpea and salad cucumber and to study the persistence and dissipation of residues of insecticides in cowpea and salad cucumber. The results obtained are summarized here under.

- A preliminary survey conducted among 20 polyhouses in Thiruvananthapuram district revealed the poor structural conditions of polyhouses, 75 per cent having slits in ante room, constructed using low quality cladding material and were with slits and without proper construction. Only 25 per cent polyhouses had good construction.

- Monocropping pattern of cultivation of cowpea and salad cucumber was followed in 30 and 25 per cent polyhouses respectively and 20 per cent had multicropping.

- Sucking pests *viz.*, pea aphid, *A. craccivora*; mealy bug, *F. virgata*; pod bug, *R. pedestris*; fulgorid bug, *E. tomentosa*; thrips, *A. chaetophora;* spotted red mite, *T. truncatus* and leaf feeders *viz.,*pod borer, *L. boeticus*; tobacco caterpillar, *S. litura*; leaf beetle, *P. flavopustulata*; American serpentine leaf miner, *L. trifolii* were the pests associated with cowpea.

- The reports of the infestation of the pests *viz.*, tortrycid larvae, leaf miner and girdle beetle, *O. brevis* in cowpea were the first records of these pests on cowpea in polyhouses.

- Sucking pests *viz.*, green peach aphid, *M. persicae;* mealy bug, *F. virgata*; three thrips, *A. tumiceps; T. hawaiiensi*; *F. schultzei*; spotted red mite, *Tetranychus* sp. and leaf feeders *viz.*, pumpkin caterpillar, *D. indica* and American serpentine leaf miner, *L. trifolii* were associated with salad cucumber under polyhouse conditions.

- The natural enemies *viz.*, syrphids, coccinellids and spiders like *O. javanus*, *O. sunandae* and *A. pulchella* were associated with cowpea and salad cucumber under polyhouse. No parasitoids were reported from cowpea and salad cucumber under polyhouses during this study.

- Survey revealed that both sucking pests and leaf feeders caused significant damage in cowpea and salad cucumber under polyhouse conditions. The infestation of both sucking pests and leaf feeders were 71 per cent each in cowpea, whereas 67 per cent of polyhouses had sucking and 50 per cent had leaf feeder infestation in salad cucumber.

- Seventy three per cent of the polyhouse farmers used new generation insecticides for pest management and 40 per cent of the farmers gave prophylactic application of these insecticides. 45 per cent of polyhouse farmers sprayed insecticides on need basis. However, 60 per cent of the farmers gave seven days interval between spraying and the harvest.

- Studies on the population and infestation of sucking pests in cowpea revealed that the population and infestation in cowpea and salad cucumber was started 30 days after sowing except that of pod bug and mealy bug that appeared 60 days after sowing in cowpea. However, the population of leaf feeders started early *i.e.* 15 days after sowing except that of the tortrycid in cowpea and leaf miner and pumpkin caterpillar in salad cucumber, the population of which initiated 30 days after sowing.

- The studies on the efficacy of new generation insecticides against sucking pests revealed that thiamethoxam 0.30 g L^{-1} and imidacloprid 0.20 mL L^{-1} were the best treatments in managing sucking pests in cowpea and salad cucumber. Spiromesifen 0.80 mL L^{-1} was recorded to be the best in reducing the population of mites in cowpea and salad cucumber. Chlorantraniliprole 0.30 mL L^{-1} and spinosad 0.30 mL L^{-1} reduced leaf feeders in cowpea salad cucumber.

- Satisfactory results were obtained while validating the QuEChERS method for the pesticide residue analysis of cowpea and salad cucumber with good recovery which ranged from 79.90 to 119.90 and 83.60 to 117.20 respectively.

- The residues of promising insecticides used against sucking pests *viz.,* imidacloprid0.20 mL L^{-1} and thiamethoxam 0.30 g L^{-1} dissipated with in three and ten days in cowpea and three and five days in salad cucumber. Whereas, the effective acaricide, spiromesifen 0.80 mL L^{-1}dissipated within seven and five days in cowpea and salad cucumber, respectively. The promising insecticides against leaf feeders *viz.*, chlorantraniliprole 0.30 mL L^{-1} and spinosad 0.30 mL L^{-1} dissipated within five and seven days respectively in cowpea and three days each in salad cucumber.

- Considering the eco-toxicological effect of these insecticides, if the infestation of sucking pest is in the vegetative stage, spray thiamethoxam 0.30 g L^{-1} and if it is in fruiting stage, spray imidacloprid 0.20 mL L^{-1} inside the polyhouse. Similarly, chlorantraniliprole 0.30 mL L^{-1} comes under the toxicity class "green" can be recommended against leaf feeders both in cowpea and salad cucumber.

REFERENCES

REFERENCES

Abbassy, M. A., Marzouk, M. A., Nasr, H. M., and Mansy, A. S. 2014. Analytical determination of imidacloprid and tetraconazol residues in cucumber plants after whitefly and powdery mildew control. *SOP Trans. Anal. Chem.* 1(2): 1-14.

Ahmed, K. and Prasad, N. W. S. D. 2010. Evaluation of indoxacarb against fruit borers in chillies. *Pestic. Res. J.* 22(2): 187-189.

Akbar, P. I., Kanwar, M. S., Mir, M. S., and Hussain, A. 2013. Protected vegetable cultivation technology for cold arid agro-ecosystem of Ladakh. *Int. J. Hortic.* 3(19): 109-113.

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

Antignus, Y., David, N., Shlomo, C., and Moshe, L. 2001. Ultraviolet-deficient greenhouse environment affects whitefly attraction and flight-behavior. *Environ. Entomol.* 30(2): 394-399.

Arora, K. R. and Singh, U. 2012. Incidence of mealy bugs in horticultural crops in protected and open conditions [abstract]. In: *Abstracts, IV National symposium on plant protection in horticultural crops: Emerging challenges and sustainable pest management*; 25-28, April, 2012, Bangalore. Indian Institute of Horticultural Research, Bangalore, p. 18. Abstract No. PP-15.

Aslan, I., Ozbek, H., Calmasur, O., and Sahin, F. 2004. Toxicity of essential oil vapours to two greenhouse pests, *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. *Ind. crops and products,* 19: 167-173.

Baldin, E. L. L., Souza, D. R., Souza, E. S., and Beneduzzi, R. A. 2007. Use of plant extracts on whitefly control in tomato grown in greenhouse. *Hortic. Brasileira* 25: 602-606.

Basavaraja, N., Nandi, V. R., and Jholgikar, P. 2003. Protected cultivation of capsicum and bhendi. In: *Proc. of all India on Sem. Potential and Prospects for Protective Cultivation,* 12-13 December 2003, Institute of Engineers, Ahmednagar, pp. 197-199.

Bindu, S. S. 1997. Biocontrol of pests of vegetable cowpea. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 84p.

Buddidathi, R., Mohapatra, S., Siddamallaiah, L., Manikrao, G., and Hebbar, S. S. 2016. Dissipation pattern of flubendiamide residues on capsicum fruit (*Capsicum annuum* L.) under field and controlled environmental conditions. *J. Environ. Sci. Health,* 51(1): 44-51.

Cara, M., Vorpsi, V., Harizaj, F., Merkuri, J., and Vladi, V. 2011. Degradation of the insecticide acetamiprid in greenhouse cucumbers and an estimation of the level of residues. *J. Environ. Prot. Ecol.* 12(1): 74-81.

Chandra, P., Sirohi, P. S., Behera, T. K., and Singh, A. K. 2000. Cultivating vegetables in polyhouse. *Indian Hortic.* 45: 17-25.

Chauhan, R., Kumari, B., and Sharma, S. S. 2013. Persistence of thiamethoxam on okra fruits. *Pestic. Res. J.* 25(2): 163-165.

Cheema, D. S., Kaur, P., and Kaur, S. 2004. Off-season cultivation of tomato under net house conditions. *ActaHortic.* 1: 177-181.

Chiel, E., Messika, Y., Steinberg, S., and Antignus, Y. 2006. The effect of UV-absorbing plastic sheet on the attraction and host location ability of three parasitoids: *Aphidius colemani*, *Diglyphus isaea* and *Eretmocerus mundus. Biocontrol*, 51: 65-78.

Dehghani, M. and Ahmadi, K. 2013. Anti-oviposition and repellence activities of essential oils and aqueous extracts from five aromatic plants against greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Homoptera: Aleyrodidae). *Bulgarian J. Agric. Sci.* 19 (4): 691-696.

Deka, S., Tanwar, R. K., Sumitha, R., Sabir, N., Bambawale, O. M., and Balraj, S. 2011. Relative efficacy of agricultural spray oil and azadirachtin against two-spotted spider mite (*Tetranychus urticae*) on cucumber (*Cucumis sativus*) under greenhouse and laboratory conditions. *Indian J. Agric. Sci*. 81: 158-62.

Devee, A., Tungkhang, S., Baruah, A. A. L. H., and Bhattacharyya, B. 2011. Efficacy of certain insecticides against *Lipaphis erysimi* (Kalt.) and their relative toxicity against predatory coccinellid beetle. *Pestic. Res. J.* 23(2): 140-145.

Diaz, B. M. and Fereres, A. 2007. Ultraviolet-blocking materials as a physical barrier to control insect pests and plant pathogens in protected crops. *Pest Tech.* 1(2): 85-95.

Dixit, A. 2007. Performance of leafy vegetables under protected environment and open field condition. *Asian J. Hortic.* 2(1): 197-200.

Dong, S., Qiao, K., Zhu, Y., Wang, H., Xia, X., and Wang, K. 2014. Managing *Meloidogyne incognita* and *Bemisia tabaci* with thiacloprid in cucumber crops in China. *Crop Prot.* 58: 1-5.

El-Kady, G. A., El-Sharabasy, H. M., Mahmoud, M. F., and Bahgat, I. M. 2007. Toxicity of two potential bio-insecticides against moveable stages of *Tetranychus urticae* Koch. *J. Appl. Sci. Res.* 3(11): 1315-1319.

Ellaithy, A. Y. M., Shafeek, M. R., Hussein, H. E., and Abo-Elella, G. M. 2015. Piercing sucking pests, growth and yield of sweet pepper cultivars as affected by alternative covers under plastic tunnel conditions. *Int. J. Chem. Tech. Res.* 8(9): 149-161.

El-Sayed, W. 2013. Field evaluation of plant extracts and certain insecticides against *Bemisia tabaci* (Gennadius) on tomato plants and *Myzus persicae* (Sulzer) on pepper plants. *J. Appl. Sci. Res.* 9(3): 2372-2377.

Ganesan, M. 2002. Effect of poly-greenhouse on plant micro climate and fruit yield of tomato. *Karnataka J. Agric. Sci.* 15 (4): 750-752.

Gantait, S. S. and Pal, P. 2011. Comparative performance of spray chrysanthemum cultivars under polyhouse and open-field cultivation at different dates of planting. *J. Hortic. Sci.* 6(2):123-129.

Gavkare, O., Kumar, S., Shinde, Y., and Bhopale, S. P. 2014. Abundance of the *Myzus persicae* (Sulzer) under protected environment in Himachal Pradesh, India. *J. Ind. Pollut. Control* 30(2): 285-287.

Gerson, U. and Weintraub, P. G. Mites for the control of pests in protected cultivation. *Pest Manag. Sci.* 63: 658-676.

GOK [Government of Kerala]. 2013. *Technical report*. Report on the visit to various polyhouses in the southern districts of Kerala by the Karshaka Santhwanam Team. Kerala Agricultural University, College of Agriculture, Vellayani, 13p.

Gulidov, S. and Poehling, H. 2013. Control of aphids and whiteflies on brussels sprouts by means of UV-absorbing plastic films. *J. Plant Dis. Prot.* 120(3): 122-130.

Guncan, A., Madanlar, N., Yoldas, Z., Ersin, F., and Tuzel, Y. 2006. Pest status of organic cucumber production under greenhouse conditions in Izmir (Turkey). *Turk. Entomol. Derg.* 30(3): 183-193.

Halder, J., Kodandaram, M. H., Rai, A. B., and Singh, B. 2015. Bio-efficacy of some newer acaro-insecticides against yellow mite (*Polyphagotarsonemus latus* Banks) and thrips (*Scirtothrips dorsalis* Hood) in chilli. *Pestic. Res. J.* 27(2): 171-174.

Hanafi, A., Bouharroud, R., Amouat, S., and Miftah, S. 2007. Efficiency of insect nets in excluding whiteflies and their impact on some natural biological control agents. *Acta Hort.* 747: 383-388.

Hassanzadeh, N., Sari, A. E., and Bahramifar, N. 2012. Dissipation of imidacloprid in greenhouse cucumbers at single and double dosages spraying. *J. Agr. Sci. Tech.* 14: 557-564.

Hazarika, T. K. and Phookan, D, B. 2005. Performance of tomato cultivars for poly house cultivation during spring summer in Assam. *Indian J. Hortic*. 62 (3): 268-271.

Hegde, J. N., Chakravarthy. A. K., Nagamani, M. K., and Prabhakar, M. S. 2011. Management of thrips, *Scirtothrips dorsalis* Hood, on rose under open-field and protected conditions. *J. Hortic. Sci.* 6(2):118-122.

Hossain, M. B. 2005. Effects of azadirachtin and the natural pesticides spinosad and avermectin on the leafminer *Liriomyza sativae* (Diptera: Agromyzidae) and its parasitoids on tomatoes under protected cultivation in the humid tropics. M.Sc. (Ag) thesis, Bangladesh, 117p.

IRAC [Insecticide Resistance Action Committee]. 2016. *Mode of Action Classification scheme* [On-line]. Available: http://www.irac-online.org/documents/moa-classification/ [29 May 2016].

Ismail, M. S. M., Soliman, M. F. M., El-Naggar., M. H., Ghallab, M. M. 2007. Acaricidal activity of spinosad and abamectin against two-spotted mites. *Exp. Appl. Acarol.* 43: 129-135.

Jeevansab, 2000. Effect of nutrient sources on growth, yield and quality of capsicum grown under different environments. M. Sc. (Ag.) thesis, University of Agricultural Sciences, Dharwad, Karnataka, India, 73p.

Jyothsna, M., Reddy, C. N., and Reddy, D. J. 2013. Efficacy of selective insecticides against cucumber moth (*Diaphania indica* Saunders) on gherkins. *Progressive Res.* 8(2): 266-268.

Kamaruddin, R., Shahid, M. and Abdullah, F. 2006. Response of fertigation on capsicum growth under naturally ventilated tropical greenhouse. *Acta Hort*. 710: 275-280.

Kanika, Gulati, R., and Geroh, M. 2013. Influence of abiotic stresses on population dynamics of two spotted spider mite (*Tetranychus urticae* Koch) in cucumber ecosystem. *Ann. Pl. Protec. Sci.* 21(2): 242-246.

Kashyap, L. 2013. Efficacy and persistence of biorational pesticides against insect and mite pests of tomato under protected environment. Ph.D. thesis, COA, CSK Himachal Pradesh KrishiVishvavidyalaya, Palampur, 154p.

KAU [Kerala Agricultural University]. 2015. RKVY project on Development of technologies including alternatives for banned pesticides for the management of pests and diseases of major crops in Kerala, Vellayani, 115p.

Kaur, S. and Singh, S. 2013. Efficacy of some insecticides and botanicals against sucking pests on capsicum under net house. *Agric. Sustain. Dev.* 1: 25-29.

Kaur, S., Kaur, S., Srinivasan, R., Cheema, D. S., Lal, T., Ghai, T. R., and Chandha, M. L. 2010. Monitoring of major pests on cucumber, sweet pepper and tomato under net-house conditions in Punjab, India. *Pest Manag. Hortic. Ecosyst.* 16(2): 148-155.

Kavitha, M., Natarajan, S., Pugalendhi, L. and Meenakshi, N. 2009. Protected cultivation of tomato (*Solanum lycopersicon* L.) under shade net. In: *Proceedings on national workshop cum seminar on status and future strategies of horticulture development in A& N islands*, 23-25 January 2009, Port Blair, Andaman, 170 p.

Kharbade, S. B., Tamboli, N. D., and Chormule, A. J. 2015. Population dynamics and management of capsicum mite, *Polyphagotarsonemus latus* Bank. *Ann. Pl. Protec. Sci.* 23(2): 257-260.

Kooner, R., Sharma, S., Sandhu, S. S., Arora, R., and Pandey, S. 2015. Bioefficacy of some neonicotinoids against *Aphis gossypii* Glover on tomato. *J. Insect Sci.* 28(1): 44-48.

Kumar, A. and Singh, R. 2014. Bioefficacy of some insecticides against the greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Homoptera: Aleyrodidae) on tomato. *The Bioscan*9(3): 1073-1076.

Kumar, B. and Poehling, H. M. 2007. Effects of azadirachtin, abamectin and spinosad on sweetpotato whitefly (Homoptera: Aleyrodidae) on tomato plants under laboratory and greenhouse conditions in the humid tropics. *J. Econ. Entomol.* 100:411-420.

Kumar, M., Kohli, U. K., Gupta, S. K., and Vikram, A. 2007. Effect of growing media, irrigation regime, fertigation and mulching on productivity of tomato in naturally-ventilated poly-houses in hills. *Indian J. Agric. Sci.* 77(5): 302-304.

Kumar, P. and Srivastava, R. M. 2015. IPM for various insect-pests infesting capsicum crop grown under protected condition. In: Sharma, D. R., Kumar, S., and Singh, B. (eds), *Entomology for Sustainable Agriculture.* Proceedings of the Fourth Congress on Insect Science,16-17 April, 2015, Ludhiana. INSAIS, Punjab Agricultural University, Ludhiana, pp. 86.

Kumar, V., Maurya, S. K., Singh, M. P., and Bhatt, J. C. 2008. Evaluation of promising cultivars of bitter gourd under naturally ventilated polyhouse to study the correlation among the yield and yield attributes. *Annate of Hortic.* 1(1): 37-40.

Kumar, V., Pathania, N. K., and Kumar, N. 2015. Evaluation of bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) genotypes for quality traits in modified naturally ventilated poly house. *Ann. Hortic.* 8 (1): 69-72.

Kutty, C. N., Sreelatha, U., Jyothi, M. L., and Gopalakrishnan, T. R. 2014. Advances in protected cultivation of vegetables in Kerala. In: Singh, B., Singh, B., Sabir, N., and Hasan, M. (eds), *Advances in protected cultivation*. New India Publishing Agency, New Delhi, pp. 133-142.

Lekshmi, S. L. and Celine, V. A. 2015. Evaluation of tomato hybrids for fruit, yield and quality traits underpolyhouse conditions. *Int. J. Appl. Pure Sci. Agric.* 1(7): 58-64.

Lenin, N. 2011. Infestation of the pumpkin caterpillar *Diaphania indica* (Saunders) in cucurbits and its management. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 80p.

Lu, X., Jiang W. W., Wang, L., Jian, Q., Shen, Y., Liu, J., and Yu, X. 2014. Persistence and dissipation of chlorpyrifos in brassica chinensis, lettuce, celery, asparagus lettuce, eggplant and pepper in a greenhouse. *Plos one* 9(6): e100556. doi:10.1371/journal.pone.0100556.

Mahajan, G. and Singh, K. G. 2006. Response of greenhouse tomato to irrigation and fertigation. *Agric. Water Manag.* 84 (2): 202-206.

Maklad, A. M. H., Abolmaaty, S. M., Hassanein M. K., and Abd El-Ghafar, N. Y. 2012. Impact of type of greenhouse cover sheets on certain major cucumber pests under protected cultivation. *N. Y. Sci. J*. 5:19-24.

Maklad, A. M. H., Yassin, S. A., and Abd El-Ghafar, N. Y. 2014. Influence of certain climatic factors on some major pepper pests under Egyptian conditions. *Egypt. Acad. J. Biol. Sci.* 7: 31-37.

Meena, B. T. 2007. Bioecology and management of pod bugs infesting vegetable cowpea, *Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 159p.

Minkenberg, O. P. J. M. and Lanteren, R. C. V. 1986. The leaf miners *Liriomyza bryoniae* and *Liriomyza trifolii* (Diptera: Agromyzidae), their population and host plants a review. *Agric. Univ. Wag. Pap.* 86: 1-50.

Miresmailli, S. and Isman, M. B. 2006. Efficacy and persistence of rosemary oil as an acaricide against two spotted spider mite (Acari: Tetranychidae) on greenhouse tomato. *J. Econ. Entomol.* 99(6): 2015-2023.

Misra, H. P. 2011. Bio-efficacy of fenazaquin 10 EC against two spotted spider mite, *Tetranychus urticae* Koch. (Acari: Tetranychidae) in tomato. *Pest Manag. Hortic. Ecosyst.* 17(1): 19-22.

Murphy, G., Ferguson, G., and Shipp, L. 2006. Aphids in greenhouse crops. Available: http://www.omafra.gov.on.ca/english/crops/facts/06-081.html. [07 Mar. 2016].

Mutwiwa, U. N., Borgemeister, C., Elsner, B. V., and Tantau, H. J. 2005. Effects of UV-absorbing plastic films on greenhouse whitefly (Homoptera: Aleyrodidae). *J. Econ. Entomol.* 98 (4): 1221-1228.

Nagarajan, M., Senthilvel, S., and Planysamy, D. 2002. Material substitution in Greenhouse construction. *Kisan World* 11: 57-58.

Nair, H. M. 2014. Greenhouse cultivation in Kerala. *Kerala Karshahan* 2(1): 14-18.

Nair, R. and Barche, S. 2014. Protected cultivation of vegetables-present status and future prospects in India. *Indian J. Appl. Res.* 4: 245-247.

Nandini. 2010. Survey and management of pests of capsicum under protected cultivation. M.Sc (Ag) thesis, University of Agricultural Sciences, Dharwad, 129p.

Navas, M. 2014. Basis for agroecological management of aphids (*Aphis craccivora* Koch) on cowpea (*Vigna unguiculata* L.) in Cuban agroecosystems. M. Sc. (Ag) thesis, Norwegian University of Life Sciences, Norway, 86p.

Nithya, P. R. 2015. Improved formulation of *Lecanicillium lecanii* (Zimmermann) Zare and Gams and its evaluation against sucking pests. M.Sc.(Ag) thesis, Kerala Agricultural University, Thrissur, 137p.

Nonomura, T., Matsuda, Y., Kakutani, K., Takikawa, Y., Kimbara, J., Osamura, K., Kusakari, S., and Toyoda, H. 2014. Prevention of whitefly entry from a greenhouse entrance by furnishing an airflow-oriented pre-entrance room guarded withelectric field screens. *J. Agric. Sci.* 6(12): 172-184.

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

Pathipati, V. L., Lakshmi, T. V., Ramana, C. V., Kumari, S. S., and Naidu, L. N. 2012. Evaluation of certain new acaricides/insecticides for the management of chilli mite in Andhra Pradesh. *Pest Manag. Hortic. Ecosys.* 18(1): 111-113.

Pawar, D. B. and Patil, S. K. 2013. Efficacy of insecticides and NSKE against American serpentine leaf miner, *Liriomyza trifolii* Burgess on cucumber (*Cucumis sativus* L.). *Pest Manag. Hortic. Ecosyst.* 19(2): 251-253.

Peter, C. and David, B. V. 1991. Population dynamics of the pumpkin caterpillar, *Diaphania indica* (Saunders) (Lepidoptera: Pyralidae). *Tropical Pest Manag.* 37(1): 75-79.

Prabhu, M., Kumar, R. A., Balasubramanian, V., Jagadeesan, R., and Ponnuswami, V. 2009. Protected cultivation of vegetables. *The Asian J. Hortic.* 4(2): 529-533.

Rai, M. 2014. Protected cultivation of vegetables in plains. In: Bhardwaj, M. L., Sharma, H. D., Kumar, M., Kumar, R., Kansal, S., Thakur, K., Singh, S. P., Kumar, D., Kumari, S., Gupta, M., and Sharma, V. (eds), *Vegetable production under changing climate scenario*, 01 September - 21 September, 2012, Solan. Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solanpp: 29-36.

Rajasekar, M., Arumugam, T., Kumar, S. R., Balakrishnan, S., and Krishnasamy, S. 2014. Screening vegetables under shade net for yield and quality during summer and winter seasons. *Res. Environ. Life Sci.* 7(4): 253-258.

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

Reddy, D. S., Nagaraj, R., Latha, M. P., and Chowdary, R. 2014. Comparative evaluation of novel acaricides against two spotted spider mite, *Tetranychus urticae* Koch infesting cucumber (*Cucumis sativus*) under laboratory and greenhouse conditions. *The Bioscan*, 9(3): 1001-1005.

Reddy, S. G. E. and Kumar, K. N. K. 2006. A comparison of management of thrips in sweet pepper grown under protected and open field cultivation. *Pest Manag. Hortic. Ecosyst.* 12(1): 45-54.

Reddy, S. G. E. and Kumar, K. N. K. 2006. Integrated management of yellow mite, *Polyphagotarsonemus latus* on sweet pepper grown under protected cultivation. *J. Hortic. Sci.* 1(2):120-123.

Reddy, S. G. E. and Kumar, K. N. K. 2006. Integrated management of two spotted spider mite, *Tetranychus urticae* (Koch) on tomato grown under polyhouse. *Pestic. Res. J.* 18(2): 162-165.

Reddy, S. G. E., Sharma, D., and Kumar, N. K. K. 2007. Residues of insecticides on sweet pepper and tomato grown under greenhouse and open field cultivation. *Pestic. Res. J.* 19: 239-243.

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

Sabir, N., Deha, S., Tanwar, R. K., Singh, B., Raj, S., Adhikari, S., and Sindhu, S. S. 2012. Comparative evaluation of pesticides and biorationals against key pests of greenhouse chrysanthemum. *Indian J. Hort.* 69(1): 101-105.

Sabry, A. H., Rahman, T. A. A., and Abolmaaty, S. M. 2015. Influence of some new insecticides on sweetpotato whitefly, *Bemisia tabaci* and American serpentine leaf miner, *Liriomyza trifolii* and their residues in cucumber fruits. *Int. J. Adv. Res.* 3(10): 1874-1881.

Sanjeev, K., Patel, N. B., Saravaiya, S. N., and Desai, K. D. 2015. Economic viability of cucumber cultivation under NVPH. *Afr. J. Agric. Res.* 10(8): 742-747.

Sari, N., Guler, H.Y., Abak, K., Pakyurek, Y., Babik, I. and Rumpel, J. 1994. Effect of mulch and tunnel on the yield and harvesting period of cucumber and squash. Seventh International symposium on timing field production of vegetables. *Acta Hort.* 371: 305-310.

Sarwar, M., Kongming, W., Xuenong, X., and Endong, W. 2011. Evaluations of four mite predators (Acari: Phytosiidae) released for suppression of spider mite infesting protected crop of sweet pepper (*Capsicum annuum* L.). *J. Agric. Res.* 6(15): 3509-3514.

Saryazdi, G. A., Hejazi, M. J., and Saber, M. 2012. Residual toxicity of abamectin, chlorpyrifos, cyromazine, indoxacarb and spinosad on *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) in greenhouse conditions. *Pestic. Phytomed*. 27(2): 107–116.

Sethi, V. P. and Dubey, R. K. 2010. Developmentof a modified screen net house using low cost technology. *The Institution of Engineers (India) Journal – Agricultural Engineering*, **91**: 11-17.

Shah, D. R. and Shukla, A. 2014. Chemical control of two-spotted spider mite, *Tetranychus urticae* (Koch.) infesting gerbera (*Gerbera jamesonii* L.) under polyhouse condition. *Pest Manag. Hortic. Ecosys.* 20(2): 155-161.

Shalaby, F. F., Ali, F. A., Hafez, A. A., and Saad, H. M. 2013. Planting date in relation to insect and animal pests attacking cucumber plants under protected cultivation at Giza governorate. *Egypt. J. Agric. Res.*, 91(4): 1347–1360.

Sharma, D., Hebbar, S. S., Divakara, J., and Mohapatra, S. 2012. Residues of pesticides acephate and methamidaphos in capsicum grown under greenhouse and open field. *Qua. Ass. Safety of Crops and Foods* 4(5): 33-37.

Sharma, M., Budha, P. B., and Pradhan, S. B. 2015. Efficacy test of bio-pesticides against tobacco whitefly *Bemisia tabaci* (Gennadius, 1889) on tomato plants in Nepal. *J. Inst. Sci. Tech.* 20(2): 11-17.

Shimoda, M. and Honda, K. 2013. Insect reactions to light and its applications to pest management. *Appl. Entomol. Zool.* 48: 413-421.

SHM [State Horticulture Mission]. 2016. SHM home page [on line]. Available: http://hortnet.kerala.nic.in/scheme.htm#protected-cultivation. [20 Aug. 2016].

Shweta, Bhatia, S. K., and Malik, M. 2014. Protected farming. *Pop. Kheti*, 2(1):74-79.

Siddeque, A., Saika, S. and Deepa, B. P. 1993. Protected cover cultivation for high humid region. *Natl. Conf. Plast. Agric.* 52: 55-93.

Singh, A. K., Shrivastava, R., Gupta, M. J. and Chandra, P. 2005. Effect of protected and unprotected condition on biotic stress, yield and economics of spring summer vegetables. *Indian J. Agric. Sci*. 75: 485-487.

Singh, A. K., Singh, B., and Gupta, R. 2011. Performance of sweet pepper (*Capsicum annum*) varieties and economics underprotected and open field conditions in Uttarakhand. *Indian J. Agric. Sci.* 81(10): 973–975.

Singh, B. 2000. Vegetables production in cold desert of India: A success story on solar greenhouses. *Acta Hort.* 534: 205-209.

Singh, B. 2014. DRDO-Harbinger of protected cultivation of vegetable crops in India. In: Singh, B., Singh, B., Sabir, N., and Hasan, M. (eds), *Advances in protected cultivation*. New India Publishing Agency, New Delhi, pp. 133-142.

Singh, B. and Kumar, M. 2006. Techno-economic feasibility of israeli and indigenously designed naturally ventilated greenhouses for year-round cucumber cultivation. *Acta Hortic*. 710: 449-454.

Singh, B., Singh, R., and Kumar, R. 2006. Studies on chemical control of two spotted spider mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae) on screen house roses. *J. Ornamental Hortic.* 9(3): 212-214.

Singh, D., Kaur, S., Dhillon, T. S., Singh, P., Hundal, J. S., and Singh, G. J. 2004. Protected cultivation of sweet pepper hybrids under net-house inIndian conditions. *Acta Hort*. 659: 515-521.

Singh, K., Singh, R., Khurana, D. S. and Singh, J. 2013. Effect of low- tunnel on the growth, yield and harvesting span of sweet pepper. *Hortic. Flora. Res. Spectrum,* 2 (1): 45-49.

Singh, R., Asrey, R. and Nangare, D. D. 2003. Studies on the performance of tomato and capsicum under medium cost greenhouse. In: *Proceedings of All India Sem. On Potential and Propsects for Protective Cultivation,* 12-13 December 2003. Institute of Engineers, Ahmednagar, pp. 158-161.

Singh, V., Sood, A. K., Verma, K. S., Mehta, P. K., Sood, S. 2016. Record of host of host plants and natural enemies of solenopsis mealybug, *Phenacoccus solenopsis* Tinsley - A potential pest under protected cultivation in Himachal Pradesh. *The Bioscan,* 11(1): 251-254.

Sirohi, P. S. and Bahera, T. K. 2000. Protected cultivation and seed production in vegetables. *Indian Hortic.* 45: 23-25.

Sood, A. K. 2012. *Principles and practices of insect pest management under protected environment.* In: short course on Pest Management in high value crops under protected cultivation organized by SKHPKV, Palampur from June 11-12. pp: 20-27.

Sood, A. K., Sood, S., and Mehta, P. K. 2006. Development of greenhouse whitefly, *Trialeurodes vaporariorum* on summer vegetable crops. *Indian J. Ent.* 68: 44-47.

Sood, A. K., Sood, S., and Singh, V. 2015. Efficacy evaluation of spiromesifen against red spider mite, *Tetranychus urticae* Koch on parthenocarpic cucumber under protected environment. *The Bioscan*, 10(3): 963-966.

Sreedhara, D. S., Kerutagi, M. G., Basavaraja, H., Kunnal, L. B., and Dodamani, M. T. 2013. Economics of capsicum production under protected conditions in Northern Karnataka. *Karnataka J. Agric. Sci.* 26(2): 217-219.

Sreenivas, A. G., Ramanujam, B. R., Mohanraj, P., Nargund V. B., and Shivaramu, K. 2005. Efficacy of entomopathogenic fungi against red spider mite, *Tetranychus neocalodonicus* Zacher (Acari: Tetranychidae). *Karnataka J. Agric. Sci.* 18(4): 966-969.

Srichandran, S., Panda, S.C., Sahu, G. S., Mahapatra, P. and Mishra, R. C. 2006. Effect of shade net on growth and yield of cauliflower. *Orissa J. Hortic*. 34(1): 28-31.

Susheela, P. 2015. *Greenhouse Cultivation.* Kerala Agricultural University Press, Mannuthy, Thrissur, 156 p.

Swamy, G. N., Srinivasalu, B., Madhumathi, C., Thirupal, D., and Ravi, M. 2014. Assessment of capsicum varieties and hybrids for qualitative traits under shade net. *Plant Arch.*14(2): 1051-1054.

Thamilvel, D. 2009. Population dynamics and management of aphids in vegetable ecosystem. Ph. D. thesis, Kerala Agricultural University, Thrissur, 267p.

Thangam, M. and Thamburaj, S. 2008. Comparative performance of tomato varieties and hybrids under shade and open conditions. *Indian J*. *Hortic*. 65(4): 429-433.

Umarani, S. and Umamaheswari, S. 2013. Spiders are of economic value to man. *J. Ent. Res.* 37(4): 365-368.

Varghese, L. and Celine, V. A. 2015. Evaluation of yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis* (L.) Verdcourt) genotypes for yield and quality characters under polyhouse condition in Kerala. *Int. J. Appl. Pure Sci. Agric.* 1(7): 7-13.

Varghese, T. S., Mathew, T. B., George, T., Beevi, N. S., and Xavier, G. 2011. Dissipation of propargite and spiromesifen in/on chilli fruits. *Pestic. Res. J.* 23(2): 135-139.

Varughese, A., Balan, M. T., Sajna, A., and Swetha, K. P. 2014. Cowpea inside polyhouse with varying irrigation and fertigation levels. *Int. J. Eng. Res. Dev.* 10(8): 18-21.

Vashisth, S., Chandel, Y. S., and Kumar, S. 2013. Observations on insect-pest problems of polyhouse crops in Himachal Pradesh. *J. Ent. Res.* 37 (3): 253-258.

Vattakunnel, P. R., Rani, T. S., and Geethakumari, V. L. 2015. Varietal influence on quality aspects of chilli under different growing conditions and fertigations. *Green Farming Int. J.* 6(5): 997-999.

Venthamoni, P. I. and Natarajan, S. 2008. Cultivation of sweet pepper cultivars (*Capsicum annuum*var.*grossum*) under shade net in tropical plains of Tamil Nadu. *Asian J. Hortic*. 3 (2): 372-376.

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

Wang, K. and Shipp, J. L. 2001. Simulation model for population dynamics of *Frankliniella occidentalis* (Thysanoptera: Thripidae) on greenhouse cucumber. *Environ. Entomol.* 30(6): 1073-1081.

Wani, K. P., Singh, P. K., Amin, A., Mushtaq, F., and Dar, Z. A. 2011. Protected cultivation of tomato, capsicum and cucumber under Kashmir valley conditions. *Asian J. Sci. Tech.,* 1(4): 56-61.

Yadav, N. K. and Singh, P. S. 2013. Seasonal abundance of insect pests on mung bean and its correlation with abiotic factors. *J. Ent. Res.* 37(4): 297-299.

Yadav, S. and Kaushik, H. D. 2014. Pest management in crops grown under protected environment. In: Saini, R. K., Yadav, G. S., and Kumari, B. (eds), *Novel approaches in pest and pesticide management in agro-system*, 19 August- 08 September, 2014, Hisar. CCS Haryana Agricultural University, Hisar. pp: 119-133.

Zoebisch, T. G., Schuster, D. J., Smerage, G. H., and Stimac, J. L. 1992. Mathematical description of oviposition and egg and larval development of *Liriomyza trifolii* (Diptera: Agromyzidae) on tomato foliage. *Environ. Ent.* 21: 1341-1344.

APPENDICES

APPENDIX – I

Proforma for survey of pests infesting cowpea and salad cucumber in polyhouses

<table>
<tr><th>Sl. No</th><th>Particulars</th><th colspan="4">Response of farmers</th></tr>
<tr><td>1</td><td>Name of the farmer</td><td colspan="4"></td></tr>
<tr><td>2</td><td>Age</td><td colspan="4"></td></tr>
<tr><td>3</td><td>Address of the farmer</td><td colspan="4"></td></tr>
<tr><td>4</td><td>Education</td><td colspan="4"></td></tr>
<tr><td>5</td><td>Location</td><td colspan="4"></td></tr>
<tr><td>5a</td><td>Block</td><td colspan="4"></td></tr>
<tr><td>5b</td><td>Taluk</td><td colspan="4"></td></tr>
<tr><td>5c</td><td>Panchayat</td><td colspan="4"></td></tr>
<tr><td>6</td><td>Area of the polyhouse (m^2)</td><td colspan="4"></td></tr>
<tr><td>7</td><td>Year of construction</td><td colspan="4"></td></tr>
<tr><td>8</td><td>Any assistance from SHM</td><td colspan="4"></td></tr>
<tr><td rowspan="4">9</td><td rowspan="4">General conditions of polyhouse</td><td colspan="3">Polyhouses with good construction</td><td></td></tr>
<tr><td colspan="3">Polyhouses with slits in anteroom</td><td></td></tr>
<tr><td colspan="3">Polyhouses with low quality cladding material</td><td></td></tr>
<tr><td colspan="3">Polyhouses with slits and without proper construction</td><td></td></tr>
<tr><td rowspan="2">10</td><td rowspan="2">Details of crops under cultivation</td><td>Crops</td><td>Variety</td><td>Area (m^2)</td><td>Yield</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

Appendix - I (Continued)

<table>
<tr><td>11</td><td>Cropping pattern</td><td colspan="4"></td></tr>
<tr><td>12</td><td>Annual Income (Rs)</td><td colspan="4"></td></tr>
<tr><td>13</td><td>Types of pest</td><td colspan="4"></td></tr>
<tr><td rowspan="2">13a</td><td rowspan="2">Sucking pest</td><td>Crop</td><td>Name of pest</td><td>% damage</td><td>Stage of crop</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">13b</td><td rowspan="2">Borers / leaf feeders</td><td>Crop</td><td>Name of pest</td><td>% damage</td><td>Stage of crop</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">14</td><td rowspan="2">Natural enemies</td><td>Crop</td><td>Species</td><td colspan="2">Stage of crop</td></tr>
<tr><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="4">15</td><td rowspan="4">Type of plant protection practices followed</td><td colspan="2">a) Botanicals</td><td colspan="2"></td></tr>
<tr><td colspan="2">b) Biocontrol agents</td><td colspan="2"></td></tr>
<tr><td colspan="2">c) Chemical insecticides</td><td colspan="2"></td></tr>
<tr><td colspan="2">d) Botanicals and biocontrol agents</td><td colspan="2"></td></tr>
</table>

		e) Botanicals and chemical insecticides	
		f) Biocontrol agents and chemical insecticides	
16	Type of chemicals insecticides used for pest control	a) Organochlorine	
		b) Organophosphates	
		c) Carbamates	
		d) Synthetic pyretheroids	
		e) New generation insecticides	
17	Dose of chemical	a) Recommended dose	
		b) Non-recommended dose	
18	Is there any practice of manual mixing of pesticides for spraying?	c) Manual mixing	
		d) No Manual mixing	
19	Whether following the directions in the pesticide label during handling and application of pesticides?	c) Reading labels before use	
		d) No attention towards labels	
20	Is there any prophylactic application of PP chemicals	c) Prophylactic application	
		d) Need based application	
21	Interval between the	a) 7 days	

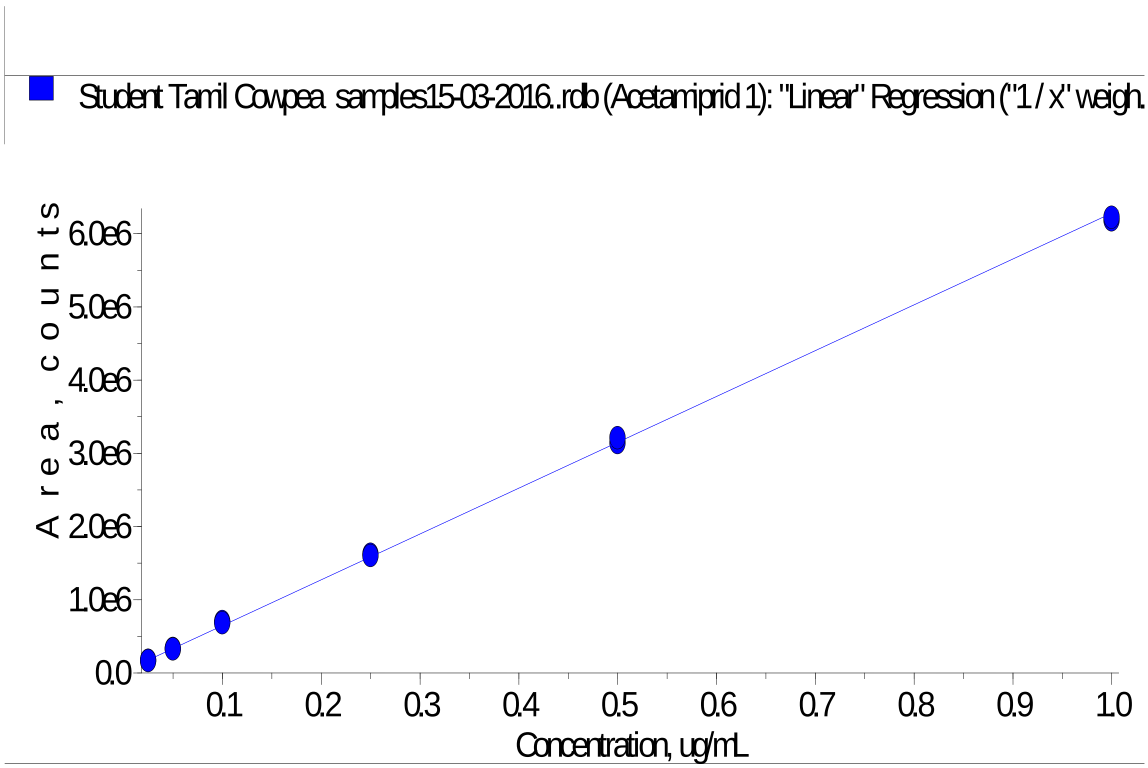
	sprayings	b) 10 days	
		c) 15 days	
		d) > 15 days	
22	Type of sprayer used		
23	Time of application of pesticides	d) Morning	
		e) Afternoon	
		f) Evening	
24	Interval between pesticide application and harvest	d) 5 days	
		e) 7 days	
		f) > 7 days	
25	Whether receive any technical advice for the adoption of plant protection operations?	i) KrishiBhavan only	
		j) State Horticulture Mission only	
		k) Kerala Agricultural University only	
		l) KrishiBhavan and State Horticulture Mission	
		m) State Horticulture Mission and Other progressive farmers	
		n) Kerala Agricultural University and KrishiBhavan	
		o) Kerala Agricultural University and Progressive farmer	
		p) State Horticulture Mission, Kerala	

Appendix – I (Continued)

		Agricultural University and Other progressive farmers	

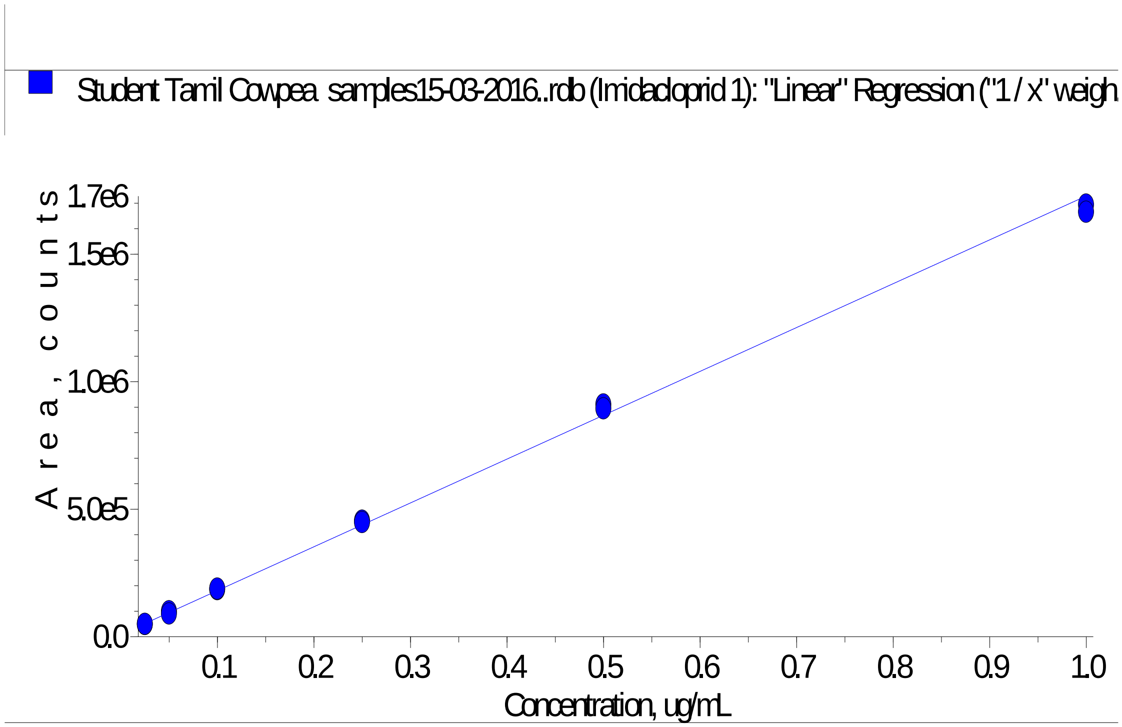
Signature of the farmer

Appendix – II



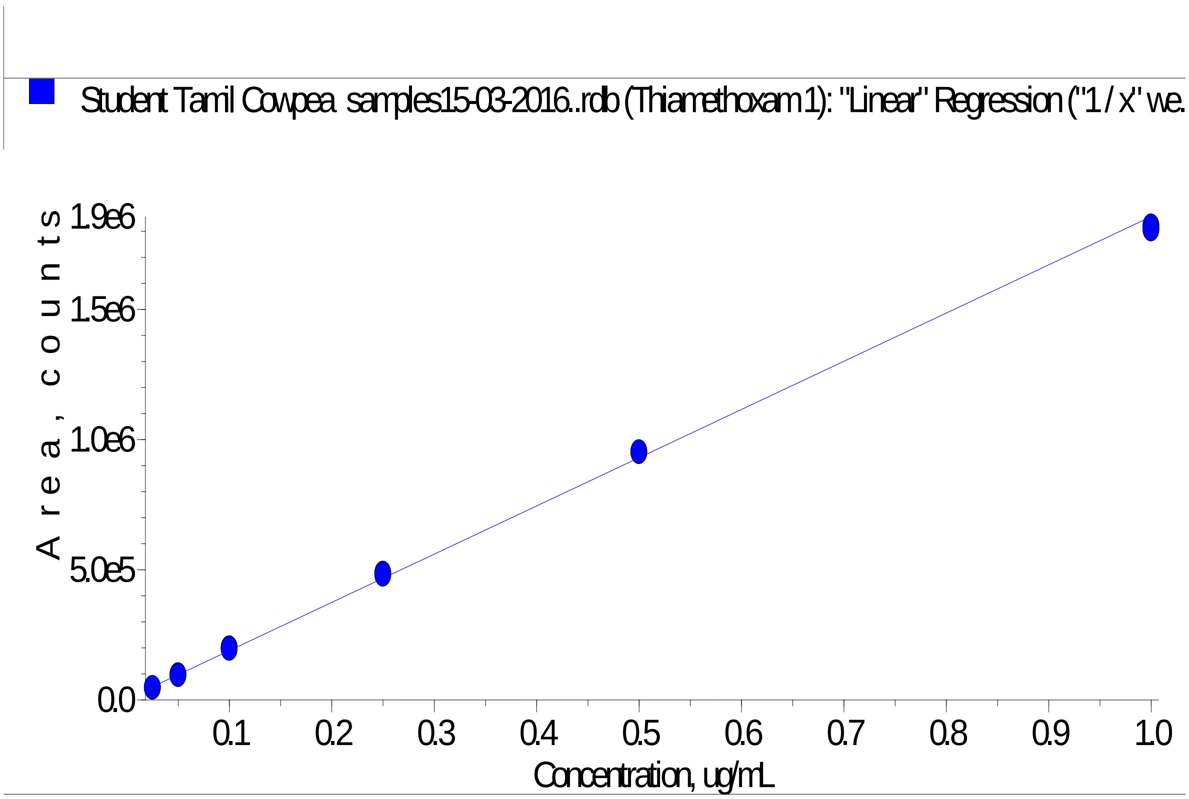
Calibration curve of Acetamiprid

Appendix – III



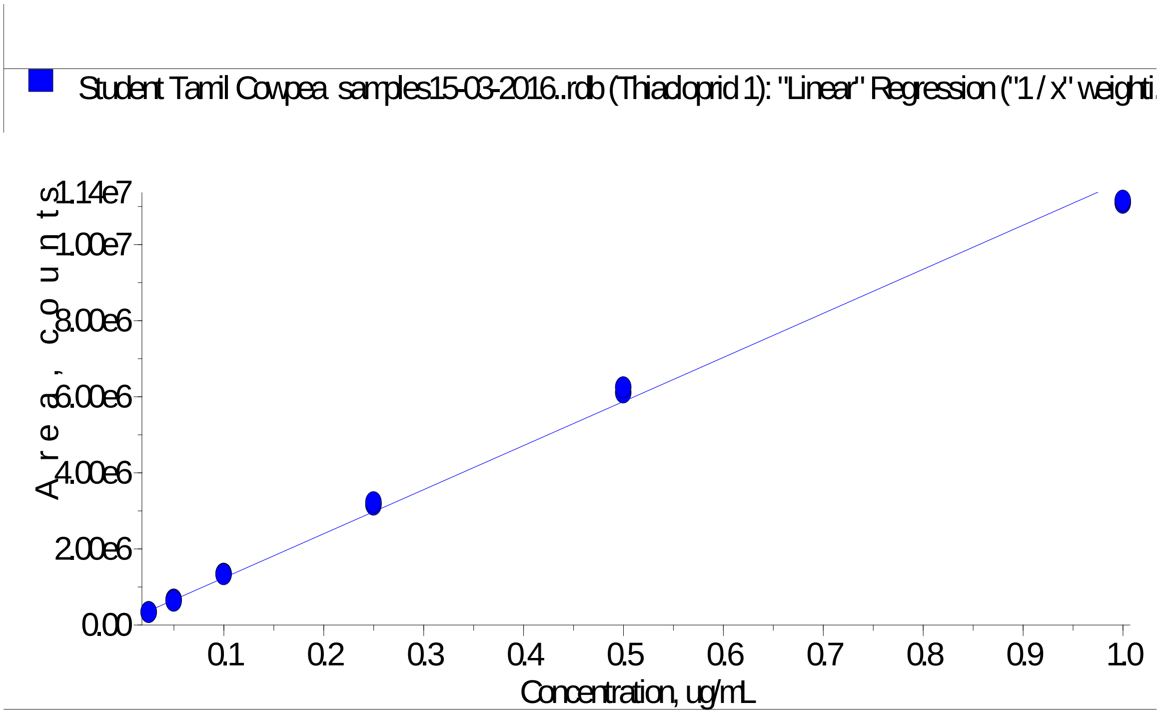
Calibration curve of Imidacloprid

Appendix – IV



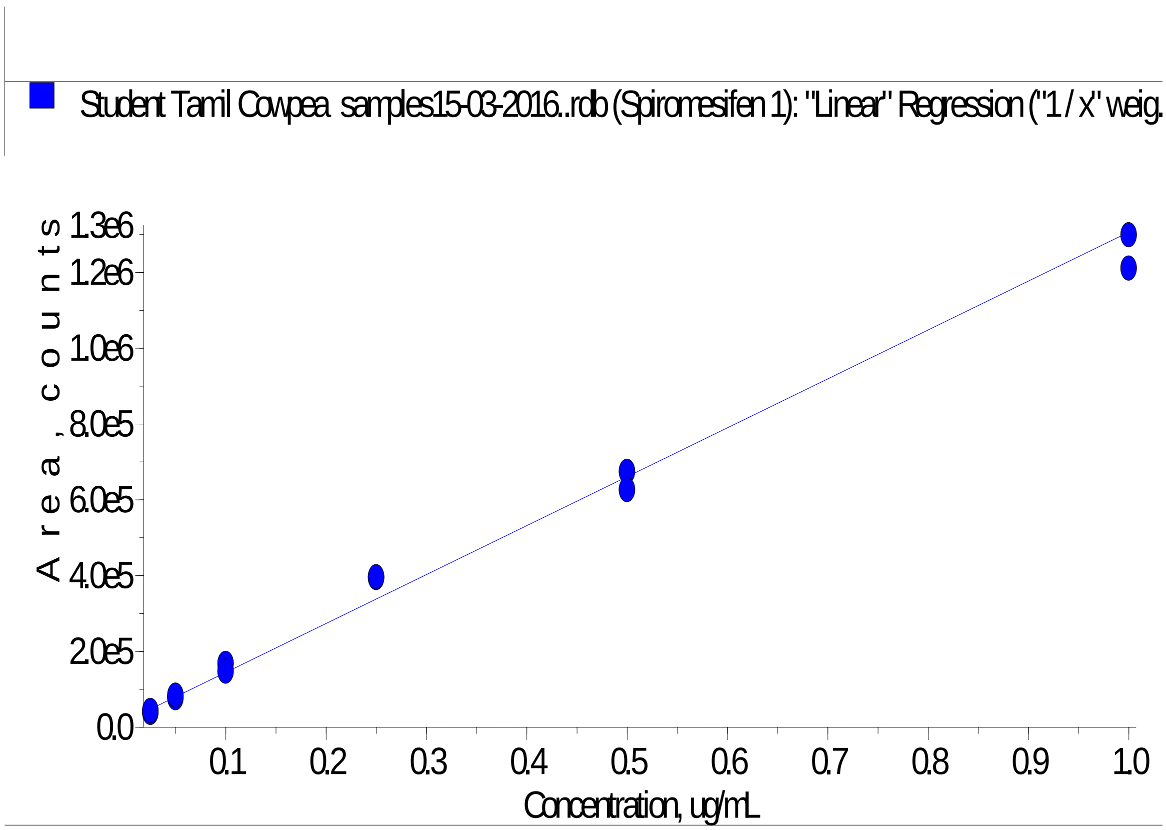
Calibration curve of Thiamethoxam

Appendix – V



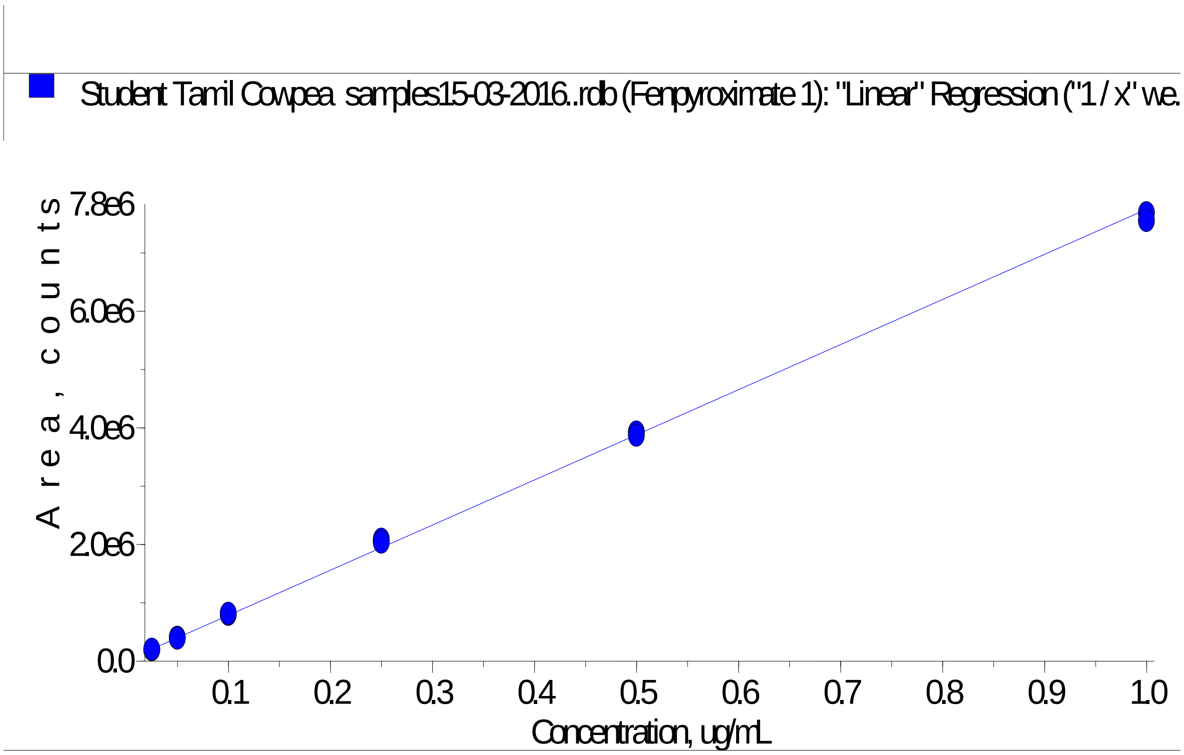
Calibration curve of Thiacloprid

Appendix – VI



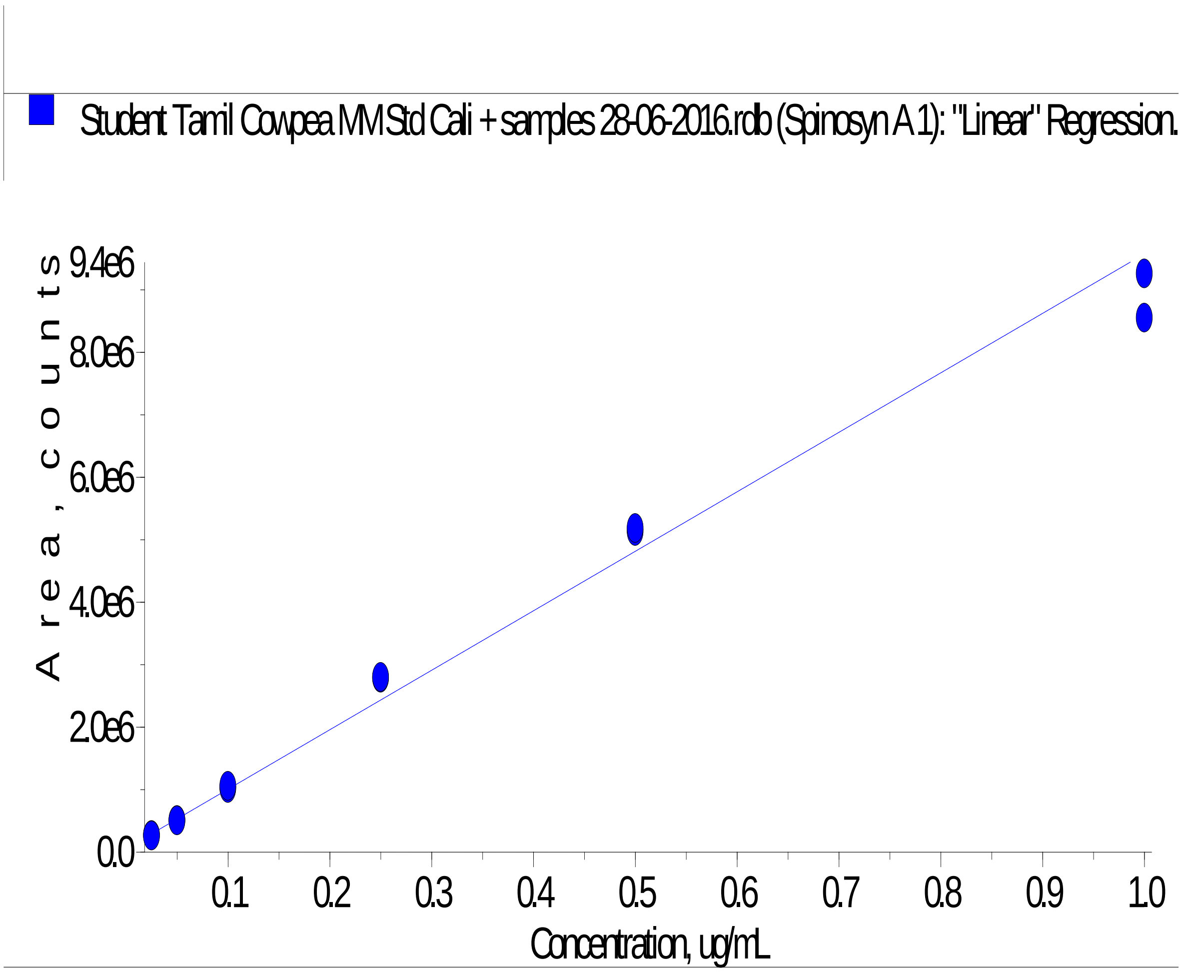
Calibration curve of Spiromesifen

Appendix – VII



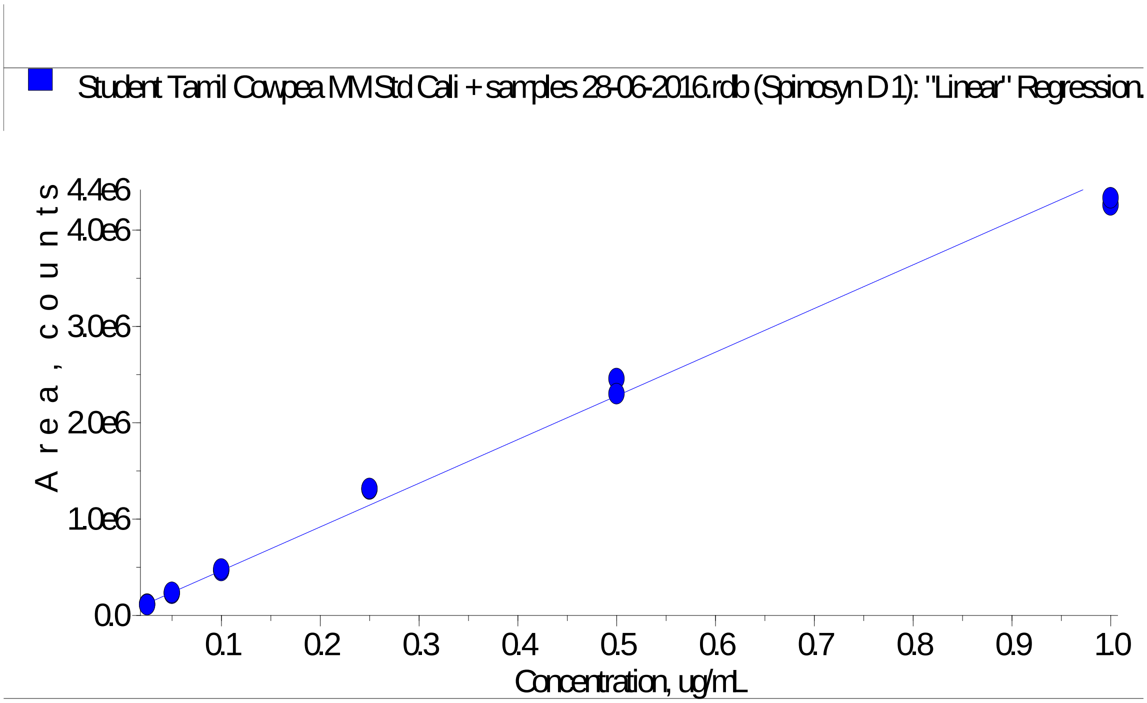
Calibration curve of Fenpyroximate

Appendix – VIII a



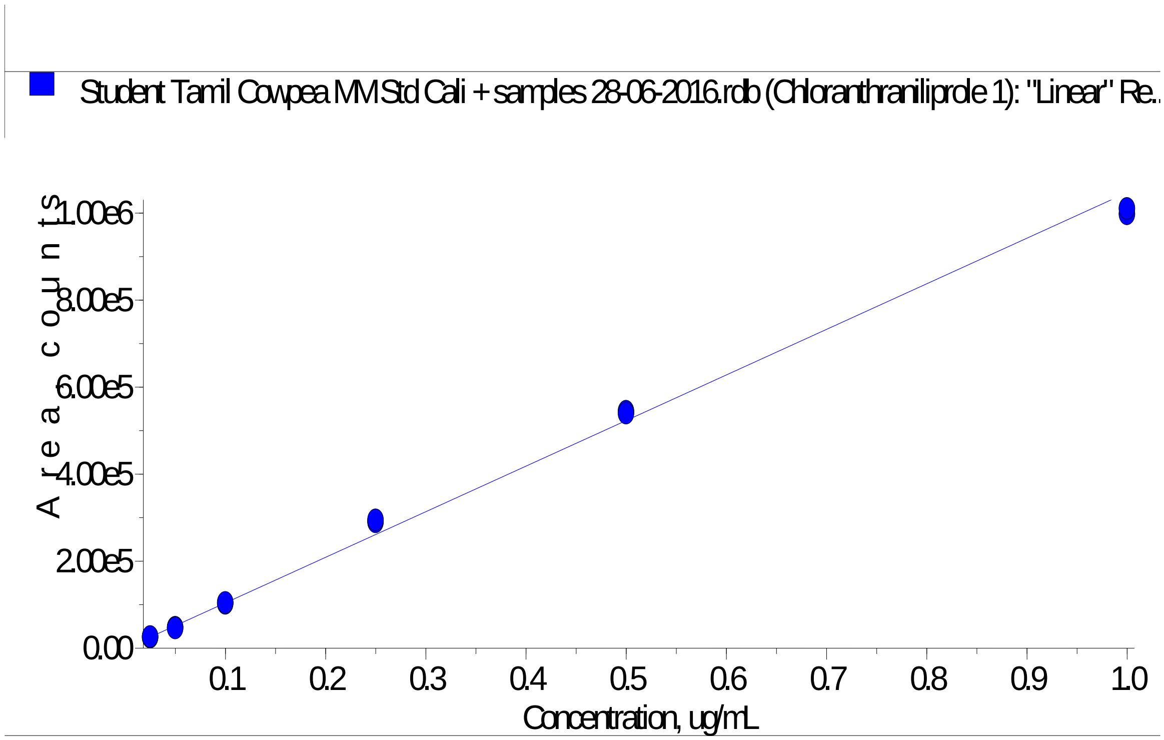
Calibration curve of Spinosyn A

Appendix – VIII b



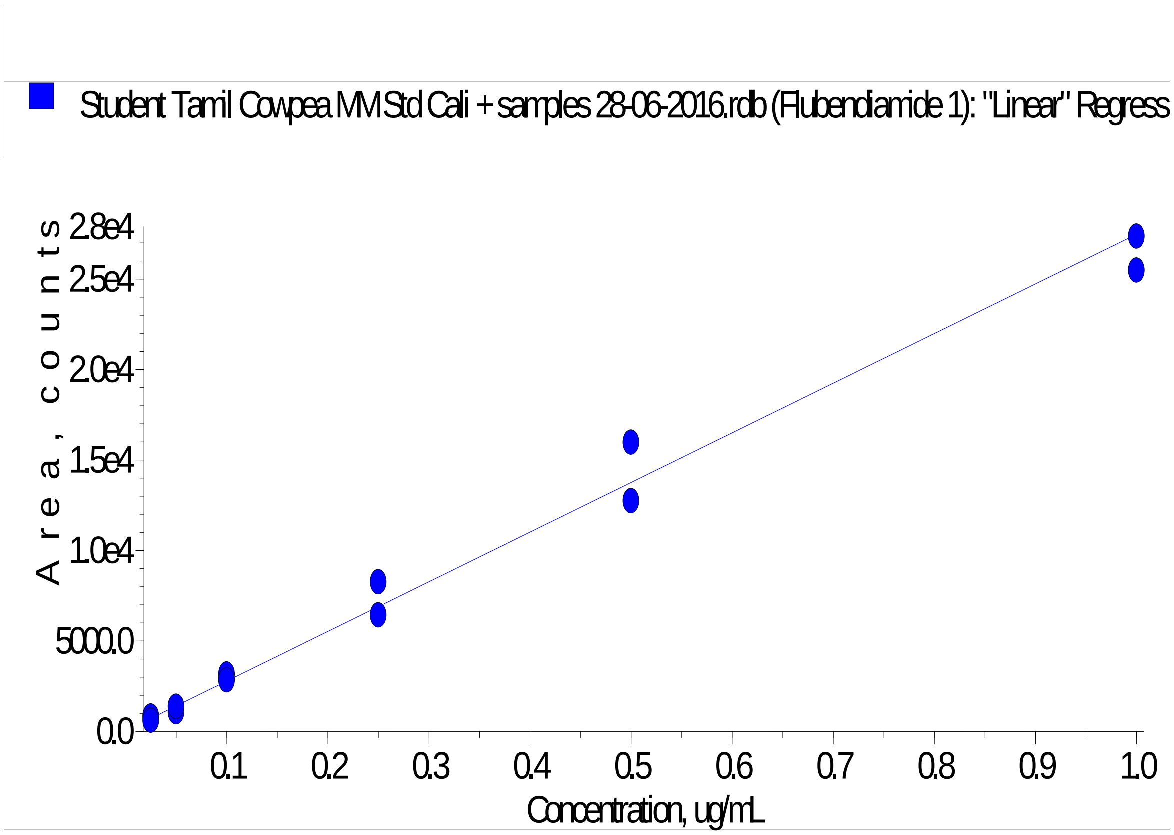
Calibration curve of Spinosyn D

Appendix – IX



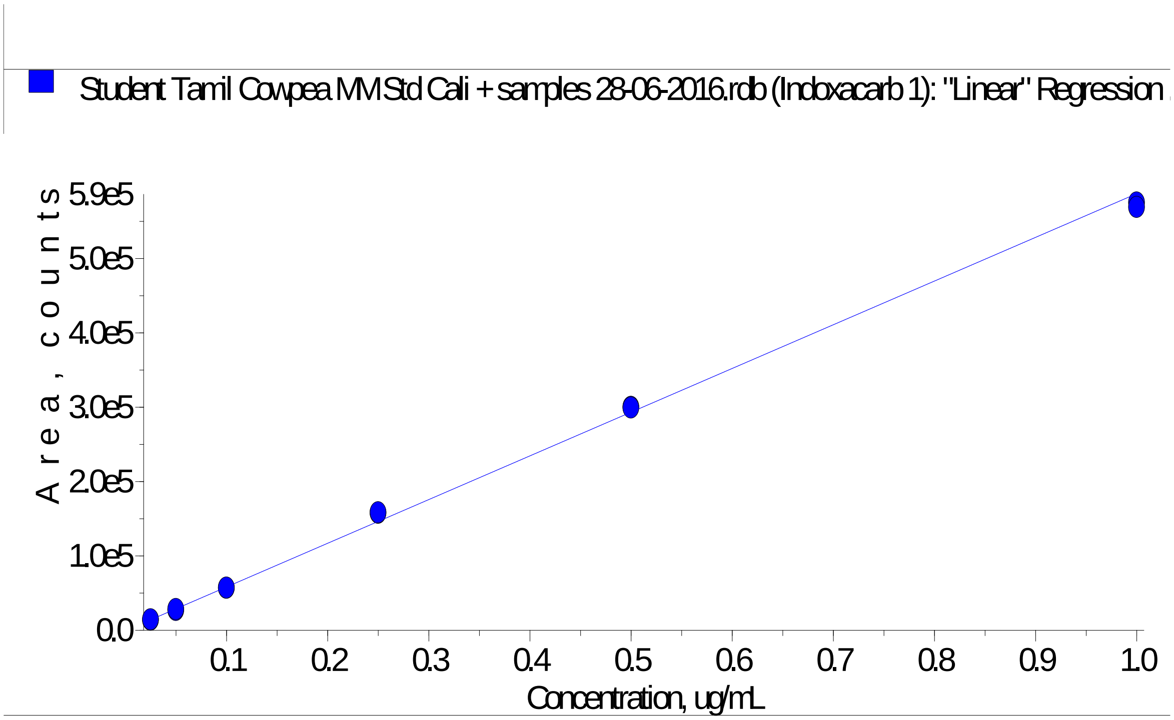
Calibration curve of Chlorantraniliprole

Appendix – X



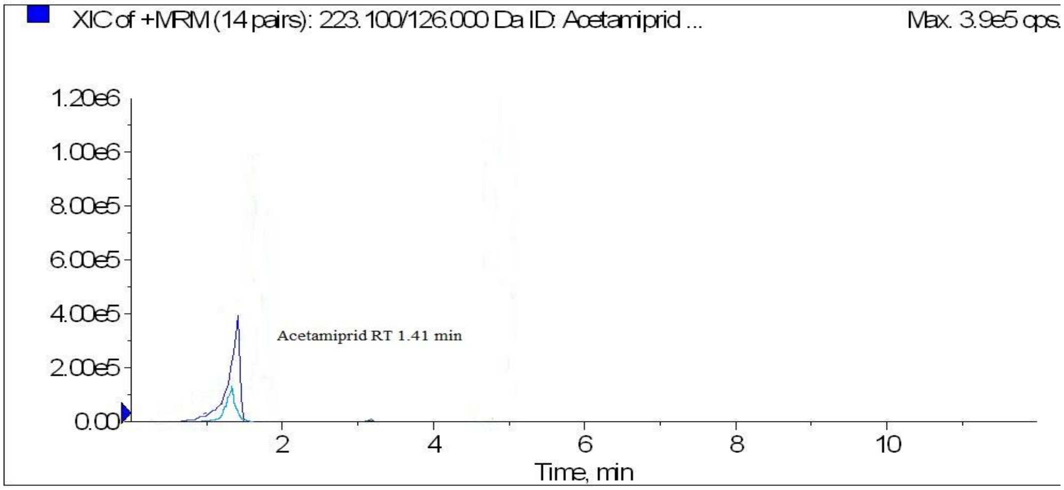
Calibration curve of Flubendiamide

Appendix – XI

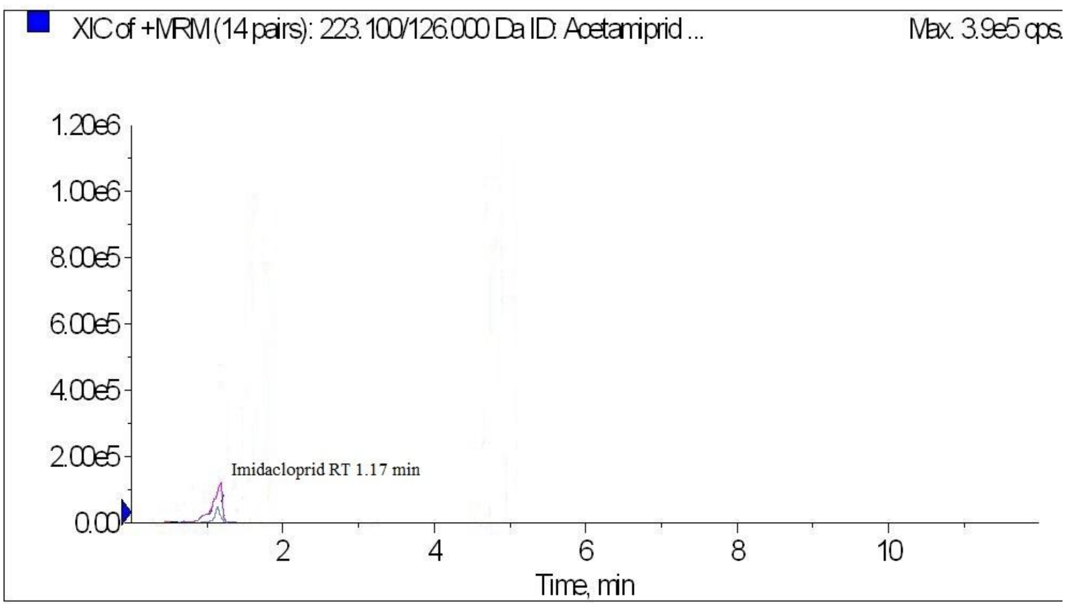


Calibration curve of Indoxacarb

Appendix - XII

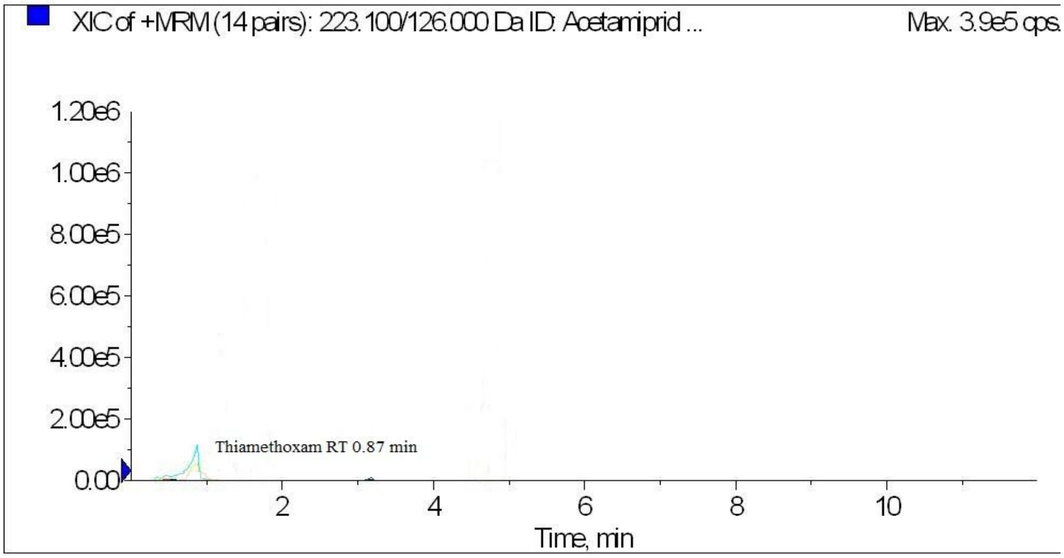


LC-MS/MS chromatogram of Acetamiprid

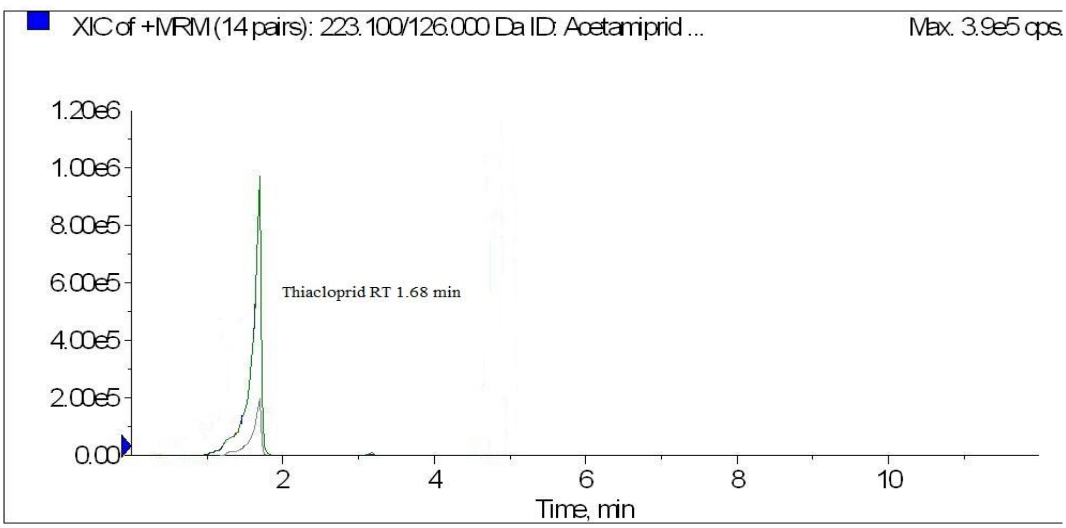


LC-MS/MS chromatogram of Imidacloprid

Appendix - XIII

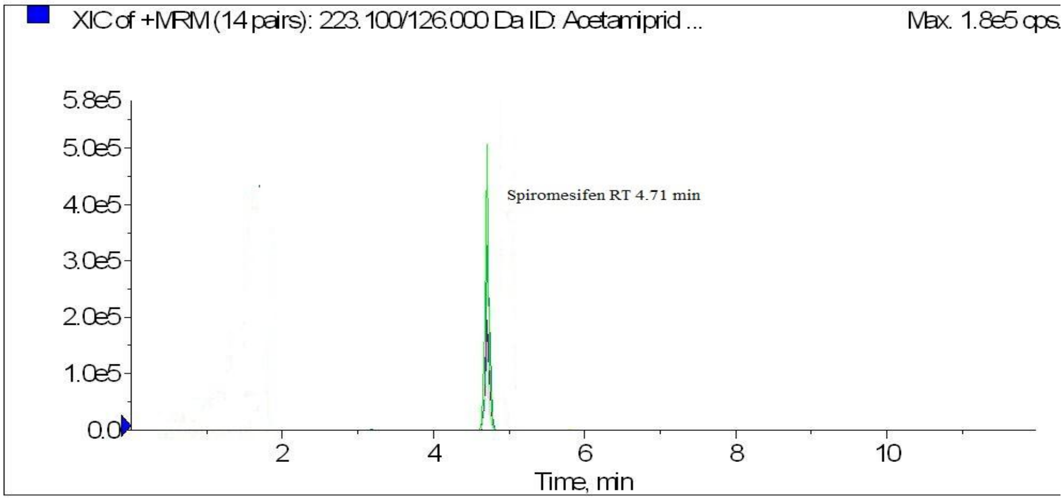


LC-MS/MS chromatogram of Thiamethoxam

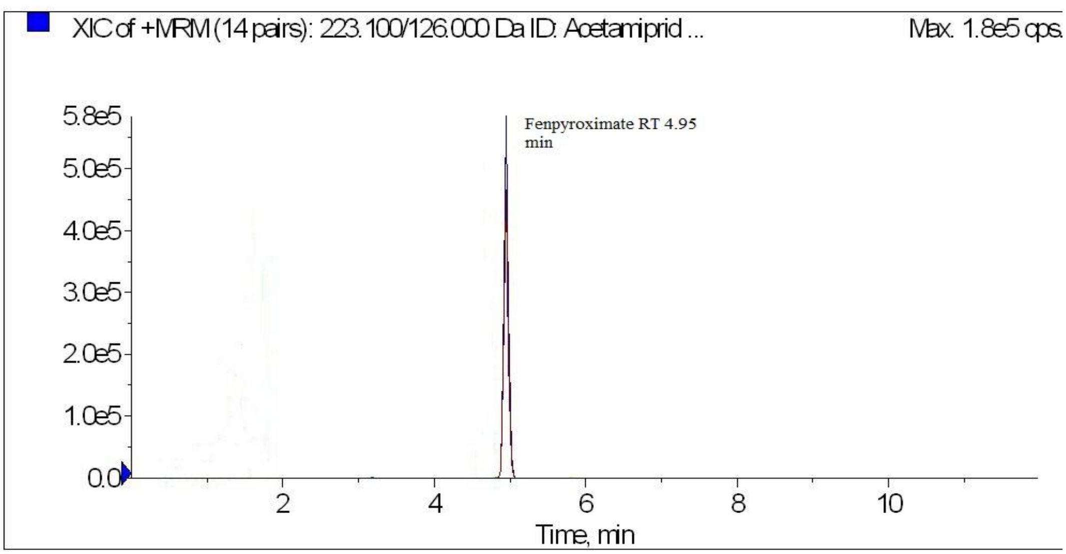


LC-MS/MS chromatogram of Thiacloprid

Appendix - XIV

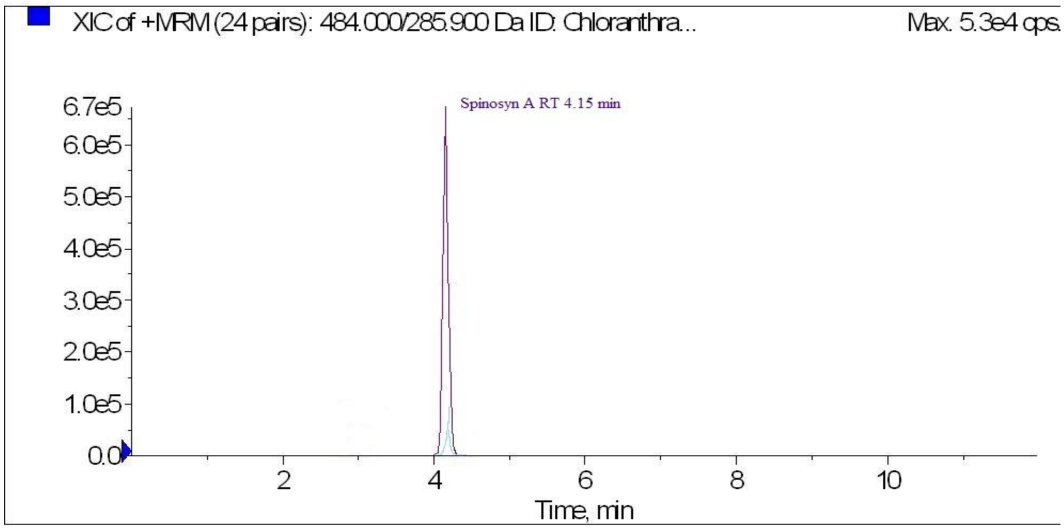


LC-MS/MS chromatogram of Spiromesifen

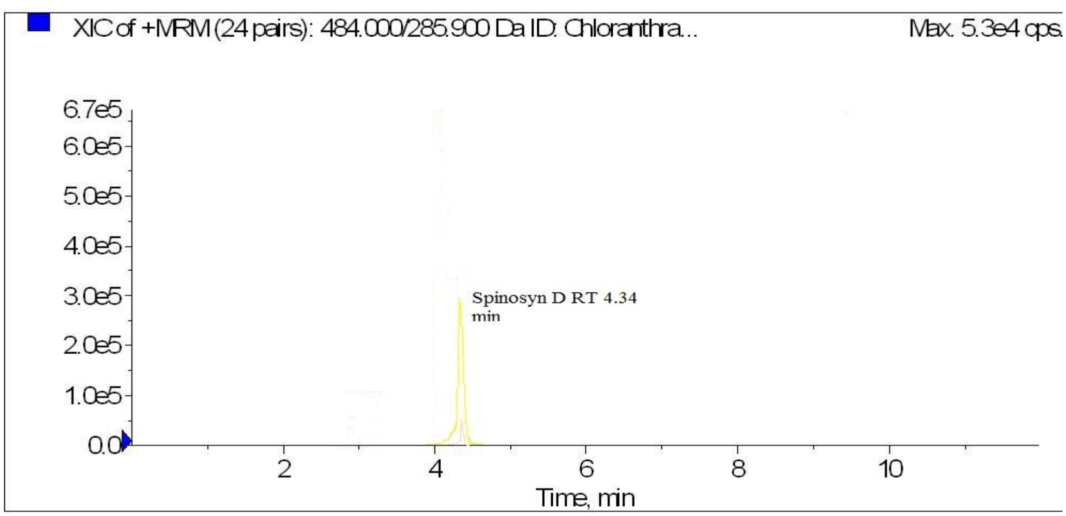


LC-MS/MS chromatogram of Fenpyroximate

Appendix - XV

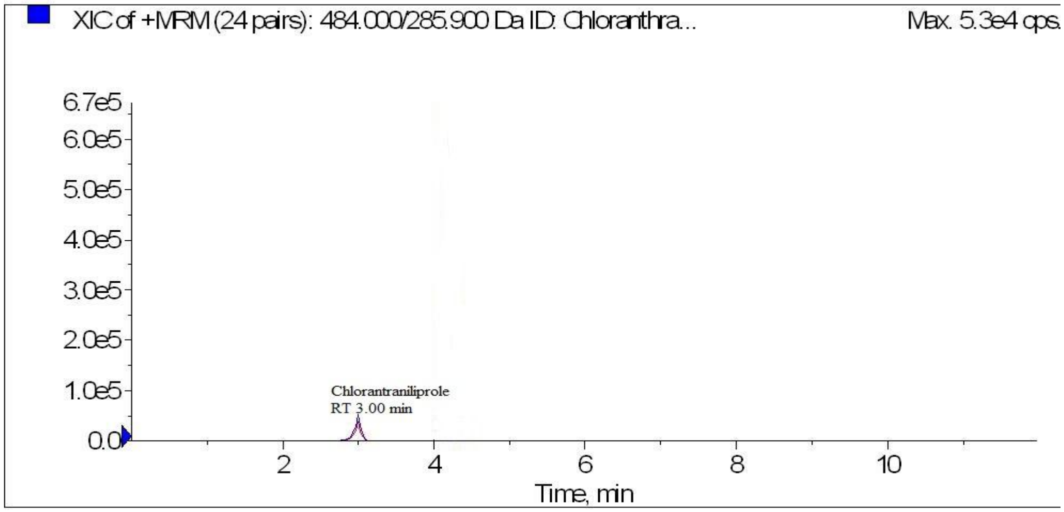


LC-MS/MS chromatogram of Spinosyn A

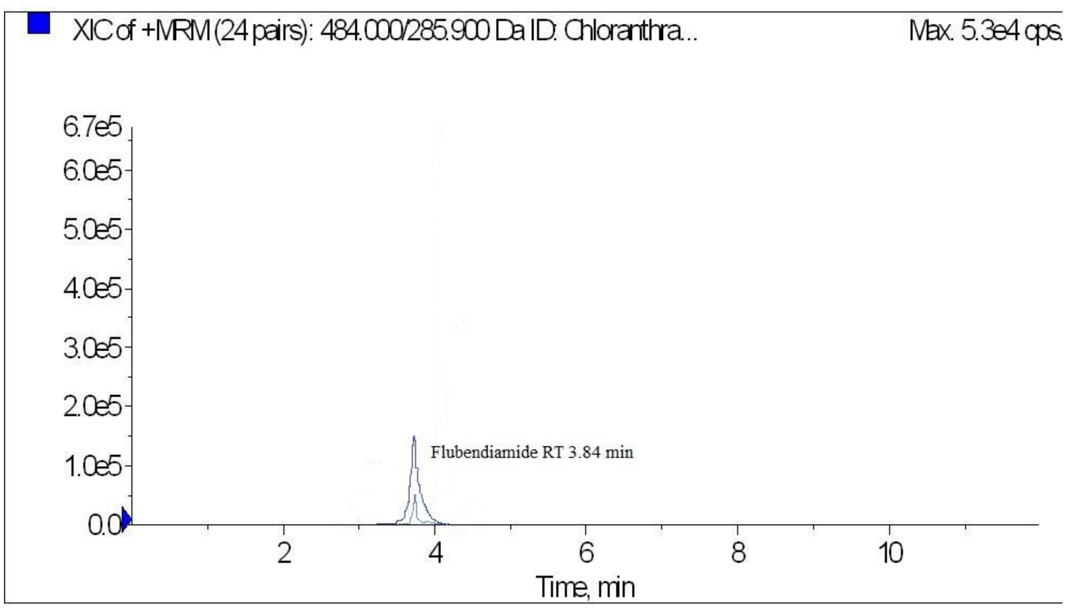


LC-MS/MS chromatogram of Spinosyn D

Appendix - XVI

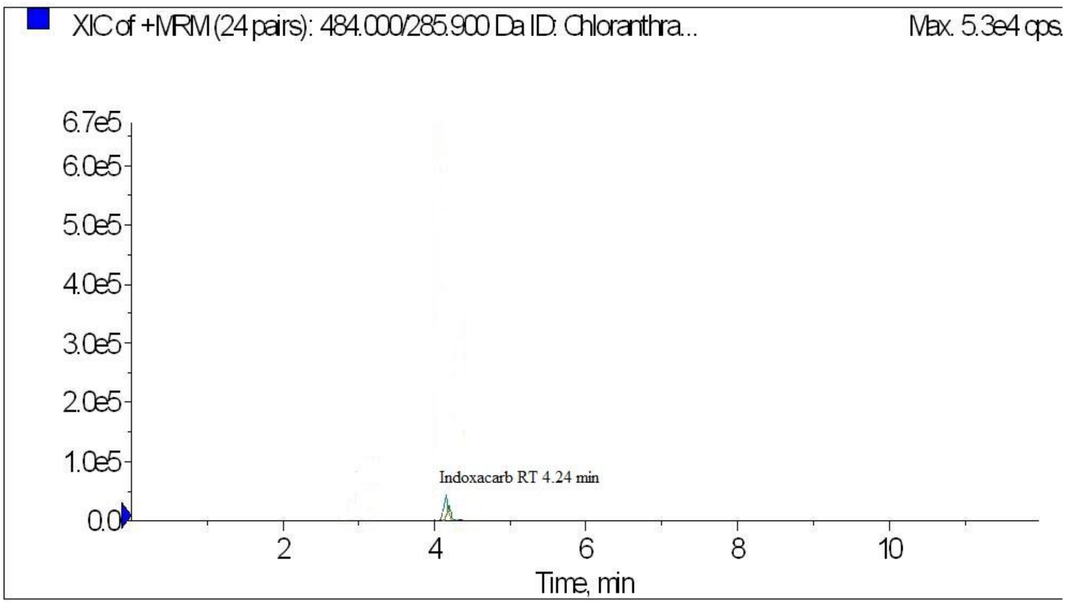


LC-MS/MS chromatogram of chlorantraniliprole



LC-MS/MS chromatogram of Flubendiamide

Appendix - XVII



LC-MS/MS chromatogram of Indoxacarb

MANAGEMENT OF PESTS OF COWPEA AND SALAD CUCUMBER IN POLYHOUSE

by

THAMILARASI N
(2014-11-241)

Abstract of the thesis
Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

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

2016

ABSTRACT

A study on "Management of pests of cowpea and salad cucumber in polyhouse" was undertaken in polyhouses of Thiruvananthapuram district and College of Agriculture, Vellayani during January 2015 to May 2016. The main objectives were to document the pests and natural enemies on cowpea and salad cucumber in polyhouses and to evaluate the efficacy of new generation insecticides against the major pests.

A purposive survey was conducted in 20 polyhouses in Thiruvananthapuram district to document the pests and natural enemies. Sucking pests *viz.*, pea aphid, *Aphis craccivora* (Koch), mealy bug, *Ferrisia virgata* (Cockerell), pod bug, *Riptortus pedestris* (Fabricius), fulgorid bug, *Eurybrachys tomentosa* (Fabricius), thrips, *Ayyaria chaetophora* (Karny), spotted red mite, *Tetranychus truncatus* (Ehara) and leaf feeders *viz.*, pod borer, *Lampides boeticus* (Linnaeus), tobacco caterpillar, *Spodoptera litura* (Fabricius), leaf beetle *Pagria flavopustulata* (Baly), American serpentine leaf miner, *Liriomyza trifolii* (Burgess) are the pests associated with cowpea. New pests *viz.*, tortrycid larvae, leaf miner and girdle beetle, *Oberiopsis brevis* (Gahan) were reported from cowpea under polyhouse. Sucking pests *viz.*, green peach aphid, *Myzus persicae* (Sulzer), mealy bug, *Ferrisia virgata* (Cockerell), thrips, *Astrothrips tumiceps* (Karny), *Thrips hawaiiensis* (Morgan), *Frankliniella schultzei* (Trybom) spotted red mite, *Tetranychus* sp, and leaf feeders *viz.*, pumpkin caterpillar, *Diaphania indica* (Saunders), American serpentine leaf miner, *Liriomyza trifolii* (Burgess) are associated with salad cucumber under polyhouse conditions. The natural enemies observed were coccinellids, syrphids and spiders *viz.*, *Oxyopes javanus* (Thorell), *Oxyopes sunandae* (Tikader) and *Argiope pulchella* (Thorell) from both cowpea and salad cucumber. The data on preliminary survey revealed that both sucking and leaf feeder pests caused significant damage to cowpea and salad cucumber inside polyhouse.

Experiments were carried out in CRD to evaluate the efficacy of new generation insecticides *viz.* acetamiprid 0.10 g L^{-1}, imidacloprid 0.20 mL L^{-1}, thiamethoxam 0.30 g L^{-1}, thiacloprid 0.25 mL L^{-1}, dimethoate 1.50 mL L^{-1} against sucking insects *viz., A. craccivora, M. persicae* and *R. pedestris* and acaricides *viz.,* spiromesifen 0.80 mL L^{-1}, fenpyroximate 0.60 mL L^{-1}, dimethoate 1.50 mL L^{-1} against *Tetranychus* sp. Spinosad 0.30 mL L^{-1}, chlorantraniliprole 0.30 mL L^{-1}, flubendiamide 0.10 mL L^{-1}, indoxacarb 1.00 mL L^{-1}, quinalphos 3.00 mL L^{-1} were tested against leaf feeders *viz., L. trifolii* and *D. indica*.

Evaluating the efficacy of new generation insecticides, thiamethoxam 0.30 g L^{-1} and imidacloprid 0.20 mL L^{-1} were found to be effective against sucking pests which reduced the mean population of *A. craccivora* to 7.33 and 12.67 aphids $plant^{-1}$ respectively and *M. persicae* to 4.67 and 11.67 aphids $plant^{-1}$ respectively after 15 days of treatment. However, thiamethoxam 0.30 g L^{-1} and imidacloprid 0.20 mL L^{-1} were found to be equally effective in managing *R. pedestris* which reduced the population to 0.20 bugs $plant^{-1}$. Spiromesifen was recorded to be the best by reducing the population to 10.50 and 16.25 mite $plant^{-1}$ in cowpea and salad cucumber respectively. Chlorantraniliprole 0.30 mL L^{-1} and spinosad 0.30 mL L^{-1} reduced the population of leaf miner to 0.60 and 0.40 larvae $plant^{-1}$ in cowpea respectively and 0.20 and 0.60 larvae $plant^{-1}$ in salad cucumber respectively and no larvae of *D. indica* were recorded in chlorantraniliprole 0.30 mL L^{-1} and flubendiamide 0.10 mL L^{-1} treated salad cucumber 15 days after spraying.

The dissipation (persistence/ degradation of residues) study showed that the promising insecticide thiamethoxam 0.30 mL L^{-1} persisted upto 7 and 5 days in cowpea and salad cucumber respectively and imidacloprid 0.20 mL L^{-1} persisted upto one day in both cowpea and salad cucumber and spiromesifen 0.80 mL L^{-1} persisted upto 7 and 5 days in cowpea and salad cucumber respectively. Chlorantraniliprole 0.30 mL L^{-1} and spinosad 0.30 mL L^{-1} persisted upto 5 and 7 days in cowpea and 3 days each in salad cucumber respectively.

From the present study it is concluded that both sucking pests and leaf feeders are causing significant damage in cowpea and salad cucumber under polyhouse conditions. Application of thiamethoxam 0.30 g L^{-1} and imidacloprid 0.20 mL L^{-1} effectively manage the sucking pests *viz., A. craccivora, M. persicae* and *R. pedestris*. Spiromesifen 0.80 mL L^{-1} was found to be the best to manage the *Tetranychus* sp. Chlorantraniliprole 0.30 mL L^{-1} and spinosad 0.30 mL L^{-1} were found to be effective in managing leaf feeders in both cowpea and salad cucumber. A harvest interval of 5 to 7 days should be given to ensure the safety of the produce from the polyhouse to the end users.