BIO-EFFICACY OF NEWER INSECTICIDES AGAINST DIAMONDBACK MOTH (*Plutella xylostella* L.) AND THEIR RESIDUES IN CABBAGE

by

Sawant Chandrakant Gyanoba
(Reg. No.PH.D.AG /014/29)

DOCTOR OF PHILOSOPHY (AGRICULTURE)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

2018

BIO-EFFICACY OF NEWER INSECTICIDES AGAINST DIAMONDBACK MOTH (*Plutella xylostella* L.) AND THEIR RESIDUES IN CABBAGE

by

Sawant Chandrakant Gyanoba
(Reg. No.PH.D.AG /014/29)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

In the partial fulfillment of the requirements for the degree
of

DOCTOR OF PHILOSOPHY (AGRICULTURE)
in

(AGRICULTURAL ENTOMOLOGY)

DEPARTMENT OF AGRICUTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE

MAHATMA PHULE KRISHI VIDYAPEETH

RAHURI – 413 722, DIST. AHMEDNAGAR

MAHARASHTRA, INDIA

2018

BIO-EFFICACY OF NEWER INSECTICIDES AGAINST DIAMONDBACK MOTH (*Plutella xylostella* L.) AND THEIR RESIDUES IN CABBAGE

by

Sawant Chandrakant Gyanoba
(Reg. No. PH.D.AG/014/29)

A thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST- AHMEDNAGAR
MAHARASHTRA, INDIA

in the partial fulfilment of the requirements for the degree
of
DOCTOR OF PHILOSOPHY (AGRICULTURE)
in
AGRICULTURAL ENTOMOLOGY

APPROVED BY

Dr. C. S. Patil
(Chairman and Research Guide)

Dr. S. S. Jadhav
(Committee member)

Dr. D. S. Pokharkar
(Committee member)

Dr. M. N. Bhalekar
(Committee member)

Dr. A. D. Kadlag
(Committee member)

DEPARTMENT OF AGRICUTURAL ENTOMOLOGY
POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA
2018

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part

thereof has not been submitted

by me or other person to any

other University or Institute

for a Degree or

Diploma

Place: M.P.K.V., Rahuri

Date: /08/2018 (Sawant Chandrakant Gyanoba)

Dr. C. S. PATIL
Residue Analyst
AINP on Pesticide Residue
Department of Agricultural Entomology
Mahatma Phule Krishi Vidyapeeth
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra, INDIA.

CERTIFICATE

This is to certify that the thesis entitled, "Bio-efficacy of newer insecticides against diamondback moth (*P. xylostella* L.) and their residues in cabbage" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of piece of bonafide research work carried out by **Mr. SAWANT CHANDRAKANT GYANOBA** under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place: MPKV, Rahuri (C. S. Patil)

Date: /08/2018 Research Guide

Dr. D. S. POKHARKAR
Head
Department of Agricultural Entomology
Mahatma Phule Krishi Vidyapeeth
Rahuri-413722, Dist. Ahmednagar
Maharashtra, INDIA.

CERTIFICATE

This is to certify that the thesis entitled, "Bio-efficacy of newer insecticides against diamondback moth (*P. xylostella* L.) and their residues in cabbage" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** embodies the results of a piece of bonafide research work carried out by **Mr. SAWANT CHANDRAKANT GYANOBA,** under the guidance and supervision of **Dr. C. S. PATIL,** Residue Analyst, AINP on Pesticide Residue, Department of Agricultural Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri and that no part of the thesis has been submitted for any other degree or diploma.

Place: MPKV, Rahuri

Date: /08/2018 (D. S. Pokharkar)

Dr. R.S. PATIL
Associate Dean
Post Graduate Institute
Mahatma Phule KrishiVidyapeeth
Rahuri-413 722, Dist. Ahmednagar
Maharashtra, INDIA.

CERTIFICATE

This is to certify that the thesis entitled, "Bio-efficacy of newer insecticides against diamondback moth (*P. xylostella* L.) and their residues in cabbage" submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of bonafide research work carried out by **Mr.SAWANT CHANDRAKANT GYANOBA**, under the guidance and supervision of **Dr. C. S. PATIL**, Residue Analyst, AINP on Pesticide Residue, Department of Agricultural Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri and that no part of the thesis has been submitted for any other degree or diploma.

Place : M.P.K.V., Rahuri

Date : /08/2018 (R.S. Patil)

ACKNOWLEDGEMENT

I think it is a matter of pleasure to glance back and recall the path am travels the days of hard work and perseverance. It is still great at the juncture to recall all the face and spirit in the form of teachers, friends, near and dear ones.

"Words cannot express my profound sense of gratitude and devoted thanks to respected Chairman of my Advisory Committee Dr. C. S. Patil, Residue Analyst, All India Network Project on Pesticide Residues, Department of Agril. Entomology, MPKV, Rahuri for his scholastic and peerless guidance, meticulous supervision and through assessment right from the selection of this investigation to preparation of this manuscript. I am highly grateful for his indefatigable efforts and creative ideologies to instill scientific temper in me. "He has been and will be a source of encouragement and inspiration for me.

It is pleasure to expend my grateful thanks to the respected members of advisory committee Dr. D. S. Pokharkar, Head, Department of Entomology , PGI, MPKV, Rahuri and Dr. S. S. Jadhav, Former Head, Department of Entomology, PGI, MPKV, Rahuri for providing prompt guidance, constant inspiration, moral support and valuable help during the period of investigation. The other members, Dr. M. N. Bhalekar, Senior Vegetable Breeder, Department of Horticulture, MPKV, Rahuri and Dr. A. D. Kadlag, Assistant Residue Analyst, All India Network Project on Pesticide Residues, Department of Agril. Entomology, MPKV, Rahuri for their valuable suggestion and guidance from time to time during the investigations and correcting the manuscript.

I express my deep sense of honor to Dr. R.S. Patil, Associate Dean, and Dr. D. S. Pokharkar, Head, Department of Entomogy, P.G.I., M.P.K.V., Rahuri for providing me the necessary facilities during the course of study.

My sincere special thanks to the Department of Science and Technology, Ministry of Science and Technology, Govt. of India for awarding me 'INSPIRE Fellowship' for my Doctorial research.

Heartful gratitude is extended to our course teaches Dr. D. S. Pokharkar, Professor and Head, Department of Entomology , Dr. S. R Kulkarni, Associate Professor, Department of Entomology, Dr. N. L. Mhase, Associate Professor, Department of Entomology, Dr. S. K. Patil, Assistant Professor, Department of Entomology, Post Graduate Institute, MPKV., Rahuri for their constructive suggestions and advice during the course of studies.

I extend my sincere thanks to Dr.B.V. Deore and Dr. Y. S. Saindane, Assistant Residue Analyst, Dr. S. A. Landge, Junior Research Assistant, Mr. Dattatraya Autade, Mr. Vijay Girhe, Mr. Gaurav Jadhav, Mr. Sameer Sheikh, Mr. Sachin Kanwade, Mr. Nilesh Gaikwad and all staff members working at All India Network Project on Pesticide Residues for their help during conducting research work.

My sincere thanks to Mrs. Chemate, Mrs. Shinde, Mr. Mehtre, Mr. Kushare and all non teaching staff members of Department of Agril. Entomology, M.P.K.V., Rahuri for their co-operation and providing me all sorts of facilities for conducting the experiment successfully.

I am very lucky to have friendly advice, encouragement and moral support from my seniors, Dr. Vrushali Pashte, Dr. Nazir Tamboli, Mr. Rupesh Patil, Dr. Bhanudas Bhonde , Dr. Shantikumar, lovely and dashing Dr. Manoj bhau and friends Mr.Ganesh Badade, Mr. Nandu Bhagus, Mr. Pankaj, Mr. Prasad , Mr. Karan, Mr. Shrikant, Mr. Ganesh, Mr. Sunil, Mr. Sachin, Mr. Laxman and Mr. Guru.

Today, here is smile on lips and light of hope in my eyes, because my fortunate has changed for better. Behind this picture of prosperity lies the hard work, bondless love and firmless sacrifice of my respectful father Mr. Gyanaba Sawant and mother Mrs. Sanjivani Gyanoba Sawant who educated me. Keeping in all comforts without which this work could not have seen the light of this day at all. Life in general and my research in particular would have remained a cipher space if not the tremendous encouragement, genuine faith and love bestowed on me by Mr. Balaji Shere and Mrs. Meena Balaji Shere lovable nephew Vaibhav and Shivraj. I am grateful to them.

My sincere special thanks to all farmers of Ahmednagar, Pune, Nashik districts who helped during survey may be regarded as a lighthouse of the ocean liners who have been kindly navigating my ship of academic pursuit and I would like to mention my gratitude to them.

I am deeply obliged to all the authors past and present whose literature has been cited. I am thankful to Mahatma Phule Krishi Vidyapeeth, Rahuri for providing me this opportunity to undertake the Post Graduate Studying in their institute of national repute.

While traveling on this path of education, many hands pushed me forth; learned hearts put me on the right track enlightened by their knowledge and experience. I ever rest thanks to all of them.

Place: M.P.K.V., Rahuri.

Date: /08/2018 **(C.G. Sawant)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF CHROMATOGRAMS

LIST OF ABBREVIATIONS

%	:	Per cent
&	:	And
/	:	Per
@	:	At the rate of
<	:	Less than
>	:	More than
B	:	Beta
Λ	:	Lambda
±	:	Plus minus
µg	:	Microgram
a. i.	:	Active ingredient
AINP	:	All India Network Project
Anon.	:	Anonymous
AChE	:	Acetyl Choline Esterase
Ach	:	Acetyl Choline
AOAC	:	Association Off Analytical Chemistry
BDL	:	Below Detectable Level
BQL	:	Below Quantification Level
Ch	:	Choline
C.D.	:	Critical Difference
CRM	:	Certified Reference Material
DAS	:	Days after sprying
DAT	:	Days after treatment
DDT	:	Dichlorodiphenyltrichloroethane
DDVP	:	Dichlorvos
DOS	:	Day of spraying
DSI	:	Direct Sample Introduction
EC	:	Emulsifiable Concentrate
ECD	:	Electron Capture Detector
et al.	:	et alli (and others)
Etc	:	et. ceteras (so on)
Fig.	:	Figure
FPD	:	Flame Photometric Detector
GC	:	Gas Chromatography
GC/MS	:	Gas Chromatography coupled with a tandem Mass Spectrometer
GC-MS	:	Gas chromatography- Mass spectrometry
GLC	:	Gas Liquid Chromatography
Hr	:	Hours
Ha	:	Hectare
Ha^{-1}	:	Per hactare
HCH	:	Hexachlorohexene

HPLC	:	High performance liquid chromatography
i.e.	:	Id est (That is)
Kg	:	Kilograms
LC	:	Liquid Chromatography
LC-MS	:	Liquid chromatography- Mass spectrometry
LC/MS	:	Liquid Chromatography coupled with a tandem Mass Spectrometer
lit.	:	Litres
LOD	:	Limit of detection
LOQ	:	Limit of quantification
Mg	:	Milligram
Ml	:	Millilitre (s)
$MgSo_4$	:	Magnesium sulphate
MPKV	:	Mahatma Phule Krishi Vidyapeeth
MRL	:	Maximum Residue Limit
MS	:	Mass spectrometry
MT	:	Metric Tonne (s)
NaCl	:	Sodium Chloride
Ng	:	Nanogram
No.	:	Number
NSE	:	Neem seed extract
ºC	:	Degree Celsius (Centigrades)
OCPs	:	Oranoclorinated pesticides
PGI	:	Post Graduate Institute
PHI	:	Pre Harvest Interval
Ppm	:	Parts Per Million
Q	:	Quintal
T	:	Tonne
ha^{-1}		Per hecter
$Plant^{-1}$		Per plant
PSA	:	Primary secondary amine
QuEChERS	:	Quick, Easy, Cheap, Effective, Rugged and Simple
RL_{50}	:	Residual Life 50
RSD	:	Relative Standard Deviation
Rpm	:	Rotations Per Minutes
S.E.	:	Standard Error
SD	:	Standard deviation
Sp.	:	Species
SPE	:	Solid Phase Extraction
$T_{1/2}$	:	Half life
UV	:	Ultra Violet
viz.	:	Videlicet (Namely)

ABSTRACT

"BIO-EFFICACY OF NEWER INSECTICIDES AGAINST DIAMONDBACK MOTH (*Plutella xylostella* L.) AND THEIR RESIDUES IN CABBAGE"

by

MR. SAWANT CHANDRAKANT GYANOBA

A candidate for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

2018

Research Guide	:	**Dr. C. S. Patil**
Discipline	:	**Agricultural Entomology**

The investigations were carried out on 'Bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* L.) and their residues in cabbage' during the year 2015-16 and 2016-2017 at M.P.K.V., Rahuri, Maharashtra. Investigations comprised studies on pesticide use pattern, bio-efficacy of newer insecticides against *P. xylotella,* dissipation of triazophos, quinalphos and bifenthrin in cabbage and decontamination of residues in cabbage. Field studies were conducted at farmer's field (at Nandur Madhyameshwar, Tq. Niphad, Dist. Nashik and at Khandgaon, Tq. Sangamner, Dist. Ahmednagar), Instructional Farm, P.G.I, M.P.K.V., Rahuri and laboratory studies were carried out at A.I.N.P. on Pesticide Residue, Department of Agril. Entomology, M.P.K.V., Rahuri.

Insecticide usage pattern of selected farmers from Ahmednagar, Pune and Nashik district of western Maharashtra indicated that, farmers relied mostly on chemical pesticides to control the insect pests of cabbage. Irrespective of location, farmers from these locations used conventional insecticides. Among three cabbage growing areas, the use of conventional insecticides was maximum by the farmers from Pune districts (1.43 kg a.i. ha^{-1} $season^{-1}$) followed by Ahmednagar (1.22 kg a.i. ha^{-1} $season^{-1}$) and Nashik districts (1.07 kg a.i. ha^{-1} $season^{-1}$). As regards, use of novel insecticides, farmers from Nashik district used 0.38 kg a.i.ha^{-1} $season^{-1}$ followed by Pune (0.24 kg a.i. ha^{-1} $season^{-1}$) and Ahmednagar district (0.20 kg a.i. ha^{-1} $season^{-1}$). Very few farmers from above locations used biopesticides i.e. Mycoinsecticides and neem based formulations. The most commonly used conventional insecticides were triazophos, quinalphos, dimethoate, dichlorvos, cypermethrin, profenophos and chlorpyriphos. About 50 per cent farmers were aware of natural enemies. Nearly 60 per cent farmers knew about the recommended insecticides and their doses on cabbage. Majority of the farmers indicated that they were aware of the residual effects of insecticides, but they did not follow any precautions to avoid harmful effects. It was also found that majority of the farmers did not knew about safe

waiting period for harvesting of cabbage after application of insecticides. Majority of the farmers sprayed at an interval of 7-10 days giving 5-7 rounds of spraying during cropping season of cabbage.

Studies on bio-efficacy revealed that, chlorantraniliprole @ 10 g a.i. ha^{-1} was found to be the most effective with 91.30 per cent reduction in larval population of *P. xylostella* followed by spinosad @ 17.5 g a.i. ha^{-1} (87.55%) and flubendiamide @ 18.24 g a.i.ha^{-1} (86.61%). The maximum marketable yield of cabbage heads (238.15 q ha^{-1} with 129.23 % increase over control) was obtained from the plots treated with chlorantraniliprole @ 10 g a.i. ha^{-1} followed by spinosad @ 17.5 g a.i. ha^{-1} (233.83 q ha^{-1} with 125.07 % increase over control) and flubendiamide @ 18.24 g a.i. ha-1 (224.98 q ha^{-1} with 116.56 % increase over control). The highest cost:benefit ratio was registered in the treatment of chlorantraniliprole @ 10 g a.i. ha^{-1} (1:16.40) followed by flubendiamide @ 18.24 g a.i. ha^{-1} (1:14.98) and spinosad @ 17.5 g a.i. ha^{-1} (1:12.22).

Studies on dissipation showed that, residues of triazophos persisted in cabbage up to 7^{th} and 10^{th} day with half-life of 2.66 and 2.87 days at recommended and double the recommended dose, respectively. Residues of quinalphos persisted in cabbage up to 5^{th} and 7^{th} day with half-life of 2.10 and 1.97 days at recommended and double the recommended dose, respectively. As regards bifenthrin residues persisted in cabbage up to 7^{th} and 10^{th} day with half-life of 2.30 and 2.52 days at recommended and double the recommended dose, respectively.

Among the various decontamination methods evaluated, cooking in close pan was found to be the most effective method in removing triazophos, quinalphos and bifenthrin residues from chopped cabbage samples (85.18, 85.42 and 86.27 %, respectively). Boiling was the next effective treatment which removed the triazophos, quinalphos and bifenthrin residues to the extent of 74.07, 81.25 and 80.39 per cent from chopped cabbage samples, respectively. Dipping of cabbage heads in 2 per cent salt solution reduced triazophos, quinalphos and bifenthrin residues to the extent of 51.85, 56.25 and 64.70 per cent, respectively. Reduction of residues due to dipping in 2 per cent tamarind solution was to the extent of 42.59, 41.67 and 56.86 per cent for triazophos, quinalphos and bifenthrin residues, respectively from cabbage heads. Washing of cabbage heads with tap water was observed to be the least effective in removing the residues of triazophos, quinalphos and bifenthrin residues (up to 25 %).

1. INTRODUCTION

Cabbage (*Brassica oleracea var. capitata* Linn.) is the most common, popular and principal annual vegetable crop. It has been staple vegetable in our diet since ancient times. Cabbage is grown mostly in winter season and occupies an important position in meeting the dietary requirements of most of the people all over the world. Among the winter vegetables, cabbage has been popular and extensively cultivated because of its nutritional and economical values. It is grown for its edible enlarged terminal buds, which is a rich source of Ca, P, Na, K, S, Vit A, Vit C and dietary fibers.

It is estimated that its cultivation cover 4.0 per cent vegetable area with a contribution of 6.00 per cent to total vegetable production (Anon., 2015). India is the second largest producer of cabbage and cauliflower after China among the tropical and sub-tropical nations. The area under vegetable crops in India is about 9541 thousand ha and production is 168300 MT. The corresponding figures for cabbage in Maharashtra are 379 thousand ha and production is 8597 MT (Anon., 2015).

The cabbage crop is attacked by a number of insect pests. Among them, cabbage caterpillar, *Pieris brassicae* Linnaeus; diamondback moth, *Plutella xylostella* Linnaeus; cabbage semi-looper, *Thysanoplusia orichalcea* Fabricius and *Autographa nigrisigna* Walker; tobacco caterpillar, *Spodoptera litura* Fabricius ;cabbage leaf webber, *Crocidolomia binotalis* Zeller; cabbage borer, *Hellula undalis* Fabricius and cabbage flea beetles, *Phyllotreta cruciferae* Goeze., *Phyllotreta chotanica* Duviv., *Phyllotreta birmanica* Harold., *Phyllotreta oncera* Maulik and *Phyllotreta downesi* Baly are the pests of major importance (Atwal and Dhaliwal, 2002). Out of these, diamondback moth, *P. xylostella* is the most destructive pest (Mahla *et al*., 2005; Kumar *et al*., 2007) and it is one of the limiting factor for the successful cultivation of cruciferous crops. (Patil *et al*., 1999). The pest is active throughout the year at places having moderate climate but, it is adversely affected by severe cold (Talekar and Sheltan, 1993). The young caterpillar scraps and mines on the lower surface of leaves and later on feed on exposed leaves. It produces shot holes in the leaves and causes serious damage.

Cabbage (*B. oleracea* var. *capitata*) and cauliflower (*B. oleracea* var. *botrytis*) are preferred hosts of *P. xylostella* worldwide. These vegetables are high value crops with high cosmetic standards, therefore effective control of the pest is necessary. Insecticides are the most common strategy to control *P. xylostella* on vegetable crops and farmers are always in need of new effective insecticides due to *P. xylostella's* long history of eventually becoming resistant to every insecticide used extensively against it. The first record of insecticide resistance in *P. xylostella* was reported in 1953 from Java, Indonesia (Ankersmith, 1953) and this was also the first crop pest in the world to develop resistance to DDT. It also has the distinction of being the first agricultural insect to develop resistance in the field to sprays of *Bacillus thuringiensis* Berliner (Tabashnik *et al*.,1990; Shelton *et al*., 1993) and more recently it has developed resistance to newer insecticides such as spinosad, indoxacarb and emamectin benzoate (Zhao *et al*., 2006). These multiple cases of resistance could be due to inherent differences in physiological and behavioral responses of *P. xylostella* larvae and adults to insecticides (Moore and Tabasink, 1989; Head *et al*., 1995; Eziah *et al.,* 2009).

Farmers use substantial amount of pesticides throughout the period of crop growth and sometimes even at the fruiting stage. Indiscriminate use of pesticides particularly during fruiting stage and non-adoption of safe waiting period results in accumulation of residues in consumable vegetables. Moreover, the produce is harvested at short interval and consumed fresh. Therefore, it is unwise to use chemical insecticides alone to manage these pests. An insecticide should be effective and economic, but should not leave toxic residues.

Survey conducted in major cabbage growing areas indicated that triazophos, quinalphos and bifenthrin were commonly used insecticides by farmers without recommendation on cabbage. The residues of these insecticides have been reported in different vegetables (Sapahin *et al*., 2014; Deviprasad *et al*., 2015; Willam *et al*., 2006).

It is absolutely essential that any approved insecticide should remain active after its application on a crop or soil sufficiently long to provide protection from target pests and yield economically viable produce. However, insecticides should dissipate to safe toxicological levels by the time man needed the produce from the treated crop for the consumption. In view of this hard reality, it is essential to study the dissipation behaviour of insecticides (Gupta, 2006).

The dissipation of an insecticide varies with the nature of insecticide, dose, number of applications, interval between application, crop variety, etc. Food products become safe for consumption only if safe waiting period is observed. Hence, it is necessary that pesticides should be effective against a pest along with toxicologically acceptable residues on food commodity (Singh *et al*., 2007). The residues if present in excessive amount may be a potential health hazard to the consumer and can cause many chronic diseases (Singh and Dhaliwal, 2000).

Therefore, investigations were carried out on bio-efficacy of insecticides, dissipation and decontamination methods on cabbage with the following objectives.

1. To study the usage pattern of insecticides in cabbage against diamondback moth (*Plutella xylostella* L.).
2. To study the bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* L.).
3. To study the dissipation pattern of triazophos, quinalphos and bifenthrin in cabbage.
4. To study the impact of household processes on the residues of insecticides.

2. REVIEW OF LITERATURE

Keeping in view the objectives of the present studies, research work on relevant aspects was reviewed and presented under this chapter.

Nature and extent of damage caused by diamondback moth (*Plutella xylostella* L.)

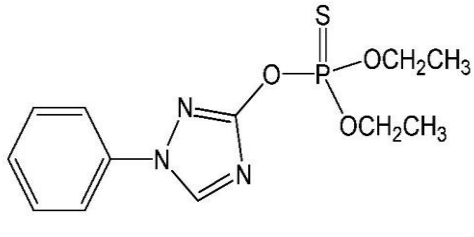
In India, diamondback moth (*P. xylostella* L.) was first recorded in 1914 (Fletcher, 1914) on cruciferous vegetables. This species is now distributed all over India wherever crucifers are grown. It is now the most devastating pest of cole crops in the states of Punjab, Haryana, Himachal Pradesh, Delhi, Uttar Pradesh, Bihar, Tamil Nadu, Maharashtra and Karnataka. Though DBM infests important crucifers *viz,.* cabbage, cauliflower, radish, knolkhol, turnip, beet root, mustard, *Brassica campestris* var. *toria* and *B. campestris* var. *sarson* (Chand and Choudhary, 1977), the pest exhibits a marked preference for cauliflower and cabbage.

Plant damage is caused by larval feeding. Although the larvae are very small, they can be quite numerous, resulting in complete removal of foliar tissues except for the leaf veins. This particularly cause damage to seedlings and may disrupt head formation in cabbage, broccoli and cauliflower. The presence of larvae in florets can result in complete rejection of produce, even if the level of plant tissue removal is insignificant. The crop loss was estimated to vary from 52 (Krishnakumar *et al.* 1984) to 100 per cent (Calderon and Hare, 1986).

2.1 Profiles of tested insecticides

2.1.1 Triazophos

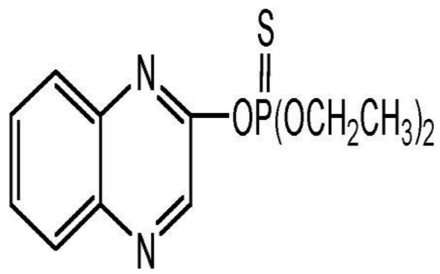
Chemically it is known as 0, 0-diethyl 0-1-phenyl-1, 2, 4-triazol-3-yl phosphorothioate. Its empirical formula is $C_{12}H_{16}N_3O_3PS$ with the following chemical structure.



It is light brown yellowish liquid having vapour pressure of 2.9×10^{-6} mm Hg. It is soluble in most organic solvents. The water solubility is 39 mg L^{-1} at 20 ^{0}C. Its toxicity to rats is 48-107 mg kg^{-1} body weight (Acute oral LD_{50}) and 1100 mg kg^{-1} body weight (Acute dermal LD_{50}). It has insecticidal and acaricidal properties as well as some nematicidal properties. It is effective against a variety of pests particularly lepidopteran larvae on fruits and vegetables. It is usually recommended @ 500 g a.i. ha^{-1} on cotton against boll worm. It has also been reported effective against cutworms.

2.1.2 Quinalphos

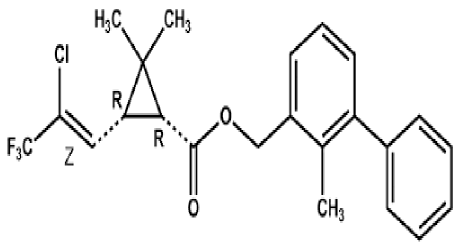
Chemically it is known as O,O-diethyl O-quinoxalin-2-yl phosphorothioate. Its empirical formula is $C_{12}H_{15}N_2O_3PS$ with the following structure



It is contact poison having good penetrating power. The pure material is colorless crystals having vapor pressure of 3.9×10^{-12} mm Hg at 20 ^{0}C. It is soluble in acetone, ethanol and xylem and slightly soluble in light petroleum. The water solubility is @ 22 mg l-1. Its toxicity to rats is 62-137 mg kg^{-1} body weight (Acute oral LD_{50}) and 1250-1400 mg kg^{-1} body weight (Acute dermal LD_{50}). It is widely used against caterpillars and borers on cotton, vegetables and other crops. It has also acaricidal properties. It can be degraded very fast in plants.

2.1.3 Bifenthrin

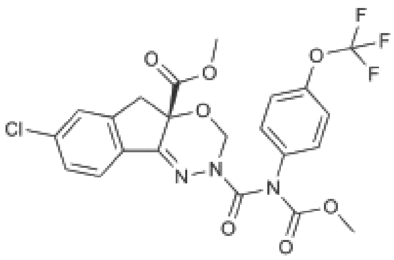
Chemically it is known as 2-Methyl-3-biphenylyl methyl (1R, 3R)-3-[(Z)-2-chloro-3, 3, 3-trifluoroprop-1-enyl]-2,2-dimethylcyclopropane-1-carboxylate. Its empirical formula is $C_{23}H_{22}ClF_3O_2$ with the following structure.



Bifenthrin is a member of pyrethroid group of insecticides. It is pale tan to off-white in color. It can be crystalline, waxy solid or viscous liquid. It has a weak, aromatic odour having vapour pressure of 0.0178 mm Hg at 25 ^{O}C. It has a low aqueous solubility and is not volatile. The water solubility is 0.001 mg L^{-1}. Its toxicity to rats is 54-70 mg kg^{-1} body weight (Acute oral LD_{50}) and > 2000 mg kg^{-1} body weight (Acute dermal LD_{50}). It is an insecticide and acaricide which affects the nervous system and causes paralysis in insects.

2.1.4 Indoxacarb

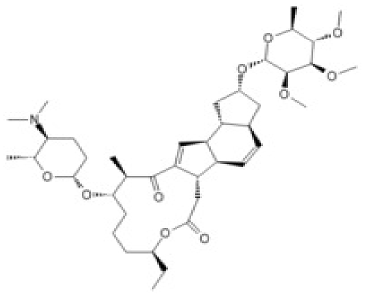
The insecticide belongs to the oxadiazine chemical family. Chemically it is known as (S)-methyl 7-chloro-2, 5-dihydro-2-[(methoxycarbonyl) [4 (trifluoromethoxy) phenyl] amino] carbonyl] indeno [1, 2-e] [1, 3, 4] oxadiazine-4a (3*H*)-carboxylate. Its empirical formula is C_{22} H_{17} ClF_3 N_3O with the following chemical structure.

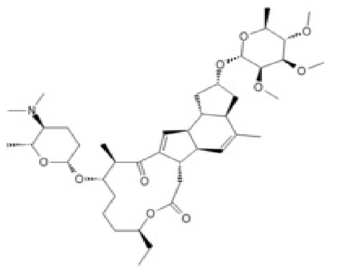


Vapour pressure of indoxacarb is 7.3×10^{-11} mm Hg. It is soluble in most organic solvents. The water solubility is 0.20 mg/L at 20 ^{0}C. Its toxicity to rats is 1000 mg kg^{-1} body weight (Acute oral LD_{50}) and 5000 mg kg^{-1} body weight (Acute dermal LD_{50}). It is being registered for the control of lepidopterous pests in the larval stages. Insecticidal activity occurs via blockage of the sodium channels in the insect nervous system and the mode of entry is via the stomach and contact routes.

2.1.5 Spinosad

Spinosad is an insecticide based on chemical compounds found in the bacterial species *Saccharopolyspora spinosa*. The name spinosad is derived from combining the characters from spinosyn A and spinosyn D. Chemically **Spinosyn A** is known as 2-[(6-deoxy-2, 3, 4- tri-O- methyl -*alpha*-L- mannopyranosyl) oxy)-13-[(5 dimethylamino) tetrahydro-6-methyl-2H-pyran-2-yl) oxy)-9-ethyl 2,3, 3a,5a, 5b,6,9,10,11,12,13,14,16a, 16b tetradecahydro-14- methyl-1H-as-indaceno(3,2-d)oxacyclododecin-7,15-dione. **Spinosyn D** is known as 2-((6-deoxy-2,3,4-tri-o-methyl-*alpha*-L manno pyranosyl) oxy)- 13- ((5- (dimethylamino) tetrahydro-6-methyl-2H-pyran-2-yl) oxy)-9-ethyl-2, 3, 3a, 5a, 5b, 6, 9, 10, 11, 12, 13, 14, 16a, 16b tetradecahydro-4,14- dimethyl-1H-as-indaceno (3,2-d) oxacyclododecin-7,15-dione. Empirical formula of **Spinosyn A** is $C_{41}H_{65}NO_{10}$ and **Spinosyn D** is $C_{42}H_{67}NO_{10}$ with following chemical structure.



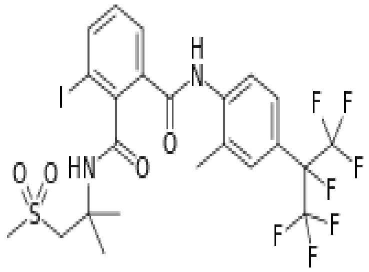


Spinosyn A **Spinosyn D**

It is a tan or white low melting crystal soluble in a number of organic solvents but low soluble in water. Its toxicity to rats is 5000 mg kg^{-1} body weight (Acute oral LD_{50}) and 2000 mg kg^{-1} body weight (Acute dermal LD_{50}). It has insecticidal property and used for controlling a variety of insect pests i.e. lepidoptera, diptera, thysanoptera, coleoptera, orthoptera, and hymenoptera and many others. Its binding leads to disruption of acetylcholine neurotransmission. It also has secondary effects as Gama amino-butyric acid (GABA) neurotransmitter agonist.

2.1.6 Flubendiamide

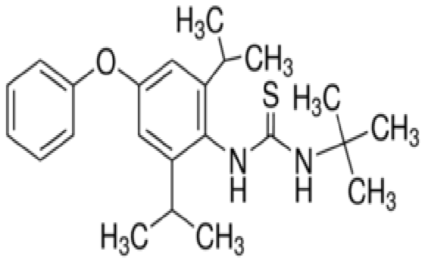
Flubendiamide is a pesticide of ryanoid class. Chemically it is known as 1-*N*-[4-(1, 1, 1, 2, 3, 3, 3-heptafluoropropan-2-yl)-2-methylphenyl]-3-iodo-2-*N*-(2-methyl-1-methylsulfonylpropan-2-yl) benzene-1, 2-dicarboxamide. Its empirical formula is $C_{23}H_{22}F_7IN_2O_4S$ with following chemical structure.



It is technically white crystalline powder having vapour pressure of 10^{-4} pa at 20 ^{0}C. It is soluble in most organic solvents. The water solubility is 29.90 g/mL at 20 ^{0}C. Its toxicity to rats is 2000 mg kg^{-1} body weight (Acute oral LD_{50}) and 2000 mg kg^{-1} body weight (Acute dermal LD_{50}). It has insecticidal property acts at receptors in insect muscles and used against variety of lepidopteran pests including diamond back moth.

2.1.7 Diafenthiuron

The insecticide belongs to the thiourea group. Chemically it is known as 1-tert-butyl-3-(2, 6-diisopropyl-4-phenoxyphenyl) thiourea *N*-[2, 6-bis (1-methylethyl)-4 phenoxyphenyl]-*N*'-(1, 1- dimethylethyl) thiourea. Its empirical formula is $C_{23}H_{32}$ N_2OS with following chemical structure.

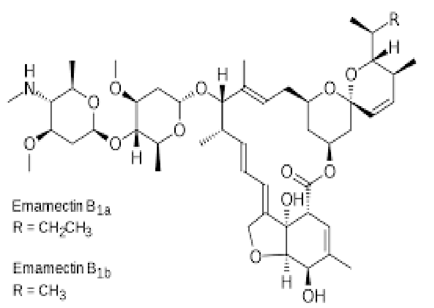


It is white amorphous powder having vapour pressure of 2×10^{-3} mPa. The water solubility is 0.06 g/mL at 20 ^{0}C. Its toxicity to rats is 2068 mg kg^{-1} body weight (Acute oral LD_{50}) and > 2000 mg kg^{-1} body weight (Acute dermal LD_{50}). It has insecticidal and acaricidal property.

2.1.8 Emamectin benzoate

Emamectin benzoate is an avermectin class of insecticide consists of homologous semi-synthetic macrolides derived from the natural fermentation products of *Streptomyces* bacteria. Chemically it is mixture of **Emamectin B1a** and **Emamectin B1b**. Chemical name of **Emamectin B1a** is (10E,14E,16E,22Z)-(1R,4S,5'S, 6S,6'R,8R, 12S, 13S, 20R, 21R, 24S)-6'-[(S)-sec-butyl]-21,24-dihydroxy-5',11,13,22-tetramethyl-2-

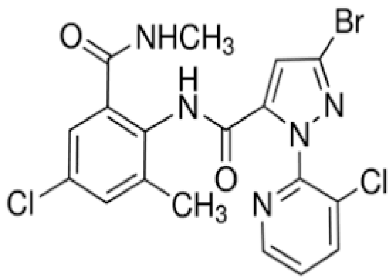
oxo-(3,7,19-trioxatetracyclo [15.6.1. 14, 8. 020, 24] pentacosa -10, 14,16,22-tetraene)-6-spiro-2'-(5',6'-dihydro-2'H-pyran)-12 -yl2,6- dideoxy-3-O-methyl-4-O-(2,4,6-trideoxy-3-O-methyl-4-methylamino-a-L-lyxo- hexapyranosyl)-a-L- arabino-hexapyranoside and **Emamectin B1b** is (10E,14E,16E,22Z)-(1R, 4S, 5'S, 6S, 6'R, 8R, 12S, 13S, 20R, 21R, 24S) 21,24-dihydroxy-6'-isopropyl-5', 11, 13, 22- tetramethyl-2-oxo- (3,7,19 trioxatetracyclo[15.6.1.14, 8.020, 24] pentacosa-10, 14, 16, 22-tetraene)-6-spiro-2'-(5', 6'-dihydro-2'H-pyran)-12-yl 2,6-dideoxy-3-O-methyl-4-O-(2, 4, 6-trideoxy-3-O-methyl-4-methylamino-a-L-lyxo-hexapyranosyl)-a-L-arabinohexapyranoside. Its empirical formula is $C_{49}H_{75}NO_{13}$ (**Emamectin B1a**) and $C_{48}H_{73}NO_{13}$ (**Emamectin B1b**)



It is white or light yellow crystal having vapour pressure of 4×10-6 ± 2×10-6 Pa at 21.1 ± 0.1°C. It is soluble in a number of organic solvents. The water solubility is 8.9 mg/L at 25 ^{0}C. Its toxicity to rats is 76-89 mg kg^{-1} body weight (Acute oral LD_{50}) and > 2000 mg kg^{-1} body weight (Acute dermal LD_{50}). It has insecticidal property works as a chloride channel activator by binding gamma amino butyric acid (GABA) receptor and glutamate-gated chloride channels disrupting nerve signals within arthropods.

2.1.9 Chlorantraniliprole

Chlorantraniliprole is anthranilic diamide insecticide. Chemically it is known as 3-Bromo-*N*-[4-chloro-2-methyl-6-(methylcarbamoyl) phenyl]-1-(3-chloro-2-pyridine-2-yl)-1H-pyrazole-5-carboxamide. Its empirical formula is $C_{18}H_{14}N_5O_2BrCl_2$ with following chemical structure.



Technically it is fine, crystalline and off-white powder having vapour pressure of 6.3 x 10-12 Pa at 20°C, 2.1 x 10-11 Pa at 25°C. It is soluble in most of organic solvent. The water solubility is 0.9-1.0 mg/L at 20 ^{0}C. Its toxicity to rats is >5000 mg kg^{-1} body weight (Acute oral LD_{50}) and > 5000 mg kg^{-1} body weight (Acute dermal LD_{50}). It has insecticidal property, controls pests belonging to lepidoptera and some coleoptera, diptera and isoptera species. It acts on the insect ryanodine receptors (RyRs) and stimulates the release and depletion of intracellular calcium stores from the Sarcoplasmic Reticulum of muscle cells, causing impaired muscle regulation, paralysis and ultimately death of sensitive species.

3. Usage pattern of pesticides in vegetables

3.1 Usage pattern of pesticides in cabbage

Mohayidin *et al.* (1994) surveyed cabbage growing farmers and reported that 58 per cent of farmers found that among insects, particularly *P. xylostella*, required more effort to control during wet season.

Cabbage growers in the Accra-Tema Metropolitan area of Ghana invariably relied on insecticide retailers or agents for advice on the choice and use of insecticides for insect pest control. The pesticides *viz*., *Bacillus thuringiensis* subsp. *Kurstaki* Berliner, lambda-cyhalothrin, chlorpyriphos, dimethoate, deltamethrin, triazophos, cypermethrin, profenophos and pirimiphos methyl were used either in alternation or as mixtures. Pesticides were sprayed frequently at short intervals on cabbage without the consideration of threshold levels (Gbewonyo and Ninsin, 1997).

Waibel and Schmidt (2000) found that the continued higher use of pesticides was a problem for farmer health and the environment. Increased pressure to maintain high levels of cabbage production with high physical quality for both domestic consumption and export resulted in increased use of pesticides on fresh produce.

Muzlon and Mumford (2005) investigated Cameron Highland’s cabbage farmers' knowledge and practices of pest management, particularly the use of pesticides against *Plutella xylostella*. A survey of 99 cabbage farmers was conducted in five different zones in the Cameron Highlands. This survey and others conducted by previous researchers showed little change in farming systems over the past decade. *P. xylostella* remained the major pest in cabbage and more than 90 per cent of farmers used pesticides for control. There were 11 types of insecticides used to control this pest and each farmer usually used 3-4 types of insecticides to control the pest over a season. Both high and low toxicity pesticides were commonly used. The study also revealed that more than 50 per cent of farmers observed 10-14 days pre-harvest intervals, while 4 per cent observed a pre-harvest interval of only 1-4 days.

Katinka and Srinivasan (2009) conducted survey in the states of Gujarat, West Bengal and Karnataka to obtain comprehensive information on pest management practices among farmers growing cabbage and cauliflower in India. Three hundred farmers were interviewed to obtain information on pesticide use in cabbage and cauliflower production, the cost of pesticide use and socio-economic characters that influence cabbage and cauliflower production. They also found that farmers relied on pesticides as the major and often exclusive crop protection strategy. More than one third of farmers (36.60 %) sprayed pesticides before the incidence of pest damage, as a preventive measure. In addition, most farmers (86.90 %) sprayed pesticides when the pest damage was still low. Only 8 per cent of farmers reported considering the level of pest incidences or the level of attack before spraying. The use of non-chemical control methods was very limited among the respondents. Across all three states, 72 per cent of respondents did not use any method other than pesticides to control insect pests.

Nagendra (2009) reported that only 11.6 per cent and 5.8 per cent farmers were aware about pesticide recommendations and contacted agricultural officers respectively, to control pests in cabbage. Further, they reported that only 15 per cent cabbage growers were aware of lethal effects of pesticides on human health and 76.67 per cent farmers did not follow any protective measures while spraying pesticides.

Weinberger and Srinivasan (2009) conducted a survey in the states of Gujarat, West Bengal and Karnataka from October 2006 to January 2007. Three hundred farmers were interviewed to obtain information on pesticide use in cabbage and cauliflower production, the cost of pesticide use, and socio-economic characters that influenced cabbage and cauliflower production.

Studies conducted by Amoako *et al.* (2012) revealed that as many as 26 different pesticides were used to control insect pests in cabbage production. Further, they reported that 8 per cent of the farmers sprayed pesticides between 1 and 5 times in a growing season. Majority (45 %) of the farmers, however, sprayed pesticides between 11 and 15 times within a single growing season of cabbage cultivation to control insect pests. Twenty seven per cent farmers sprayed pesticides between 16 and 20 times within a growing season of cabbage cultivation.

Chandi *et al.* (2012) reported that eighteen insecticides and four mixtures were being used extensively by the vegetable growers of Ludhiana. On an average, 4.9 sprays (3 to 11 sprays) were given by each cabbage/cauliflower grower. Out of these, 12.2 per cent sprays were done with recommended insecticides, 71.9 per cent with non-recommended insecticides and 15.80 per cent with non- recommended mixtures. Spinosad 48 SC and chlorantraniliprole 18.5 SL, being non-recommended, were used to the tune of 28 per cent, while endosulfan (6.30 %) lead in recommended insecticides. Cypermethrin and fenvalerate were the most frequently used mixtures.

Odhiambo *et al.* (2014a) studied the insecticide use pattern in cabbage and observed that the growers sprayed the insecticides frequently and at short intervals with 70 per cent of them spraying at a frequency less than a week. This high frequency of spraying was reflected by 46 per cent farmers who observed pre-harvest interval as short as less than a week. In addition, some of the farmers during heavy pest infestation could spray cabbage and sell them immediately. Subsequently, Odhiambo *et al.* (2014b) conducted a survey at three localities in eastern region of Ghana to determine insecticide use pattern on cabbage farms. The results showed that use of organophosphates was on the rise in the surveyed locations. On the contrary, pyrethroids and biopesticides i.e. *Bt* formulations (Biobit and Dipel) usage had declined over the years. Further, they also reported that insecticides were either sprayed alternatively by 63.30 per cent of the farmers or applied as cocktail mixtures by 36.70 per cent of them.

1.2 Usage pattern of pesticides in other vegetables

Midmore *et al.* (1996) surveyed and found that less than 10 per cent of farmers followed IPM strategies in different vegetables.

Watts (1997) advocated development of a comprehensive pesticide hazard scoring system to guide pesticide usage in New Zealand.

Patrick and Anis (1999) recorded insecticides usage in different vegetables such as potatoes (1.30 kg a.i. ha^{-1} $annum^{-1}$), onions (2.10 kg a.i. ha^{-1} $annum^{-1}$), brassicas

(2.8 kg a.i. ha^{-1} $annum^{-1}$) and field tomatoes (0.02 kg a.i.ha^{-1} $annum^{-1}$). Pesticide use in process vegetables such as asparagus, green peas and sweet corn was relatively low and was mainly concentrated on early season weed and pest control. In contrast, fresh vegetables such as lettuce, brassicas and potatoes tend to had intensive spray programmes throughout the growing season. Onions received very frequent pesticide applications.

Yen *et al.* (1999) conducted survey of local farmers and revealed that a wide range of pesticides such as methamidophos, triazophos, profenophos, diazinon, ethion, pirimiphos methyl, malathion, and dimethoate were used on several crops to control different pests. Application rates exceeding manufacturers' recommendations were common, as was the disregard of recommended pre-harvest intervals after pesticide application.

Khuhro and Nizamani (2000) surveyed vegetable growers and reported that farmers frequently sprayed pesticides 2-3 times in a week and it was their common practice to supply the vegetables to the local market a day after spraying with contamination of residues beyond MRLs.

Sibanda *et al.* (2000) reported that small-scale vegetable farmers used some cultural control methods and occasionally botanical pesticides; the pest control was predominantly by use of synthetic pesticides.

Ananta and Bed (2001) surveyed pocket areas of vegetable production of eastern Chitwan, Nepal during January 2001 and revealed that farmers have very little knowledge or no knowledge about safe use of chemical pesticides. Meanwhile, they were not aware of safe waiting period, environmental and health hazards and all those accidents led by misuse of chemical pesticides. Pesticides used in commercial farming and freshly marketable commodities appears excessively uncontrolled and without consideration of health of consumers.

Epstein and Bassein (2003) surveyed and observed that farmers used more pesticides based on the applications on calendar spray pesticides program without necessarily giving much priority to health and environmental considerations. Results revealed that there was reduction in use of organophosphate insecticides, largely by substitution with pyrethroids. Theoretically, replacement of "calendar spray" pesticide programs with "environmentally driven" programs could reduce pesticide use in years with lower disease pressure, but this assumes that the majority of growers currently use a "calendar spray" program and that growers who use less than recommended by an environmentally driven program would not increase their use.

Farmers were not receiving agricultural extension services and relied heavily on pesticide use when dealing with pest problems but were constrained by the lack of appropriate knowledge (Ngowi 2003).

Mukherjee and Singh (2005) conducted survey in the villages of Karsara, Madaon and Tikari in Varanasi, Uttar Pradesh, India to determine the type and quantity of insecticides used by the farmers. The most commonly used insecticides included endosulfan, methyl parathion, carbofuran, dimethoate, phosphomidon, quinalphos, HCH and in some cases, cartap hydrochloride and DDT.

Jeyanthi and Kombairaju (2005) studied the pesticide use in important vegetable crops, *viz.* chilli, cauliflower, brinjal and bhendi. Average pesticide usage has been estimated at 5.13, 2.77, 4.64 and 3.71 kg a.i. ha^{-1} on chilli, cauliflower, brinjal and bhendi crops, respectively.

Nearly 49 per cent of the farmers were aware of beneficial insects in egg plant fields, but only 26 per cent were aware of the harmful effect of pesticides on natural enemies of fruit and shoot borer. At the same time, 54 per cent of them were aware of the adverse effect of pesticides on eggplant consumers (Baral *et al*. 2006).

Borjan *et al*. (2006) conducted pesticide use survey of licensed pesticide applicators in New Jersey in every three years since 1985 for the purpose of tracking pesticide use amounts and patterns. Information indicated slow increase in golf course and mosquito control pesticide use and slow decrease in agriculture use over the past 20 years, with lawn care pesticide use remaining relatively even.

Pesticide use practices of 137 vegetables growing farmers in Ghana were surveyed by Willam *et al*. (2006). The results revealed that 43 pesticides were used for crop production. The pesticides comprised herbicides (44%), insecticides (23%) and fungicides (23%). Majority of farmers used cypermethrin as the most effective insecticide against insect pests followed by lambda cyhalothrin and endosulfan. The number of spray applications per crop, season, however, varied widely among crops, location and the farmer interviewed in the survey. For instance, in a tomato, farmer sprayed an average of 6-12 applications with 3-6 insecticides on a calendar basis in 90 days season of tomato.

Magdoleen *et al.* (2007) studied seasonal variation of pesticide residues in some salad vegetables in Khartoum State, Sudan. Studies revealed that out of 77 farmers checked for such practices, almost more than one fourth of these farmers used malathion with all the salad vegetables although most of the latter group used this pesticide with tomatoes. About 20 per cent of these farmers used Sevin with all salad vegetables, with emphasis on tomatoes. The remaining farmers exhibited variations in using other pesticides such as cypermethrin (11%) and Sumicidin (8%).

Studies were conducted based on use of questionnaires and interviews for farmers' practices, perceptions and related cost and health effects on vegetable pest management using pesticides. The types of pesticides used by the farmers in the study areas were insecticides (59%), fungicides (29%) and herbicides (10%) with the remaining 2 per cent being rodenticides. Pesticides were bought from pesticides shops (60%), general shops (30%) and cooperative shops (10%). More than 50 per cent of the respondents applied pesticides up to 5 times or more as per cropping season depending on the crop. Insecticides and fungicides were routinely applied by 77 per cent and 7 per cent, respectively. About 53 per cent of the farmers reported that the trend of pesticide use was increasing, while 33 per cent was constant and 14 per cent was decreasing. Whereas, 68 per cent of farmers reported having felt sick after routine application of pesticides. Pesticide-related health symptoms that were associated with pesticide use included skin problems and neurological system disturbances (Ngowi *et al*. 2007).

Nagenthirajah and Thiruchelvam (2008) reported that 60 per cent farmers were aware of pesticide recommendations and only 6 per cent of the farmers had good level of knowledge towards the recommended plant protection measures.

Xu *et al*. (2008) revealed that more than 50 per cent of farmers attempted to control the pest outbreak by increasing the frequency and dosage of pesticides, as well as to combine them in a tank mixture when pest organism was reluctant to respond to single kind of pesticide. Farmers were also tend to ignore the recommended pre-harvest interval written on the label in order to keep the good appearance of vegetable products.

Mahantesh and Alka Singh (2009) conducted a survey on farmer's knowledge, perception and intensity of pesticide use in vegetable cultivation in western Uttar Pradesh. The result showed that on an average 41 per cent of the farmers were aware about pesticide hazards in vegetable cultivation. It was also observed that farmers did not follow adequate safety measures regarding pesticide application and most of the pesticides belonged to high and moderate risk chemicals.

Plianbangchang *et al.* (2009) surveyed 130 small-scale farmers regarding pesticide use patterns in rural Phitsanulok, Northern Thailand using a structured questionnaire. The results indicated that pesticides were readily available and widely used in crop production, pesticide use was inappropriate; farmers did not wear suitable personal protection, apply pesticides in an appropriate fashion, or discard the waste safely.

Devi (2010) conducted survey on pesticide usage pattern against bitter gourd in Kerala and revealed that out of 15 pesticides, eight insecticides, four fungicides, one herbicide and rest were plant growth stimulators. Further, farmers changed the chemicals in each spray. Acetamiprid was used six times, phorate and dimethoate five times each. Quinalphos and indoxacarb four times each and rest 3 to 4 times during a crop cycle of 90 days in bitter gourd in all total 50 sprays.

Shetty *et al.* (2010) conducted intensive survey involving 1039 farmers belonging to 28 districts of 12 states in India, to study the influence of farmer's awareness, education and practices related to pesticide use as well as Integrated Pest Management (IPM) measures. Survey revealed that more than 50 per cent of the respondents applied both single and cocktail pesticides to manage their crop pests. Only 20 per cent of the respondents obtained their information on plant protection aspect from the agricultural extension officer.

Al-Sayed *et al.* (2011) carried out a survey of farmers (n=126) in five districts of the West Bank and Gaza Strip, where pesticides were mostly used on irrigated land cultivated with vegetables. Data analysis of received questionnaires revealed that total number of 217 pesticides including 13 soil sterilizers, while 134 kinds with different active ingredients (insecticides 62; fungicides 45; herbicide 20) were applied in all districts. Based on the total irrigated land cultivated, the rate of pesticides per annum per farmer reached 0.77 L in Gaza Strip and 0.18 L in the West Bank districts.

Nyakundi *et al.* (2011) surveyed 100 respondents for pesticide usage pattern against major horticultural crops in Kenya during 2009-10. Results indicated that 62 per cent respondents were using recommended dosage of pesticide and 12 per cent used above recommended dosage. Most commonly used insecticides were methomex 90 SP and diazo 60 EC. All pesticides were stated by their trade names without any awareness of the common names.

According to Kamarulzaman *et al.* (2012), there were great challenges to promote biopesticides usage among vegetable farmers though it had proven to be able in controlling pest. Unfortunately, the lack of understanding on the benefits of biopesticides and less promotion towards the usage was the common reasons for the less use of this alternative product than synthetic pesticides in vegetable productions. Therefore, it was not surprisingly found that only few farmers in the study preferred to apply biopesticides though it had safety advantages to synthetic pesticides.

Survey on pesticide usage pattern in Ahmednagar district revealed that the farmers used 5.504 kg a.i. ha^{-1} $year^{-1}$ synthetic insecticides against *S. litura*. Organophosphates, carbamates, synthetic pyrethroids and oxadiazines were used at 2.231, 0.400, 0.767 and 0.036 kg a.i. ha^{-1} $year^{-1}$, respectively (Patil, 2012).

Tibugari *et al*. (2012) reported that, in African countries, there was a great reliance on broad spectrum insecticides such as pyrethroids, organophosphates and carbamates, that are applied weekly or twice per week. Use of unregistered insecticides has also been reported.

Dey *et al*. (2013) studied the pesticide use pattern in the three districts of Barak valley, Assam and revealed that the farmers often used pesticides ranging from high to extremely hazardous categories like organochlorine, organophosphate and carbamate. Various signs and symptoms of diseases/ physiological disorders were observed and the relative risk was also observed to be high. Lack of adoption of adequate protective measures were noticed to have increased the declining state of the health of farmers in the region.

Banerjee *et al.* (2014) studied the pesticide use pattern among farmers in the district of Burdwan of West Bengal, India and observed that alpha-cypermethrin (46%) was the most commonly used pesticide followed by methyl parathion (25.60 %), imidacloprid (16.40%), dichlorvos (7.80%) and phorate (4.20%).

Sutharsan *et al*. (2014) conducted a study to find out pesticide usage practices of farmers on vegetable cultivation in Batticaloa district, Sri Lanka. It was observed that the usage of pesticides was higher in the studied area. Around 90 per cent of the farmers applied more than the recommended dosage and frequency of the pesticides. It was noticed that more than 89 per cent of the farmers harvested their produce before the recommended pre harvest interval.

Tandi *et al*. (2014) studied the perception on pesticide usage and practices in Buea Cameroon. They conducted survey of 93 small-scale tomato cultivators. It was observed that many farmers (47.60%) used pyrethroid and organophosphorus insecticides and identified these chemicals as the most effective in pest control. Most farmers (83.80%) used knapsack sprayers to apply pesticides, with 76.30 per cent using no or partial personal protective equipment (PPE). Most farmers (85%) reported at least one symptom of acute pesticide poisoning following spraying.

Afari Sefa *et al.* (2015) reported that 43 pesticides were found in use for vegetable farming in the Ashanti and Western regions of Ghana. The pesticides consisted of 7 fungicides, 9 herbicides and 30 insecticides. It was important to note that one systemic insecticide, carbofuran was used by most farmers both as an insecticide and nematicide as they perceive and have also found it effective in the short run. The class of pesticides commonly used by vegetable farmers in the surveyed area was insecticide (61.7%), followed by fungicide (32.7) and herbicides (5.5%).

Deviprasad *et al*. (2015) studied the pesticide use pattern in four districts of Karnataka. The results indicated that majority of the farmers were used synthetic pesticide formulations as crop protection to combat various pests and insects. The widely used insecticides were chlorpyriphos, monocrotophos, cypermethrin, quinalphos, fungicides included copper oxide, bavistin, mancozeb, glyphosate and paraquat were used under herbicides group. Survey results further revealed that, multiple formulations of pesticides were used for a single crop.

Prashar *et al*. (2015) studied the pattern of pesticide usage and management among 100 farmers in cauliflower and tomato cultivating areas of Faridabad district of Hariyana, India using structured questionnaire, interviews and group discussions. The results revealed that cypermethrin and profenophos were found as the most popular insecticides and 56 per cent of the farmers did not adopt any safety measures and precautions while applying the pesticides.

Ramakrishnan *et al*. (2015) surveyed farmers regarding insecticide usage pattern in curry leaf and revealed that about 62 per cent of farmers used insecticides at 10 day intervals. Only 16 per cent of farmers had knowledge on natural enemies, use of plant products and fungal bioagents. Around 50 per cent of farmers use 30 mL/tank of insecticides. About 84 per cent of farmers got plant protection advice from pesticide dealers. Further, it was concluded that extension educational interventions were necessary to produce fresh curry leaf free from insecticide residues.

Sharaniya and Loganathan (2015) surveyed 120 randomly selected farmers among vegetable cultivators in Vavuniya district in Shri Lanka and revealed that all farmers were dependent on synthetic pesticides for the management of pest and 51 per cent of the farmers applied the pesticides 10-20 per cent higher than recommended level. About 62 per cent of the farmers used banned pesticides and 95 per cent of farmers read the instructions given in the label but they did not followed the label. Around 60 per cent of the farmers harvested the products within seven days though the pre-harvest interval for most vegetables is 14 days.

Dhore (2016) conducted survey of 25 brinjal farmers on insecticide use pattern in predominant brinjal growing area of Rahuri Tahsil (Ahmednagar district) during June to August, 2015. Results revealed that 8.595 kg a.i.ha^{-1} organophosphorus insecticides were used against insect pest of brinjal in Ahmednagar.

Halimatunsadiah *et al*. (2016) conducted a survey of 85 lowland vegetable farmers to collect information on their pest management practices in farms. Results showed that the pesticide application by farmers on vegetables crops indicated a calendar spraying practices. In most cases, farmers tend to harvest the vegetable products shortly after a few days of last pesticide spraying. In order to enhance the food safety control starting from the primary production, extensive monitoring of the current pesticide usage by farmers in vegetable productions was vital to provide an updated data on the food safety risk regarding the pesticide residues.

Raut (2016) conducted a survey on pesticide usage pattern in chilli and revealed that the farmers used 5.87 kg a.i ha^{-1} of organophosphorus insecticides in chilli. Similarly, Sali (2016) conducted a survey on pesticide use pattern in tomato and revealed that the farmers were used 5.67 kg a.i ha^{-1} organophosphorus insecticides against insect pests of tomato.

Patil (2017) reported that usage of insecticides as 6.36, 6.17 and 5.46 kg a.i. ha^{-1} $season^{-1}$ from Ahmednagar, Pune and Jalgaon, respectively in brinjal. Further, studies reported that 6.16, 5.50 and 6.55 kg a.i. ha^{-1} $season^{-1}$ of insecticides used by tomato growers in Ahmednagar, Pune and Nashik, respectively.

Sneha *et al.* (2017) conducted a survey of black gram farmers from Nizamabad district of Andhra Pradesh. Survey revealed that 40 per cent of the farmers were aware of recommended pesticides used against different pests. Farmers followed common waiting period of 7 days (63.33 %) followed by 4 days (26.66 %) and 2 days (10 %). About 16.66 per cent of the farmers were aware of the fact that pesticide residues are found in vegetables. Studies also revealed that more than 85 per cent farmers did not know about any kind of bad effects due to pesticide residues.

4. Bio-efficacy of newer insecticides against diamondback moth (*P. xylostella* L.)

4.1 Bio-efficacy of conventional insecticides

Singh *et al*. (1976) reported that application of quinalphos at the rate of 0.25 kg a.i. ha^{-1} resulted in 100 per cent mortality of larvae within 48 h of spraying.

Application of quinalphos, methamidophos, dioxathion or endosulfan at 0.5 kg a.i. ha^{-1} gave effective control of diamondback moth larvae (Krishnaiah and Mohan, 1977).

Rosli *et al*. (1979) revealed that acephate, methamidophos and bendiocarb all at 0.1% a.i. ha^{-1} , *Bacillus thuringiensis* at 1 g/L, diflubenzuron at 0.007 % a.i. ha^{-1}

caused significant reduction ($P \leq 0.05$) in larval population. These insecticides were also provided equal protection against larval damage of DBM on leaves of cabbage. Consistently, the control plots gave significantly lower yield ($P \leq 0.05$) of marketable heads as compared to the insecticide treated plots.

Calderon and Hare (1986) reported that profenophos effectively reduced the population of *P. xylostella* larvae in crucifers.

Leibee and Savege (1992) demonstrated that chlorpyriphos, endosulfan, mevinphos and *B.t.* var. *Kurstaki* were more effective than cypermethrin.

Andaloro *et al.* (1993) reported that methamidophos and pyrethroids consistently proved the most effective control of lepidopteron pests in cabbage.

Nagesh and Verma (1997) conducted a field trial during 1995-96 at IARI, New Delhi, India to determine the comparative efficacy of certain eco-friendly biopesticides (neem, *Bt*, diflubenzuron, lufenuron and cartap hypochloride) and synthetic organic insecticides (endosulfan, chlorpyriphos, quinolphos, phosalone and cypermethrin) against DBM. Cartap followed by lufenuron and *Bt* were found to be the most effective against DBM in comparison with other insecticides.

Sprays of malathion, carbaryl, endosulfon, deltamethrin and cartap hydrochloride were recorded more effective against diamondback moth (Rao and Lal, 2001).

Tambe and Mote (2003) conducted field experiment on spinosad 2.5% SC @ 10, 12.5, 15, 17.52 and 25 g a.i. ha^{-1} in comparison with microbial insecticide, Dipel 8L (*B. thuringiensis*) @ 1000 ml ha^{-1} and conventional insecticides, quinalphos 25 EC @ 250 g a.i. ha^{-1} and chlorpyriphos 20 EC @ 400 g a.i. ha^{-1}. Spinosad 2.5 SC @ 20 g a.i. ha^{-1} was found to be significantly superior to the remaining treatments in reducing the infestation of the DBM larvae at 2 and 6 days after application and increased the yield of marketable cabbage head.

Ameta *et al.* (2008) reported that bifenthrin 10 EC @ 80 g a.i.ha^{-1} was effective against brinjal pest complex (Shoot and fruit borers, Leafhopper and Whitefly). The highest marketable yield of 237.6 and 255.9 q ha^{-1} was recorded in case of bifenthrin

10 EC at the rate of 160 g a. i.ha^{-1} which was at par with its lower dosages (120 and 80 g a.i.ha^{-1}).

The effectiveness of bifenthrin 10 EC (1000 ml ha^{-1}) against bollworms was on par with bifenthrin 10 EC (800 and 600 ml ha^{-1}), standard check, spinosad 45 SC (175 ml ha^{-1}) and indoxacarb 14.5 SC (500 ml ha^{-1}) (Balakrishnan *et al.* 2009).

Chlorpyriphos 20 % EC, chlorpyriphos 50 % EC + cypermethrin 5 % EC and permethrin 25 % EC recorded 100 per cent mortality of *P. xylostella* at one day after spraying followed by malathion 50 % EC (0.50 larva per plant) (Boopathi *et al*. 2010)**.**

Sinha and Sharma (2010) recorded treatment with bifenthrin 10 EC registered lowest yield (24.93 MT ha^{-1}) and cost benefit ratio (1:3.16) in brinjal.

Higher larval population of *T. absoluta* (1.0 to 2.0 larvae plant^{-1}) was observed after 2nd spray when tomato crop was applied with bifenthrin 10 EC (Mohamed and Lobna, 2012).

Ravi *et al*. (2014) evaluated the efficacy of different insecticides *viz*., emamectin benzoate 5 SG @ 11 and 22 g a.i. ha^{-1}, profenophos 50 EC @ 500 and 1000 g a.i. ha^{-1}, spinosad 45 SC @ 100 g a.i. ha^{-1}, bifenthrin 10 EC @ 100 g a.i. ha^{-1} and *Bt* @ 25 g a.i. ha^{-1} against tomato fruit borer (*H. armigera*). Among all the insecticides, profenophos (1000 g a.i. ha^{-1}) was found to be the most effective with maximum reduction in larval population (65.20 %), minimum per cent fruit damage (28.80 %) and maximum yield (11.21 tonne ha^{-1}) followed by bifenthrin @ 100 g a.i.ha^{-1} with reduced larval population of 64.51 per cent, 32.60 per cent damaged fruits and 12.67 tonne ha^{-1} yield. Also, spinosad 45 SC @ 100 g a.i. ha^{-1} was found effective both in reducing larval population (47.29 %) as well as maximizing yield (12.22 tonne ha^{-1}) of tomato over control.

Bifenthrin 10 EC @ 100 g a.i.ha^{-1}, applied twice as foliar spray was found to be the most effective in controlling the *P. xylostella* (Reddy *et al*. 2014c).

Bifenthrin 10 EC recorded 11.11 and 6.54 per cent leaf damage in I & II trial, respectively during 2011 against *Antigastra catalaunalis* in sesame (Shasikumar and Kumar, 2015).

Four sprays of bifenthrin 8 SC @ 200 g a.i. ha^{-1} was effective with the lowest mean per cent damage of 1.1 and 1.2 per cent on shoot basis, 9.44 and 7.0 per cent on number basis and 7.0 and 4.9 per cent on weight basis in *Kharif* and *Rabi* season, respectively followed by bifenthrin 8 SC @ 160, 140 and 120 g a.i. ha^{-1}. The highest marketable yield of 6.9 and 10.0 tonne ha^{-1} was recorded in case of bifenthrin 8 SC @ 200 g a.i. ha^{-1} (Ram and Kumar, 2015).

Dhaka *et al*. (2016) reported 10.0 to 11.6 per cent shoot damage and 10.0 and 15.3 per cent fruit damage during 7th and 14th DAS of observations. Yield of 80.96 q ha^{-1} with ICBR of 1:1.78 was recorded against *E. vitella* due to the application of bifenthrin 10 EC in okra.

Deepak *et al*. (2017) recorded higher fruit damage caused by *E. vittela* on number basis (29.29%) and weight basis (24.47%) after 2nd spray when okra crop was applied with bifenthrin 10 EC @ 80 g a. i. ha^{-1}.

Prashanthi *et al*. (2017) evaluated efficacy of chlorantraniliprole 18.5 SC @ 0.4 ml L^{-1}, indoxacarb 15.8 EC @ 0.5 ml L^{-1}, fipronil 5 % SC @ 2.0 ml L^{-1}, flubendiamide 480 SC @ 0.15 ml L^{-1}, bifenthrin 10 EC @ 1.0 ml L^{-1}, azadirachtin 10000 ppm @ 1.0 ml L^{-1}, *Ha*NPV 0.43 % AS @ 1.0 ml L^{-1}, novaluron 10 EC @ 1.0 ml L^{-1} and spinosad 2.5 SC @ 0.3 ml L^{-1} against gram pod borer. Plots treated with chlorantraniliprole 18.5 SC @ 0.4 ml L^{-1} recorded lower larval population (2.15 larvae $plant^{-1}$) over control with 9.49 q ha^{-1} of yield followed by bifenthrin 10 EC @ 1 ml L^{-1}(2.96 larvae $plant^{-1}$ with 8.54 q ha^{-1} yield).

Reddy *et al.* (2017) recorded profenophos (1000 g a.i.ha-1) was found to be the most effective one with a maximum reduction in *P.xylostella* population (70.20%), followed by bifenthrin 10 EC at 100 g a.i.ha-1 (68.18%). Further, recorded 59 per cent reduction in larval population of *P. xylostella* following the application of spinosad 45 SC @ 100 g a.i.ha^{-1} on cabbage.

4.2 Bio-efficacy of newer insecticides

Peter *et al.* (2000) evaluated commercial formulation, spinosad 2.5 % SC against cabbage pest. Spinosad was better in controlling diamondback moth (*P. xylostella*), cabbage stem borer (*Hellula undalis* F.), cabbage leaf webber (*Crocidolomia* *binotalis* Z.) when applied @ 15, 20 and 25 g a.i. ha^{-1}. They also reported that spinosad persisted for 7 days.

Setiawati (2000) reported that the use of spinosad, could reduce the number of insecticide sprays by 60 to 75 per cent and gave good yield. The results indicated that spinosad 25 SC was effective in controlling DBM and cabbage head borer in cabbage. It was further revealed that spinosad was suitable for IPM in cabbage, for its selectivity towards the natural enemy of the pest.

Umeda *et al.* (2000) followed two sprays of RH-2485, Success, Proclaim, Avaunt, and Larvin against DBM. The second application of Success and Proclaim gave complete control of DBM within one week. Its effect continued to offer very good control of DBM for two weeks after the second application.

Dey and Somchaudhary (2001) evaluated spinosad against lepidopteran pest complex of cabbage under field conditions. They reported that spinosad was effective in controlling *P. xylostella* and *S. litura* on cabbage @ 15-25 g a.i. ha^{-1}.

Abhishek (2002) conducted field experiment on bio-efficacy of some insecticides *viz.*, Beta-cyfluthrin, *Bt. krustaki*, azadirachtin, spinosad, diflubenzuron and endosulfan against *P. xylostella* in cabbage. Results revealed that significant effect of spinosad @ 12.5 g a.i.ha^{-1} was observed at 1^{st} and 2^{nd} spray on cabbage during year 2001-2002. The per cent reduction in population recorded in the range of 37.61 to 56.79 per cent during 1^{st} spray and 36.70 to 46.87 per cent during 2^{nd} spray at 1, 3, 7, 10 and 14 days after sprays, respectively. Higher yield of cabbage to the tune of 172.64 q ha^{-1} with higher C:B ratio (1:6.55) over untreated control was registered following the application of spinosad 45 SC @ 12.5 g a.i ha^{-1}.

Pramanik *et al*. (2003) determined the comparative efficacy of chemical insecticides (novaluron, acetamiprid and cartap hydrochloride) and microbial insecticides (*B. thuringiensis* subsp. *kurstaki*, spinosad and abamectin) against the DBM infesting cabbage under field condition. Spinosad at 0.005 % was most effective in reducing the pest population and increased the yield of the crop over rest of the insecticides. The order of average efficacy of different insecticides was spinosad > *B. thuringiensis* subsp. *Kurstaki* > abamectin > cartap hydrochloride > acetamiprid > novaluron.

Kanna *et al.* (2005) showed excellent efficacy of emamectin benzoate by way of reducing the population of *P. xylostella* up to 81.20 per cent and maintained the status till 14 days which was comparable with spinosad 15 SC (12.5 g a.i. ha^{-1}).

Spinosad 2.5 SC @ 12.5, 15.0, 17.5 and 20.0 g a.i. ha^{-1}, was evaluated in comparison with chlorpyriphos, quinalphos, cypermethrin and *Bt* against DBM infesting cauliflower on farmers field. Results revealed that spinosad 2.5 SC @ 15 g a.i. ha^{-1} gave significantly better control of DBM larvae for a period of one week (Mohite and Patil, 2005).

Suganyakanna *et al.* (2005) conducted field trials on cabbage to evaluate the efficacy of different insecticides against DBM. Results showed that emamectin benzoate 5 SG at 10 g and 8.75 g a.i. ha^{-1} were reported to be more effective against the pest when compared to profenophos 50 EC @ 750 g a.i. ha^{-1} and lambda cyhalothrin 5 EC @ 30 g a.i. ha^{-1} by recording highest yield of 36 and 37.7 tonnes ha^{-1}, respectively.

Kumar and Devappa (2006) carried out the field experiments to evaluate the bio-efficacy of emamectin benzoate (5% SG) against diamondback moth and recorded that emamectin benzoate @ 150 and 200 g a.i ha^{-1} was found to be effective in reducing the larvae and increasing the yield of cabbage.

Shivalingaswamy *et al.* (2006) evaluated the field efficacy of different insecticides against DBM infesting cauliflower under field conditions. The lowest larval population (0.2 larvae $plant^{-1}$) was recorded in spinosad (20 g a.i. ha^{-1}) treated plots as against precount (2-3 larvae $plant^{-1}$). Spinosad performed better among *Bt* and other conventional insecticides in the management of DBM.

Hiramoto (2007) reported that after two treatments, chlorantraniliprole proved the most effective against *P.xylostella* in cabbage.

Muthukumar *et al*. (2007) evaluated different insecticides for the control of DBM. The results revealed that maximum mean per cent reduction of larval population of DBM was recorded 76.40 and 67.30 per cent (Spinosad @ 75 g a.i.ha^{-1}), 80.30 and 78.80 per cent (Emamectin benzoate @ 10 g a.i.ha^{-1}), 66.80 and 63.90 per cent (Cartap hydrochloride @ 250 g a.i.ha^{-1}) and 70.80 and 70.90 (Indoxacarb @ 75 g a.i.ha^{-1}) after the first and second spraying, respectively.

Prashant *et al.* (2007) registered higher marketable yield (205.56 q ha^{-1}), maximum net profit (Rs. 15626.00) and higher cost benefit ratio of 1:7.55 over untreated control from the plots treated with spinosad (15 g a.i. ha^{-1}) against *P. xylostella* in cabbage.

Gill *et al*. (2008) determined the efficacy of new insecticides *viz*., spinosad 2.5 SC @ 600 ml ha^{-1}, emamectin benzoate @ 170 g ha^{-1} and indoxacarb 15 EC @ 333 ml ha^{-1} for the control of *P. xylostella* on cauliflower and cabbage under field condition. These insecticides were compared with conventional insecticides, endosulfan 35 EC @ 1000 ml ha^{-1} and cartap hydrochloride 50 SP @ 500 g ha^{-1}. All the three new insecticides resulted in significantly maximum reduction in *P. xylostella* larval population ranged from 84.54 to 93.58 and 89.24 to 91.49 per cent on cauliflower and cabbage crop respectively.

Khan *et al.* (2008) evaluated multiple applications of spinosad, emamectin benzoate, *B. bassiana*, azadirachtin and *B. thuringiensis* for control of diamondback moth. It was revealed that spinosad and emamectin benzoate were the most effective in consistently providing excellent control of DBM populations as compared to azadirachtin, *B. bassiana* and *B. thuringiensis.*

Mishra (2008) evaluated rynaxypyr 20 SC in field against brinjal shoot and fruit borer and reported that the treatment with rynaxypyr 20 SC @ 40-50 g a.i. ha^{-1} was most effective by recording 95-97 per cent reduction in the shoot damage and 87-90 per cent reduction in fruit damage on number basis and 88-90 per cent on weight basis. Highest yield was registered (20.73 tonne ha^{-1}) with chlorantraniliprole @ 40 and 50 g a.i.ha^{-1}.

Jagginavar *et al.* (2009) compared the bio-efficacy of flubendiamide 480 SC (Fame) at three concentrations of 60, 72 and 90 g a.i. ha^{-1} with five other insecticides against brinjal fruit and shoot borer, *L. orbonalis* (G). Flubendiamide 480 SC @ 90 and 72 g a.i. ha^{-1} were found to be significantly superior over other treatments.

Mandal *et al.* (2009) conducted a field trial by using spinosad (Spinotor 45 SC 0.4 ml L^{-1}), thiamethoxam (Actara 25 WSG 0.4 g L^{-1}) and emamectin benzoate (Proclaim 5 WSG 0.3 g L^{-1}) at 10-day interval for the control of the diamondback moth on cauliflower. Result revealed that spinosad was found superior over all other packages in terms of significantly lower larval count (1.64 larvae plant^{-1}) and significantly higher yield (198.16 q ha^{-1}).

Tatagar *et al.* (2009) conducted field experiment to test the bio-efficacy of a new molecule, flubendiamide 20 WG against chilli fruit borers, *H. armigera* and *S. litura*. Among different dosages, flubendiamide 20 WG @ 60 g a.i. ha^{-1} recorded highest yield of 7.48 q ha^{-1} with 1:4.97 ICBR and lowest fruit damage of 3.45 per cent followed by flubendiamide 20 WG @ 40 g a.i. ha^{-1} (6.72 q ha^{-1} with 1:5.02 ICBR), emamectin benzoate 5 SG @ 11 g a.i. ha^{-1} (7.22 q ha^{-1} with 1:3.87 ICBR) and spinosad 45 SC @ 75 g a.i. ha^{-1} (7.32 q ha^{-1} with 1:3.82 ICBR).

Vishwakarma *et al.* (2009) conducted field experiments during winter crop season of 2007-08 and 2008-09 on the impact of two plant extracts and an entomopathogenic fungus in reducing diamondback moth incidence in red cabbage. Emamectin benzoate + *B. bassiana* when used @ 3.0+0.75 g L^{-1}. water was found to be superior in producing 98.03 per cent larval mortality followed by emamectin benzoate + *B. bassiana* @ 2.5+0.50 g L^{-1}. of water with 96.54 per cent reduction in population of diamondback moth. The minimum mortality was recorded (53.63 %) to *Pachyrhizus erosus* at 2.0 ml L^{-1}. of water compared with untreated control.

Sharma and Saika (2009) recorded lowest population of pests on cabbage due to the application of spinosad @ 45 SC. Imidacloprid 17.8 SL + spinosad 2.5 SC @ 26.70 + 18.75 g a.i.ha^{-1} was recorded the lowest population of *P xylostelIa* i.e 2.33, 4.74, 10.26 and 17.94 larvae/10 plants on 3th. 7th, 10th and 14th day after spraying, respectively. It was followed by spinosad 45 SC @ 96.4 g.a.i.ha^{-1} (2.55, 5.00, 12.05 & 19.96 larvae 10 plants^{-1}) and indoxacarb 14.5 SC @ 73 g a.i.ha^{-1} (2.73, 5.13, 13.45 & 22.51 larvae/10 plants) on 3th, 7th, 10th and 14th days after spraying, respectively.

Sable *et al*. (2007) recorded least larval population of *P. xylostella* (2.55, 5, 12.05 and 19.96 larvae/10 plants) at 3rd, 7th, 10th and 14th days after spray, respectively. The highest cabbage yield was recorded 239.92 q ha^{-1} in plots treated with imidacloprid + spinosad which was significantly superior over spinosad @ 45 SC (214.42 q ha^{-1}) and indoxacarb @ 14.5 SC (206.94 q ha^{-1}), respectively.

Gill *et al*. (2010) compared the bio-efficacy of new insecticide i.e. flubendiamide 480 SC (NNI 0001) with cartap (50 SP) and endosulfan 35 EC against *P.*

xylostella under field conditions on cabbage. Four experiments were conducted during 2006 and 2007. Flubendiamide 480 SC @ 37 and 50.0 ml ha^{-1} significantly reduced the larval population and increased the marketable yield. Flubendiamide 480 SC @ 25.0 ml ha^{-1} and cartap 50 SP were at par in reducing population and increasing the yield.

Puja and Jandial (2010) studied bio-efficacy of some eco-friendly insecticides against *P. xylostella.* Spinosad was most effective against *P. xylostella,* which recorded overall mean population of 0.55 larvae $plant^{-1}$ followed by *Bt* (0.70 larvae $plant^{-1}$).

Liang *et al*. (2011) tested five new pesticides against *P. xylostella* on cabbage in field trial. The results revealed that avermectin, chlorobenzene acid 6 % SC, chlorobenzene 14 %, Lambda cyhalothrin 5 % SC and flubendiamide 20 % WDG had significant effect on *P. xylostella* with the control efficacy over 86 per cent and 98 per cent at 3rd and 14th day after the treatments. It also revealed that these pesticides had effective period more than 15 days in the field.

Jugal (2011) revealed that the highest per cent (83.97, 86.23 & 84.98 %) reduction in larval population of *P. xylostella* at 1st, 2nd and 3rd spray, respectively after the application of spinosad 2.5 SC on cabbage. The higher (173.17 q ha^{-1}) yield of cabbage heads was obtained from the plots treated with spinosad 45 SC.

Chlorantraniliprole (18.5% SC @ 10 g a.i.ha^{-1}) showed highest per cent reduction over control of diamond back moth, *Plutella xylostella* (83.65 and 82.08) and cabbage butterfly, Pieris brassicae (84.42 and 84.54) at 3rd day after 3rd spray during 2009–10 and 2010–11,respectively (Venkateswarlu *et al*.2011).

Han *et al*. (2012) reported chlorantraniliprole had a high level of toxicity against larvae of *P. xylostella,* and the 48 h LC_{50} values were 0.23 and 0.25 mg L^{-1} for a susceptible and field strain, respectively.

Ratnsari (2012) revealed efficacy of different novel insecticides against defoliator pests of cabbage and found that higher net profit with higher ICBR (1:11.49) was obtained through the use of chlorantraniliprole 18.5 SC.

Shah *et al*. (2012) conducted field trial on bio-efficacy of different insecticides *viz*., emamectin benzoate (0.0025 %), flubendiamide (0.01%), rynaxypyr (0.006 %), lufenuron (0.005 %), novaluron (0.01%), indoxacarb (0.007 %), thiodicarb (0.075 %), spinosad (0.0135 %), endosulfan (0.07 %), dichlorvos (0.076 %) and fenvalerate (0.01 %) against *Leucinodes orbonalis* in brinjal. Higher yield (39.86 q ha^{-1}) with higher incremental C:B ratio (1:6.10) was obtained following the application of flubendiamide 480 SC.

Jat and Ameta (2013) revealed that flubendiamide 480 SC @ 200 mL ha^{-1} was found significantly most effective, which caused highest per cent reduction of tomato fruit borer (89.94 %) and fruit damage (3.10 %). The highest marketable yield of 265.68 q/ha was recorded from flubendiamide 480 SC @ 200 mL ha^{-1} with highest C: B ratio of 1:2.075 followed by spinosad 45 SC @ 200 ml ha^{-1} (251.29 q ha^{-1}) and Beta-cyfluthrin 2.5 SC @ 750 ml ha^{-1} (238.38 q ha^{-1}).

Meena and Singh (2013) observed spinosad 0.002 per cent was most effective in reducing the larval population of *P. xylostella* followed by indoxacarb 0.01 per cent and Dipel 0.2 per cent, respectively. The highest yield of cabbage heads was recorded in spinosad (233.5 q ha^{-1}) followed by indoxacarb (226.8 q ha^{-1}) and *B. thuringiensis* (224.9 q ha^{-1}). The incremental C:B ratio of 90.5 was obtained from the treatment of spinosad.

Meena *et al*. (2013) demonstrated that the maximum reduction in larval population (0.17 to 0.47 larvae $plant^{-1}$) as well as lowest fruit damage (3.13%) was observed from flubendiamide 39.35 SC @ 60 g a.i. ha^{-1} treated plots followed by lower dose of 48 g a.i. ha^{-1} (0.20 to 0.67 larvae $plant^{-1}$ & 4.17 % fruit damage) against *S. litura* in chilli. Higher yield of 9.71 q ha^{-1}, maximum benefit (Rs.65700/-) and highest ICBR of 1:6.48 was registered due to the application of flubendiamide 39.35 SC @ 48 g a.i. ha^{-1} followed by its higher dose (60 g a.i. ha^{-1}).

Nikam (2013) demonstrated that spinosad was most effective on the basis of larval count and yield of marketable cabbage head followed by emamectin benzoate, chlorantriniliprole and flubendiamide. The larval count and yield of marketable cabbage heads in the different treatment ranged from 0.27 to 0.89 larvae $plant^{-1}$ and 250.88 to 189.60 q ha^{-1}, respectively as against 9.16 and 103.56 q ha^{-1} in untreated control. Among all insecticides, spinosad was recorded less number of larvae (0.27 larvae plant^{-1}) with the highest marketable cabbage yield (250.88 q ha^{-1}).

Chauhan *et al*. (2014) evaluated different indecticides *viz*., spinosad 2.5 SC @ 25 g a.i.ha^{-1}, alphamethrin 10 SC @ 50 g a.i.ha^{-1} , cypermethrin + chlorpyriphos 55 EC @ 1100 g a.i.ha^{-1}, cypermethrin 25 EC @ 75 g a.i. ha^{-1} g a.i.ha^{-1}, indoxacarb14.5 SC @ 350 g a.i.ha^{-1}, endosulphan 35 EC @ 450 g a.i. ha^{-1}, cartap hydrochloride 50 SP @ 400 g a.i.ha^{-1}, and NSKE 5 % @ 3250 g a.i.ha^{-1} against diamondback moth (*Plutella xylostella* L.) on cauliflower. Higher diamondback moth control and maximum marketable yield was recorded in spinosad 2.5 SC @ 25 g a.i. ha^{-1} (59.71 %) followed by indoxacarb 14.5 SC @ 350 g a.i. ha^{-1} (53.56 %).

Sunitha (2014) determined the bio-efficacy and relative toxicity of different insecticides *viz*., flubendiamide, spinosad, indoxacarb, fipronil, chlorantraniliprole, emamectin benzoate and chlorfenapyr against *Plutella xylostella* in cabbage. Among all the insecticides, chlorantraniliprole @ 30 g a.i ha^{-1} proved effective which recorded least larval population (0.82 larvae plant^{-1}), highest per cent larval reduction (88.60 %) and highest yield of marketable cabbage heads (230.38 q ha^{-1}) followed by flubendiamide, indoxacarb and spinosad.

Vaseem *et al*. (2014) evaluated the bio-efficacy of newer insecticides *viz*., Coragen 18.5 SC, spinosad 45 SC, indoxacarb 14.5 SC, lambda cyhalothrin 5 EC, thiamethoxam 25 WG and carbosulfan 25 EC against diamondback moth (*P. xylostella*) on cabbage under polyhouse condition. The most effective treatment was coragen @ 50 ml ha^{-1} in reducing the infestation of diamondback moth followed by spinosad @ 150 ml ha^{-1}, indoxacarb @ 230 ml ha^{-1}, lambda cyhalothrin @ 300 ml ha^{-1}, thiamethoxam @ 75 gm ha^{-1} and carbosulfan @ 800 ml ha^{-1}. However, carbosulfan 25 EC was found least effective but was significantly superior over control. The maximum net return was obtained from indoxacarb 14.5 SC treated plots where cost benefit ratio of this treatment was highest (1:9.18). Carbosulfan 25 EC was found with least cost benefit ratio (1:4.85).

Zhen-di *et al.* (2014) observed that chlorantraniliprole showed good efficacy and played an important role in controlling the diamondback moth, *Plutella xylostella* Linnaeus.

Ambule *et al*. (2015) revealed that flubendiamide 0.004 per cent was the most effective insecticide which recorded minimum larval population (0.43 larvae plant^{-1}) and less fruit damage (10.09 %) on weight basis followed by chlorantraniliprole 0.0055 per cent (0.58 larvae plant^{-1} and 10.62 % fruit damage) and spinosad 0.0068 per cent (0.68 larvae plant^{-1} and 11.34 % fruit damage). Higher marketable yield recorded from treatments of flubendiamide followed chlorantraniliprole and spinosad with 25.21, 24.84 and 22.20 tonnes ha^{-1}, respectively.

Chowdary *et al*. (2015) tested rynaxypyr (Coragen) 20 SC in different doses i.e. 20 and 30 g a.i.ha^{-1} against larvae of head borer on cabbage during 2013-2014. Rynaxypyr @ 30 g a.i.ha^{-1} followed by its lower dosage was found to be effective in suppressing the larval population of the pest compared to other insecticides. These two treatments also recorded higher yield of cabbage heads per hectare compared to other treatments.

Nikam *et al.* (2015) conducted experiment to evaluate relative toxicity of different newer insecticides against *P. xylostella.* Among chemical insecticides tested, spinosad was found to be the most toxic, followed by emamectin benzoate, chlorantraniliprole, flubendiamide and lufenuron. The order of toxicity, spinosad was the most effective followed by emamectin benzoate, chlorantraniliprole, flubendiamide, lufenuron and novaluron. The LC_{50} values were recorded 0.00009 and 0.00011 for spinosad, 0.00016 and 0.00022 for emamectin benzoate, 0.00076 and 0.00099 for chlorantraniliprole, 0.00119 and 0.00148 for flubendiamide, 0.00280 and 0.00284 for lufenuron, 0.01557 and 0.01888 per cent for novaluron, respectively against third and fourth instar larvae of *P. xylostella.*

Patra *et al.* (2015) evaluated effectiveness of rynaxypyr 18.5 SC, flubendiamide 20 WG, spinetoram 12 SC, dinotefuran 20 SG, indoxacarb 14.5 SC, novaluron 10 EC and mixed formulation of indoxacarb 4.5% and novaluron 5.25% against *P. xylostella*. Results revealed that rynaxypyr 18.5 SC @ 30 g a.i.ha^{-1} was most effective in reducing larval population followed by flubendiamide 20 WG @ 40 g a.i. ha^{-1} and spinetoram 12 SC @ 50 g a.i.ha^{-1}. Based on LC_{50} values, rynaxypyr was the most toxic insecticide followed by flubendiamide, spinetoram, indoxacarb and dinotefuran. Rynaxypyr showed highest acute toxicity with the lowest LC_{50} value (6.32 ppm), whereas novaluron showed lowest acute toxicity with the highest LC_{50} value (208.6 ppm).

Ram *et al.* (2015) demonstrated that the per cent fruit infestation on number and weight basis was significantly lowest in chlorantraniliprole (6.57 and 6.31) and spinosad (12.08 and 11.15) treated plots of brinjal. The chlorantraniliprole treated plot recorded the maximum marketable yield (32.03 MT ha^{-1}) against *L. orbonalis* followed by spinosad (30.93 MT ha^{-1}) with 34.39 and 29.77 per cent increase in marketable fruit yield over untreated check, respectively.

Singh *et al*. (2015) recorded highest yield (24.77 tonne ha^{-1}) with highest incremental cost benefit ratio to the tune of 1:37.34 following the application of spinosad 2.5 SC @ 100 ml ha^{-1} against *P. xylostella* in cabbage.

Sunitha and Mohite (2015) revealed that flubendiamide was found most effective followed by indoxacarb, spinosad and fipronil. The LC_{50} values recorded for flubendiamide 0.009, 0.009, 0.010 and 0.013, for indoxacarb 0.013, 0.014, 0.015 and 0.017, for spinosad 0.029, 0.030, 0.036 and 0.060, and for fipronil 0.117, 0.120 0.136 and 0.156 μg/L, respectively against first, second, third and fourth instar larvae of *P. xylostella*, respectively. The flubendiamide exerted more effective chemical in causing mortality of third instar larvae of *P. xylostella*. The treatment with indoxacarb, spinosad, and fipronil were in the order of their efficacy.

Natwick and Martin (2016) evaluated the efficacy of different insecticides against worm pests of cabbage (DBM and cabbage looper) and demonstrated that chlorantraniliprole was proved effective by recording 2.06 worm pests per 50 plant on cabbage under desert growing conditions.

Patel *et al.* (2016) revealed that chlorantraniliprole 35 WG @ 30 g $a.i.ha^{-1}$ reduced larval population of *H. armigera* as well as lowest per cent of fruit damage compared to standard checks. Fruit yield was also recorded significantly higher in plots treated with chlorantraniliprole 35 WG @ 30 (270.71 q ha^{-1}) followed by chlorantraniliprole 18.5 SC @ 30 g $a.i.ha^{-1}$ (267.36 q ha^{-1}).

Pawar *et al.* (2016) revealed that chlorantraniliprole 18.5 SC was found highly effective against fruit borer of tomato recording 6.8 per cent on number and 5.1

per cent on weight basis fruit damage. Effectiveness of spinosad 45 SC @ 125 g a.i.ha^{-1} was also reported by recording fruit damage in the range of 7.0 to 8.0 per cent on number basis and 6.4 to 6.9 per cent on weight basis, respectively. Further, they registered highest yield of 46.03 tonne ha^{-1} with ICBR of 1:14.20 from chlorantraniliprole 18.5 SC plots.

Purushotam (2016) showed that the highest cabbage yield of 195.67 q ha^{-1} with ICBR of 1:11.11 was obtained from the plots treated with spinosad which was at par with indoxacarb (192.23 q ha^{-1}). It was followed by flubendiamide (184.47 q ha^{-1} with 1:7.72 ICBR), emamectin benzoate (180.95 q ha^{-1} with 1:3.87 ICBR), chlorantraniliprole (175.30 q ha^{-1} with 1:5.60 ICBR), fipronil (175.20 q ha^{-1} with 1:9.28 ICBR) and chlorfenapyr (172.23 q ha^{-1} with 1:5.60 ICBR 17.21). Whereas, the minimum yield was recorded from acephate (158.60 q ha^{-1}) followed by pyridalyl (155.47 q ha^{-1}).

Sridhar *et al.* (2016) evaluated newer insecticides against *Tuta absoluta* on tomato for two seasons i.e., *kharif* and *Rabi* under field conditions at ICAR-IIHR, Bengaluru. The most effective insecticides identified against *T. absoluta* were spinetoram 12 SC @1.25 ml L^{-1}, cyantraniliprole 10 OD @ 1. 8 ml L^{-1}, flubendiamide 480 SC @ 0.3 ml L^{-1}, spinosad 45 SC @ 0.3 ml L^{-1} and chlorantraniliprole 18.5 SC @ 0.3 ml L^{-1} both on leaf and fruits. Further, concluded that above insecticides is the most effective to manage *T. absoluta* on tomato.

Sunitha and Mohite (2016) reported that chlorantraniliprole was most effective in suppressing the larval population of *P. xylostella* compared with other newer insecticides during bio-efficacy experiment. Larval mortality due to the spinosad was to the tune of 47.50 to 100.00, 42.50 to 94.84, 30.93 to 84.63 and 27.50 to 72.50 against first, second, third and fourth instar larvae of *P. xylostella*, respectively.

Sudhendu *et al.* (2016) recorded mean larval population of *P. xylostella* during two sprays of chlorantraniliprole 20 SC at three different dosages in cabbage. After 1st spray (10 DAS) larval population recorded were 0.73, 0.63 and 0.60 larvae plant^{-1} at 25, 37.5 and 50 g a.i.ha^{-1} respectively. After 2nd spray (10 DAS) there was 100 per cent reduction in larvae of *P. xylostella*. Further, they registered highest yield of 156.80, 164.80 and 177.60 q ha^{-1} at different dosages of chlorantraniliprole 20 SC (25, 37.5 and 50 g a.i.ha^{-1}, respectively) in cabbage.

Rahimgul and Thakur (2016) revealed that maximum (49.45 %) per cent reduction of DBM population was observed in spinosad 45 SC followed by indoxacarb 14.5 SC (45.305 %), cypermethrin 5 EC (44.215 %) and emamectin benzoate 5 SG (42.78 %). The highest yield was recorded from spinosad 45 SC (187.60 q ha^{-1} with 1:5.90 ICBR), followed by indoxacarb 14.5 SC (178.25 q ha^{-1}), cypermethrin 10 EC (175.48 q ha^{-1}) and emamectin benzoate 5 SG (173.75 q ha^{-1}) over untreated check (80.24 q ha^{-1}).

Tarun and Gopal (2016) evaluated different insecticides *viz.,* flubendiamide 39.35 SC (0.01%), chlorantraniliprole 20 SC (0.006%), cypermethrin 25 EC (0.006%), spinosad 45 SC (0.01%), indoxacarb 14.5 SC (0.01%), fipronil 5 SC (0.005%) and imidacloprid 17.8 SL (0.004%) against *L. orbonalis.* Minimum per cent of shoot, fruit infestation and higher B:C ratio was recorded in chlorantraniliprole (2.98%, 3.266% & 1:5.48, respectively) followed by flubendiamide (3.06%, 3.560% & 1:4.91, respectively) and spinosad (4.59%, 4.103% & 1:4.65, respectively).

Three applications of spinosad 2.5 SC @ 500 ml ha^{-1} was found to be the most effective (14.22 % lower leaf damage) and recorded highest (24.77 tonne ha^{-1}) yield of cabbage against *P. xylostella* (Arun *et al*. 2017).

Chatterjee and Mondal (2017) demonstrated that flubendiamide (91.0%), spinosad (89.2%) and chlorfenapyr (84.7 %) were highly effective in reducing the per cent damage caused by diamondback moth on cabbage and led to increase in yield (24.15, 23.50 and 20.25 t ha^{-1}, respectively).

Dotasara *et al.* (2017) showed highest per cent reduction over control (89.97%) with less number of larvae (0.58 larvae $plant^{-1}$) due to spinosad (45 SC @ 0.5 ml L^{-1}) against the DBM in cauliflower. Flubendiamide 48 SC @ 0.3 ml L^{-1} (87.59% reduction and 0.70 larvae $plant^{-1}$) and chlorantraniliprole 18.5 SC @ 0.3 g L^{-1} (85.55 % reduction and 0.68 larvae $plant^{-1}$) were next effective pesticides to reduce the pest incidence significantly.

Kaushik *et al.* (2017) revealed that Ampligo 150 ZC (chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC) was recorded lowest per cent of shoot (1.26%) and fruit (2.49%) infestation followed by Ampligo 150 ZC @ 28 g a.i. ha^{-1} (1.59% shoot and 2.97% fruit infestation) and chlorantraniliprole 18.5 % SC @ 30 g a.i.ha^{-1} (3.76 % shoot and 3.32 % fruit infestation), respectively. The highest marketable fruit yield was obtained in the treatment with Ampligo 150 ZC @ 28 and 35 g a.i.ha^{-1} (143.91-150.88 q ha^{-1}). Further, concluded that new mixture formulation i.e. Ampligo 150 ZC @ 28-35 g a.i.ha^{-1} proved to be significantly superior to other treatments against *L. orbonalis*.

Marmat and Anoorag (2017) evaluated different chemical insecticides and biopesticides against *Leucinodes orbonalis* in brinjal *viz*., cypermethrin 25 % EC @ 2 ml L^{-1}, spinosad 45 % SC @ 0.5 ml L^{-1}, Neem oil @ 20 ml L^{-1}, Pongamia oil @ 30 ml L^{-1}, NSKE @ 50 gm L^{-1}, Garlic bulb extract @ 50 ml/lit and Neem leaf extract @ 50 ml L^{-1}. Spinosad 45 SC recorded lowest per cent shoot infestation (6.87 %) followed by cypermethrin 25 EC (8.57%), Neem oil (9.27%), NSKE (9.60%) and Pongamia oil (10.93%). The highest yield and benefit cost ratio was recorded in spinosad 45 SC (195.22 q ha^{-1} and 1:7.06 respectively).

Narendra (2017) evaluated effectiveness of different dosages of chlorantraniliprole 20 SC @ 15, 20, 25 and 50 g a.i.ha^{-1} and cynantraniliprole 15.20 OD @ 60 g a.i. ha^{-1} against *P.xylostella* infesting cabbage. The maximum reduction in larval number was recorded in chlorantraniliprole @ 50 g a.i. ha^{-1} (88.87 %) followed by chlorantraniliprole @ 25 g a.i.ha^{-1} (84.08 %), cynantraniliprole@ 60 g a.i.ha^{-1}(75.38%), chlorantraniliprole @ 15 g a.i.ha^{-1}(67.82%) and chlorantraniliprole @ 20 g a.i.ha^{-1} (67.00 %). Further, they recorded highest yield with highest cost benefit ratio (1:2.89) obtained from chlorantraniliprole @ 50 g a.i. ha^{-1} (27.9 tonne ha^{-1}) followed by chlorantraniliprole @ 25 g a.i.ha^{-1} (1:2.53).

Narendra *et al*. (2017) evaluated nine newer and biorational insecticides against fruit borer, *H. armigera* infesting tomato at SKRAU, Bikaner. Rajasthan during the *rabi* season 2013-14. Indoxacarb 14.5 SC (0.01 %) was found most effective against fruit borer followed by novaluron 10 EC (0.01 %) and acephate 75 SP (0.037 %). The treatments of chlorantraniliprole 18.5 SC (0.02 %), abamectin 5 SG (0.01 %) and spinosad 2.5 SC (0.01 %) ranked in middle order of their efficacy. *Bt* 8 L (0.012 %) proved least effective. The maximum yield with highest cost benefit ratio (265.20 q ha^{-1} with 1:30.33 ICBR) was recorded in indoxacarb followed by novaluran (262.85 q ha^{-1} with 1:19.14 ICBR), acephate (258.22 q ha^{-1} with 1:14.41 ICBR) and chlorantraniliprole (250.71 q ha^{-1} with 1:4.34 ICBR).

Purushotam *et al*. (2017) revealed that spinosad was found to be most effective which reduced up to 94.33 per cent larval population of *P. xylostella* in cabbage followed by indoxacarb (91.00%) and flubendiamide (78.66%). The insecticides, *viz*., fipronil, emamection benzoate and chlorantraniliprole were found moderately effective as they resulted in 70.66, 70.33 and 68.66 per cent larval reduction, respectively.

Sarnabati and Ray (2017) revealed that coragen (7.27% shoot infestation) was highly effective followed by imidacloprid (7.96%) and profenofos + cypermethrin (8.84%). The maximum yield of 13.83 t ha^{-1} was obtained with coragen (30 g a.i. ha^{-1}). However, cost benefit ratio was also highest in coragen (1:26.27).

Selvaraj and Kennedy (2017) investigated effects of some newer insecticides *viz*., novaluron 10 EC @ 75 g a.i.ha^{-1}, flubendiamide 20 WG @ 40 g a.i.ha^{-1}, indoxacarb 4.5 SC + novaluron 5.25 SC @ 80 g a.i.ha^{-1}, indoxacarb 14.5 SC @ 60 g a.i.ha^{-1} , acephate 75 SP @ 600 g a.i.ha^{-1}, cartap hydrochloride 50 SP @ 450 g a.i.ha^{-1} and rynaxypyr 18.5 SC @ 30 g a.i.ha^{-1} against *P. xylostella* on cauliflower at Thondamutur, Coimbatore, Tamil Nadu. Cartap hydrochloride @ 450 g a.i.ha^{-1} was found the most effective in reducing the larval population (91.53 %) and also recorded highest yield (27.25 t ha^{-1}) followed by rynaxypyr, indoxacarb, novaluron and flubendiamide. Cartap hydrochloride also showed highest acute toxicity towards both the parasitoids with LC_{50} value (0.0099 & 0.0043) for *T. chilonis* Ishii and *C. zastrovi silemi* (Esben-Petersen), respectively.

Venkate and Mahesh (2017) revealed effectiveness of spinosad by recording larval population of 1.25 and 1.08 larvae $plant^{-1}$ at 10 DAS during two successive seasons (2009-10 and 2010-11, respectively) following the application of spinosad 45 SC @ 73 g a.i.ha^{-1} against *P. xylostella* in cabbage. Further, recorded (37.64 and 38.13 t ha^{-1}) yield of cabbage during 2009-10 and 2010-11, respectively.

Yadav *et al*. (2017) revealed that spinosad was the most effective newer insecticide against *P. xylostella* in cauliflower. Spinosad 48 SC @ 45 g a.i ha^{-1} recorded highest per cent (49.08, 47.95 and 50.44 %) field efficacy at 1st, 2nd and 3rd spraying, respectively.

5. Dissipation pattern of triazophos, quinalphos and bifenthrin

5.1 Dissipation pattern of different insecticides in cabbage

Rajukkanu *et al.* (1979) studied the residues of quinalphos in tomato and suggested the waiting period of 2.01 days for safe consumption of tomato.

Agnihotri *et al.* (1980) recorded more than 90 per cent dissipation of initial residues (16.75 ppm) in 10 days after spraying of 0.07 % endosulfan on cabbage and cauliflower.

Barooah and Yein (1996) reported mean initial residues of quinalphos ranged from 1.26 to 1.79 mg kg^{-1} in brinjal fruits sampled 1 h after the last spray. Quinalphos dissipated with half-life values of 2.1 to 2.2 day and reached below detectable levels in 15 day after last spray. Further, suggested safe waiting periods of 4.9 and 6.1 days.

Pandit *et al.* (1996) evaluated the persistence of α-cypermethrin in cabbage at applied dose of 30, 45 and 60 g a.i. ha^{-1} and revealed that the initial deposits of 0.349, 0.565 and 0.736 ppm in cabbage head and 0.110, 0.170 and 0.228 ppm in the cropped soil, respectively. Residues were readily dissipated and went beyond detection on 20th day after application in cabbage head and 10 days in cropped soil samples. Calculated half life and safe waiting period in cabbage head was ranged from 1.956-2.105 and 3.594-5.269 days, respectively.

Fenvalerate was persisted with residues of 0.10, 0.14 and 0.11 mg kg^{-1} on Chinese broccoli, Chinese mustard and Chinese cabbage respectively, at 21th day (Ripley *et al*., 2001).

Babu *et al.* (2001) reported safe waiting period of 3 days for cabbage heads after application of cypermethrin in cabbage. Beta-cyfluthrin on cabbage dissipated to below detectable limits at 20 days after second spray when beta-cyfluthrin sprayed at 25.0 g a.i.ha^{-1} (Singh *et al.,* 2003).

Residues of chlorpyriphos, dimethoate, cyhalothrin, cypermethrin, fenvalerate, deltamethrin and chlorothalonil in the autumn Chinese cabbage (*Brassica chinensis* L.) was determined by using gas chromatography. The results indicated that the Chinese cabbage was treated once at normal rate, the half-life values of the seven pesticides in the cabbage were 4.7, 5.3, 2.9, 3.5, 5.4, 4.3 and 4.0 days respectively. When the Chinese cabbage was treated four times at 5 day intervals, the half-life values of chlorpyriphos, cypermethrin and chlorothalonil in the cabbage were 3.6, 2.9 and 5.9 days, respectively (Zhi-Yong *et al.*, 2006).

Zhi-Yong *et al.,* (2007) recorded the half-life of chlorpyriphos, dimethoate, cyhalothrin, cypermethrin, fenvalerate, deltamethrin and chlorothalonil in cabbage to be 2.0, 1.6, 1.6, 2.3, 2.2, 1.5 and 1.8 days, respectively. If the cabbage crop was treated one time at normal dosage of pesticides and Maximum Residue Limits (MRLs) of all tested pesticides was not exceeded according to the recommended pre-harvest interval. However, if the cabbage was treated four times at the maximal dosage with a five-days interval, the half-life of chlorpyriphos, cypermethrin and chlorothalonil was 2.9, 2.6 and 4.1 days, respectively and the final residual amount of chlorothalonil exceeded its MRL, but the final residual amounts of cypermethrin and chlorpyrifos was below its MRLs. Furthermore, in both one-time and four-time spraying treatments, the final degradation rates of pesticides residues were above 80 per cent.

Degradation of difenoconazole residues in Chinese cabbage and soil was studied to evaluate residual behavior and environmental safety of difenoconazole. Degradation rate of difenoconazole in both Chinese cabbage and soil followed the first order kinetics with the half life value of 6.6–7.8 and 54.2–55.0 days, Respectively (Zhi *et al*., 2008).

According to Aktar *et al.* (2010) quinalphos 20 AF was applied @ 500 and 1,000 g a.i.ha^{-1} in cabbage for two consecutive seasons and the samples harvested at intervals of 0 (3 h), 2, 4, 6, 8, and 10 days interval after application. Initial residues of quinalphos as 4.42 and 9.75 mg kg^{-1} in cabbage at 500 and 1000 g a. i. ha^{-1}, respectively. The residues persisted up to 10 days with a half-life of 1.27 and 1.38 days, respectively.

Chahil *et al.* (2011) reported degradation dynamics of quinalphos on cabbage and reported that average initial deposit of quinalphos on cabbage were found to be 0.41 and 0.75 mg kg^{-1}, following application at 500 and 1000 g a. i. ha^{-1}, respectively. The residues dissipated below its determination limit of 0.01 mg kg^{-1} in 7 and 10 days at recommended and double the recommended doses, respectively. The half-life on cabbage was observed to be 3.02 and 2.70 days, in single and double dose, respectively.

Duhan *et al.* (2011) determined residue levels of endosulfan in cabbage heads after being sprayed with a formulation containing the insecticide. Upon stored at room temperature (15-27^{0}C) and in a refrigerator (2–5^{0}C), the half-life values were calculated to be 4.8 and 5.5 days for the corresponding storage conditions of cabbage.

Reddy *et al.* (2012a) revealed that initial deposit of fipronil (1.69 mg kg-1) was dissipated to below detectable limit at 10 days after third spray. While, in case of bifenthrin, the initial deposit (1.03 mg kg-1) was dissipated to below detectable level at 7 days after third spray. The waiting period for safe harvest of cabbage heads after three sprays of fipronil and bifenthrin @ 100 and 50 g a.i. ha^{-1} was 5.19 and 5.16 days, respectively. The half life values for fipronil and bifenthrin were 3.13 and 3.38 days, respectively.

Liu *et al.* (2013) investigated the dissipation and residues of pyridaben in cabbage under field conditions. The average recoveries were in the range of 90.29–95.00 per cent with relative standard deviations ranging from 1.72 to 6.39 per cent. The field results showed that pyridaben dissipated rapidly in cabbage and had a half-life of 2.8–3.5 days. During harvest, the terminal residues of pyridaben were 0.01–0.80 mg kg^{-1}.

Reddy *et al*. (2014a) revealed that initial deposit of bifenthrin residues was 2.24 mg kg^{-1} at 2 h after last spray and that was dissipated to 1.72, 1.38, 0.82 and 0.23 mg kg^{-1} at 1, 3, 5 and 7 days after last spray, respectively and below determination level (BDL) at 10th day. The pre-harvest interval of 3 days was suggested taking into consideration of MRLs of bifenthrin in cabbage as per European Union (EU) which was 1.0 mg kg^{-1}, and the calculated safe waiting period to be 1.34 days.

Reddy *et al*. (2014b) conducted experiment during *Kharif* 2012 with cabbage variety *Varun*. Dissipation pattern of profenophos and bifenthrin showed that initial deposit of 2.75 mg kg^{-1} which was dissipated to below detectable limit in 15 days after third spray. The maximum detectable limit for profenophos and bifenthrin were 0.2 and 0.1 mg kg^{-1}, respectively. The safe waiting period for harvest of cabbage heads after three sprays of profenophos and bifenthrin at head formation stage was four and one day, respectively.

Gupta *et al.* (2015) studied the initial deposits of deltamethrin and triazophos in cabbage following the application of Anaconda Plus (triazophos +

deltamethrin), were 0.015-0.254 μg g^{-1} at low dose (1 L ha^{-1}) and 0.026-0.413 μg g^{-1} at high dose (2 L ha^{-1}), respectively. Further, it was revealed that profenophos, chlorpyriphos and triazophos dissipated with the half-life values of 0.58-0.74, 0.68-0.76, and 0.79-1.29 days, respectively, as against reported values of 0.91-5.4, 2.7-3.3, and 2.3-3.2 days for corresponding insecticides on various vegetable crops.

5.2 Dissipation pattern of insecticides in other vegetables

Jain *et al.* (1979) recorded reduction of fenvalerate residues on tomatoes to the level of 62 per cent.

Singh *et al.* (1988) reported that the initial deposits of quinalphos on cauliflower curds were 1.20 and 1.83 mg kg^{-1} when sprayed at 250 and 500 g a.i.ha^{-1}, respectively.

Bordia and Gupta (1992) reported that 50 per cent dissipation of endosulfan on cauliflower was observed within 3 days of application.

Reduction of fenvalerate residues by cooking process to an extent of 27 to 56 per cent in brinjal was reported by Sharma and Kumar (1993).

Khan *et al.* (1999) observed dissipation of dichlorvos on okra fruit to the extent of 41.06 and 80.19 per cent after 1 and 3 days of application, respectively.

Raj *et al.* (1999) recorded dissipation of triazophos in brinjal when applied @ 350 and 700 g. a.i. ha^{-1}. They reported that initial residues of triazophos were 0.165 and 0.218 mg kg^{-1} which dissipated with half-life of 1 and 2 days for 350 and 700 g a.i. ha^{-1}, respectively.

Initial deposits of triazophos on cauliflower heads after second spray were 1.5 and 3.8 mg kg^{-1} at the dosage of 350 and 700 g a.i.ha-^{1}, respectively. The residues of triazophos were not detected in cauliflower on 7th day following lower rate of application (Chahal *et al.,* 2000). According to Kumar *et al.* (2000) mean initial residues of triazophos was 0.43 mg kg^{-1} in chilli when triazophos applied @ 700 g a.i. ha^{-1}. The residues persisted up to 15 day with a half-life of 10.03 days.

Dissipation of alphamethrin residues to the extent of 25-32 per cent in brinjal and tomatoes and 12-17 per cent in cauliflower (Gill *et al.,* 2001).

Gupta and Singh (2001) observed half life values of fenvalerate on cauliflower curds to be 1.19 and 1.46 days after the application of fenvalerate @ 75 and 150 g a.i.ha^{-1}, respectively.

Li Xue Shong (2005) determined the degradation dynamics and final residues of triazophos in litchi by single application of triazophos at a dose of 500 times. The results revealed that the initial residues in litchi flesh and skin were 0.04-0.07 and 4.05-4.77 mg kg^{-1}, respectively and the half life values were 6.8 and 8.2 days, respectively.

Paras Nath *et al.* (2005) studied the persistence and dissipation of ready mix Polytrin C 44 EC (profenophos 40% + cypermethrin 4%) and Spark 36 EC (triazophos 35% + deltamethrin 1%) applied @ 1 lit ha^{-1} in okra crop. Results revealed that deposits of triazophos were 1.52 µg g^{-1} ± 0.0008 on zero days. The residues dissipated by 37.6 per cent with average deposits of 0.95 µg g^{-1} ± 0.002 on the first day which further dissipated by 72.1 per cent leaving residues of 0.42 µg g^{-1} ± 0.003 on third day and 77.0 per cent degradation on fifth day showing average deposits of 0.35 µg g^{-1} ± 0.003. Finally, on 7th day, the residues dissipated to the tune of 86.2 per cent leaving deposits of 0.21 µg g^{-1} ± 0.003. Half-life values of 1.35, 2.55, 4.1 and 7.6 days for profenophos, triazophos, cypermethrin and deltamethrin, respectively.

Devendran *et al.* (2006) studied the dissipation behavior of endosulfan and dichlorvos in/on cauliflower (var. Snowball-16). Endosulfan and dichlorvos were sprayed @ 350 and 110 g a.i.ha^{-1} with 115 g a.i. ha^{-1}, respectively at 80 days after transplanting. Samples were taken at the interval of 0 (1 h after spray), 3, 5, 7, and 10 days after spray (DAS) in triplicate and residues were estimated on GC-ECD system equipped with capillary column. The initial deposits of 3.452 and 0.295 μg g^{-1} of endosulfan and dichlorvos dissipated to 0.084 (97.56 %) and 0.009 (96.95 %) respectively, after 10 DAS. Residues of endosulfan reached below Maximum Residue Limit of 2 μg g^{-1} one day after spray and of dichlorvos were below MRL value of 0.5 μg g^{-1} even on 0 (Zero) day. Dissipation pattern followed first order kinetics for both the insecticides with half-life periods of 1.81 and 2.08 days for endosulfan and dichlorvos, respectively.

Banerji *et al.* (2008) registered mean initial residues of triazophos was 0.31 mg kg^{-1} in bitter gourd dissipated within 7 days.

Persistence and efficacy of bifenthrin (25 and 50 g a.i. ha^{-1}), fipronil (50 and 100 g a.i.ha^{-1}) and indoxacarb (70 and 140 g a.i.ha^{-1}) has been studied in okra fruits by Gupta *et al*. (2009). The residues persisted up to 10 days with half-life of 1.32-1.58 days for bifenthrin. Based on acceptable daily intake (ADI), the waiting period of one day had been suggested for bifenthrin.

Tewary *et al.* (2009) studied the degradation rate of bifenthrin in both wet and dry season in tea leaves. The half-life values in green leaves were 0.52-0.77 and 1.20-1.32 days and in made tea were 0.55-0.66 and 1.03-1.06 days for both seasons, respectively. Processing of green shoots caused considerable loss of residues i.e. 42 per cent.

Dhas and Srivastava (2010) studied the dissipation of carbaryl on brinjal fruit and observed that the initial deposit on fruit was 11.47 ppm for 0.2 per cent carbaryl which dissipated to 9.93 ppm within one day and decrease in residue was about 13.40 per cent.

Patyal *et al*. (2010) studied the persistence behavior of bifenthrin (Brigade 8% SC) on apple fruits and tree basin soil following foliar application @ 60 g a.i. ha^{-1} and 120 g a.i. ha^{-1} on fruit bearing trees at two locations *viz.,* Solan and Mashobra for three consecutive years from 2003 to 2005. Initial deposits of bifenthrin were in the range of 0.669-1.062 mg kg^{-1} at 60 g a.i. ha^{-1} dose and 1.348-1.784 mg kg^{-1} at 120 g a.i. ha^{-1} dose which were reduced to half in 4.85-5.22 and 4.38-6.66 days at the respective doses. Based on the Maximum Residue Limit (MRL) value of 0.5 mg kg^{-1} of bifenthrin on apple, a safe waiting period of 2.1-5.4 and 6.7-11.3 days were worked out for respective treatments.

Gupta *et al.* (2011) studied dissipation of cypermethrin, chlorpyriphos and profenophos in tomato fruits and reported persistence of profenophos beyond 10^{th} and 15^{th} days at lower and higher dose which were dissipated with the half-life of 2.2 and 5.4 days, respectively.

Pradhan *et al.* (2011) studied the residue and persistence of Spark (1+35 % EC) (deltamethrin + triazophos) in brinjal fruit after the application @ 1.25 lit ha^{-1} and @ 2.50 lit ha^{-1}. The half life of deltamethrin ranged from 0.67 to 1.14 days and that of triazophos from 0.96 to 1.72 days, respectively. The residues were found to be below detectable limit on 10-15 day samples.

Waghulde *et al.* (2011) studied the dissipation of chlorpyriphos, endosulfan, dimethoate and malathion residues in/on chilli (*Capsicum annum* L) and okra (*Abelmoschus esculentus* L) fruits at North Maharashtra region (India). The samples were procured up to 21 days after application of pesticides by knapsack sprayer. The dissipation of residues was found to be initially fast. As time advanced the dissipation rate of extractable residues decreased. The half life value ranged between 3.22 and 5.49 days and waiting period from 9.38 to 18.08 days. The half life in okra ranged between 3.68 to 6.92 days and waiting period from 14.54 to 20.93 days. Highest per cent recovery was recorded in endosulfan (89.1 %) from chilli and chlorpyriphos (91.4 %) from okra.

Banerjee *et al.* (2012) compared the persistence of imidacloprid and beta-cyfluthrin, when applied through a ready mix formulation, Solomon 300 OD @ 200 and 400 mL ha^{-1} in the fruits of brinjal, tomato and okra. The study indicated that degradation constant and half-life values of beta-cyfluthrin were varied between 0.287 to 0.642 days and 1.07 to 2.41 days, while that of imidacloprid between 0.21 to 0.34 days and 1.98 to 3.30 days, respectively. Further, which suggested that the persistence of beta-cyfluthrin was lower than that of imidacloprid in fruits of these vegetables.

Chauhan *et al.* (2012) conducted a field trial of bifenthrin applied on tomato crop @ 25 and 50 g a.i. ha^{-1}. The residues of bifenthrin were evaluated on 0 (1h), 3, 5 and 7 days after spray and half-life values were 2.02 and 2.10 days in soil at single and double doses, respectively.

Gupta *et al.* (2012) reported half-life values of 2.2- 5.4 days for profenophos, 2.7–3.3 days for chlorpyriphos, 2.3–3.2 days for triazophos, 1.5-4.8 days for cypermethrin and 1.9- 2.6 days for deltamethrin on tomato, bitter gourd and cauliflower, respectively.

Gupta *et al.* (2013) studied persistence of cypermethrin, deltamethrin, profenophos, and triazophos in cauliflower curds following the applications of two pre-mix formulations *viz.*, Roket 44 EC (profenophos 40 % + cypermethrin 4 %) and Anaconda Plus 36 EC (triazophos 35 % + deltamethrin 1 %) at recommended (1.0 L ha^{-1}) and double doses (2.0 L ha^{-1}). In case of Roket 44 EC, residues of cypermethrin dissipated with the half-life values of 1.5-2.1 days, whereas residues of profenophos dissipated with the half-life values of 2.9-3.3 days. In case of Anaconda, residues of triazophos and deltamethrin dissipated with the half-life values of 2.6-3.0 and 2.2-2.6 days, respectively.

Parmar *et al*. (2012) studied dissipation of insecticide residues on okra fruits. The samples were procured up to 7 days after application of insecticide. The average initial deposits of deltamethrin, alphamethrin, deltamethrin in combination, triazophos, ethion, cypermethrin and profenophos were 0.152, 0.136, 0.025, 0.543, 0.254, 0.172 and 4.519 mg kg^{-1}, respectively, which dissipated to 0.025 (83.55 %), 0.023 (83.09 %), 0.010 (60.00 %), 0.015 (0.015 %), 0.013 (94.88 %), 0.020 (88.37 %) and 0.508 (88.76 %) mg kg^{-1}. The half-life values for respective insecticide were 2.09, 2.09, 2.61, 1.68, 1.27, 2.59 and 1.88 days, respectively.

Shalaby *et al*. (2012) revealed that profenophos, cyfluthrin, lufenuron, chlorpyriphos-methyl and indoxacarb were the most toxic insecticides as compared to other chemicals on tomato fruits. The initial deposits of profenophos, cyfluthrin, lufenuron and chlorpyriphos-methyl ranged from 28.6 to 6.3 ppm, depending on the rate of insecticide application. The loss rate of these amounted to 91.70 to 97.57 per cent at15 days after treatment.

Mohapatra and Deepa (2013) recorded initial residues of quinalphos were 1.19 and 1.84 mg kg^{-1} on cauliflower at the recommended and double the recommended dose, respectively. The residues persisted up to 15 days. The residues of quinalphos dissipated with the half-life of 4.8 and 5.3 days. Maximum residue limit of 0.05 mg kg^{-1} and the safe pre-harvest interval was worked out as 17 and 22 days for the recommended and double the recommended dose, respectively.

Sachin Kumari (2013) reported that bifenthrin residues reached below detectable level of 0.005 mg kg^{-1} on 15 and 30^{th} day in single and double dose, respectively. Half-life values for bifenthrin were found to be 1.58 and 2.18 days at single and double dose, respectively.

In chilli, initial deposit of bifenthrin residues was 1.33 mg kg^{-1} at 50 g a.i. ha^{-1} which persisted up to 7^{th} day by recording half-life value of 2.21 (Anon, 2015).

Cherukuri *et al.* (2015) studied dissipation dynamics of profenophos, triazophos and cypermethrin in tomato and investigated that initial deposits of 1.698, 1.108 and 0.158 µg g^{-1} for profenophos, triazophos and cypermethrin dissipated to below determination level by 10^{th}, 7^{th} and 5^{th} day, respectively.

Mukherjee *et al.* (2015) studied persistence of deltamethrin and triazophos in tomato with the application of ready mix formulation of Annaconda Plus (1 % deltamethrin + 35 % triazophos) in which deltamethrin persisted till 5 days, while triazophos persisted upto 10 days in tomato. Residues of deltamethrin and triazophos dissipated with half-life of 2.6-4.2 and 1.7- 4.1 days on tomato, respectively. Based on the Codex MRL limits, a safe waiting period of 5 days was suggested for tomato.

Shashi *et al.* (2015) studied dissipation dynamics of profenophos, triazophos and cypermethrin in tomato and revealed that initial deposits of 1.698, 1.108 and 0.158 mg kg^{-1} for profenophos, triazophos and cypermethrin which dissipated to below determination level by 10^{th}, 7^{th} and 5^{th} day, respectively.

Singh *et al*. (2015) studied dissipation pattern of triazophos on capsicum following two applications of triazophos (Truzo 40 EC) at 500 and 1000 g a.i. ha^{-1}; Mean initial deposits were found to be 3.61 and 6.26 mg kg^{-1}, respectively. These residues dissipated below the limit of quantification (LOQ) of 0.05 mg kg^{-1} in 10 and 15 days and half-life values were 2.31 and 2.14 days at recommended and double the recommended doses, respectively.

Raut *et al.* (2016) recorded mean initial residues of 1.12 mg kg^{-1} in chilli fruits after application of triazophos @ 500 g a.i. ha^{-1} which dissipated within 10 days with a half-life of 1.72 days. The residues persisted up to 10 days with a half life of a day. Mean initial residues of triazophos were 0.86 mg kg^{-1} in capsicum as reported by Shukla *et al.* (2016).

Brar *et al.* (2017) studied persistence pattern of profenophos and triazophos in Brinjal fruits @ 500 g a.i. ha^{-1} and 1000 g a.i. ha^{-1}. Initial deposits of profenophos in brinjal fruits from the two treatments were leads to 1.966 and 2.460 mg kg^{-1} on brinjal fruits which reduced to half in1.5 and 1.9 days, respectively. Initial deposits of triazophos residues were 1.100 and 2.233 mg kg^{-1} at 500 and 1000 g a.i. ha^{-1} dissipated to half in 1.6 and 1.9 days, respectively.

5.3 QuEChERS method of Multi-residue analysis

The literature available on the multi-residue analytical methods (QuEChERS) using GC/GC-MS for different groups of insecticides *viz*., organophosphates (OPs) and synthetic pyrethroids (SPs) in crop samples are briefly reviewed in this chapter.

Lehotay (2000) carried out analysis of pesticide residues in mixed fruit and vegetable extracts by direct sample introduction to GC-MS/MS. Direct sample introduction (DSI), or "dirty sample injection", was investigated in the determination of 22 diverse pesticide residues in mixed apple, green bean and carrot. Average recoveries of the pesticides were 103 ± 7 per cent with RSD of 14 ± 5 per cent on average and limits of detection were <2 ng g^{-1} for nearly all pesticides studied.

Anastassiades and Lehotay (2003) introduced the method, known as the quick, easy, cheap, effective, rugged and safe (QuEChERS) method for pesticide residues. It involved the extraction of the sample with acetonitrile and simultaneous liquid-liquid partitioning followed by adding anhydrous magnesium sulfate ($MgSO_4$) plus sodium acetate (NaAc), which is a simple clean up step known as dispersive solid-phase extraction (dispersive-SPE) in which 150 mg anhydrous $MgSO_4$ and 25 mg primary secondary amine (PSA) sorbent are simply mixed with 1 ml acetonitrile extract. GC-MS is then used for quantitative and confirmative analysis of GC amenable pesticides. Recoveries between 85 and 101 per cent (mostly >95 %) and repeatability typically <5 per cent have been achieved for a wide range of fortified pesticides.

Beltran *et al.* (2003) determined the residues of 7 pyrethroid insecticides (bifenthrin, lambda-cyhalothrin, permethrin, cyfluthrin, cypermethrin, fenvalerate, and tau-fluvalinate) in water, vegetable (tomato) and fruit (strawberry) samples, based on direct immersion mode and subsequent desorption into the injection port of a GC/MS. The SPME procedure showed linear behavior in the range tested (0.5-50 mg L^{-1} in water and 0.01-0.1 mg kg^{-1} in tomato) with R^2 values ranging between 0.97 and 0.99. Detection limits for tomato samples were between 0.003 and 0.025 mg kg^{-1} with relative standard deviations around 25 per cent.

Lehotay (2005) reported validation of QuEChERS a simple, fast and inexpensive method for the determination of 229 pesticides fortified at 10-100 ng g^{-1} in lettuce and orange matrices. Each analytical method was designated to analyze 144 pesticides with 59 targeted by instrument. Recoveries for all but 11 of the analytes in at least one of the matrices were between 70-120 per cent (90-110 % for 206 pesticides) and repeatability typically <10 per cent were achieved for a wide range of fortified pesticides.

Xie *et al*. (2005) established a quick multi-residue detecting technique to detect 12 organophosphate insecticides in the spring cabbage.

Lehotay (2007) conducted the experiment to determine multiple pesticide residues in fruits and vegetables using gas chromatography/mass spectrometry (GC/MS) and liquid chromatography/tandem mass spectrometry (LC/MS/MS). Twenty representative pesticides were fortified in 3 matrixes (grapes, lettuces, and oranges) at 3 duplicate levels unknown to the collaborators ranging from 10 to 1000 ng/g. Per cent recovery and reproducibility relative standard deviation (RSDR, %)] were atrazine, 92 (18); azoxystrobin, 93 (15); bifenthrin, 90 (16); carbaryl, 96 (20); chlorothalonil, 70 (34); chlorpyrifos, 89 (25); cyprodinil, 89 (19); o,p'-DDD, 89 (18); dichlorvos, 82 (21); endosulfan sulfate, 80 (27); imazalil, 77 (33); imidacloprid, 96 (16); linuron, 89 (19);methamidophos, 87 (17); methomyl, 96 (17); procymidone, 91 (20); pymetrozine, 69 (19); tebuconazole, 89 (15); tolylfluanid (in grapes and oranges), 68 (33); and trifluralin, 85 (20). The results demonstrated that the method is fit for the purpose.

Bifenthrin residues were extracted from mango fruit samples using acetone by blending. The extract was partitioned with hexane and the organic phase collected was concentrated. The concentrated sample was passed through a chromatographic column packed with 10 g florisil and eluted with 100 ml of hexane:ethyl acetate (9:1 v/v) which was concentrated. Residues of bifenthrin were estimated by GLC (Varian 3800) equipped with ECD and fitted with a capillary column BPX5 (30 m x 0.25mm i. d.) (Mohapatra *et al*. 2007).

A modification of a rapid and inexpensive multi-residue method for determination of pesticides in fruits and vegetables (QuEChERS method) was carried out by Schenck *et al*. (2008). The modified QuEChERS method resulted in a 65 per cent reduction in solvent usage, when compared with the traditional multi-residue methods previously used.

Paramasivam *et al*. (2011) developed a rapid, simple and efficient multi-residue method and this method was found more efficient and reliable enabling more number of samples to be analyzed in less time. Moreover lipid removal was achieved to a large extent to get desired result.

Smith and usher (2012) developed method by the scientists of USDA to easily clean up and prepare food samples for multi class and multi residue pesticide analysis and it described the use of AOAC buffered extraction method followed by the use of the universal dispersive SPE method for preparing lettuce and apple sample for the residue analysis by GC/MS. Twenty six pesticides of different classes were studied. The analysis performed by GC/MS using selective ion monitoring mode. Percent recovery and standard deviation data are reported for the three different spike concentrations, 25, 100 and 150 n g/g. excellent recovery and linearity were noted for all pesticides except the planner pesticides, hexachlorobenzene, which is known to be strongly absorbed onto graphitized carbon black used in the d-SPE step.

Restrepo *et al*. (2014) validated (SANCO /12495/ 2011 and NTC-ISO/IEC 17025) multi-residue multi-class methods using QuEChERS sample preparation and GC–MS for the analysis of regulated pesticides in tomatoes (*Solanum lycopersicum*) and golden berries (*Physalis peruviana*). The residues were validated over a range from 0.02 mg/kg to 0.20 mg/kg, with 24 analytes validated in tomatoes and 28 in golden berries.

6. Impact of household processes on the residues of insecticides

Potato and cabbage samples fortified with dimethoate at 2 ppm level on 30 min boiling gave percentage hydrolysis in the range of 37-53 and 56–86 per cent, respectively (Askew *et al.* 1968).

Washing was the most common method of processing and which was a preliminary step in both household and commercial preparation. Loosely held residues of several pesticides were removed with reasonable efficiency by varied types of washing processes (Street, 1969).

Geisman *et al.* (1975) revealed that washing, peeling, blanching and cooking operation had a cumulative effect on the reduction of the pesticides.

Hotellier (1982) reported that deltamethrin residues were reduced appreciably by cooking.

Bitter gourds treated with endosulfan sprays recorded initial deposits of 18.97 and 26.01 mg/kg which were respectively removed to extent of 59.05 and 42.66 per cent by washing (Nath and Agnihotri, 1984).

Dip treatment of fruits in NaCl solution, HCl, acetic acid, NaOH solution and potassium permanganate removed 50-60 per cent of surface residues of synthetic pyrethroids compared to 40-50 per cent removal by hydrolytic degradation with NaOH (Awasthi, 1986).

Elkins (1989) revealed that washing, peeling, blanching and cooking played an important role in the reduction of pesticide residues.

Dipping of mango fruits in water for 10 min plus tap water washing reduced residues of dimethoate and fenthion (66–68 %) as against 21-27 per cent for fenvalerate and cypermethrin (Awasthi, 1993).

Reduction of fenvalerate residues was achieved to the extent of 27-56 per cent by cooking in brinjal fruits (Sharma and Kumar, 1993).

Cooking after washing mitigated 5 days old residues by 94.49, 37.97 and 11.64 per cent from recommended rates of application of endosulfan, fenvalerate and monocrotophos, respectively, (Dinabandhoo and Sharma, 1994).

Washing the apples fruits followed by cooking (including processing apple to sauce) reduced the amount of residue by 98 per cent. The total amount of residue on the control unwashed fruit was determined to be 0.67 ppm. Household washing procedures are normally carried out with running or standing water at moderate temperatures. Detergents, chlorine or ozone can be added to the wash water to improve the effectiveness of the washing procedure (Ong *et al*. 1996).

Kumar (1997) observed that 2 per cent tamarind solution was the best decontaminating solution in removing residues of phosphamidon and monocrotophos in bittergourd and cowpea pods. Nagesh and Verma (1997a) studied the decontamination of cabbage treated with chlorpyriphos and quinalphos. Washing of the vegetable treated with chlorpyriphos @ 0.05 % reduced initial deposits from 13.81 to 8.56 mg kg^{-1}, showing a reduction of 38.02 per cent. For quinalphos, though reduction of residues was 39.06-44.0 per cent, but it did not help much in bringing the residues below MRL of 0.25 mg kg^{-1}.

Lee and Lee (1997) revealed that 45 per cent of organophosphorous pesticide (OP) residues were eliminated when foods were washed in water, 56 per cent with detergent washing, 91 per cent with peeling, 51 per cent with blanching + boiling and 90 per cent in milling and processing.

Commercial and household processing such as washing, peeling, cooking, blanching and concentrating can reduce residue level in food and then reduce impact on human health (Abou-arab, 1999).

Dipping the green chillies in 2 per cent salt solution for 10 min followed by washing, removed the residues to an extent of 32.60 and 84.20 per cent at zero and 5 days following six applications of triazophos, respectively (Kumar *et al.* 2000).

Reduction of alphamethrin in the range of 25-32 per cent in brinjal and tomatoes and 12-17 per cent in cauliflower was reported by Gill *et al.* (2001) and Malik *et al.* (1999). Reddy *et al*. (2001) observed that washing with water followed by steam cooking removed triazophos to an extent of 64 to 68 per cent in brinjal.

Kadian *et al*. (2001) studied the effect of household processing on cypermethrin residues in some common vegetables. There was a decline in residue level after all processing procedure i.e. about 5- 14 per cent by washing, 6 to 26 per cent by blanching, 6-19 per cent by washing in brine solution, 15-33 per cent by cooking. The results suggested that cooking was more effective to reduce cypermethrin residues in vegetables.

Reddy and Rao (2001) observed the initial deposit of 2.26 mg kg^{-1} which was dissipated to 0.05 mg kg^{-1} by 20 days after spray of bifenthrin with half-life of 6.13 days. Washing of grape berries after dipping in 1 % acetic acid solution proved effective with removal of 69.95 and 58.18 per cent residues correspondingly at 1 and 5 days after spray, respectively.

Zohair (2001) reported that soaking of contaminated potatoes in neutral (NaCl) solution (5 and 10 %) for 10 min resulted in 100 per cent reduction of pirimiphos methyl residues. Tomatoes contaminated at level of 1 mg kg^{-1} upon washing with 10 % NaCl solution gave 42.90, 46.10, 27.20, 90.80, 82.40 and 91.40 per cent loss in HCB, lindane, p,p-DDT, dimethoate, profenophos and pirimiphos-methyl, respectively (Dhiman, 2006). Washing of cauliflower treated with chlorpyriphos, quinalphos, endosulfan, fenvalerate and deltamethrin reduced 28.92-78.64 per cent residues of these insecticides (Dhiman *et al.* 2003).

Singh *et al.* (2004) reported that washing of okra fruits with tap water removed cypermethrin residues to an extent of 41.2-48.3 per cent in 0 (Zero) day samples and 37.1-46.0 per cent in 5^{th} day samples.

Mukherjee *et al.* (2006) studied the reduction of chlorpyriphos residues from contaminated cauliflower curds by effect of washing, cooking, washing + cooking, salt water dipping, dipping in boiled salt water, dipping in detergent solution and dipping in boiled detergent solution. The analysis showed that various food processing techniques substantially lowered the residues of chlorpyriphos in cauliflower curd from 27.9 to 73.3 per cent but none was able to satisfactorily bring down the residues below the tolerance level of 0.01 kg g^{-1}.

Sood (2006) reported percentage reduction of cypermethrin residue in okra was 36.26, 35.79 and 47.69 per cent at 1, 3 and 7 days of spray, respectively by employing tap water washing.

Randhawa *et al*. (2007) observed 15-30 per cent reduction of endosulfan residues on brinjal by washing. Boiling was found comparatively more effective than washing in dislodging the residues. Boiling process reduces maximum per cent of OP insecticides in brinjal followed by 92 per cent in cauliflower and 75 per cent in okra. Washing with tap water reduced the residues by 20-77 per cent (Beena Kumari, 2008).

Aktar *et al.* (2008) reported total quinalphos degraded to an extent of 72 per cent. Decontamination processes like washing and cooking were observed to dislodge quinalphos residues to the extent of 25.50–81.50 per cent on okra, depending on doses, whereas 20.00–69.60 per cent surface residue was removed by washing alone.

Klinhom *et al.* (2008) reported that washing of leafy Chinese-Kale with 0.9 % NaCl solution reduced residues of methomyl and carbaryl by 39.33 and 91.98 per cent.

Lal *et al*. (2008) studied residue removal nature of beta-cyfluthrin and lambda-cyhalothrin in okra crop and the removal of residues of 35.3 and 36.1 per cent, respectively by tap water wash.

Kwon *et al*. (2009) reported the reduction rate of pesticide residues on spinach (bifenthrin, metalaxyl, procymidone), chard (bifenthrin, imidacloprid) and mallow (bifenthrin, chlorpyrifos, imidacloprid) were tested on each step of washing and boiling (spinach: 1, 3, 5 min., chard: 3, 6, 9 min., mallow: 10, 20, 30 min). The reduction rates of bifenthrin and procymidone by washing were 58-64 and 82 per cent, respectively and these were not changed significantly after boiling.

Washing under running tap water removed on an average of 27.72-32.48 per cent quinalphos residues from cabbage head. After cooking, this reduction was 41.30-45.20 per cent and in washing plus cooking, it further increased to a range of 66.45-68.19 per cent. Further, reported dipping of cabbage sample in 2 % salt solution reduced 66.45 and 68.19 per cent residues of quinalphos when applied at 500 and 1000 g.a.i. ha^{-1}, respectively in cabbage (Aktar *et al.* 2010).

Duhan *et al.* (2011) determined residues level of endosulfan in cabbage heads. Peeling removed the residues by 92 per cent. Similarly, washing and washing followed by cooking removed 72 and 97 per cent residues in cabbage stored at room temperature, respectively.

Bonnachere *et al*. (2012) reported that washing step allowed decreasing the concentration of residues for all pesticides up to 90 per cent.

Chauhan *et al*. (2012a) studied the effects of processing like washing, washing followed by boiling to dislodge the residues of lambda-cyhalothrin on tomato fruits. Residues were estimated by GC-ECD capillary system. The process of washing followed by boiling reduced the residues effectively (74.84 %) whereas by washing only, residues could be reduced in the range of 37.40 per cent.

Liang and co workers (2012) reported that 63.40, 60.00, 50.00, 31.10 and 66.70 per cent reduction in the residues of trichlorfon, dimethoate, dichlorvos, fenitothion and chlorpyriphos, respectively, were observed in cucumber when dipped in 2 % sodium chloride solution for 20 min.

Parmar *et al.* (2012) studied the dissipation and decontamination of different insecticides *viz.,* deltamethrin, alphamethrin, deltamethrin in combination, triazophos, ethion, cypermethrin and profenophos in okra fruits. In decontamination methods, cooking was the best culinary process in which triazophos residues were dislodged up to 66.34 per cent from okra fruits. Further, reported that washing with normal tap water reduced the residues with 42.06, 26.32, 41.75, 26.32 and 93.72 per cent reduction, respectively.

Reddy *et al.* (2012b) reported that the washing of brinjal fruits collected on 5th day after third spray of lambda-cyhalothrin with tap water for 2 minutes removed residues to an extent of 33.34 to 36.11 per cent and washing of brinjal fruits with 2 % salt water for 2 minutes removed residues of lambda-cyhalothrin to the extent of 62.96 to 63.89 per cent on 5th day after third spray.

Satpathy *et al*. (2012) reported that washing of vegetables with 0.9 % NaCl reduced the residues by 20-89 per cent.

Thanki *et al*. (2012) reported that washing; boiling and cooking process minimized the pesticide residues of nine pesticides in the range of 3.32-70.0, 21.08-70.67 and 31.63-85.30 per cent, respectively in cauliflower and also reported that cooking was found more effective than washing and boiling.

Aasia and Saghir (2013) revealed that the residual level of pesticides in unwashed unprocessed cauliflower samples were beyond their recommended MRLs i.e. bifenthrin, endosulfan, profenophos, emamectin benzoate, imidacloprid and diafenthiuron and the respective values were 0.151, 0.671, 0.172, 1.04, 1.011 and 0.052 ppm, respectively, which is far above their respective MRLs set by FAO i.e. 0.05, 0.5, 0.05, 0.5, 0.4 and 0.02 ppm, respectively. The results showed that, the plain washing and detergent washing reduced the fat soluble pesticides by 28 and 48 per cent, respectively. Whereas, water soluble pesticides to the extent of 40 and 55 per cent, respectively.

Sachin Kumari *et al*. (2013) carried out experiments to observe the effect of different household processes on reduction of bifenthrin residues on okra fruits and found that processing was quite effective in reducing the levels of bifenthrin residues in okra fruits and stated that maximum reduction (64.58 to 68.42 %) was observed by washing + boiling followed by washing (36.71 to 40 %).

Panhwar *et al.* (2013) reported that plain water washing reduced fat soluble residues of bifenthrin, endosulphan and profenofos in cauliflower by 25, 28.1 and 14.32 per cent, respectively.

Varghese and Mathew (2013) reported that 2 % tamarind solution was the best decontaminating solution in removing residues of spiromesifen (90.03 %) and propargite (96.69 %) from green chilli fruits.

The most commonly used pesticides such as profenophos, chlorpyriphos, dimethoate, malathion, phosalone, quinalphos, triazophos and cyhalothrin were sprayed at fruit formation stage on brinjal crop at recommended doses and samples were subjected to various household treatments. Out of all treatments, dipping in 2 per cent salt solution for 10 min was very effective in removing 50 per cent profenophos and cooking removed insecticides in the range of 55 to 80 per cent. Tap water washing led to (45.60 %) reduction in quinalphos residues in brinjal. Dipping fruits and vegetables in 2 per cent salt solution for 15 min was the best household method for removal of pesticide residues and also the method was effective in reducing the residues below Maximum Residue Limit (Cherukuri *et al*. 2014).

Harinathareddy *et al*. (2014) studied the extent of pesticide residues removal from tomato through household processing, such as washing with tap water, 2 % salt solution, vinegar and cooking etc. Washing with tap water reduced the residues in the range of 37.0-73.2 per cent, 2 % salt solution 44.3-78.7 per cent, where as vinegar reduced residues in the range of 17.1-58.5 per cent. Cooking reduced the residues in the range of 42.9-83.2 per cent.

Pallavi *et al.* (2014) evaluated that effect of different decontaminating solutions in the removal of pesticide residues, okra var. *Varsha Upahar* was sprayed with a mixture of pesticides which were frequently detected. Okra samples in 2 % tamarind solution for 15 minutes followed by washing in tap water was more effective in removing the residues one day after spraying, recording a residue removal of 54.46-73.25 per cent.

Shashi *et al*. (2014) studied different decontamination methods *viz*., washing under running tap water, 2 per cent salt solution, direct cooking, dipping in 2 per cent salt solution and cooking and analyzed for final remaining residues. Cumulative effect of all four household process caused substantial reduction in residues up to 95 per cent. However, cooking with pressure cooker for 5 minutes reduced pesticides from 30-93 per cent of profenophos. Effectiveness of cooking was also endorsed by Shashi *et al*. (2015a) in brinjal where direct cooking removed 58.20 and 59.00 per cent residues of quinalphos and profenophos, respectively. Further, Shashi *et al*. (2016) reported 39.40, 52.90 and 48.70 per cent reduction in residues of quinalphos, profenophos and lambda cyhalothrin, respectively when tomato fruits were subjected to cooking.

Geetha (2015) reported reduction of triazophos and Deltamethrin + triazophos residues in spinach by employing different household processes. Hot water cooking for 10 min (54.52 and 90.71 + 55.42 %) was found to be more effective than tap water treatment (19.88 and 54.59+ 24.54 %). Whereas, 46.87 and 43.78 per cent reduction in residues of cypermethrin and triazphos were observed by employing 2 % salt solution, respectively.

Harinathareddy *et al.* (2015) reported that 2% tamarind solution reduced the residues in tomato in the range of 26.1 to 69.10 per cent.

Subhash Chandra *et al*. (2015) who reported that fruit washing in salt solution (2 %) followed by washing with tap water was effective in removing 68.0-69.4 per cent of the pesticide residues from the okra fruits. Almost 99 per cent monocrotophos, chlorpyriphos and cypermethrin residues were dislodged from treated brinjal and okra fruits by boiling in water.

Talekar *et al*. (2016) revealed that the removal of triazophos, quinalphos and perthane® (1,1-dichloro-2,2-bis (4-ethylphenyl) ethane) residues in chinese cabbage by washing with tap water. Boiling reduced the residues of malaoxon, quinalphos, fenitrothion, chlorpyriphos methyl and perthane® but the concentrations of residues of cyanofenphos, malathion, leptophos, triazophos, tokuthion® (O-ethyl S-N-propyl 0-2,4-

dichlorophenyl phosphorodithioate) and carbofuran were increased in boiled cabbage samples.

3. MATERIAL AND METHODS

The investigations were carried out on 'Bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* L.) and their residues in cabbage' during the year 2015-16 and 2016-2017 at MPKV, Rahuri, Maharashtra. The survey on usage pattern of insecticides in cabbage was undertaken in Ahmednagar, Pune and Nasik districts of western Maharashtra. The field experiments on bio-efficacy were conducted on farmer's field at Nandur Madhyameshwar, Tq. Niphad, Dist. Nashik and at Khandgaon, Tq. Sangamner, Dist. Ahmednagar. Field experiment on dissipation was conducted at Research Farm of Post Graduate Institute, Department of Agril. Entomology, M.P.K.V., Rahuri. The laboratory studies on dissipation and decontamination of pesticides residues were carried out at the A.I.N.P. on Pesticide Residue Laboratory, Department of Agricultural Entomology, M.P.K.V., Rahuri. The material used and methods followed during the experimentation are described here under.

3.1 Material

3.1.1 Seeds

The seed of cabbage var. Saint was purchased from Agro service centre, Rahuri.

3.1.2 Insecticides for bio-efficacy study

The details of ten treatments and newer insecticides used for bio-efficacy study are given in Table 1.

3.1.3 Insecticides for dissipation study

In this experiment, seven treatments including untreated control were maintained. The test insecticides were obtained from local market. The treatment details regarding name of insecticides, formulations, dose and concentration of spray solution are presented in Table 2. Particulars of evaluated insecticides *viz*., common name, chemical name, trade name, formulation and manufacturer of product/source are presented in Table 4.

3.1.4 Insecticides for decontamination study

In this experiment, four treatments including untreated control were maintained. The test insecticides were obtained from local market. The treatment details consisting name of insecticides, formulations, dose and concentration of spray solution are presented in Table 3. Particulars of evaluated insecticides *viz.*, common name, chemical name, trade name, formulation and manufacturer of product/source are presented in Table 4.

3.1.5 Glassware

All glass items were of 'A' grade. Glasswares were initially cleaned with aqueous soap solution and were rinsed thoroughly with tap water. Acetone rinsed glasswares were oven-dried prior to use.

3.1.6 Chemicals and Reagents

a. Ethyl acetate (HPLC Grade), Avantor Performance Materials India Limited, Thane, (M.S.)

b. Sodium sulphate anhydrous purified, SDFCL, Mumbai

c. PSA (Primary Secondary Amine), Agilent Technology, Bangalore

d. Acetone (Analytical Reagent grade), Merck Specialties Private Limited, Mumbai (M. S.).

e. Toluene (Analytical Reagent grade), Avantor Performance Materials India Limited, Thane, (M.S).

Table 1. Insecticides for bio-efficacy study

Insecticides	Trade Name	Dose (g a.i.ha^{-1})	Formulation (mL ha^{-1})	Spray Concentration (mL plot^{-1})
Indoxacarb 14.5 % SC	Avaunt®	40	276	0.41
Spinosad 2.5 % SC	Success®	17.5	700	1.05
Flubendiamide 39.35 % SC	Fame®	18.24	46	0.07
Diafenthiuron 50 % WP	Pegasus®	300	600	0.90
Emamectin benzoate 5 % G	Proclaim®	10	200	0.30
Chlorantraniliprole 18.5 % SC	Coragen®	10	54	0.08
Quinalphos 25 % EC	Ekalux®	250	1000	1.50
Triazophos 40 % EC	Trizocel®	500	1250	1.87
Bifenthrin 10 % EC	Capture®	50	500	0.75
Untreated control	---	-----	------	---

Table 2. Treatment details of supervised field trial on dissipation of triazophos, quinalphos and bifenthrin

Treatment	Trade Name	Dose (g a.i.ha^{-1})	Formulation (mL ha^{-1})	Spray concentration (mL plot^{-1})
Triazophos 40 % EC	Tritox	500*	1250	1.12
Triazophos 40 % EC	Tritox	1000**	2500	2.25
Quinalphos 25 % EC	Ekalux	250*	1000	0.90
Quinalphos 25 % EC	Ekalux	500**	2000	1.80
Bifenthrin 10 % EC	Capture	50*	500	0.45
Bifenthrin 10 % EC	Capture	100**	1000	0.90
Untreated control	----	----	----	---

*Recommended Dose ** Double the Recommended Dose

Table 3. Treatment details of supervised field trial on decontamination of triazophos, quinalphos and bifenthrin

Treatment	Trade name	Dose (g a.i.ha^{-1})	Formulation (mL ha^{-1})	Spray concentration (mL plot^{-1})
Triazophos 40 % EC	Tritox	500*	1250	1.12
Quinalphos 25 % EC	Ekalux	250*	1000	0.90
Bifenthrin 10 % EC	Capture	50*	500	0.45
Untreated control	----	----	----	--

*Recommended Dose

Table 4. Particulars of insecticides for dissipation and decontamination study

Common Name	Chemical Name	Trade Name	Formulation	Source
Triazophos	0,0-diethyl 0-1-phenyl-1H 1, 2,4-trizol-3-phosphorothioate	Tritox	40 EC	M/s. Cheminova, Mumbai 400 051
Quinalphos	0,0- diethyl 0- quinoxalin-2-yl phosphorothioate	Ekalux	25 EC	M/s. Syngenta India Ltd., Pune 411045
Bifenthrin	(2-methyl-3-3-phenyl phenyl1)methyl(1R,3R)-3-[(Z)-2-chloro-3,3,3-trifluoroprop-1-enyl]-2,2-dimethylcyclopropane-1-carboxylate	Capture	10 EC	M/s. Syngenta India Ltd., Pune 411045

3.1.7 Apparatus, Equipments and Instruments

3.1.7.1 Apparatus and Equipments (Plate 1)

Apparatus/Equipment	Make	Model	Range and Accuracy
Weighing balance	Citizen	Cy-204	0.0001 to 220 gm
Weighing balance	Citizen	CTG 302-300	Min 0.02 to 300 mg
Grinder	Robot Coupe	Blixer 6 v.v.	7 L
Centrifuge	Remi	R-8-CHDLC-10151	5000 RPM
Vortex	Spinix	--	--
Deep Freezer	Sanyo	MDF-U5411	Ambient to - 40^0 C
Micro Pipette	Eppendorf	--	100 to 1000 µL
Micro Pipette	Eppendorf	--	10 to 100 µL

3.1.7.2 Instrument (Plate 2)

a. Gas Chromatograph equipped with Flame Photometric Detector (FPD) and Electron Capture Detector (ECD)-Shimadzu-GC 2010.

3.1.7.3 Certified reference material of tested insecticides

Specification	CRM		
	Triazophos	**Quinalphos**	**Bifenthrin**
Make	Sigma-Aldrich	Sigma-Aldrich	Sigma-Aldrich
Purity	98.9	99.4	98.6
DOP	29.03.2014	19.12.2013	19.12.2013
DOE	April- 2016	Sept-2015	April- 2016
Lot No.	SZBD102XV	SZBA249XV	SZBB102XV
Storage condition	-20ºC	-20ºC	-20ºC

3.1.8 Appliance

Manually operated knapsack sprayer (Aspee make) with hollow cone nozzle was used for spraying insecticide on cabbage crop.

3.2 Method

3.2.1 Usage pattern of insecticides in cabbage

The survey on use pattern of insecticides in cabbage was undertaken in Ahmednagar, Pune and Nasik districts of western Maharashtra [Plate 3] on the basis of questionnaire (Appendix-I). The questionnaire was prepared in the form of closed and multiple choice format questions with Yes/No as answers. A format of questionnaire was used for the collection of information by interviewing the individual farmers [Plate 4]. The information on insecticide usage pattern was generated from 50 farmers who were interviewed regarding usage and application of insecticides on cabbage. Interviews were carried out in the appropriate local language (Marathi).A record of all collected information was analyzed.

3.2.2 Field experiment on bio-efficacy of newer insecticides against diamondback moth (*P. xylostella*)

3.2.2.1 Cultivation of cabbage crop

The experiment was laid out during the year 2015-16 and 2016-17 on farmer's field at Nandur Madhyameshwar, Tq. Niphad, Dist. Nashik and at Khandgaon, Tq. Sangamner, Dist. Ahmednagar [Plate 5]. Cabbage seedlings were grown on raised beds by sowing disease free seeds of var. Saint. The seedlings were ready for transplanting at 30 days after sowing. Land for planting the cabbage was ploughed once and later given two harrowing. The layout of the experiment was done by preparing ridges and furrows. All the cultural practices were carried out as per recommendations.

Other experimental details are given below.

Experimental details for bio-efficacy study:

Season	:	*Rabi and Summer*
Design of Experiment	:	Randomized Block Design (RBD)
Number of Treatments	:	Ten
Number of Replications	:	Three
Number of spray applications	:	Two
Time of spraying	:	At Economic Threshold Level (ETL)
Plot size	:	3.0 m x 5.0 m
Spacing	:	45 cm x 30 cm
Variety	:	Saint

3.2.2.2 Application of insecticides

The insecticides were applied in the form of foliar sprays when the attack of larvae of diamondback moth reached at ETL (2 larvae plant^{-1}) on cabbage. The insecticides solutions were prepared by adding required quantity of the insecticide and sticker (Spreader Sticker®) in a given quantity of water and the solution thus prepared was used for spraying on the cabbage plots. Proper care was taken to cover the entire plant canopy with the insecticidal solution. The spraying of insecticide was carried out in morning hr using knapsack sprayer having capacity of 16 L. After application of each insecticidal solution, the bucket and delivery tubes were thoroughly washed with clean water. Untreated control plots of cabbage were maintained separately.

3.2.2.3 Method of recording observations

Five plants from each plot were selected randomly and labeled in each replication. The observations on total number of larvae of diamondback moth on head and outside the head were recorded on a day before and at 1, 3, 7 and 14 days after first and second application of insecticides. The average population of larvae of diamondback moth per plant was worked out for statistical analysis.

While recording yield data, only marketable heads were taken into account. Yield obtained from net plot was converted into per hectare. The cost:benefit ratio was determined on the basis of net income gained from yield over control.

3.2.3 Experiment on dissipation of insecticides in cabbage

3.2.3.1 Cultivation of cabbage crop

The experiment was laid out during *Rabi* 2015 at the Instructional Farm of Post Graduate Institute, MPKV, Rahuri [Plate 8]. Cabbage seedlings were grown on raised beds by sowing disease free seeds of variety Saint. Seedlings were ready for transplanting at 30 days after sowing. Land for planting the experiment was ploughed once and later given two harrowing. The layout of the experiment was done by preparing ridges and furrows. All the recommended package of practices were followed to maintain healthy crop stand.

3.2.3.2 Application of insecticides

The spraying was done manually by hand operated knapsack sprayer fitted with hollow cone nozzle. Two foliar sprays of each insecticide were given at an interval of 10 days. First spray was given at 50 per cent head formation stage. Quantity of spray fluid required per plot was calibrated by spraying control plot with water. Due care was taken to wash the spray pump with water in the beginning as well as while switching over from one insecticide to another during spraying. All sprays were given during morning hour to avoid drift due to heavy winds from one treatment plot to other.

3.2.3.3 Sampling

Cabbage samples (1 kg sample/plot) were randomly collected from each treated plot. Cabbage head samples were collected at an interval of 0 (2 hr after spray), 1, 3, 5, 7, 10 and 15 days after application of triazophos, quinalphos and bifenthrin. The collected representative samples were placed in plastic bags, brought to the laboratory and stored at -20 ^{0}C until the analysis.

Experimental details for dissipation study:

Experiment Design	:	Randomized Block Design (RBD)
No. of replications	:	3 (Three)
Treatments	:	7 (Seven)
Plots including control	:	24 (Twenty four)
Plot size	:	3.0 x 3.0 m^2
Spacing	:	45 cm x 30 cm
Date of sowing of seeds	:	1st September 2015
Date of transplanting	:	3rd October 2015
Time of application	:	50 % head formation stage
Number of application	:	Two at 10 days interval
Date of application	:	1st spray -29th December, 2015 2nd spray- 8th January, 2016
Substrate	:	Cabbage heads
Sample interval	:	0 (2 hrs), 1, 3, 5, 7, 10 and 15 days after last spray
Sample quantity	:	1 kg
No. of sample taken	:	3 (Three)

3.2.4 Experiment on decontamination of insecticides in cabbage

Impact of different household processes commonly followed at home before consumption of cabbage were studied by subjecting the cabbage heads to different treatments [Plate 9]. For this study, one foliar spray of each insecticide at recommended dose was given at 50 per cent head formation stage of cabbage. After 2 hr of application, the samples were collected and processed. Analytical methods as given in 3.2.5.3 for estimation of residues of triazophos, quinalphos and bifenthrin were used for the unprocessed and processed samples. Difference in residue levels obtained in such samples were used to calculate the effect of household processes on per cent reduction of residues deposited on the cabbage head exposed to spray treatment on cabbage crop. Different decontamination processes followed during study are given as below.

3.2.4.1 Washing

Cabbage head sample was taken in a tray containing water and gently rubbed twice or thrice by hand for about two minutes. Water was decanted and sample was subjected to residue analysis.

3.2.4.2 Washing with 2 % sodium chloride (NaCl)

Cabbage head sample was dipped in a beaker containing 2 % sodium chloride solution (NaCl). After 5 min., the sample was gently rubbed by hand in salt solution and the salt water was decanted. Then, the sample was washed in tap water and subjected to residue analysis.

3.2.4.3 Boiling

Chopped cabbage sample was boiled by placing 75 mL of water in open pan. The sample (50 g) was added immediately to boil for 5-10 min. The water was decanted and sample was subjected to residue analysis.

3.2.4.4 Steam cooking

Chopped cabbage sample was cooked by placing 75 mL water in closed pan. Cabbage (50 g) was added immediately to cook for 10 min. Water was decanted and then sample was subjected to residue analysis.

3.2.4.5 Washing with 2 % Tamarind water

Cabbage head sample was dipped in 2 per cent tamarind solution for 5 min. and the water was decanted. Then, sample was subjected to residue analysis.

3.2.4.6 Treated control (No processing)

Cabbage sample was taken from insecticide treated plot as such without any household process and subjected to residue analysis.

3.2.4.7 Untreated Control

Cabbage sample was taken from untreated plot and subjected to residue analysis.

Per cent removal of pesticide:

$$\textbf{Per cent removal} = \frac{\text{Initial deposit-Residues after treatment}}{\text{Initial deposit}} \times 100$$

3.2.5 Residue analysis

3.2.5.1 Standard preparation

Primary stock solution- An accurately weighed 10 mg of an individual analytical grade pesticide (based on purity) was dissolved in 10 ml volumetric flask using toluene as solvent to prepare the standard stock solution of 1000 µg mL^{-1}.

Intermediate stock solution- Intermediate stock solution of each insecticide was diluted to obtain intermediate lower concentration of 100 µg mL^{-1}. They were stored in a refrigerator at -2° C.

Working standards- From the intermediate standards, working standards of triazophos, quinalphos and bifenthrin were prepared at concentration of 0.025, 0.05, 0.10, 0.25, 0.40, 0.50, and 1 µg $mL^{-1}$by suitably diluting the stock solution in ethyl acetate and used as standard check in analysis, linearity and recovery studies.

3.2.5.2 Method validation

Method validation is the process used to confirm that the analytical procedure employed for a specific test is suitable for its intended use. Results from method validation can be used to judge the quality, reliability and consistency of analytical results. It is an integral part of any good analytical practice. Limit of detection (LOD), Limit of quantification (LOQ), linearity and recovery studies were performed in order to validate the method.

Limit of Detection (LOD) and Limit of Quantification (LOQ)

The limit of detection (LOD) of triazophos, quinalphos and bifenthrin were determined by considering a signal-to-noise ratio of three with reference to the background noise obtained for the blank sample. The limit of quantification was (LOQ) determined as two and half times of LOD.

Specificity

Specificity studies were performed by spiking the cabbage sample and reagent blank with working standards of triazophos, quinalphos and bifenthrin at the concentration of 0.05 mg kg^{-1}. The area of cabbage sample and reagent blank was compared with spiked matrix match area.

Linearity studies

Six linear concentrations (0.05, 0.10, 0.25, 0.40, 0.50 and 1.00 mg kg^{-1}) of working standard *i.e.,*triazophos, quinalphos and bifenthrin were injected three times and the linearity lines were drawn.

Recovery studies

The analytical method for estimation of residues of triazophos, quinalphos and bifenthrin in cabbage was validated by conducting recovery studies using cabbage samples from control samples. Ten g each of control samples of cabbage were taken in separate 50 mL centrifuge tubes in three replicates; each were spiked separately with triazophos, quinalphos and bifenthrin at the required fortification levels *i.e.* LOQ, 5 x LOQ and 10 x LOQ, adding an appropriate volume of working standard of 10 mg $kg-^{1}$. This mixture was then shaken, in order to attain a proper homogeneity of insecticide in the samples. The extraction and cleanup was followed as per QuEChERS method as described in 3.2.5.4

The per cent recovery was calculated by using following formula.

$$\textbf{Per cent recovery} = \frac{\text{Quantity of insecticide recovered}}{\text{Quantity of insecticide added}} \times 100$$

Repeatability

Repeatability or retest reliability was performed to check the variation in measurements taken by the same person on same instrument on the same item under the same conditions. Standards of triazophos, quinalphos and bifenthrin were separately spiked into the control samples of cabbage at the required fortification levels *i.e.* LOQ, 5 x LOQ and 10 x LOQ.

Reproducibility

Reproducibility was performed to test the ability of an entire analysis of an experiment by another person on same instrument on the same item under the same conditions.

3.2.5.3 Sample preparation

The upper most dried leaves of cabbage heads were removed before extraction.

Substrate	Interval between last application and sampling	Date of sample collection
Cabbage heads	0 day	08-01-2016
	1 day	09-01-2016
	3 day	11-01-2016
	5 day	13-01-2016
	7 day	15-01-2016
	10 day	18-01-2016
	15 day	23-01-2016

3.2.5.4 Extraction and clean up of cabbage for triazophos, quinalphos and bifenthrin

Modified QuEChERS method

The cabbage samples were extracted and cleaned up using modified QuEChERS method (Sharma, 2014). The entire laboratory sample (1 kg) was macerated thoroughly in a mixer and grinder and approximately 10 g homogenised sample weighed in a 50 ml polypropylene tube which was kept in deep freezer for 10 min. Homogenised samples were extracted with 10 ml ethyl acetatein presence of 10 g anhydrous Na_2SO_4 and centrifuged at 3500 rpm for 5 min. Two ml supernatant was transferred to 15 ml tube containing 50 mg PSA. The content was vortexed for 30 sec. and then cetrifuged at 2500 rpm for 2 min. The supernatant was filtered through 0.2 micron filter and GC analysis was carried out in Pesticide Residue Laboratory, AINP on pesticide Residue, Department of Agril. Entomology, MPKV, Rahuri (MS), India.

3.2.5.5 Residue Determination

Residue estimation of triazophos, quinalphos and bifenthrin were performed using GC-FPD and GC-ECD. Identification of insecticide residue was accomplished by retention time (RT) and compared with known standard (CRM) at the same conditions. The quantities were calculated on peak area basis by using following formula.

$$\text{Residues (mg kg}^{-1}) = \frac{\text{Area of sample}}{\text{Area of standard}} \times \frac{\mu\text{l of sample injected}}{\mu\text{l of standard injected}} \times \frac{\text{Conc. of standard (ppm)}}{\text{wt .of sample}} \times \text{Final volume (ml)}$$

$$\text{Wt. of sample (g)} = \frac{\text{Sample Wt. (g) X Aliquot taken (ml)}}{\text{Volume of solvent added (ml)}} = \text{g}$$

3.2.5.6 GC-FPD and GC-ECD Condition

The analysis of samples for triazophos, quinalphos and bifenthrin residues were carried out with GC-FPD and GC-ECD Shimadzu GC-2010 with auto injector. Shimadzu GC-FPD solution software was used as the data analysis system. The operating parameters of the instrument are given below.

Gas Chromatographic Parameters:

Column	DB-1, 30 m x 0.25 µm × 0.25 mm
Column Temperature	170^0 C …… 3 min hold @ 6.5^0 C/min 220^0 C …… 2 min hold @ 10^0 C/min 280^0 C …… 6 min hold
Injector Temperature	250^0C
Column Temperature	170^0C
Detector Temperature	300^0C
Injection Volume	1 µl
Column flow	0.96 ml min^{-1}
Hydrogen Flow	90 ml min^{-1}
Air Flow	120 ml min^{-1}

3.2.6 Statistical Analysis

The simple statistical analysis was carried out in the Microsoft Excel programme with the help of computer. The mean residues, standard deviation, regression equation, R^2 value and half life were calculated in excel programme.

4. EXPERIMENTAL RESULTS

The present investigation on "Bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* L.) and their residues in cabbage" was undertaken at the Instructional farm of Post Graduate Institute, Department of Agricultural Entomology, M.P.K.V., Rahuri during 2015-16 and 2016-17. The results obtained are presented under the following headings.

4.1 Usage pattern of insecticides in cabbage against diamondback moth (*Plutella xylostella* L.)

4.2 Bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* L.)

4.3 Dissipation pattern of triazophos, quinalphos and bifenthrin in cabbage

4.4 Impact of household processes on residues of the insecticides

4.1 Usage pattern of insecticides in cabbage against diamondback moth (*Plutella xylostella* L.)

A survey was conducted to study the usage pattern of insecticides in predominantly cabbage growing areas of western Maharashtra *viz.,* Ahmednagar, Pune and Nashik districts during October, 2015 to December, 2016. The information on insecticide usage pattern was generated from 50 farmers who were interviewed for usage and application of insecticides on cabbage. Interviews were carried out in the appropriate local language i.e. Marathi.

During survey, the respondents were asked about their awareness and technical know-how about insecticide use, sources of recommendations, residues persistence of insecticides, their safe waiting periods, etc. The results are presented in Tables 5 and 6.

Survey of insecticide usage pattern on cabbage explicated wide range of insecticides used by the farmers in respective areas. Farmers relied on conventional insecticides as well as novel insecticides and also on bio-pesticides. The usage of insecticides was largely dependent on the incidence of pests in the respective locality. Farmers used organophosphates, carbamates, neonicotinoids, synthetic pyrethroids and newer chemicals for the control of diamondback moth (DBM).

The most widely used insecticides to control cabbage pests in the study areas during the survey period are shown in Table 5. The results showed that organophosphates were used predominantly by the farmers.

4.1.1 Usage pattern of insecticides in cabbage

Ahmednagar District

Survey reports revealed that in Ahmednagar district, share of conventional insecticides was highest (81.01%) followed by novel insecticides (12.37 %) and biopesticides (6.64%). Majority of the farmers used combination of insecticides. The data on quantity of insecticides used by individual farmer in respect of cabbage (Table 5; Fig 1 and 2) revealed that total consumption of conventional insecticides was 1.22 kg a.i. ha^{-1} which was 81.01 per cent. Whereas, consumption of novel insecticides was @ 0.20 kg a.i. ha^{-1} (12.37 %), followed by biopesticides (0.10 kg a.i. ha^{-1}) in cabbage crop.

The quantity of organophosphate insecticides used by individual farmer was 1.04 kg a.i ha^{-1} for the control of insect pests in cabbage. Among the insecticides groups, per cent shares of organophosphates, carbamates and synthetic pyrethroid were 69.06, 6.77 and 5.18 per cent, respectively. Whereas, use of novel insecticides *viz.,* neonicotinoids, oxadizines, avermectins, spinosyns, diamides, pyrroles, phenylpyrazoles and IGR's was 3.67, 1.00, 0.44, 0.72, 1.39, 0.84, 0.60 and 3.71 per cent, respectively. Insecticides used were triazophos, quinalphos, acephate, chlorpyriphos, profenophos, dichlorvos, cypermethrin, imidacloprid, thiamethoxam, fipronil, emamectin benzoate, indoxacarb, flubendiamide, spinosad, chlorantraniliprole and cyantraniliprole.

Pune District

It could be seen that the total quantity of insecticides used by the individual farmer was 1.79 kg a.i. ha^{-1} $season^{-1}$ in Pune district (Table 5; Fig 3 and 4).

Further, it was revealed that share of conventional insecticides was highest (79.39 %), followed by novel insecticides (13.91%) and biopesticides (6.70 %). Total consumption of conventional insecticides was 1.43 kg a.i.ha^{-1} (79.39 %) as compared to 0.24 kg a.i. ha^{-1} (13.91 %) of novel insecticides and 0.12 kg a.i. ha^{-1} (6.70 %) of biopesticides.

The quantity of organophosphorous insecticides used by individual farmer was 1.36 kg a.i. ha^{-1} for the control of insect pests in cabbage. Among the insecticidal groups, per cent shares of organophosphates, carbamates and synthetic pyrethroids were 75.83, 0.38 and 3.18 per cent, respectively. Whereas, use of novel insecticides *viz.,* neonicotinoids, oxadizines, avermectins, spinosyns, diamides, pyrroles, phenyl pyrazoles and IGR's was 2.92, 3.02, 0.40, 0.80, 1.98, 1.07, 1.24 and 2.48 per cent, respectively. Insecticides included triazophos, quinalphos, acephate, chlorpyriphos, profenophos, dichlorvos, cypermethrin, imidacloprid, fipronil, emamectin benzoate, indoxacarb, flubendiamide, spinosad, chlorantraniliprole and cyantraniliprole.

Nashik District

From surveyed information in Nashik district, it could be seen that the total quantity of insecticides used by the individual farmer was 1.65 kg a.i. ha^{-1} $season^{-1}$ (Table 5; Fig 5 and 6).

Further, it was revealed that share of conventional insecticides was highest (65.10 %), followed by novel insecticides (22.77 %) and bio-pesticides (12.14 %). Majority of the farmers used individual formulations as well as combination of insecticides. The data on quantity of insecticides used in respect of cabbage revealed that, total consumption of conventional insecticides used by individual farmer was 1.07 kg a.i. ha^{-1} with 65.10 per cent share. This was followed by novel insecticides (0.38 kg a.i. ha^{-1}) and biopesticides (0.20 kg a.i. ha^{-1}) in cabbage crop.

The quantity of organophosphate insecticides used by individual farmer was 0.99 kg a.i. ha^{-1} for the control of insect pests in cabbage. Among the insecticidal groups, per cent shares of organophosphates, carbamates and synthetic pyrethroids were 60.34, 3.16 and 1.60 per cent, respectively. Whereas, the use of novel insecticides *viz.,* neonicotinoids, oxadizines, avermectins, spinosyns, diamides, pyrroles, phenyl pyrazoles and IGR's was 3.39, 3.28, 0.51, 1.09, 5.61, 1.82, 3.47 and 3.60 per cent, respectively. Insecticides included triazophos, quinalphos, acephate, chlorpyriphos, profenophos, cypermethrin,imidacloprid, thiamethoxam, lambda cyhalothrin, fipronil, emamectin benzoate, indoxacarb, flubendiamide, spinosad, chlorantraniliprole and cyantraniliprole.

Irrespective of location, in general farmers used organophosphates and neonicotinoids for the control of sucking pests, and organophosphates, carbamates, synthetic pyrethroids and novel groups of insecticide for the lepidopteran pests control.

4.1.2 Response of cabbage growers to the questionnaire from the surveyed area

Responses of cabbage growers in Ahmednagar, Pune and Nashik districts are presented in Table 6.

I. Awareness about natural enemies

The information generated through survey from Ahmednagar, Pune and Nashik districts indicated that about fifty per cent of the cabbage growers knew about the natural enemies. The data revealed that 54 per cent, 44 per cent and 46 per cent growers of Ahmednagar, Pune and Nashik districts, respectively, were aware of natural enemies of *P. xylostella*.

II. Awareness about recommended insecticides in cabbage

More than 50 per cent farmers knew about the recommended insecticides in surveyed areas of cabbage. In Ahmednagar, 68 per cent farmers were aware of recommendation of insecticides in cabbage as against 52 per cent and 50 per cent in Pune and Nashik, respectively. It was also found that, insecticides were applied without adequate knowledge of insect pest ecology, economic threshold levels and type of pesticides to control specific insect pest, their quantities and method of application. Almost 50 per cent of farmers were reluctant to follow the recommended insecticides as prescribed on the label. Some respondents said that they used excessive dosage of non recommended chemicals as their neighbor used the same dosage. The major reasons stated by the farmers for use of non recommended insecticides were lack of knowledge and dealer oriented purchase.

III. Awareness about application of bio-pesticides

It was found that neem based formulations were one of the commercial biopesticide that farmers commonly applied to control insect pests. This product contains *Azadirachtin* alkaloid with capability to suppress specific lepidopteran larvae without destroying beneficial insects. Unfortunately, lack of understanding on the benefits of biopesticides and less promotion towards the usage was the main reason for the heavy reliance on conventional and synthetic pesticides in vegetable cultivation.

The data revealed that in Ahmednagar district, only 58 per cent farmers knew about bio-pesticides and its application in cabbage. Whereas, in Pune and Nashik, 30 and 68 per cent farmers respectively, were aware of application of bio-pesticides. The rest of the growers used approximate quantity of chemical insecticides depending upon incidence of insect pests.

IV. Knowledge of safe waiting period

It was revealed that majority of the farmers did not knew about safe waiting period after application of insecticides. Only 20 per cent cabbage growers from Ahmednagar and Pune district know about safe waiting period. Whereas, only 36 per cent cabbage growers from Nashik district were aware of safe waiting period.

During rainy seasons, the period between two sprays was shorter due to the quick wash off of insecticides on the crops. Though farmers responded that they were not aware of implication of excessive use of insecticides and the accumulation of insecticide residues in the vegetables. It was also found that some of the farmers sprayed insecticides on cabbage close to harvesting time in order to avoid pest attacks. Meanwhile, the result of present study demonstrated that farmers usually ignore the recommended safe waiting period (seven days and above).

Table 5. Usage pattern of insecticides in cabbage against diamondback moth (*P. xylostella* L.) during 2015-2016

Sr. No.	Insecticide category	Insecticide group	Quantity of insecticides used by individual farmer (kg a.i. ha^{-1} $season^{-1}$)			Per cent share of insecticide used by individual farmer		
			A. Nagar	Pune	Nashik	A. Nagar	Pune	Nashik
1	Conventional insecticides (A)	Organophosphates	1.04	1.36	0.99	69.06	75.83	60.34
		Carbamates	0.10	0.01	0.05	6.77	0.38	3.16
		Synthetic pyrethroids	0.08	0.06	0.03	5.18	3.18	1.60
		Total (A)	**1.22**	**1.43**	**1.07**	**81.01**	**79.39**	**65.10**
2	Novel insecticides (B)	Neonicotinoids	0.06	0.05	0.06	3.67	2.92	3.39
		Oxadiazines	0.02	0.05	0.05	1.00	3.02	3.28
		Avermectins	0.01	0.01	0.01	0.44	0.40	0.51
		Spinosyns	0.01	0.01	0.02	0.72	0.80	1.09
		Diamides	0.02	0.04	0.09	1.39	1.98	5.61
		Pyrroles	0.01	0.02	0.03	0.84	1.07	1.82
		Phenylpyrazoles	0.01	0.02	0.06	0.60	1.24	3.47
		IGR’s	0.06	0.04	0.06	3.71	2.48	3.60
		Total (B)	**0.20**	**0.24**	**0.38**	**12.37**	**13.91**	**22.77**
3	Bio-insecticides (C)	Neem based formulations	0.10	0.12	0.20	6.64	6.70	12.14
Grand total (A+B+C)			**1.52**	**1.79**	**1.65**	**100**	**100**	**100**

V. Awareness about the harmful effects of insecticides residues

Data revealed that farmers tend to ignore the insecticide risk and they kept applying the insecticide within a certain period, even though there was no sign of any pest attacks on the crops. It was a routine practice of farmers that insecticides were usually applied once in every seven to ten days.

Majority of farmers indicated that they were aware of the residues of insecticides, but did not follow any precautions to avoid harmful effects of agrochemicals during their application in the field. Most of the cabbage growers i.e. 86 per cent in Ahmednagar district, 64 per cent in Pune district and 78 per cent in Nashik district, were aware of the harmful effects of insecticide residues on human health. Majority of the farmers knew about ill- effects of insecticides i.e. causing cancer, skin irritation, eye contamination etc. Most of the cabbage growers sprayed the field in the afternoon and harvested cabbage heads in the next day morning for market.

Table 6. Response of cabbage growers about the questionnaire from the surveyed area of western Maharashtra

SN	Variables	Response of farmers (%)		
1	**Types of insecticides used**	**Ahmednagar**	**Pune**	**Nashik**
	i) Conventional insecticides	81.01	79.39	65.10
	ii) Novel insecticides	12.35	13.91	22.77
	iii) Bio-pesticides	6.64	6.70	12.14
2	Awareness about natural enemies	54	44	46
3	Awareness about recommended insecticides of cabbage	68	52	50
4	Awareness about application of bio-pesticides	58	30	68
5	Knowledge of safe waiting period	20	20	36
6	Awareness about the harmful effect of insecticide residues	86	64	78

4.2 Bio-efficacy of newer insecticides against *P. xylostella* in cabbage

Bio-efficacy of insecticides against diamondback moth was undertaken in two separate fields experiments during 2015-16 and 2016-17.

4.2.1 Bio-efficacy of newer insecticides against *P. xylostella*

Treatments under the studies included six newer insecticides, two conventional insecticides and one synthetic pyrethroid *viz.*, indoxacarb @ 40 g a. i. ha^{-1}, spinosad @ 17.5 g a. i. ha^{-1}, flubendiamide @ 18.24 g a. i. ha^{-1}, diafenthiuron @ 300 g a. i. ha^{-1}, emamectin benzoate @ 10 g a.i. ha^{-1}, chlorantraniliprole @ 10 g a. i. ha^{-1}, quinalphos @ 250 g a. i. ha^{-1}, triazophos @ 500 g a. i. ha^{-1} and bifenthrin @ 50 g a. i. ha^{-1}. In all, two rounds of applications were given based on ETL. The observations on surviving larval population of *P. xylostella* were recorded at 1, 3, 7 and 14 days after the spray (DAS). At the end of trial yield was also registered from each replication of respective treatments.

I Year (2015-16)

The field experiment was undertaken during January, 2016 to April, 2016 at Nandur Madhyameshwar, Tq. Niphad, Dist. Nashik.

First spray

Data pertaining to the efficacy of different insecticides against larvae of *P. xylostella* after first spray are presented in Table 7.

The precount was non-significant showing even distribution and mean data on survival population at 1, 3, 7 and 14 days after spray (DAS) indicated that, all the insecticidal treatments were significantly superior to control. The average larval population ranged between 1.20 to 4.65 $plant^{-1}$ as against 9.32 in untreated control.

Chlorantraniliprole @ 10 g a.i. ha^{-1} recorded lowest number of larval population (2.53 larvae $plant^{-1}$) at 1 DAS and proved significantly superior to rest of the treatments. This was followed by spinosad @ 17.5 g a.i. ha^{-1} (3.33 larvae $plant^{-1}$) and flubendiamide 18.24 g a.i. ha^{-1} (3.47 larvae $plant^{-1}$). However, they were at par with each other. Treatment with indoxacarb @ 40 g a.i. ha^{-1} and emamectin benzoate @ 10 g a.i. ha^{-1} was proved quite effective by recording 4.07 larvae $plant^{-1}$ and 4.47 larvae $plant^{-1}$, respectively. This was followed by quinalphos @ 250 g a.i. ha^{-1}, diafenthiuron @ 300 g a.i.ha^{-1}, triazophos @ 500 g a.i.ha^{-1} and bifenthrin @ 50 g a.i. ha^{-1} which recorded 6.13, 6.40, 6.87 and 7.00 larvae $plant^{-1}$, respectively. Untreated plots recorded maximum population (8.33 larvae $plant^{-1}$).

At 3 DAS, chlorantraniliprole @ 10 g a.i.ha^{-1} continued to be effective by recording least (0.33 larvae plant^{-1}) larval population. Spinosad @ 17.5 g a.i. ha^{-1} and flubendiamide @ 18.24 g a.i. ha^{-1} being at par were next in the order, by recording 0.67 and 0.87 larvae plant-1, respectively. Next promising treatments were indoxacarb @ 40 g a.i. ha^{-1} (1.33 larvae plant^{-1}), emamectin benzoate @ 10 g a.i. ha^{-1} (1.60 larvae plant^{-1}) and diafenthiuron @ 300 g a.i.ha^{-1} (2.40 larvae plant^{-1}). Maximum population (8.73 larvae plant^{-1}) was recorded in the untreated check.

Almost a similar trend of efficacy was noticed at 7 DAS.

At 14 DAS, chlorantraniliprole @ 10 g a.i. ha^{-1} maintained its superiority by recording lowest population (1.67 larvae plant^{-1}). This was followed by spinosad @ 17.5 g a.i. ha^{-1} (1.93 larvae plant^{-1}) and flubendiamide 18.24 g a. i. ha^{-1} (2.13 larvae plant^{-1}). They were, however found at par with each other. Next best treatments in descending order of efficacy were indoxacarb @ 40 g a.i. ha^{-1}, emamectin benzoate @ 10 g a.i. ha^{-1} and diafenthiuron @ 300 g a.i.ha^{-1}. Untreated control recorded maximum larval population (10.67) of *P. xylostella.*

Considering the mean larval population it was indicated that, significantly lowest larval population was observed in the treatment of chlorantraniliprole @ 10 g a.i.ha^{-1} (1.20 larvae plant^{-1}). This was followed by spinosad @ 17.5 g a.i. ha^{-1} (1.60 larvae plant^{-1}) and flubendiamide 18.24 g a.i. ha^{-1} (1.77 larvae plant^{-1}), but they were at par with each other. Indoxacarb @ 40 g a.i. ha^{-1} (2.15 larvae plant^{-1}), emamectin benzoate @ 10 g a.i. ha^{-1} (2.50 larvae plant^{-1}), diafenthiuron @ 300 g a.i. ha^{-1} (3.37 larvae plant^{-1}), quinalphos @ 250 g a.i. ha^{-1} (3.67 larvae plant^{-1}), triazophos @ 500 g a.i.ha^{-1} (4.25 larvae plant^{-1}) and bifenthrin @ 50 g a.i. ha^{-1} (4.65 larvae plant^{-1}) were next to follow in the order of effectiveness. Untreated control recorded maximum larval population of *P. xylostella* (9.32 larvae plant^{-1}).

Second spray

The results with respect to efficacy of different insecticides on larval population of *P. xylostella* after second spray are presented in Table 7.

The data (Table 3) revealed that all the insecticides under investigation were observed to be significantly superior over untreated control in reducing the larval population of *P. xylostella*.

Among the insecticides evaluated, chlorantraniliprole @ 10 g a.i. ha^{-1} recorded lowest larval population (2.13 larvae $plant^{-1}$) at 1 day after spray (DAS) and proved significantly superior to rest of the treatments. This was followed by spinosad and flubendiamide, being at par recorded 3.07 and 3.13 larvae $plant^{-1}$, respectively. Indoxacarb @ 40 g a.i. ha^{-1} and emamectin benzoate @ 10 g a.i.ha^{-1} were next in the order of effectiveness by recording 4.00 and 4.33 larvae $plant^{-1}$. This was followed by diafenthiuron @ 300 g a.i.ha^{-1}, triazophos @ 500 g a.i. ha^{-1}, quinalphos @ 250 g a.i. ha^{-1} and bifenthrin. Whereas, untreated plots recorded 12.20 larvae $plant^{-1}$.

Almost a similar trend of efficacy was noticed at 3 and 7 DAS.

Chlorantraniliprole @ 10 g a.i. ha^{-1} maintained its superiority even at 14 DAS by recording 1.40 larvae $plant^{-1}$. This was followed by spinosad and flubendiamide, being at par with each other recorded 1.73 and 1.80 larvae $plant^{-1}$, respectively. Next best treatments in order of statistical significance were indoxacarb @ 40 g a.i. ha^{-1} (2.00 larvae $plant^{-1}$) followed by emamectin benzoate @ 10 g a.i. ha^{-1} (2.33 larvae $plant^{-1}$) and diafenthiuron @ 300 g a.i. ha^{-1} (3.60 larvae $plant^{-1}$). Significantly higher larval population (16.13 larvae $plant^{-1}$) of *P. xylostella* was recorded in untreated plots.

The mean of larval population indicated that, chlorantraniliprole @ 10 g a.i. ha^{-1} (1.00 larvae $plant^{-1}$) was found to be the most promising treatment. Spinosad @ 17.5 g a.i. ha^{-1} was next in the order and recorded 1.45 larvae $plant^{-1}$. It was however at par with flubendiamide 18.24 g a.i. ha^{-1} which was recorded 1.53 larvae $plant^{-1}$. Next best treatments in the descending order were indoxacarb @ 40 g a.i. ha^{-1} (2.00 larvae $plant^{-1}$), emamectin benzoate @ 10 g a.i. ha^{-1} (2.37 larvae $plant^{-1}$), diafenthiuron @ 300 g a.i. ha^{-1} (3.55 larvae $plant^{-1}$), quinalphos @ 250 g a.i. ha^{-1} (3.93 larvae $plant^{-1}$), triazophos @ 500 g a.i. ha^{-1} (4.27 larvae $plant^{-1}$) and bifenthrin @ 50 g a.i. ha^{-1} (4.72 larvae $plant^{-1}$). Maximum population (14.08 larvae $plant^{-1}$) was recorded in the untreated plots.

Cumulative mean of I Year (2015-2016)

The data (Table 8 and fig. 7) revealed that all the insecticides under investigation were observed to be significantly superior over untreated control in reducing the larval population of *P. xylostella* at all the days (1, 3, 7 and 14 DAS) of observations.

The overall results of first and second sprayings indicated that, chlorantraniliprole @ 10 g a.i. ha^{-1} recorded lowest number of larval population of *P.*

xylostella (2.33, 0.30, 0.23 and 1.53 larvae plant^{-1}) and proved to be superior over all the remaining treatments at all the days of observations. Whereas, spinosad @ 17.5 g a.i. ha^{-1} with 3.20, 0.63, 0.43 and 1.83 larvae plant^{-1} was the next promising treatment. It was however at par with flubendiamide 18.24 g a.i. ha^{-1}, which recorded 3.30, 0.80, 0.53 and 1.97 larvae plant^{-1}. Indoxacarb @ 40 g a.i. ha^{-1} was next in the order of effectiveness showing larval population of 4.03, 1.30, 0.83 and 2.13 larvae plant^{-1}. It was followed by emamectin benzoate @ 10 g a.i. ha^{-1} and diafenthiuron @ 300 g a.i. ha^{-1} which were recorded 4.40, 1.63, 1.23 and 2.47 larvae plant^{-1}, 6.13, 2.37, 2.03 and 3.30 larvae plant^{-1}, respectively. Untreated plots showed maximum number of larval population i.e. 10.27 to 13.40 larvae plant^{-1}.

Table 7. Bio-efficacy of newer insecticides against *P. xylostella* during first year (2015-16)

SN	Treatment details	Dose (g a.i. ha^{-1})	Pre-count	Mean number of larvae per plant									
				First spray					Second spray				
				1 DAS	3 DAS	7 DAS	14 DAS	Mean	1 DAS	3 DAS	7 DAS	14 DAS	Mean
1	Indoxacarb 14.5 % SC	40	8.93 (3.07)*	4.07 (2.14)	1.33 (1.35)	0.93 (1.20)	2.27 (1.66)	2.15 (1.63)	4.00 (2.12)	1.27 (1.33)	0.73 (1.11)	2.00 (1.58)	2.00 (1.58)
2	Spinosad 2.5 % SC	17.5	8.67 (3.03)	3.33 (1.96)	0.67 (1.08)	0.47 (0.98)	1.93 (1.56)	1.60 (1.45)	3.07 (1.89)	0.60 (1.05)	0.40 (0.95)	1.73 (1.49)	1.45 (1.40)
3	Flubendiamide 39.35 % SC	18.24	8.47 (2.99)	3.47 (1.99)	0.87 (1.14)	0.60 (1.05)	2.13 (1.62)	1.77 (1.50)	3.13 (1.91)	0.73 (1.11)	0.47 (0.98)	1.80 (1.52)	1.53 (1.43)
4	Diafenthiuron 50 % WP	300	8.00 (2.92)	6.40 (2.63)	2.40 (1.70)	1.67 (1.47)	3.00 (1.87)	3.37 (1.97)	5.87 (2.52)	2.33 (1.68)	2.40 (1.70)	3.60 (2.02)	3.55 (2.01)
5	Emamectin benzoate 5 % SG	10	8.47 (2.99)	4.47 (2.23)	1.60 (1.45)	1.33 (1.35)	2.60 (1.76)	2.50 (1.73)	4.33 (2.20)	1.67 (1.47)	1.13 (1.28)	2.33 (1.68)	2.37 (1.69)
6	Chlorantraniliprole 18.5 % SC	10	8.40 (2.98)	2.53 (1.74)	0.33 (0.91)	0.27 (0.87)	1.67 (1.47)	1.20 (1.30)	2.13 (1.62)	0.27 (0.87)	0.20 (0.84)	1.40 (1.38)	1.00 (1.22)
7	Quinalphos 25 % EC	250	8.40 (2.98)	6.13 (2.58)	2.87 (1.83)	2.13 (1.62)	3.53 (2.01)	3.67 (2.04)	6.33 (2.61)	2.80 (1.81)	2.73 (1.80)	3.87 (2.09)	3.93 (2.11)
8	Triazophos 40 % EC	500	8.53 (3.01)	6.87 (2.71)	3.53 (2.01)	2.53 (1.74)	4.07 (2.14)	4.25 (2.18)	6.13 (2.58)	3.53 (2.01)	3.00 (1.87)	4.40 (2.21)	4.27 (2.18)
9	Bifenthrin 10 % EC	50	8.40 (2.98)	7.00 (2.74)	3.93 (2.11)	3.07 (1.89)	4.60 (2.26)	4.65 (2.27)	6.67 (2.68)	4.07 (2.14)	3.40 (1.97)	4.73 (2.29)	4.72 (2.28)
10	Untreated control	---	8.27 (2.96)	8.33 (2.97)	8.73 (3.04)	9.53 (3.17)	10.67 (3.34)	9.32 (3.13)	12.20 (3.56)	13.27 (3.71)	14.73 (3.90)	16.13 (4.08)	14.08 (3.82)
	S.E.±		0.025	0.020	0.022	0.035	0.029	0.015	0.020	0.032	0.016	0.017	0.013
	C. D. at 5%		NS	0.062	0.066	0.109	0.079	0.047	0.062	0.099	0.050	0.053	0.041

DAS: Days after spray

NS: Non-significant

*Figures in parentheses denote $\sqrt{n + 0.5}$ transformed values

Table 8. Bio-efficacy of newer insecticides against *P. xylostella* during first year 2015-16 (Average of two sprays)

Sr. No.	Treatment details	Dose (g a.i.ha^{-1})	Pre-count	Mean number of larvae per plant Mean of first and second spray				Overall larval count	% Reduction over untreated control
				1 DAS	3 DAS	7 DAS	14 DAS		
1	Indoxacarb 14.5 % SC	40	8.10 (2.93)*	4.03 (2.13)	1.30 (1.34)	0.83 (1.15)	2.13 (1.62)	2.08 (1.60)	82.22
2	Spinosad 2.5 % SC	17.50	8.03 (2.92)	3.20 1.92)	0.63 (1.06)	0.43 (0.97)	1.83 (1.53)	1.53 (1.42)	86.92
3	Flubendiamide 39.35 % SC	18.24	8.00 (2.92)	3.30 (1.95)	0.80 (1.14)	0.53 (1.02)	1.97 (1.57)	1.65 (1.47)	85.89
4	Diafenthiuron 50 % WP	300	7.83 (2.89)	6.13 (2.58)	2.37 (1.69)	2.03 (1.59)	3.30 (1.95)	3.46 (1.99)	70.43
5	Emamectin benzoate 5 % SG	10	7.93 (2.90)	4.40 (2.21)	1.63 (1.46)	1.23 (1.32)	2.47 (1.72)	2.43 (1.71)	79.23
6	Chlorantraniliprole 18.5 % SC	10	7.90 (2.90)	2.33 (1.68)	0.30 (0.89)	0.23 (0.86)	1.53 (1.43)	1.10 (1.26)	90.59
7	Quinalphos 25 % EC	250	7.77 (2.88)	6.23 (2.59)	2.83 (1.83)	2.43 (1.71)	3.70 (2.05)	3.80 (2.07)	67.52
8	Triazophos 40 % EC	500	8.00 (2.92)	6.50 (2.65)	3.53 (2.01)	2.77 (1.81)	4.23 (2.18)	4.26 (2.18)	63.59
9	Bifenthrin 10 % EC	50	7.83 (2.89)	6.83 (2.71)	4.00 (2.12)	3.23 (1.93)	4.67 (2.27)	4.68 (2.28)	60.00
10	Untreated control	----	10.13 (3.24)	10.27 (3.28)	11.00 (3.39)	12.13 (3.55)	13.40 (3.73)	11.70 (3.49)	---
	S.E. ±	----	NS	0.016	0.018	0.016	0.019	0.012	---
	C. D. at 5 %	----	NS	0.051	0.057	0.050	0.058	0.038	---

DAS: Days after spray
NS: Non-significant
*Figures in parentheses denote $\sqrt{n + 0.5}$ transformed values.

II Year (2016-17)

The field experiment was conducted during August, 2016 to October, 2016 at Khandgaon, Tq. Sangamner, Dist. Ahmednagar.

First spray

Data pertaining to efficacy of different insecticides on larval population of *P. xylostella* after first spray are presented in Table 9.

The pre count population did not differ significantly and ranged between 7.00 to 7.47 larvae plant^{-1}.

Chlorantraniliprole @ 10 g a.i.ha^{-1} recorded 2.13 larvae plant^{-1} at 1 DAS and proved significantly superior to rest of the treatments, except spinosad @ 17.5 g a.i. ha^{-1} (2.93 larvae plant^{-1}) and flubendiamide 18.24 g a.i. ha^{-1} (3.07 larvae plant^{-1}) to which it was at par. Indoxacarb @ 40 g a.i. ha^{-1} and emamectin benzoate @ 10 g a.i. ha^{-1} were next to follow in the order of effectiveness by recording 3.93 and 4.40 larvae plant^{-1}. This was followed by quinalphos @ 250 g a.i. ha^{-1} (5.67 larvae plant^{-1}), diafenthiuron @ 300 g a.i. ha^{-1} (6.07 larvae plant^{-1}), triazophos @ 500 g a.i. ha^{-1} (6.07 larvae plant^{-1}) and bifenthrin @ 50 g a.i. ha^{-1} (6.40 larvae plant^{-1}). Maximum larval population of 7.67 larvae plant^{-1} was recorded in the untreated plots.

Almost a similar trend was noticed at 3 and 7 DAS.

Chlorantraniliprole @ 10 g a.i. ha^{-1} maintained its superiority even at 14 DAS by recording least larval population of *P. xylostella* (1.60 larvae plant^{-1}). This was followed by spinosad @ 17.5 g a.i. ha^{-1} (1.87 larvae plant^{-1}) and flubendiamide 18.24 g a.i. ha^{-1} (1.93 larvae plant^{-1}) but, they were at par with each other. Indoxacarb @ 40 g a.i. ha^{-1} and emamectin benzoate @ 10 g a.i. ha^{-1} were next in the order by recording 2.20 larvae plant^{-1} and 2.53 larvae plant^{-1}, respectively. Untreated plots recorded in 10.47 larvae plant^{-1}.

Data on mean of larval population revealed that significantly lowest larval count was observed in chlorantraniliprole @ 10 g a.i. ha^{-1} (1.02 larvae plant^{-1}). This was followed by spinosad and flubendiamide recorded 1.43 and 1.55 larvae plant^{-1}, respectively being at par with each other. Next to follow in order of efficacy were indoxacarb @ 40 g a.i. ha^{-1} (2.05 larvae plant^{-1}), emamectin benzoate @ 10 g a.i. ha^{-1}

(2.40 larvae plant^{-1}) and diafenthiuron @ 300 g a.i. ha^{-1} (3.32 larvae plant^{-1}). Untreated plots recorded 9.05 larvae plant^{-1}.

Second spray

Data pertaining to efficacy of newer insecticides against the larval population of *P. xylostella* after second spray are presented in Table 9.

The results revealed that, all the insecticides were found to be significantly superior over untreated control.

At 1 DAS, chlorantraniliprole @ 10 g a.i. ha^{-1} was found most effective by recording 1.80 larvae plant^{-1}. This was followed by spinosad @ 17.5 g a.i. ha^{-1} and flubendiamide 18.24 g a.i. ha^{-1} which recorded 2.87 and 2.93 larvae plant^{-1}. They were however at par with each other. Indoxacarb @ 40 g a.i. ha^{-1} and emamectin benzoate @ 10 g a.i. ha^{-1} were next in the order of effectiveness by recording 3.67 and 4.40 larvae plant^{-1}. This was followed by diafenthiuron @ 300 g a.i.ha^{-1} and quinalphos @ 250 g a.i. ha^{-1}. Whereas, maximum larval population (13.13 larvae plant^{-1}) was recorded in untreated plots.

Almost a similar trend of efficacy was noticed at 3 and 7 DAS.

Plots treated with chlorantraniliprole @ 10 g a.i. ha^{-1} maintained their superiority even at 14 DAS by recording 1.47 larvae plant^{-1}. Next in the order of effectiveness were spinosad @ 17.5 g a.i. ha^{-1} and flubendiamide 18.24 g a.i. ha^{-1}, being at par with each other, recorded 1.80 and 1.87 larvae plant^{-1}, respectively. Next best treatments in order of statistical significance were indoxacarb @ 40 g a.i. ha^{-1} (2.13 larvae plant^{-1}), emamectin benzoate @ 10 g a.i.ha^{-1} (2.40 larvae plant^{-1}) and diafenthiuron @ 300 g a.i. ha^{-1} (2.67 larvae plant^{-1}). Significantly maximum larval population (16.00 larvae plant^{-1}) was recorded in untreated plots.

The mean of observations revealed that all the insecticidal treatments were significantly superior over untreated control. Chlorantraniliprole @ 10 g a.i. ha^{-1} recorded least number of larval populations (0.87 larvae plant^{-1}) and proved to be the most effective treatment. This was followed by spinosad @ 17.5 g a.i. ha^{-1} which recorded 1.36 larvae plant^{-1}. It was however, at par with flubendiamide 18.24 g a.i. ha^{-1} which recorded 1.42 larvae plant^{-1}. Next in the order of effectiveness were indoxacarb @ 40 g a.i. ha^{-1} (1.80 larvae plant^{-1}), emamectin benzoate @ 10 g a.i. ha^{-1} (2.18 larvae plant^{-1}) and diafenthiuron @ 300 g a.i.ha^{-1} (2.75 larvae plant^{-1}). Maximum larval population (14.47 larvae plant^{-1}) was recorded in the untreated plots.

Cumulative mean of II Year (2016-2017)

The data (Table 10 and fig. 8) revealed that, all the insecticides under investigation were observed to be significantly superior over untreated control in reducing the larval population of *P. xylostella* at all the days i.e. 1, 3, 7 and 14 DAS of observations. The average number of larval population ranged between 0.90 to 3.98 as against 12.00 in untreated control.

Chlorantraniliprole @ 10 g a.i. ha^{-1} excelled over all other treatments by recording significantly least number of larvae (1.97, 0.17, 0.10 and 1.53) at 1, 3, 7 and 14 days after sprays, respectively. This was followed by spinosad @ 17.5 g a.i. ha^{-1} (2.90, 0.58, 0.27 and 1.83 larvae plant^{-1}) and flubendiamide 18.24 g a.i. ha^{-1} (3.00, 0.63, 0.40 and 1.90 larvae plant^{-1}) but they were at par with each other. Indoxacarb @ 40 g a.i. ha^{-1}, emamectin benzoate @ 10 g a.i. ha^{-1} and diafenthiuron @ 300 g a.i. ha^{-1} were next in the order of effectiveness. Untreated plots recorded maximum larval population of *P. xylostella*.

Cumulative bio-efficacy of newer insecticides against *P. xylostella* (Pooled mean of 2015-16 and 2016-17)

The pooled analysis data of both the years (2015-16 and 2016-17) on bio-efficacy of newer insecticides against the larval population of *P. xylostella* on cabbage are presented in Table 11 and fig. 9. It could be seen that, all the insecticidal treatments were significantly superior in reducing the infestation of *P. xylostella* over untreated control. The average number of larval population ranged between 1.02 to 4.42 as against 11.73 in untreated plots.

Chlorantraniliprole @ 10 g a.i. ha^{-1} consistently proved its superiority by recording least larval population i.e. 2.15 to 1.53 larvae plant^{-1}. Next in order of effectiveness were spinosad @ 17.5 g a.i. ha^{-1} (3.05 to 1.83 larvae plant^{-1}) and flubendiamide @ 18.24 g a.i. ha^{-1} (3.15 to 1.93 larvae plant^{-1}), but they were at par with each other at 1 and 14 days after spray. The next effective treatments were indoxacarb @ 40 g a. i. ha^{-1} (3.92 to 2.15 larvae plant^{-1}) followed by emamectin benzoate @ 10 g a.i. ha^{-1} (4.40 to 2.47 larvae plant^{-1}). Maximum larval population was recorded in the untreated control (10.33 to 11.73 larvae plant^{-1}).

Table 9. Bio-efficacy of newer insecticides against *P. xylostella* during second year (2016-17)

SN	Treatment details	Dose (g a.i. ha^{-1})	Pre-count	Mean number of larvae per plant									
				First spray					Second spray				
				1 DAS	3 DAS	7 DAS	14 DAS	Mean	1 DAS	3 DAS	7 DAS	14 DAS	Mean
1	Indoxacarb 14.5 % SC	40	7.40 (2.81)*	3.93 (2.11)	1.20 (1.30)	0.87 (1.17)	2.20 (1.64)	2.05 (1.60)	3.67 (2.04)	0.93 (1.20)	0.47 (0.93)	2.13 (1.62)	1.80 (1.52)
2	Spinosad 2.5 % SC	17.5	7.07 (2.75)	2.93 (1.85)	0.60 (1.05)	0.33 (0.91)	1.87 (1.54)	1.43 (1.39)	2.87 (1.83)	0.57 (1.03)	0.20 (0.84)	1.80 (1.52)	1.36 (1.36)
3	Flubendiamide 39.35 % SC	18.24	7.20 (2.77)	3.07 (1.89)	0.67 (1.08)	0.53 (1.01)	1.93 (1.56)	1.55 (1.43)	2.93 (1.85)	0.60 (1.05)	0.27 (0.87)	1.87 (1.54)	1.42 (1.38)
4	Diafenthiuron 50 % WP	300	7.07 (2.75)	6.07 (2.56)	2.40 (1.70)	1.73 (1.49)	3.07 (1.89)	3.32 (1.95)	5.00 (2.35)	1.93 (1.56)	1.40 (1.38)	2.67 (1.78)	2.75 (1.80)
5	Emamectin benzoate 5 % SG	10	7.40 (2.81)	4.40 (2.21)	1.40 (1.38)	1.27 (1.33)	2.53 (1.74)	2.40 (1.70)	4.40 (2.21)	1.27 (1.33)	0.67 (1.08)	2.40 (1.70)	2.18 (1.64)
6	Chlorantraniliprole 18.5 % SC	10	7.13 (2.76)	2.13 (1.62)	0.20 (0.84)	0.13 (0.79)	1.60 (1.45)	1.02 (1.23)	1.80 (1.52)	0.13 (0.79)	0.07 (0.75)	1.47 (1.40)	0.87 (1.17)
7	Quinalphos 25 % EC	250	7.00 (2.74)	5.67 (2.48)	3.00 (1.87)	2.00 (1.58)	3.47 (1.99)	3.53 (2.01)	5.73 (2.50)	2.20 (1.64)	1.87 (1.54)	3.07 (1.89)	3.22 (1.93)
8	Triazophos 40 % EC	500	7.27 (2.79)	6.07 (2.56)	3.27 (1.94)	2.40 (1.70)	3.80 (2.07)	3.88 (2.09)	6.40 (2.63)	2.47 (1.72)	2.20 (1.64)	3.73 (2.06)	3.70 (2.05)
9	Bifenthrin 10 % EC	50	7.47 (2.82)	6.40 (2.63)	3.60 (2.02)	2.87 (1.83)	4.20 (2.17)	4.27 (2.18)	6.80 (2.70)	2.73 (1.80)	2.53 (1.74)	4.07 (2.14)	4.03 (2.13)
10	Untreated control	---	7.40 (2.81)	7.67 (2.86)	8.40 (2.98)	9.67 (3.19)	10.47 (3.31)	9.05 (3.09)	13.13 (3.69)	13.80 (3.78)	14.93 (3.93)	16.00 (4.06)	14.47 (3.87)
	S.E. ±		NS	0.018	0.017	0.037	0.021	0.010	0.020	0.023	0.026	0.022	0.010
	C. D. at 5%		NS	0.056	0.052	0.114	0.065	0.031	0.060	0.069	0.080	0.066	0.030

DAS: Days after spray

NS: Non-significant

* Figures in parentheses denote $\sqrt{n + 0.5}$ transformed values

Table 10. Bio-efficacy of newer insecticides against *P. xylostella* during second year 2016-17 (Average of two sprays)

Sr. No.	Treatment details	Dose (g a.i.ha^{-1})	Pre-count	Mean number of larvae per plant Mean of first and Second spray				Overall larval count	% Reduction over untreated control
				1 DAS	3 DAS	7 DAS	14 DAS		
1	Indoxacarb 14.5 % SC	40	6.97 (2.73)*	3.80 (2.07)	1.07 (1.25)	0.67 (1.08)	2.17 (1.63)	1.78 (1.51)	85.17
2	Spinosad 2.5 % SC	17.50	6.97 (2.73)	2.90 (1.84)	0.58 (1.04)	0.27 (0.88)	1.83 (1.53)	1.30 (1.34)	89.17
3	Flubendiamide 39.35 % SC	18.24	7.07 (2.75)	3.00 (1.87)	0.63 (1.06)	0.40 (0.95)	1.90 (1.55)	1.39 (1.37)	88.41
4	Diafenthiuron 50 % WP	300	7.03 (2.74)	5.53 (2.46)	2.17 (1.63)	1.57 (1.44)	2.87 (1.83)	2.80 (1.81)	76.67
5	Emamectin benzoate 5 % SG	10	7.13 (2.76)	4.40 (2.21)	1.33 (1.35)	0.97 (1.21)	2.47 (1.72)	2.14 (1.62)	82.17
6	Chlorantraniliprole 18.5 % SC	10	7.07 (2.75)	1.97 (1.57)	0.17 (0.82)	0.10 (0.77)	1.53 (1.43)	0.90 (1.18)	92.50
7	Quinalphos 25 % EC	250	6.90 (2.72)	5.70 (2.49)	2.60 (1.76)	1.93 (1.56)	3.27 (1.94)	3.18 (1.92)	73.50
8	Triazophos 40 % EC	500	7.20 (2.77)	6.23 (2.59)	2.87 (1.83)	2.30 (1.67)	3.77 (2.07)	3.57 (2.02)	70.25
9	Bifenthrin 10 % EC	50	7.23 (2.78)	6.60 (2.66)	3.17 (1.91)	2.70 (1.79)	4.13 (2.15)	3.98 (2.11)	66.84
10	Untreated control	---	9.47 (3.16)	10.40 (3.30)	11.10 (3.41)	12.30 (3.58)	13.23 (3.71)	12.00 (3.54)	---
	S.E. ±	---	NS	0.013	0.014	0.023	0.014	0.030	---
	C. D. at 5 %	---	NS	0.040	0.043	0.070	0.045	0.092	---

DAS: Days after spray

NS: Non-significant

*Figures in parentheses denote $\sqrt{n + 0.5}$ transformed values

4.2.2 Marketable yield of cabbage heads

I Year (2015-16)

The results pertaining to the marketable yield of cabbage after harvest of first trial are presented in Table 12 and fig.10.

It could be seen that differential efficacy of treatments is reflected in the yield. Yield of cabbage in all the treatments were significantly higher than untreated control. Plots treated with chlorantraniliprole @ 10 g a.i. ha^{-1} registered highest yield of cabbage heads (242.27 q ha^{-1}) with maximum per cent (124.24 %) increase over control. This was followed by spinosad @ 17.5 g a.i. ha^{-1} with 236.91 q ha^{-1} (119.27 %). It was however, at par with flubendiamide @ 18.24 g a.i. ha^{-1} 228.49 q ha^{-1} (111.48 %) and indoxacarb @ 40 g a.i. ha^{-1} 196.76 q ha^{-1} (82.11 %). Emamectin benzoate @ 10 g a. i. ha^{-1} (179.56 q ha^{-1}) was next in the order but at par with diafenthiuron @ 300 g a.i. ha^{-1} (173.78 q ha^{-1}). Significantly lowest yield of cabbage heads was registered in the untreated plots i.e.108.04 q ha^{1}.

II Year (2016-17)

The data (Table 13 and fig.11) revealed that, almost a similar trend was noticed during second year. Chlorantraniliprole @ 10 g a.i. ha^{-1} registered highest yield of 234.02 q ha^{-1} with 134.65 per cent increase over control. The spinosad @ 17.5 g a.i. ha^{-1} was next in the order with cabbage yield of 230.76 q ha^{-1} with 131.84 per cent followed by flubendiamide @ 18.24 g a.i. ha^{-1}.

Cumulative yield of cabbage heads in first and second year (Pooled mean of 2015-16 and 2016-17)

Cumulative mean of two years experimental data on yield of cabbage revealed (Table 14 and fig. 12) that, all the treated plots resulted in higher cabbage yield which ranged between 120.74 to 238.15 q ha^{-1} and proved to be significantly superior over the control (103.89 q ha^{-1}). The highest yield of 238.15 q ha^{-1} was registered chlorantraniliprole @ 10 g a.i. ha^{-1} with maximum per cent increase (129.23 %) over control. This was followed by spinosad @ 17.5 g a.i. ha^{-1} (233.83 q ha^{-1} with 125.07 % increase over control). Next in the order of effectiveness were flubendiamide (224.98 q ha^{-1}), indoxacarb (198.17 q ha^{-1}) and emamectin benzoate (181.51 q ha^{-1}). The lowest yield (103.89 q ha^{-1}) was recorded in the untreated plots.

Table 11. Bio-efficacy of newer insecticides against *P. xylostella* during first & second year 2015-16 and 2016-17 (Pooled mean of 2015-16 and 2016-17)

Sr. No.	Treatment details	Dose (g a.i.ha^{-1})	Pre-count	Mean number of larvae per plant Mean of first and second year				Overall larval count	% Reduction over untreated control
				1 DAS	3 DAS	7 DAS	14 DAS		
1	Indoxacarb 14.5 % SC	40	7.53 (2.83)*	3.92 (2.10)	1.18 (1.30)	0.75 (1.12)	2.15 (1.63)	2.00 (1.58)	82.95
2	Spinosad 2.5 % SC	17.50	7.50 (2.83)	3.05 (1.88)	0.61 (1.05)	0.35 (0.92)	1.83 (1.53)	1.46 (1.40)	87.55
3	Flubendiamide 39.35 % SC	18.24	7.53 (2.83)	3.15 (1.91)	0.72 (1.10)	0.47 (0.98)	1.93 (1.56)	1.57 (1.44)	86.61
4	Diafenthiuron 50 % WP	300	7.43 (2.82)	5.83 (2.52)	2.27 (1.66)	1.80 (1.52)	3.08 (1.89)	3.25 (1.94)	72.29
5	Emamectine benzoate 5 % SG	10	7.53 (2.83)	4.40 (2.21)	1.48 (1.41)	1.10 (1.26)	2.47 (1.72)	2.36 (1.69)	79.88
6	Chlorantraniliprole 18.5 % SC	10	7.48 (2.83)	2.15 (1.63)	0.23 (0.86)	0.17 (0.82)	1.53 (1.43)	1.02 (1.23)	91.30
7	Quinalphos 25 % EC	250	7.33 (2.80)	5.97 (2.54)	2.72 (1.79)	2.18 (1.64)	3.48 (2.00)	3.59 (2.02)	69.39
8	Triazophos 40 % EC	500	7.60 (2.85)	6.37 (2.62)	3.20 (1.92)	2.53 (1.74)	4.00 (2.12)	4.03 (2.13)	65.64
9	Bifenthrin 10 % EC	50	7.53 (2.83)	6.72 (2.69)	3.58 (2.02)	2.97 (1.86)	4.40 (2.21)	4.42 (2.22)	62.31
10	Untreated control	---	9.80 (3.20)	10.33 (3.29)	11.05 (3.40)	12.22 (3.57)	13.32 (3.72)	11.73 (3.50)	---
	S.E. ±	---	NS	0.011	0.009	0.011	0.011	0.006	---
	C. D. at 5%	---	NS	0.033	0.029	0.034	0.033	0.019	---

DAS: Days after spray

NS: Non-significant

*Figures in parentheses denote $\sqrt{n + 0.5}$ transformed values.

4.2.3 Cost economics

I year

The cost effectiveness of the different insecticides used against *P. xylostella* during the first year of experimentation was assessed through incremental cost benefit ratio (ICBR) and presented in Table 15. The ICBR in respect of different treatments ranged between 1.28 to 16.91. The benefit derived from every rupee invested on plant protection was highest in chlorantraniliprole 18.50 % SC (1:16.91) followed by flubendiamide 39.35 % SC (1:15.37) and spinosad 2.5 % SC (1:12.50).

II year

It is evident from Table 16 that during second year (2016-17), the benefit derived from every rupee ranged between 2.24 to 15.89. Maximum benefit was derived to the tune of 1:15.89 by the application of chlorantraniliprole @ 18.50 % SC (1:15.89) followed by flubendiamide 39.35 % SC (1:14.60) and spinosad 2.5 % SC (1:11.94).

Pooled incremental cost:benefit ratio of first and second year (2015-16 & 2016-17)

The data generated on cost effectiveness of different insecticides applied against *P. xylostella* in cabbage during two years (2015-16 & 2016-17) are presented in Table 17. The ICBR in respect of different treatments ranged between 1.78 to 16.40. It could be seen that, chlorantraniliprole @ 10 g a.i. ha^{-1} ranked first indicating the maximum return of Rs. 16.40 per rupee invested followed by flubendiamide @ 18.24 g a.i. ha^{-1} (Rs. 14.98) and spinosad @ 17.5 g a.i. ha^{-1} (Rs.12.22).

Table 12. Influence of newer insecticides on the marketable yield of cabbage in first year (2015-16)

Sr. No.	Treatments	Marketable yield of cabbage heads		Per cent increase over control
		Kg/plot	q/ha	
1	Indoxacarb 14.5 % SC	29.51	196.76	82.11
2	Spinosad 2.5 % SC	35.54	236.91	119.27
3	Flubendiamide 39.35 % SC	34.27	228.49	111.48
4	Diafenthiuron 50 % WP	26.07	173.78	60.84
5	Emamectin benzoate 5 % SG	26.93	179.56	66.19
6	Chlorantraniliprole 18.5 % SC	36.34	242.27	124.24
7	Quinalphos 25 % EC	23.92	159.44	47.57
8	Triazophos 40 % EC	20.00	133.31	23.39
9	Bifenthrin 10 % EC	18.23	121.51	12.46
10	Untreated control	16.21	108.04	-----
	S.E. ±	0.057	0.383	
	C. D. at 5%	0.177	1.179	

Table 13. Influence of newer insecticides on the marketable yield of cabbage in second year (2016-17)

Sr. No.	Treatments	Marketable yield of cabbage heads		Per cent increase over control
		Kg/plot	q/ha	
1	Indoxacarb 14.5 % SC	29.94	199.58	100.12
2	Spinosad 2.5 % SC	34.61	230.76	131.84
3	Flubendiamide 39.35 % SC	33.22	221.47	122.06
4	Diafenthiuron 50 % WP	26.29	175.24	75.71
5	Emamectin benzoate 5 % SG	27.52	183.47	83.96
6	Chlorantraniliprole 18.5 % SC	35.10	234.02	134.65
7	Quinalphos 25 % EC	22.18	147.84	48.24
8	Triazophos 40 % EC	20.13	134.22	34.58
9	Bifenthrin 10 % EC	18.00	119.98	20.34
10	Untreated control	14.96	99.73	---
	S.E.±	0.033	0.223	
	C. D. at 5 %	0.103	0.688	

Table 14. Influence of newer insecticides on the marketable yield of cabbage in first and second year (pooled mean of 2015-16 & 2016-17)

Sr. No.	Treatments	Marketable yield of cabbage heads		Per cent increase over control
		Kg/plot	qt/ha	
1	Indoxacarb 14.5 % SC	29.73	198.17	90.75
2	Spinosad 2.5 % SC	35.08	233.83	125.07
3	Flubendiamide 39.35 % SC	33.75	224.98	116.56
4	Diafenthiuron 50 % WP	26.18	174.51	67.98
5	Emamectin benzoate 5 % SG	27.23	181.51	74.71
6	Chlorantraniliprole 18.5 % SC	35.72	238.15	129.23
7	Quinalphos 25 % EC	23.05	153.64	47.88
8	Triazophos 40 % EC	20.07	133.77	28.76
9	Bifenthrin 10 % EC	18.11	120.74	16.21
10	Untreated control	15.58	103.89	----
	S.E. ±	0.037	0.247	
	C. D. at 5 %	0.114	0.761	

Table 15. Incremental cost benefit ratio of different insecticides used against *P. xylostella* in cabbage during first year (2015-16)

Treatments	Yield (q ha^{-1})	Increased yield over control (q ha^{-1})	Cost of insecticides for 2 sprays (Rs.ha^{-1})	Labour charges for 2 sprays (Rs.ha $^{-1}$)	Total cost (Rs.ha^{-1})	Value of additional yield over untreated control (Rs.ha^{-1})	Incremental benefit (Rs.ha^{-1})	I.C.B.R.	Rank
Indoxacarb 14.5 % SC	196.76	88.72	1740	1600	3340	38593.2	35253.2	1:10.55	4
Spinosad 2.5 % SC	236.91	128.87	2550	1600	4150	56058.4	51908.4	1:12.50	3
Flubendiamide 39.35 % SC	228.49	120.45	1600	1600	3200	52395.7	49195.7	1:15.37	2
Diafenthiuron 50 % WP	173.78	65.74	5640	1600	7240	28596.9	47652.0	1:2.94	7
Emamectin benzoate 5 % SG	179.56	71.52	2880	1600	4480	31111.2	26631.2	1:5.95	6
Chlorantraniliprole 18.5 % SC	242.27	134.23	1660	1600	3260	58390.0	55130.0	1:16.91	1
Quinalphos 25 % EC	159.44	51.40	1360	1600	2960	22359.0	19399.0	1:6.55	5
Triazophos 40 % EC	133.31	25.27	1400	1600	3000	10992.4	7992.45	1:2.66	8
Bifenthrin 10 % EC	121.51	13.47	960	1600	2560	5859.4	3299.4	1:1.28	9
Untreated control	108.04	---	---	---	---	---	---	---	---

Note: 1. Labour+ Sprayer charges: 1600/-, 2. Labour required: 2/ha, 3.Market price of cabbage: Rs. 435/- per quintal

Cost of insecticides (Rs./lit/kg.) :

a. Indoxacarb 14.5 % SC: 2175/-, b. Spinosad 2.5 % SC: 1700/-, c. Flubendiamide 39.35 % SC: 16000/-, d. Diafenthiuron 50 % WP: 3760/-,e. Emamectin benzoate 5 % SG:7200/-,f. Chlorantraniliprole 18.5 % SC: 14110/-, g. Quinalphos 25 % EC: 680/-, h. Triazophos 40 % EC:560/-,i. Bifenthrin 10 % EC: 960/-.

Table 16. Incremental cost benefit ratio of different insecticides used against *P. xylostella* in cabbage during second year (2016-17

Treatments	Yield (q ha^{-1})	Increased yield over control (q ha^{-1})	Cost of insecticides for 2 sprays (Rs.ha^{-1})	Labour charges for 2 sprays (Rs.ha^{-1})	Total cost (Rs.ha^{-1})	Value of additional yield over untreated control (Rs.ha^{-1})	Incremental benefit (Rs.ha^{-1})	I.C.B.R	Rank
Indoxacarb 14.5 % SC	199.58	99.85	1740	1600	3340	40938.5	37598.5	1:11.25	4
Spinosad 2.5 % SC	230.76	131.03	2550	1600	4150	53722.3	49572.3	1:11.94	3
Flubendiamide 39.35 % SC	221.47	121.74	1600	1600	3200	49913.4	46713.4	1:14.60	2
Diafenthiuron 50% WP	175.24	75.51	5640	1600	7240	30959.1	23719.1	1:3.27	8
Emamectin benzoate 5% SG	183.47	83.74	2880	1600	4480	34333.4	29853.4	1:6.66	5
Chlorantraniliprole 18.5 % SC	234.02	134.29	1660	1600	3260	55058.9	51798.9	1:15.89	1
Quinalphos 25 % EC	147.84	48.73	1360	1600	2960	20003.9	17043.9	1:5.75	6
Triazophos 40 % EC	134.22	34.49	1400	1600	3000	14140.9	11140.9	1:3.71	7
Bifenthrin 10 % EC	119.98	20.25	960	1600	2560	8302.5	5742.5	1:2.24	9
Untreated control	99.73	----	---	---	---	---	---	---	---

Note: 1. Labour+ Sprayer charges: 1600/-, 2. Labour required: 2/ha, 3.Market price of cabbage: Rs. 410/- per quintal

Cost of insecticides (Rs./lit/kg.) :

a. Indoxacarb 14.5 % SC: 2175/-, b. Spinosad 2.5 % SC: 1700/-, c. Flubendiamide 39.35 % SC: 16000/-,d. Diafenthiuron 50 % WP: 3760/-,e. Emamectin benzoate 5 % SG:7200/-,f. Chlorantraniliprole 18.5 %SC: 14110/-, g. Quinalphos 25 % EC: 680/-, h. Triazophos 40 % EC:560/-,i. Bifenthrin 10 % EC:960/-.

Table 17. Incremental cost benefit ratio of different insecticides used against *P. xylostella* in cabbage during first and second year (pooled I.C.B.R of 2015-16 & 2016-17)

Treatments	Yield (q ha^{-1})	Increased yield over control (q ha^{-1})	Cost of insecticides for 2 sprays (Rs.ha^{-1})	Labour charges for 2 sprays (Rs.ha^{-1})	Total cost (Rs.ha^{-1})	Value of additional yield over untreated control (Rs.ha^{-1})	Incremental benefit (Rs.ha^{-1})	I.C.B.R.	Rank
Indoxacarb 14.5 % SC	198.17	94.28	1740	1600	3340	39833.3	36493.3	1:10.92	4
Spinosad 2.5 % SC	233.83	129.94	2550	1600	4150	54899.6	50749.6	1:12.22	3
Flubendiamide 39.35 % SC	224.98	121.09	1600	1600	3200	51160.5	47960.5	1:14.98	2
Diafenthiuron 50 % WP	174.51	70.62	5640	1600	7240	29836.9	22596.9	1:3.10	8
Emamectin benzoate 5 % SG	181.51	77.62	2880	1600	4480	32794.4	28314.4	1:6.32	5
Chlorantranaliprole 18.5 % SC	238.15	134.26	1660	1600	3260	56724.8	53464.8	1:16.40	1
Quinalphos 25 % EC	153.64	49.75	1360	1600	2960	21019.3	18059.3	1:6.10	6
Triazophos 40 % EC	133.77	29.88	1400	1600	3000	12624.3	9624.3	1:3.20	7
Bifenthrin 10 % EC	120.74	16.85	960	1600	2560	7119.1	4559.1	1:1.78	9
Untreated control	103.89	----	---	---	---	----	---	---	---

Note: 1. Labour+ Sprayer charges:1600/-, 2. Labour required: 2/ha, 3.Market price of cabbage: Rs. 422.5/-per quintal

Cost of insecticides (Rs./lit/kg.) :

a. Indoxacarb 14.5 % SC: 2175/-, b. Spinosad 2.5 % SC: 1700/-, c. Flubendiamide 39.35 % SC: 16000/-,d. Diafenthiuron 50 % WP: 3760/-,e. Emamectin benzoate 5 % SG:7200/-,f. Chlorantraniliprole 18.5 % SC: 14110/-, g. Quinalphos 25 % EC: 680/-, h. Triazophos 40 % EC:560/-,i. Bifenthrin 10 % EC:960/-.

4.3 Method validation for estimation of triazophos, quinalphos and bifenthrin residues in cabbage using GC-FPD and GC-ECD system

Method validation refers to the process to confirm the suitability of analytical method employed for specific test and is an integral part of any good analytical procedure. Validation parameters *viz.,* linearity, LOD and LOQ, accuracy and precision were determined before analysis of cabbage samples.

Limit of Detection (LOD) and Limit of Quantification (LOQ)

The limit of detection (LOD) of the tested insecticides was 0.020 mg kg^{-1} and derived by considering a signal-to-noise ratio of compound with reference to the background noise obtained for the blank sample. The limits of quantification (LOQ) determined as the lowest concentration in cabbage of a given compound giving a response that could be quantified with RSD lower than 20 per cent and that was 0.05 mg kg^{-1} for triazophos, quinalphos and bifenthrin.

Specificity studies

Specificity studies were performed by spiking the cabbage sample and reagent blank with working standards of triazophos, quinalphos and bifenthrin at concentration 0.05 mg kg^{-1}. The area of cabbage sample and reagent blank were compared with spiked matrix match area. The acceptable range was ± 30 per cent (Table 18, 19 and 20).

Linearity studies

For the linearity studies, a graph of detector response versus concentration of insecticides was plotted and correlation equation and coefficients were determined.

Six linear concentrations (0.05, 0.1, 0.25, 0.40, 0.50 and 1.00 mg kg^{-1}) of working standard *i.e.,* triazophos, quinalphos and bifenthrin were injected three times and the linearity lines were drawn (Table 21 and fig. 13). The response was linear over the range tested and R^2 values were 0.996, 0.998 and 0.993 for triazophos, quinalphos and bifenthrin, respectively. These results indicated that the GC-FPD and GC-ECD analysis is a valid method for residue determination of the tested insecticides in cabbage.

¶

Table 18 Specificity studies on triazophos standard

Concentration (ppb)	Sample Area		MMS Area	Residue (mg/kg)	LOQ (mg/kg)	Variation (%)	Acceptance Criteria (%)
50	R1	48399	47965	0.050	0.05	-1	30
	R2	52703	52907	0.050	0.05	0	30
	R3	47905	49433	0.048	0.05	3	30
	Reagent Blank Area		**MMS Area**	**Residue (mg/kg)**	**LOQ (mg/kg)**	**Variation (%)**	**Acceptance Criteria (%)**
50	R1	49532	47965	0.052	0.05	-3	30
	R2	51982	52907	0.049	0.05	2	30
	R3	52451	49433	0.053	0.05	-6	30

Table 19. Specificity studies on quinalphos standard

Concentration (ppb)	Sample Area		MMS Area	Residue (mg/kg)	LOQ (mg/kg)	Variation (%)	Acceptance Criteria (%)
50	R1	38122	41371	0.046	0.05	8	30
	R2	38070	40759	0.047	0.05	7	30
	R3	40490	42769	0.047	0.05	5	30
	Reagent Blank Area		**MMS Area**	**Residue (mg/kg)**	**LOQ (mg/kg)**	**Variation (%)**	**Acceptance Criteria (%)**
50	R1	42925	41371	0.052	0.05	-4	30
	R2	44336	40759	0.054	0.05	-9	30
	R3	44058	42769	0.052	0.05	-3	30

Table 20. Specificity studies on bifenthrin standard

Concentration (ppb)	Sample Area		MMS Area	Residue (mg/kg)	LOQ (mg/kg)	Variation (%)	Acceptance Criteria (%)
50	R1	58880	58602	0.050	0.05	0	30
	R2	57586	59526	0.048	0.05	3	30
	R3	59395	61719	0.048	0.05	4	30
	Reagent Blank Area		**MMS Area**	**Residue (mg/kg)**	**LOQ (mg/kg)**	**Variation (%)**	**Acceptance Criteria (%)**
50	R1	63363	58602	0.054	0.05	-8	30
	R2	62708	59526	0.053	0.05	-5	30
	R3	62643	61719	0.051	0.05	-1	30

Table 21. Calibration details for linearity check

Insecticides	Corresponding peak area at different concentration					
	0.05 mg kg^{-1}	0.10 mg kg^{-1}	0.25 mg kg^{-1}	0.40 mg kg^{-1}	0.50 mg kg^{-1}	1.00 mg kg^{-1}
Triazophos	44303	82975	218889	456493	540290	1079940
Quinalphos	54698	103254	305861	463862	569199	1083450
Bifenthrin	63481	120296	347008	472181	634290	1126179

Matrix match linearity studies

Untreated cabbage heads were brought from control plots of research field. Matrix of cabbage was collected by following the extraction and clean-up. Six linear concentrations (0.05, 0.1, 0.25 , 0.40, 0.50 and 1.00 mg kg^{-1}) of working standards of triazophos, quinalphos and bifenthrin were added into the known quantity of sample matrix of cabbage and injected three times and the linearity lines were drawn (Table 22 and fig. 14). The response was linear over the range tested and R^2 values were 0.998, 0.992 and 0.992 for triazophos, quinalphos and bifenthrin, respectively.

Recovery studies

Accuracy of the analytical method was determined by recovery studies. Mean recovery obtained from the studies reflect the accuracy of the method. Precision of the method was reflected by the relative standard deviation.

Recovery studies were performed with untreated cabbage sample fortified with three concentrations of triazophos, quinalphos and bifenthrin *i.e.,* 0.05, 0.25 and 0.50 mg kg^{-1}. The extraction and clean-up were performed as described earlier. Recoveries of three test insecticides were determined in three replicates to confirm the validity of the method. The recovery percentages are presented in Table 23. The results of mean recovery studies of triazophos, quinalphos and bifenthrin carried out at the level of 0.05, 0.25 and 0.50 mg kg^{-1} on cabbage and recovery ranged between 70-120 per cent.

Results showed that the QuEChERS method is a valid method for residue determination of the tested insecticides in cabbage. The analytical method employed for the extraction and clean up of cabbage samples was found accurate and precise as mean recovery percentage and relative standard deviation (RSD) were within the limits prescribed by SANCO/12571/2013. According to SANCO/12571/2013 guidelines, analytical method which records mean recovery in the range of 70-120 per cent and relative standard deviation (RSD) below 20 per cent is accurate and precise.

Repeatability studies

Repeatability or retest reliability was performed to check the variation in measurements taken by the same person on same instrument on the same item under the same conditions. Standards of triazophos, quinalphos and bifenthrin were separately spiked into the control samples of cabbage at the required fortification levels *i.e.* LOQ, 5 x LOQ and 10 x LOQ. The results of repeatability studies of triazophos, quinalphos and bifenthrin [Table 24] carried out at the levels of 0.05, 0.25 and 0.50 mg kg^{-1} on cabbage and recovery ranged between 70-120 per cent.

Reproducibility studies

Reproducibility was performed to test the ability of an entire analysis of an experiment by another person on same instrument on the same item under the same conditions. The results of reproducibility studies of triazophos, quinalphos and bifenthrin carried out at the level of 0.05, 0.25 and 0.50 mg kg^{-1} are presented in Table 25. The recovery ranged between 70-120 per cent.

Table 22. Calibration details of matrix match linearity check

Insecticides	Corresponding peak area at different concentration					
	0.05 mg kg^{-1}	**0.10 mg kg^{-1}**	**0.25 mg kg^{-1}**	**0.40 mg kg^{-1}**	**0.50 mg kg^{-1}**	**1.00 mg kg^{-1}**
Triazophos	40798	89302	231725	403710	554231	1081387
Quinalphos	48889	114552	246622	430189	577335	997316
Bifenthrin	60082	129245	323717	494506	561469	1034680

Table 23. Recoveries of triazophos, quinalphos and bifenthrin in cabbage during recovery studies

Insecticides	Fortification Level (mg kg^{-1})	Recovery (%)			
		R1	R2	R3	Mean
Triazophos	0.05	90.54	95.27	99.70	95.17
	0.25	97.58	89.23	79.77	88.86
	0.50	101.68	88.56	80.64	90.30
Quinalphos	0.05	89.84	85.00	98.91	91.25
	0.25	86.94	87.05	115.60	96.53
	0.50	88.06	95.90	97.17	93.71
Bifenthrin	0.05	96.08	97.39	97.72	97.07
	0.25	101.25	95.41	100.11	98.92
	0.50	95.89	98.60	97.96	97.48

Table 24. Recoveries of triazophos, quinalphos and bifenthrin in cabbage during repeatability studies

Insecticides	Fortification Level (mg kg^{-1})	Recovery (%)			
		R1	R2	R3	Mean
Triazophos	0.05	89.46	92.23	105.99	95.89
	0.25	86.50	98.28	90.45	91.74
	0.50	88.91	93.97	89.06	90.65
Quinalphos	0.05	104.07	95.96	94.64	98.22
	0.25	94.68	83.04	93.45	90.39
	0.50	97.64	90.72	83.64	90.66
Bifenthrin	0.05	96.51	96.09	101.57	98.06
	0.25	96.45	99.33	98.66	98.15
	0.50	89.65	90.01	93.74	91.13

Table 25. Recoveries of triazophos, quinalphos and bifenthrin in cabbage during reproducibility studies

Insecticides	Fortification Level (mg kg^{-1})	Recovery (%)			
		R1	R2	R3	Mean
Triazophos	0.05	91.16	86.37	94.08	90.54
	0.25	117.68	115.04	111.92	114.88
	0.50	111.12	94.21	97.84	101.06
Quinalphos	0.05	93.23	95.73	93.20	94.05
	0.25	82.74	91.79	99.40	91.31
	0.50	88.52	95.79	93.62	92.64
Bifenthrin	0.05	98.43	96.51	98.99	97.98
	0.25	91.36	95.24	87.92	91.51
	0.50	84.33	86.63	86.26	85.74

4.4 Dissipation pattern of triazophos, quinalphos and bifenthrin in cabbage

Dissipation of triazophos, quinalphos and bifenthrin was determined by conducting a supervised field trial during 2015-16, at the Instructional Farm of Post Graduate Institute MPKV, Rahuri and Pesticide Residue Laboratory, Department of Agril. Entomology. Two sprays of insecticides were given at an interval of ten days, first being at 50 per cent head formation stage. The treated heads were collected at 0 (2 hrs.), 1, 3, 5, 7, 10 and 15 days after second application and subjected to QuEChERS method to determine residues as explained under section 3.2.5.4 of the chapter III (Material and Methods). The relevant meteorological data *viz.,* temperature, RH and rainfall were recorded during the period of experimentation and mentioned in Appendix-II.

Dissipation of triazophos, quinalphos and bifenthrin was studied after two applications at the recommended dose and double the recommended dose on cabbage crop. The results obtained indicated that insecticide residues decreased at different days after last application.

4.4.1 Dissipation pattern of triazophos in cabbage

Dissipation of insecticide residues in plant depends on climatic conditions, type of application, dosage and intervals between application and time of harvest. The results revealed that there was reduction in residue level of triazophos in cabbage with time.

In case of triazophos 40 % EC @ 500 and 1000 g a.i. ha^{-1}, the maximum initial residues were recorded as 0.54 and 1.09 mg kg^{-1} and were found to be below quantification limit (BQL) on 10^{th} and 15^{th} day, respectively (Table 26 and fig.15) Based on first order kinetics, the half-life (RL_{50}) values of triazophos for cabbage were 2.66 and 2.87 days. The residues gradually dissipated with time and recorded 85.18 and 93.57 per cent dissipation at recommended and double the recommended dose of application (Table 27), respectively. The samples taken from control plots did not record any detectable level of residues.

At recommended dose (500 g a.i.ha^{-1}), maximum initial residues of 0.54 mg kg^{-1} were recorded at 0 (2 hr) day which gradually dissipated to 0.27, 0.18, 0.10 and 0.08 mg kg^{-1} at 1, 3, 5 and 7 days after treatment, respectively with 50.00, 66.67, 81.48

and 85.18 per cent dissipation. After 7 days of treatment, the residues reached below quantification limit (BQL) of 0.08 mg kg^{-1}.

At double the recommended dose (1000 g $a.i.ha^{-1}$), maximum initial residues of 1.09 mg kg^{-1} was recorded at 0 (2 hr) day and that gradually dissipated to 0.44, 0.30, 0.20, 0.15 and 0.07 mg kg^{-1} in 1, 3, 5, 7 and 10 days after treatment with per cent dissipation of 59.63, 72.47, 81.65, 86.23 and 93.57, respectively. After 10 days of treatment, the residues reached below quantification limit (BQL) of 0.07 mg kg^{-1}.

4.4.2 Dissipation pattern of quinalphos in cabbage

In case of quinalphos 25 % EC @ 250 and 500 g $a.i.ha^{-1}$, the initial residues were recorded as 0.48 and 1.06 mg kg^{-1}. Based on first order kinetics, the half-life (RL_{50}) values were 2.10 and 1.97 days at both rates of application (Table 28 and fig.16). The initial residues dissipated to 83.34 and 92.45 per cent (Table 29) on 5^{th} and 7^{th} day, at recommended and double the recommended dose, respectively. On 7^{th} and 10^{th} day after application residues were found below quantification limit (BQL) at both rates of application. The samples from untreated control plots did not record any detectable level of residues.

The results showed that, initial residues of 0.48 mg kg^{-1} from recommended dose (250 g $a.i.ha^{-1}$) dissipated to 0.21, 0.13, and 0.08 mg kg^{-1} on 1, 3, and 5 days after treatment, respectively, thereby recording 56.25, 72.92 and 83.34 per cent dissipation during this period.

At double the recommended dose (500 g $a.i.ha^{-1}$), initial residues of 1.06 mg kg^{-1} at 0 (2 hr) day and that gradually dissipated to 0.55, 0.33, 0.16, and 0.08 mg kg^{-1} in 1, 3, 5 and 7 days after treatment with per cent dissipation of 48.11, 68.86, 84.90 and 92.45, respectively during this period. After 7 days of treatment, the residues reached below quantification limit (BQL) of 0.08 mg kg^{-1}.

Table 26. Dissipation of triazophos residues in cabbage at different intervals

Interval between last application and sampling	Residues (mg kg^{-1})											
	Control				Triazophos @ 500 g a.i. ha^{-1}				Triazophos @ 1000 g a.i. ha^{-1}			
	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean (±SD)	R-I	R-II	R-III	Mean (±SD)
0 day (2 h)	ND	ND	ND	ND	0.52	0.55	0.55	0.54 (± 0.01)	1.09	1.10	1.07	1.09 (± 0.01)
1 day	ND	ND	ND	ND	0.26	0.26	0.30	0.27 (± 0.02)	0.44	0.43	0.45	0.44 (± 0.01)
3 day	ND	ND	ND	ND	0.17	0.19	0.18	0.18 (± 0.01)	0.30	0.29	0.30	0.30 (± 0.00)
5 day	ND	ND	ND	ND	0.10	0.09	0.11	0.10 (± 0.01)	0.19	0.21	0.21	0.20 (± 0.02)
7 day	ND	ND	ND	ND	0.08	0.08	0.08	0.08 (± 0.00)	0.15	0.16	0.15	0.15 (± 0.01)
10 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	0.08	0.07	0.07	0.07 (± 0.00)
15 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
$RL_{50(days)}$	-				2.66				2.87			

* ND-Not Detected BQL-Below Quantification Limit LOQ 0.05 mg kg^{-1}

Table 27. Per cent dissipation of triazophos in cabbage

Interval between last application and sampling	Triazophos 40 % EC			
	Recommended dose (500 g a.i. ha^{-1})		Double the recommended dose (1000 g a.i. ha^{-1})	
	Mean Residues (mg kg^{-1})	Dissipation (%)	Mean Residues (mg kg^{-1})	Dissipation (%)
0 day (2 h)	0.54	------	1.09	-----
1 day	0.27	50.00	0.44	59.63
3 day	0.18	66.67	0.30	72.47
5 day	0.10	81.48	0.20	81.65
7 day	0.08	85.18	0.15	86.23
10 day	BQL	-----	0.07	93.57
15 day	BQL	----	BQL	----

4.4.3 Dissipation pattern of bifenthrin in cabbage

Data on dissipation pattern of bifenthrin 10 % EC @ 50 and 100 g. a.i. ha^{-1}, are presented in Table 30 and fig.17. It could be seen that the initial residues recorded were 0.51 and 1.08 mg kg^{-1}, respectively. The bifenthrin residues were below quantification limit (BQL) after 10 and 15 days. Based on first order kinetics, the half-life (RL_{50}) values recorded were 2.13 and 2.52 days, respectively. The residues of bifenthrin dissipated to 90.19 and 94.44 per cent [Table 31] on 7^{th} and 10^{th} at recommended (50 g a.i. ha^{-1}) and double the recommended dose (100 g a.i. ha^{-1}), respectively. The samples from untreated control plots did not record any residues.

Data revealed that initial residues of 0.51 mg kg^{-1} from recommended dose at 0 (2 hr) day gradually declined to 0.21, 0.10, 0.08 and 0.05 mg kg^{-1} on 1, 3, 5 and 7 days after treatment, respectively, thereby with 58.82, 80.39, 84.31 and 90.19 per cent dissipation, respectively.

At double the recommended dose, maximum initial residues of 1.08 mg kg^{-1} at 0 (2 hr) day gradually declined to 0.48, 0.23, 0.13, 0.09 and 0.06 mg kg^{-1} in 1, 3, 5, 7 and 10 days after treatment with per cent dissipation of 55.55, 78.70, 87.96, 91.66 and 94.44, respectively. After 10 days of treatment, the residues reached below quantification limit (BQL) of 0.06 mg kg^{-1}.

Table 28. Dissipation of quinalphos residues in cabbage at different intervals

Interval between last application and sampling	Residues (mg kg^{-1})											
	Control				Quinalphos @ 250 g a.i.ha^{-1}				Quinalphos @ 500 g a.i.ha^{-1}			
	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean (±SD)	R-I	R-II	R-III	Mean (±SD)
0 day (2 h)	ND	ND	ND	ND	0.47	0.49	0.47	0.48 (±0.01)	1.10	1.04	1.04	1.06 (±0.04)
1 day	ND	ND	ND	ND	0.20	0.23	0.18	0.21 (±0.02)	0.50	0.58	0.58	0.55 (±0.04)
3 day	ND	ND	ND	ND	0.13	0.13	0.14	0.13 (±0.01)	0.33	0.33	0.33	0.33 (±0.00)
5 day	ND	ND	ND	ND	0.08	0.09	0.08	0.08 (±0.00)	0.16	0.15	0.16	0.16 (±0.01)
7 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	0.08	0.08	0.08	0.08 (±0.00)
10 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
$RL_{50(days)}$	-				2.10				1.97			

* ND-Not Detected BQL- Below Quantification Limit LOQ 0.05 mg kg^{-1}

Table 29. Per cent dissipation of quinalphos in cabbage

Interval between last application and sampling	Quinalphos 25 % EC			
	Recommended dose (250 g a.i. ha^{-1})		Double the recommended dose (500 g a.i. ha^{-1})	
	Mean Residues (mg kg^{-1})	Dissipation (%)	Mean Residues (mg kg^{-1})	Dissipation (%)
0 day (2 h)	0.48	--	1.06	--
1 day	0.21	56.25	0.55	48.11
3 day	0.13	72.92	0.33	68.86
5 day	0.08	83.34	0.16	84.90
7 day	BQL	--	0.08	92.45
10 day	BQL	--	BQL	--
15 day	BQL	--	BQL	--

Table 30. Dissipation of bifenthrin residues in cabbage at different intervals

Interval between last application and sampling	Residues (mg kg^{-1})											
	Control				Bifenthrin @ 50 g a.i. ha^{-1}				Bifenthrin @ 100 g a.i. ha^{-1}			
	R-I	R-II	R-III	Mean	R-I	R-II	R-III	Mean (±SD)	R-I	R-II	R-III	Mean (±SD)
0 day (2 h)	ND	ND	ND	ND	0.52	0.51	0.49	0.51 (±0.02)	1.10	1.08	1.07	1.08 (±0.02)
1 day	ND	ND	ND	ND	0.22	0.21	0.21	0.21 (±0.00)	0.48	0.48	0.48	0.48 (±0.00)
3 day	ND	ND	ND	ND	0.10	0.10	0.10	0.10 (±0.00)	0.24	0.24	0.22	0.23 (±0.01)
5 day	ND	ND	ND	ND	0.08	0.08	0.08	0.08 (±0.00)	0.14	0.13	0.12	0.13 (±0.01)
7 day	ND	ND	ND	ND	0.05	0.05	0.05	0.05 (±0.00)	0.10	0.09	0.08	0.09 (±0.01)
10 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	0.06	0.07	0.06	0.06 (±0.00)
15 day	ND	ND	ND	ND	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
$RL_{50(days)}$	--				2.30				2.52			

* ND-Not Detected BQL-Below Quantification Limit LOQ 0.05 mg kg^{-1}

Table 31. Per cent dissipation of bifenthrin in cabbage

Interval between last application and sampling	Bifenthrin 10 % EC			
	Recommended dose @ (50 g a.i. ha^{-1})		Double the recommended dose @ (100 g a.i. ha^{-1})	
	Mean Residues (mg kg^{-1})	Dissipation (%)	Mean Residues (mg kg^{-1})	Dissipation (%)
0 day (2 h)	0.51	---	1.08	----
1 day	0.21	58.82	0.48	55.55
3 day	0.10	80.39	0.23	78.70
5 day	0.08	84.31	0.13	87.96
7 day	0.05	90.19	0.09	91.44
10 day	BQL	-	0.06	94.44
15 day	BQL	-	BQL	-

4.5 Impact of household processes on the residues of insecticides in cabbage

Cabbage heads were harvested on the 0 day (2 h) after single spray of triazophos, quinalphos and bifenthrin at recommended dose and further subjected to pesticide residue analysis. Cabbage heads were treated with six household processes in three replications *viz.,* washing of cabbage heads with tap water, dipping in 2 per cent NaCl solution, dipping in 2 per cent tamarind solution, boiling in open pan and cooking in closed pan.

4.5.1 Impact of household processes on the residues of triazophos in cabbage

Data pertaining to amount of residues and reduced percentage of triazophos residues in different household processes in cabbage are presented in Table 32 and 33.

The residues of triazophos in treated control sample (T_7) at 0 day (2 h after spray) was 0.54 mg kg^{-1} when applied at 500 g a.i. ha^{-1}. In cabbage, minimum amount of triazophos residues *i.e.* 0.08 mg kg^{-1} and maximum per cent reduction of residues (85.18 %) were observed in treatment with cooking (T_5). The residue level in the treatment of boiling (T_4) was 0.14 mg kg^{-1} which resulted in 74.07 per cent reduction in total amount of residues. In case of other treatments such as dipping in 2 per cent NaCl solution (T_2) and 2 per cent tamarind solution (T_3) mean residues up to 0.26 and 0.31 mg kg^{-1} were recorded with 51.85 and 42.59 per cent reduction in total amount of residues.

Whereas, washing with tap water (T_1) observed least to be effective that recorded 0.35 mg kg^{-1} residues with 35.18 per cent reduction in total amount of residues.

4.5.2 Impact of household processes on the residues of quinalphos in cabbage

Data pertaining to amount residues and per cent reduction of quinalphos residues in different household processes are presented in Table 34 and 35. Mean residues in treated control sample (T_7) was observed to be 0.48 mg kg^{-1} at recommended dose (250 g a.i. ha^{-1}).

The results further indicated that, the lowest amount of quinalphos residues was detected in the treatment of cooking (T_5) i.e. 0.07 mg kg^{-1} with highest per cent reduction i.e. 85.42. The residue after boiling (T_4) was 0.09 mg kg^{-1} which showed 81.25 per cent reduction in residues. The other treatments such as 2 per cent NaCl (T_2), 2 per cent tamarind solution (T_3) and washing with tap water (T_1) recorded residues of 0.20, 0.29 and 0.36 mg kg^{-1}, respectively with 56.25, 41.67 and 25.00 per cent reduction, respectively.

4.5.3. Impact of household processes on the residues of bifenthrin in cabbage

The data (Table 36 and 37) pertaining to the amount residues and per cent reduction due to different household processes indicated that, the mean amount of bifenthrin residues in treated control sample (T_7) at 0 day (2 h) was 0.51 mg kg^{-1} after application at recommended dose (50 g a.i. ha^{-1}).

Residues of 0.07 mg kg^{-1} were observed in the treatment of cooking (T_5) which showed maximum per cent reduction of residues (86.27 per cent). The residue level due to the process of boiling (T_4) was 0.10 mg kg^{-1} which resulted in 80.39 per cent reduction in mean residues. In case of other treatments, such as dipping in 2 per cent NaCl solution (T_2), 2 per cent tamarind solution (T_3) and washing with tap water (T_1), residues ranged between 0.18 to 0.36 mg kg^{-1}, respectively, which was 64.70, 56.86 and 29.41 per cent reduction in residues, respectively.

Table 32. Impact of household processes on the residues of triazophos in cabbage

Treatment No.	Treatment Details	Residues (mg kg-1)			
		Triazophos @ 500 g a.i. ha^{-1}			
		R-I	R-II	R-III	Mean (± S.D.)
T_1	Washing with tap water	0.35	0.34	0.36	0.35 (± 0.01)
T_2	Dipping in 2 % salt solution	0.25	0.27	0.26	0.26 (± 0.01)
T_3	Dipping in 2 % tamarind water	0.30	0.32	0.31	0.31 (± 0.01)
T_4	Boiling	0.14	0.14	0.14	0.14 (± 0.00)
T_5	Cooking	0.08	0.09	0.09	0.08 (± 0.01)
T_6	Treated Control	0.54	0.53	0.56	0.54 (± 0.01)
T_7	Untreated control	ND	ND	ND	ND

*ND-Not detected

Table 33. Per cent reduction of triazophos residues in cabbage

Treatment No.	Treatment Details	Triazophos @ 500 g a.i. ha^{-1}	
		Mean residues (mg Kg^{-1})	Reduction (%)
T_1	Washing with tap water	0.35	35.18
T_2	Dipping in 2 % salt solution	0.26	51.85
T_3	Dipping in 2 % tamarind water	0.31	42.59
T_4	Boiling	0.14	74.07
T_5	Cooking	0.08	85.18
T_6	Treated Control	0.54	---
T_7	Untreated control	ND	---

Table 34. Impact of culinary processes on the residues of quinalphos in cabbage

Treatment No.	Treatment Details	Residues (mg kg-1)			
		Quinalphos @ 250 g a.i. ha^{-1}			
		R-I	R-II	R-III	Mean (± S.D)
T_1	Washing with tap water	0.37	0.36	0.36	0.36 (± 0.00)
T_2	Dipping in 2 % salt solution	0.19	0.19	0.21	0.20 (± 0.01)
T_3	Dipping in 2 % tamarind water	0.29	0.32	0.28	0.29 (± 0.02)
T_4	Boiling	0.09	0.09	0.09	0.09 (± 0.00)
T_5	Cooking	0.06	0.06	0.07	0.07 (± 0.00)
T_6	Treated Control	0.50	0.46	0.50	0.48 (± 0.02)
T_7	Untreated control	ND	ND	ND	ND

*ND-Not detected

Table 35. Per cent reduction of quinalphos residues in cabbage

Treatment No.	Treatment Details	Quinalphos @ 250 g a.i. ha^{-1}	
		Mean residues (mg Kg^{-1})	Reduction (%)
T_1	Washing with tap water	0.36	25.00
T_2	Dipping in 2 % salt solution	0.21	56.25
T_3	Dipping in 2 % tamarind water	0.28	41.67
T_4	Boiling	0.09	81.25
T_5	Cooking	0.07	85.42
T_6	Treated Control	0.48	---
T_7	Untreated control	ND	-----

Table 36. Impact of culinary processes on the residues of bifenthrin in cabbage

Treatment No.	Treatment Details	Residues (mg kg-1)			
		Bifenthrin @ 50 g a.i. ha^{-1}			
		R-I	R-II	R-III	Mean (± S.D.)
T_1	Washing with tap water	0.35	0.36	0.36	0.36 (± 0.00)
T_2	Dipping in 2 % salt solution	0.17	0.18	0.18	0.18 (± 0.01)
T_3	Dipping in 2 % tamarind water	0.22	0.21	0.22	0.22 (± 0.00)
T_4	Boiling	0.10	0.09	0.10	0.10 (± 0.00)
T_5	Cooking	0.06	0.07	0.06	0.07 (± 0.00)
T_6	Treated Control	0.51	0.50	0.52	0.51 (± 0.01)
T_7	Untreated control	ND	ND	ND	ND

Table 37. Per cent reduction of bifenthrin residues in cabbage

Treatment No.	Treatment Details	Bifenthrin @ 50 g a.i. ha^{-1}	
		Mean residues (mg Kg^{-1})	Reduction (%)
T_1	Washing with tap water	0.36	29.41
T_2	Dipping in 2 % salt solution	0.18	64.70
T_3	Dipping in 2 % tamarind water	0.22	56.86
T_4	Boiling	0.10	80.39
T_5	Cooking	0.07	86.27
T_6	Treated Control	0.51	---
T_7	Untreated control	ND	---

*ND-Not detected

5. DISCUSSION

Diamondback moth is one of the most serious insect pest of cruciferous crops. The larva feeds foliage from seedling stage to harvest and reduce both yield and quality of the produce. The crop losses due to *P. xylostella* may often go up to 100 per cent (Calderon and Hare, 1986).

It is evident that widespread and indiscriminate use of pesticides by growers to counteract the pests in vegetable crops resulted in undesirable ecological changes such as development of resistance, resurgence of sucking pests, occurrence of pesticides residues and adverse effects on non target organisms.

Insecticides should not only suppress the insect pest population but also be safer to natural enemies and pollinators.

For the management of *P. xylostella,* growers have been depending exclusively on various synthetic insecticides. As a result field population of *P.xylostella* has developed multiple resistance and control failure is often more frequent. (Kranthi *et al*., 2002).

Indiscriminate use of insecticides, multiple generations of insects in a year and year round availability of host crops contributed to the insecticide resistance.

Insecticide resistance has often been one of the most important reason that is why insecticides with new mode of action is derived. However, it is very difficult and challenging. A new insecticide developed, should be used with due consideration for strategies to delay the development of resistance. Care must be taken to prolong useful life of valuable insecticide.

The use of pesticides during production often leads to the presence of residues of pesticides in vegetables after harvest. The presence of residues is a concern for consumer because pesticides are known to have potential harmful effects to human beings and often non target organisms.

With this background, the investigations on "Bio-efficacy of newer insecticides against diamondback moth (*P.xylostella* L.) and their residues in cabbage" were carried out at MPKV, Rahuri during the year 2015-16 and 2016-17.

Experimental findings obtained in the present research work are discussed in this chapter.

5.1 Usage pattern of insecticides

Cabbage (*Brassica oleracea* var. *capitata* Linn.) is the most common, popular and major annual vegetable crop. It has been staple vegetable in our diet since ancient times. Among the winter vegetables, the cabbage is extensively cultivated crop because of its nutritional and economical values. Cabbage is a crops of small and marginal farmers for whom it is an important source of income. Cabbage is heavily attacked by the number of insect pests. Diamondback moth (*P. xylostella*) is the most destructive insect pest and is the major limiting factor for successful cultivation of cruciferous crops resulting in loss of quality. In order to protect the crop due to damage by insect pests and diseases farmers rely heavily on pesticides during entire period of growth of vegetables. Majority of farmers ignore the recommended pesticides dose and observance of safe waiting period. This situation has led to occurrence of pesticide residues in vegetables.

The present investigation revealed that, consumption of insecticides for the control of major insects of cabbage was to the extent of 1.51, 1.79 and 1.65 kg a.i. ha^{-1} $season^{-1}$ for Ahmednagar, Pune and Nashik, respectively.

The above results are in corroboration with earlier workers. Average usage of 0.563 g a.i.ha^{-1} pesticides in cabbage was reported by Nagendra (2009) in Belgaum district of Karnataka. Jeyanthi and Kombairaju (2005) conducted a survey on pesticide use in cauliflower in Dindigul district of Tamil Nadu and reported that about 87 per cent of cauliflower growers applied pesticides amounting to 4 kg a.i.ha^{-1}. Patrick and Anis (1999) recorded insecticides use in different vegetables such as potatoes (1.30 kg a.i. ha^{-1} $annum^{-1}$), onions (2.10 kg a.i. ha^{-1} $annum^{-1}$), brassicas (2.8 kg a.i. ha^{-1} $annum^{-1}$) and field tomatoes (0.02 kg a.i. ha^{-1} $annum^{-1}$). Pesticide use in processed vegetables such as asparagus, green peas and sweet corn was relatively low and was mainly concentrated on early season weed and pest control. In contrast, fresh vegetables such as lettuce, brassicas and potatoes tend to had intensive spray programme throughout the growing season. Onions received very frequent pesticide applications. Use rate of pesticides per annum per farmer reached 0.77 L in Gaza Strip and 0.18 L in the West Bank districts in vegetable (Al-Sayed *et al*. 2011). Patil (2012) reported that farmers from Ahmednagar district used 5.504 kg a.i. ha^{-1} $season^{-1}$ quantity of insecticides against *S. litura*. However, Dhore (2016) reported that 8.595 kg a.i. ha^{-1} organophosphorus insecticides were used against insect pest of brinjal in Ahmednagar. Similarly, Sali (2016) conducted a survey on pesticide use pattern in tomato and revealed that farmers used 5.67 kg a.i ha^{-1} organophosphorus insecticides against insect pests of tomato. Raut (2016) reported that 5.87 kg a.i. ha^{-1} $season^{-1}$ of organophosphorus insecticides were used by chilli growers from Ahmednagar district during cropping season. Patil (2017) reported that usage of insecticides as 6.36, 6.17 and 5.46 kg a.i. ha^{-1} $season^{-1}$ from Ahmednagar, Pune and Jalgaon, respectively in brinjal. Further, reported 6.16, 5.50 and 6.55 kg a.i. ha^{-1} $season^{-1}$ of insecticides used by tomato growers in Ahmednagar, Pune and Nashik, respectively.

Present investigation revealed that 54, 44 and 46 per cent of the cabbage growers from Ahmednagar, Pune and Nashik, respectively were aware of natural enemies of the respective pest in cabbage. The present findings are in agreement with Baral *et al*. (2006) who reported that nearly 49 per cent of the farmers were aware of beneficial insects in eggplant fields. Mahantesh and Alka Singh (2009) reported that 41.5 per cent of vegetable cultivating farmers had knowledge about natural enemies of respective pest. However, only 16 per cent farmers knew about natural enemies in curry leaf according to Ramakrishnan *et al*. (2015).

In present study, it was observed that 68, 52 and 50 per cent farmers from Ahmednagar, Pune and Nashik, respectively knew about the recommended insecticides for cabbage. The present findings are in agreement with Nagendra (2009) who reported that only 11.67 per cent farmers were aware of recommended doses of pesticides in cabbage. According to Chandi *et al*. (2012) 71.9 per cent farmers sprayed non recommended insecticides. Studies of Nagenthirajah and Thiruchelvam (2008) revealed that only 6 per cent farmers were aware of relative plant protection practices and 35 per cent farmers were used higher concentration of pesticides than recommended level. Sutharsan *et al*. (2014) reported that 90 per cent of the vegetable farmers apply pesticides more than the recommended dose. Sharaniya and Loganathan (2015) reported that 51 per cent farmers applied pesticides, 10-20 per cent higher than recommended. Similarly, Sneha *et al.* (2017) reported 40 per cent of the black gram farmers from Nizamabad were aware of recommended pesticides used against different pests.

Present investigation revealed that near 58, 30 and 68 per cent of the cabbage growers from Ahmednagar, Pune and Nashik, respectively were aware of application of biopesticide against the respective pest of cabbage. The present findings are in agreement with Kamarulzaman *et al.* (2012) who reported that 54.3 per cent vegetable farmers sprayed biopesticides in their farms. Further, concluded that great challenges in promoting biopesticide usage among vegetable farmers though it had proven to be able in controlling pest. Odhiambo *et al.* (2014) reported that only 4.23 per cent biopesticides were used by the farmers in cabbage growing areas.

In the present study, it was found that majority i.e. 75 per cent of the cabbage growers did not know about safe waiting period for insecticide they used. The above findings are in agreement with Muzlon and Mumford (2005); Amoako *et al*. (2012); Sutharsan *et al*. (2014); Afari Sefa *et al*. (2015) and Sneha *et al*. (2017).

Muzlon and Mumford (2005) revealed that more than 50 per cent of cabbage farmers observe 10 to 14 days pre-harvest interval. Amoako *et al*. (2012) reported that 79 per cent of the cabbage farmers continued spraying pesticides during harvesting period; hence no waiting period was adopted. Sutharsan *et al*. (2014) reported that 89 per cent of the farmers harvest their produce before the recommended pre harvest interval. Similarly, Afari Sefa *et al*. (2015) reported that 76.3 per cent vegetable farmers harvest their produce within 7 days after spraying and 1.4 per cent farmers harvest their produce on the same day after spraying. Sneha *et al.* (2017) reported that most of the black gram farmers from Nizamabad district followed common waiting period of 7 days (63.33 %) followed by 4 days (26.66 %) and 2 days (10 %).

In present study, it was found that 86, 64 and 78 per cent farmers of Ahmednagar, Pune and Nashik, respectively didn't know the residual effects of insecticides which is in agreement with work done by Nagendra (2009) who reported that only 15 per cent cabbage growers were aware of lethal effect of pesticides on human health and 76.67 per cent farmers did not follow any protective measures while spraying pesticides. Dey *et al.* (2013) reported that most of the farmers (71 %) are not aware of the health hazards caused by the pesticides and also the consequences of their improper handling. Sneha *et al.* (2017) reported that 16.66 per cent of the farmers were aware of the fact that pesticide residues are found in vegetables. Studies also revealed that more than 85 per cent farmers did not know about any kind of bad effects due to pesticide residues.

5.2 Bio-efficacy of newer insecticides against *P. xylostella* in cabbage

Results indicated that all the insecticidal treatments were found to be effective against *P. xylostella* on cabbage (Fig. 18, 19 and 20). Chlorantraniliprole @ 10 g a.i. ha^{-1} consistently proved its superiority during both the years by recording highest per cent larval reduction over untreated control i.e. 91.30 per cent. Next in the order of effectiveness were spinosad @ 17.5 g a.i. ha^{-1} (87.55 %) and flubendiamide @ 18.24 g a.i.ha^{-1} (86.61 %), but they were at par with each other at 1 and 14 days after spray. The next effective treatments were indoxacarb @ 40 g a. i. ha^{-1} (82.95 %) followed by emamectin benzoate @ 10 g a. i. ha^{-1} (79.88 %). Lowest per cent larval reduction was recorded in bifenthrin @ 50 g a.i. ha^{-1} (62.31 %).

Superiority of chlorantraniliprole @ 10 g a.i.ha^{-1} against *P. xylostella* as observed in the present investigation is in conformity with Venkateswarlu *et al.* (2011) who reported 83.65 and 82.08 per cent reduction of *P. xylostella* during 2009-10 and 2010-11, respectively when cabbage crop was applied with chlorantraniliprole @ 10 g a.i.ha^{-1}. Nikam (2013) recorded mean larval population of 0.69 larvae $plant^{-1}$ with 92.12 per cent efficacy against *P. xylostella* when cabbage crop was applied with chlorantraniliprole 18.5 SC. Chlorantraniliprole @ 30 g a.i ha^{-1} recorded least larval population (0.82 larvae $plant^{-1}$) with highest per cent reduction (88.60 %) of *P. xylostella* in cabbage (Sunita, 2014). Natwick and Martin (2016) reported the efficacy of chlorantraniliprole against worm pests (DBM and cabbage looper) by recording 2.06 worm pests/50 plant on cabbage under desert growing conditions. Sudhendu *et al.* (2016) recorded mean larval population of *P. xylostella* during two sprays of chlorantraniliprole 20 SC at three different doses in cabbage. After 1st spray (10 DAS) mean larval population recorded were 0.73, 0.63 and 0.60 larvae $plant^{-1}$ at 25, 37.5 and 50 g a.i.ha^{-1} respectively. After 2nd spray (10 DAS) there was 100 per cent reduction in larvae of *P. xylostella*. Purushotam *et al.* (2017) recorded 65.74, 67.08 and 66.41 per cent reduction in larval population of *P. xylostella* after the application of chlorantraniliprole 18.5 SC at 1st, 2nd and 3rd spray, respectively in cabbage. Narendra (2017) reported effectiveness of different dosages of chlorantraniliprole 20 SC. The maximum reduction in larval population was recorded in chlorantraniliprole @ 50 g a.i. ha^{-1} (88.87 %) followed by chlorantraniliprole @ 25 g a.i.ha^{-1} (84.08 %). Han *et al*. (2012) reported chlorantraniliprole as the most effective insecticide against *P. xylostella* in radish. Selvaraj and Kennedy, (2017) recorded 86.15 and 89.95 per cent reduction in larval population of *P.xylostella* after 1st and 2nd spray, respectively when cauliflower crop was applied with chlorantraniliprole 18.5 SC. Further, effectiveness of chlorantraniliprole was demonstrated in suppressing the larval population of *P. xylostella* in cabbage by several workers (Hiromoto 2007; Vaseem *et al*. 2014 and Chowdary *et al*. 2015).

Ram *et al.* (2015) showed that the lowest fruit per cent infestation on number (6.57 %) and weight basis (6.31%) was observed against *L. orbonalis* in chlorantraniliprole (18.5 EC @ 0.25 ml/lit) treated plots of brinjal. Further, chlorantraniliprole 18.5 SC was found highly effective against fruit borer of tomato recording 6.8 per cent on number and 5.1 per cent on weight basis fruit damage (Pawar *et al.* 2016).

Sridhar *et al.* (2016) recorded 75.89, 78.57 and 79.27 per cent reduction in live mines of *T. absoluta* after 1st, 2nd and 3rd spray, respectively and 69.49 and 70.03 per cent reduction in fruit damage after 1st and 2nd spray, respectively when tomato crop was applied with chlorantraniliprole 18.5 SC @ 0.3ml/L during *kharif* 2016. Patel *et al.* (2016) recorded 1.41 larvae $plant^{-1}$ and 8.46 per cent damage in tomato against *H. armigera* after the application of chlorantraniliprole 18.5 SC @ 30 g a.i.ha^{-1}. Minimum per cent of shoot infestation (2.98 %) and fruit infestation (3.26 %) was recorded in chlorantraniliprole 20 SC treated brinjal against *L. orbanalis* (Tarun and Gopal, 2016).

Chlorantraniliprole 18.5 % SC @ 30 g a.i.ha^{-1} was effective against *L. orbonalis* and recorded 3.76 per cent shoot and 3.32 per cent fruit infestation in brinjal (Koushik *et al.* 2017). Effectiveness of chlorantraniliprole was also reported in brinjal by Mishra (2008). All these reports lend support to the present finding.

Chlorantraniliprole is a diamide insecticide. The mode of action of chlorantraniliprole is the activation of insect ryanodine receptors. This stimulates the release of calcium from the internal stores of smooth and striated muscle which causes impaired muscle regulation, paralysis and insect death.

It is a foliar insecticide that is most effective through ingestion of treated plant material. It is highly potent at low rates on largest species (Bassi *et al*. 2009).

It has an excellent profile of safety to beneficial arthropods (Dinter *et al*. 2008), pollinators and non target organisms such as earthworms and soil microorganisms. This is an important feature of chlorantraniliprole to most synthetic pyrethroids, organophosphates and neonicotinoids that are currently being used.

The effectiveness of spinosad @ 17.5 g a.i. ha^{-1} as observed in present investigation is in conformity with Abhishek (2002) who observed significant effectiveness of spinosad @ 12.5 g a.i.ha^{-1} against *P. xylostella* during 1st and 2nd spray on cabbage during year 2001-2002. The per cent reduction in population recorded were 37.61, 56.79, 53.90, 51.95 and 44.72 during 1st spray and 46.87, 45.0, 42.84, 40.53 and 36.70 per cent during 2nd spray at 1, 3, 7, 10 and 14 days after sprays, respectively. Sable *et al.* (2007) recorded least number of *P. xylostella* larvae i.e. 2.55, 5, 12.05 and 19.96 larvae/10 plants at 3rd, 7th, 10th and 14th days after spraying, respectively after the application of spinosad 45 SC @ 96.4 g a.i. ha^{-1} in cabbage. Puja and Jandial (2010) reported effectiveness of spinosad 45 SC @ 0.33 ml/L against *P.xylostella* with least larval population (0.55 larvae $plant^{-1}$) in cabbage. Jugal (2011) recorded the highest per cent (83.97, 86.23 and 84.98 %) reduction in larval population of *P. xylostella* during 1st, 2nd and 3rd spraying, respectively after the application of spinosad 2.5 SC on cabbage.

Meena and Singh *et al*. (2013) reported spinosad 45 SC as the most effective in reducing larval population (3.15 larvae $plant^{-1}$) of *P. xylostella* in cabbage. Nikam (2013) recorded least larval population (0.27 larvae $plant^{-1}$) and highest per cent efficacy of (96.61 %) against *P. xylostella* when cabbage crop was applied with spinosad 45 SC. Subsequently, Nikam *et al.* (2015) reported relative toxicity of spinosad 2.5 SC against 3rd (84.78 %) and 4th (85.82 %) instar larvae of *P. xylostella.* Sunitha and Mohite (2016) reported larvicidal activity of spinosad on various instars of *P. xylostella.* First, second, third and fourth instar larvae when fed with treated cabbage leaves, the per cent larval mortality ranged from 47.50 to 100.00, 42.50 to 94.84, 30.93 to 84.63 and 27.50 to 72.50, respectively.

Rahimgul and Thakur (2016) recorded highest (51.07 and 47.83 %) per cent reduction in larval population of *P. xylostella* at 1st and 2nd spray, respectively following the application of spinosad 45 SC on cabbage. Spinosad 2.5 SC @ 500 ml ha^{-1} was found to be the most effective against *P. xylostella* recording lower leaf damage (14.22 %) after three applications on cabbage (Arun *et al*. 2017). Purushotam *et al*. (2017) recorded highest i.e. 81.16, 84.33 and 83.41 per cent reduction in larval population of *P. xylostella* at 1st, 2nd and 3rd spray, respectively following the application of spinosad 45 SC on cabbage. Reddy *et al*. (2017) recorded 59 per cent reduction in larval population of *P. xylostella* following the application of spinosad 45 SC @ 100 g a.i.ha^{-1} on cabbage. Spinosad 45 SC @ 50 g a.i. ha^{-1} performed exceedingly well in reducing *P. xylostella* population (89.2 %) in cabbage (Chatterjee and Mondal, 2017).

Venkate and Mahesh (2017) recorded 1.25 and 1.08 larvae plant^{-1} at 10 DAS after the application of spinosad 45 SC @ 73 g a.i. ha^{-1} during two successive seasons (2009-10 and 2010-11, respectively) on cabbage. Chauhan *et al*. (2014) observed 74.56, 80.04 and 85.56 per cent reduction in larval population of *P. xylostella* during 1st, 2nd and 3rd spraying, respectively by spinosad 2.5 SC @ 25 g a.i.ha^{-1} in cauliflower. Spinosad (45 SC @ 0.5 ml L^{-1}) treated cauliflower plot showed highest per cent reduction (89.97 %) with less number of *P. xylostella* larvae (0.58 larvae plant^{-1}) as reported by Dotasara *et al.* (2017). Yadav *et al*. (2017) recorded highest per cent (49.08, 47.95 and 50.44 %) field efficacy of spinosad 48 SC @ 45 g a.i ha^{-1} at 1st, 2nd and 3rd spraying, respectively against *P. xylostella* in cauliflower.

Efficacy of spinosad has also been documented in other crops against lepidopteran pests by earlier workers. Ram *et al.* (2015) showed that the lowest fruit per cent infestation on number (12.08 %) and weight basis (11.15 %) was observed against *L. orbonalis* in spinosad 45 S L @ 0.25 ml L^{-1} treated brinjal plots. Sridhar *et al.* (2016) recorded 76.10, 78.66 and 81.09 per cent reduction in live mines of *T. absoluta* at 1st, 2nd and 3rd spray, respectively and 82.06 and 77.02 per cent reduction in fruit damage after 1st and 2nd spray, respectively when tomato crop was applied with spinosad 45 SC @ 0.2 ml L^{-1} during *kharif* 2016. Tarun and Gopal (2016) recorded 4.59 and 4.10 per cent shoot and fruit infestation, respectively following the application of spinosad 45 SC against *L. orbanalis* in brinjal. Marmat and Anoorag (2017) recorded lowest per cent shoot infestation (6.87 %) at 1st spray and fruit infestation (7.03 and 7.27 %) at 1st and 2nd

spray, respectively following the application of spinosad 45 SC @ 0.05 ml L^{-1} against *L.orbonalis* in brinjal.

During the present investigation, flubendiamide @ 18.24 g a.i. ha^{-1} was also found to be effective with 86.61 per cent reduction in larval population of *P. xylostella* over control. These findings are in agreement with Gill *et al*. (2010) who recorded lowest mean larval population (0.45 larvae $plant^{-1}$) of *P. xylostella* on cabbage after two sprays of flubendiamide 480 SC @ 50.0 ml ha^{-1}. Nikam (2013) recorded larval population of 0.76 larvae $plant^{-1}$ with 91.62 per cent efficacy against *Plutella xylostella* when cabbage crop was treated with flubendiamaide 39.35 SC. Sunita and Mohite (2015) reported larvicidal activity of flubendiamide on various instars of *P. xylostella* in cabbage. Mortality of first, second, third and fourth instar larvae recorded were 59.16 to 100.00, 42.32 to 96.34, 27.50 to 92.50 and 17.50 to 74.40 per cent, respectively. Purushotam *et al*. (2017) recorded 72.33, 71.00 and 69.83 per cent reduction in larval population of *P.xylostella* at 1^{st}, 2^{nd} and 3^{rd} spray, respectively following the application of flubendiamaide 39.35 SC on cabbage. Chatterjee and Mondal (2017) reported that flubendiamide 20 WDG @ 60 g a.i. ha^{-1} performed exceedingly well in reducing DBM population (91.0%). Dotasara *et al.* (2017) recorded highest per cent reduction (87.59 %) with less number of *P. xylostella* larval population (0.70 larvae $plant^{-1}$) in flubendiamide 48 SC treated cauliflower plots. Selvaraj and Kennedy (2017) recorded 72.09 and 78.63 per cent reduction in larval population of *P. xylostella* after 1^{st} and 2^{nd} spray, respectively when cauliflower crop was treated with flubendiamide 20 WG.

Efficacy of flubendiamide was also documented in other crops by earlier workers. Jat and Ameta (2013) reported that three applications of flubendiamide 480 SC @ 200 ml ha^{-1} was the most effective with highest per cent reduction in *H.armigera* larvae (89.94 %) and less per cent fruit damage (3.10 %) in tomato. Maximum reduction in larval population (0.17 to 0.47 larvae $plant^{-1}$) as well as lowest fruit damage (3.13%) was observed in flubendiamide 39.35 SC @ 60 g a.i. ha^{-1} followed by flubendiamide 39.35 SC @ 48 g.a.i./ha with 0.20 to 0.67 larvae $plant^{-1}$ and *4*.17 per cent fruit damage against *S.litura* in chilli (Meena *et al*. 2013). Flubendiamide (0.004 %) proved effective with minimum larval population of *H.armigera* (0.43 larvae $plant^{-1}$) and 10.09 per cent fruit damage on weight basis in tomato (Ambule *et al*. 2015). Sridhar *et al.* (2016) recorded effectiveness of flubendiamide 480 SC @ 0.3 ml lit^{-1} during *kharif* 2016 in tomato. Per cent reduction in live mines of *T. absoluta* was 83.93, 81.88 and 82.94 at 1st, 2nd and 3rd spray, respectively and 79.96 and 75.30 per cent reduction in fruit damage at 1st and 2nd spray, respectively. Similarly, Tarun and Gopal (2016) recorded 3.06 and 3.56 per cent shoot and fruit infestation, respectively following the application of flubendiamide 39.35 SC against *L. orbanalis* in brinjal.

During the present investigation, bifenthrin was found inferior to other insecticides. This finding is in corroboration with Mohamed and Lobna (2012) who recorded higher larval population of *T. absoluta* to the tune of 1.0 to 2.0 larvae plant^{-1} after 2nd spray when tomato crop was applied with bifenthrin 10 EC. Shasikumar and Kumar (2015) recorded higher per cent leaf damage up to 11.11 per cent against leaf webber in bifenthrin 10 EC @ 62.5 g a.i.ha^{-1} treated sesame plots. Dhaka *et al*. (2016) recorded highest shoot damage up to 8.3 per cent and fruit damage up to 10.0 per cent caused by *Earias vitella* following the application of bifenthrin 10 EC @ 1 ml lit^{-1} in okra. Deepak *et al*. (2017) recorded higher fruit damage caused by *E. vittela* on number basis (29.29 %) and weight basis (24.47 %) after 2nd spray when okra crop was applied with bifenthrin 10 EC @ 80 g a. i. ha^{-1}. Also, Prashanthi *et al*. (2017) reported higher *H. armigera* population (2.96 larvae plant^{-1}) in bifenthrin 10 EC @ 1 ml lit^{-1} treated chick pea. All these reports lend support to present findings.

However, bifenthrin proved effective against other lepidopteran pests as reported by earlier workers. Bifenthrin 10 EC @ 100 g a.i. ha^{-1}, applied twice as foliar sprays was found the most effective in controlling the *P. xylostella* (Reddy *et al*. 2014c). Reddy *et al*. (2017) recorded highest i.e. 67.49 and 68.18 per cent larval reduction of *P. xylostella* after 1st and 2nd spray, respectively following the application of bifenthrin 10 EC @ 100 g a.i. ha^{-1} in cabbage. Ameta *et al*. (2008) reported that bifenthrin 10 EC @ 80 g a.i.ha^{-1} was effective against brinjal pest complex (Shoot and fruit borers, Leafhopper and Whitefly). Similarly, bifenthrin 10 EC @ 100 ml ha^{-1} was found superior in controlling bollworm complex in cotton (Balakrishanan *et al*. 2009).

Ravi *et al*. (2014) recorded effectiveness of bifenthrin 10 EC @ 100 g a.i.ha^{-1} in tomato. Highest per cent reduction in larval population of *H. armigera* (47.29 and 59.99 %) at 1st and 2nd spray, respectively and 32.60 per cent fruit damage was observed. Bifenthrin 8 EC @ 200 g a.i. ha^{-1} recorded lowest mean per cent damage of 1.1

and 1.2 per cent on shoot basis, 9.44 and 7.0 per cent on number basis and 7.0 and 4.9 per cent on weight basis in *Kharif* and *Rabi* sown okra, respectively (Ram and Kumar, 2015).

Marketable yield of cabbage heads

Considerable yield advantages due to effective control of *P. xylostella* in cabbage, particularly with chlorantraniliprole 18.5 SC @ 10 g a.i.ha^{-1} as observed in present investigation. There was almost 129.23 per cent increase in yield over control. Superiority of chlorantraniliprole revealed in the present investigation is in agreement with earlier reports. Nikam (2013) recorded highest marketable yield of 230.63 q ha^{-1} cabbage heads with chlorantraniliprole 18.5 SC. Sunitha (2014) registered 230.38 q ha^{-1} marketable yield in cabbage by chlorantraniliprole 1.67 SC @ 30 g a.i.ha^{-1} treated plots. Purushotam (2016) recorded 175.30 q ha^{-1} yield following the application of chlorantraniliprole 18.5 SC against *P. xylostella* in cabbage. Sudhendu *et al.* (2016) recorded highest yield of 156.80, 164.80 and 177.60 q ha^{-1} by the application of chlorantraniliprole 20 SC at different dosages (25, 37.5 and 50 g a.i.ha^{-1}, respectively) in cabbage. Narendra (2017) recorded highest yield of cabbage in chlorantraniliprole @ 50 g a.i. ha^{-1} (27.9 tonne ha^{-1}) followed by lower doses of chlorantraniliprole. In cauliflower, highest yield of cabbage heads (27.0 tonne ha^{-1} with 87.89% increase) was registered following the application of chlorantraniliprole 18.5 SC @ 30 g a.i.ha^{-1} against *P. xylostella* (Selvaraj and Kennedy, 2017).

Higher realization of yield due to application of chlorantraniliprole was also reported in other vegetable crops by earlier workers. Mishra (2008) reported highest yield (20.73 tonne ha^{-1}) in brinjal treated with chlorantraniliprole @ 40 and 50 g a.i.ha^{-1}. Higher yield recorded from treatments of chlorantraniliprole 0.0055 per cent to the tune of 24.84 tonne ha^{-1} against *H. armigera* in tomato (Ambule *et al.* 2015). Chlorantraniliprole 18.5 SC @ 0.25 ml lit^{-1} treated plot recorded maximum yield of brinjal (32.03 mt ha^{-1} with 34.39 % increase over control) against *L. orbonalis* (Ram *et al.* 2015). Chlorantraniliprole 18.5 SC was found to be highly effective against fruit borer and registered 46.03 tonne ha^{-1} yields of tomato (Pawar *et al.* 2016). Patel *et al.* (2016) registered highest tomato yield (267.36 q ha^{-1}) in chlorantraniliprole 18.5 SC treated plots. Sridhar *et al.* (2016) recorded higher tomato yield to the tune of 47.70 and 46.80 tonne ha^{-1} during *kharif* and *rabi* 2016, respectively following the application of chlorantraniliprole 18.5 SC @ 0.3 ml lit^{-1} against *T. absoluta*. Chlorantraniliprole 18.5 SC

@ 30 g a.i.ha^{-1} registered highest yield of 137.36 q ha^{-1} against *L. orbonalis* in brinjal (Koushik *et al.* 2017). Narendra *et al*. (2017) registered higher yield of 250.71 q ha^{-1} with the treatments of chlorantraniliprole 18.5 SC @ 0.02 % against fruit borer in tomato. Maximum yield of 13.83 tonne ha^{-1} was obtained with the treatment chlorantraniliprole 18.5 SC @ 30 g a.i.ha^{-1} against *L.orbonalis* in brinjal (Sarnabati and Ray, 2017).

In present investigation, effectiveness of spinosad @ 17.5 g a.i. ha^{-1} against *P. xylostella* reflected in higher yield (233.83 q ha^{-1}) next to cholrantarniliprole. These findings are in conformity with Abhishek (2002) who recorded highest cabbage yield to the tune of 177.70 q ha^{-1} against *P. xylostella* following the application of spinosad 45 SC @ 12.5 g a.i ha^{-1}. Sable *et al.* (2007) registered highest yield of 214.42 q ha^{-1} by the application of spinosad 45 SC @ 96.4 g a.i ha^{-1} against *P. xylostella* in cabbage. Prashant *et al.* (2007) recorded higher yield of cabbage (205.56 q ha^{-1}) following the application of spinosad. The higher (173.17 q ha^{-1}) yield of cabbage heads was obtained from the plots treated with spinosad 45 SC (Jugal, 2011). Further, Meena and Singh (2013) registered highest yield (233.5 q ha^{-1}) of cabbage heads from the plots treated with spinosad 45 SC. Nikam (2013) reported highest yield of 250.88 q ha^{-1} when cabbage crop was applied with spinosad 45 SC against *P. xylostella.* Sunitha (2014) registered higher (195.56 q ha^{-1}) yield against *P. xylostella* when cabbage crop was applied with spinosad 45 SC @ 75 g a.i.ha^{-1}. Singh *et al*. (2015) recorded highest yield of 24.77 tonne ha^{-1} following the application of spinosad 2.5 SC @ 100 ml ha^{-1} against *P.xylostella* in cabbage.

Similarly, Purushotam (2016) recorded 195.67 q ha^{-1} yield of cabbage heads following the application of spinosad 45 SC against *P. xylostella*. Rahimgul and Thakur (2016) recorded highest (187.60 q ha^{-1}) yield in cabbage by the application of spinosad 45 SC @ 0.006 ml lit^{-1}. Spinosad 2.5 SC @ 500 ml ha^{-1} was found to be the most effective against *P. xylostella* and recorded highest (24.77 tonne ha^{-1}) yield of cabbage (Arun *et al*. 2017). Chatterjee and Mondal (2017) registered 23.50 tonne ha^{-1} yield from spinosad treated cabbage plots. Also, Venkate and Mahesh (2017) recorded 37.64 and 38.13 tonne ha^{-1} cabbage yield during two successive seasons of 2009-10 and 2010-11, respectively following the application of spinosad 45 SC @ 73 g a.i.ha^{-1} against *P. xylostella*. In cauliflower, highest (270.83 q ha^{-1}) yield was registered following the application of spinosad 2.5 SC @ 25 g a.i.ha^{-1} against *P. xylostella* (Chauhan *et al*. 2014).

Effectiveness of spinosad against other lepidopteran pests realizing higher yield were endorsed by Ravi *et al*. 2014 and Sridhar *et al.* 2016 (tomato); Ram *et al.* 2015 and Marmat and Anoorag, 2017 (brinjal).

Superiority of flubendiamide 39.35 SC @ 18.24 g a.i.ha^{-1} in realizing higher yield of cabbage (224.98 q ha^{-1}) as observed in present investigation is in conformity with Gill *et al*. (2010) who recorded higher yield of cabbage heads (218.05 q ha^{-1}) following the application of flubendiamide 480 SC @ 50 ml ha^{-1} against *P. xylostella* in cabbage. Effectiveness of flubendiamide against *P. xylostella* and higher realization of cabbage and cauliflower yield was also reported by earlier workers (Nikam, 2013; Sunitha, 2014; Purushotam 2016; Chatterjee and Mondal, 2017 and Selvaraj and Kennedy, 2017).

Bifenthrin proved inferior against *P. xylostella* in present investigation and also in realizing the yield of cabbage. Inferiority of bifenthrin as observed in present investigation is in conformity with Dhaka *et al*. (2016) who registered 80. 96 q ha^{-1} yield of okra fruits with bifenthrin 10 EC @ 1 lit ha^{-1} treated plots against *E. vitella*.

However, bifenthrin proved effective against other lepidopteran pests and derived maximum yield in other vegetable crops as reported by earlier workers. Ameta *et al*. (2008) reported highest yield of 237.6 and 255.9 q ha^{-1} following the application of bifenthrin 10 EC @ 160 g a.i.ha^{-1} during 2004 and 2005, respectively in brinjal. Ravi *et al*. (2014) registered highest yield of 12.67 tonne ha^{-1} against *H. armigera* from bifenthrin 10 EC @ 100 g a.i.ha^{-1} treated plots of tomato. The highest yield of 6.9 and 10.0 tonne ha^{-1} was recorded from bifenthrin 8 SC @ 200 g a.i.ha^{-1} followed by bifenthrin 8 SC @ 160 g a.i.ha^{-1} (6.7 and 9.9 tonne ha^{-1}) during *kharif* and *rabi,* respectively in okra (Ram and Kumar, 2015).

Incremental cost benefit ratio (ICBR)

Cost benefit analysis revealed that highest net profit (Rs.53464.8) was reaped from chlorantraniliprole 18.5 SC @ 10 g a.i.ha^{-1} with incremental cost benefit ratio of 1:16.40. The present finding corroboration with Ratnsari (2012) who obtained higher net profit with higher ICBR (1:11.49) through the use of chlorantraniliprole 18.5 SC against cabbage pests. Purushotam (2016) recorded ICBR of 1:5.60 after application of chlorantraniliprole 18.5 SC against DBM in cabbage. Narendra (2017) reported cost benefit ratio of chlorantraniliprole 20 SC at different dosages (50, 25, 15 and 10 g a.i.ha^{-1}) against *P. xylostella* in cabbage. The highest ICBR was recorded in chlorantraniliprole @ 50 g a.i. ha^{-1} (1:2.89) followed by chlorantraniliprole @ 25 g a.i.ha^{-1} (1:2.53).

Cost effectiveness of chlorantraniliprole 18.5 SC was also endorsed in other vegetable crops (Narendra *et al*. 2017; Pawar *et al.* 2016; Tarun and Gopal, 2016 and Sarnabati and Ray, 2017).

In present investigation, effectiveness of flubendiamide 39.35 @ 18.24 g a.i. ha^{-1} was reflected in higher incremental cost benefit ratio to the tune of 1:14.98 next to the chlorantarniliprole. Purushotam (2016) recorded higher ICBR of 1:7.72 by the application of flubendiamide 39.35 SC against *P. xylostella* in cabbage. Tatagar *et al.* (2009) recorded highest ICBR of 1:5.12 from flubendiamide 20 WG @ 50 g a.i.ha^{-1} treated plots against fruit borer in chilli. Shah *et al*. (2012) recorded higher incremental C:B ratio (1:6.10) following the application of flubendiamide 480 SC against *L. orbonalis* in brinjal. Jat and Ameta (2013) recorded highest yield with highest C:B ratio of 1:2.075 from flubendiamide 480 SC @ 200 ml ha^{-1} in tomato. Meena *et al*. (2013) recorded that flubenediamide 480 SC @ 48 g a.i.ha^{-1} reaped maximum benefit with highest ICBR of 1:6.48 in chilli. All these reports support the present finding.

In present investigation, effectiveness of spinosad @ 17.5 g a.i. ha^{-1} was reflected in higher incremental cost benefit ratio (1:12.22) next to the flubendiamide. Cost effectiveness of spinosad was also endorsed by earlier workers. Abhishek (2002) recorded highest yield of cabbage heads and highest net profit with ICBR of 1:6.55 following the application of spinosad 45 SC @ 12.5 g a.i ha^{-1} against *P. xylostella* in cabbage. Prashant *et al.* (2007) recorded higher ICBR of 1:7.55 following the application of spinosad in cabbage. Meena and Sugan (2013) recorded highest incremental C:B ratio of 1:90.5 with the treatment of spinosad 45 SC in cabbage. Singh *et al*. (2015) recorded highest yield with highest incremental cost benefit ratio to the tune of 1:37.34 following the application of spinosad 2.5 SC @ 100 ml ha^{-1} against *P.xylostella* in cabbage. Purushotam (2016) recorded higher ICBR of 1:11.11 with the application of spinosad 45 SC against *P. xylostella* in cabbage. Also, Rahimgul and Thakur (2016) registered highest yield of cabbage heads with highest ICBR of 1:5.90 against *P. xylostella* in cabbage.

In present investigation, bifenthrin 10 EC @ 50 g a.i.ha^{-1} gave lowest ICBR (1:1.78) as compared to other insecticides which is in accordance with Dhaka *et al*. (2016) who reported that application of bifenthrin 10 EC registered lowest ICBR (1:1.72) in okra against *E.vitella.*

5.3 Dissipation pattern of triazophos, quinalphos and bifenthrin in cabbage

Cabbage crop was sprayed with triazophos, quinalphos and bifenthrin to study the dissipation pattern during year 2015-2016. Two sprays of each insecticide were given at an interval of ten days; first spray being at 50 per cent head formation stage. The treated heads were collected at 0 (2 hrs.), 1, 3, 5, 7, 10 and 15 days after second application and subjected to QuEChERS method of analysis to determine residues. Maximum and minimum temperature prevailing during experimentation period ranged between 19 to 29º C.

Triazophos

At recommended dose the initial residues of triazophos were found to be 0.54 mg kg^{-1} which subsequently dissipated to 0.27, 0.18, 0.10 and 0.08 mg kg^{-1} at 1, 3, 5 and 7 days with 50.00, 66.67, 81.48 and 85.18 per cent reduction, respectively (Fig.21). Whereas, at double the recommended dose (1000 g a.i. ha^{-1}), mean initial residues of 1.09 mg kg^{-1} dissipated to 0.44, 0.30, 0.20, 0.15 and 0.07 mg kg^{-1} at 1, 3, 5, 7 and 10 days with 59.63, 72.47, 81.65, 86.23 and 93.57 per cent reduction respectively.

The data reveals that residues of triazophos persisted up to 7 and 10 days at recommended (500 g a.i. ha^{-1}) and double the recommended dose (1000 g a.i. ha^{-1}), respectively. In the present study, half-life values calculated for triazophos were 2.66 and 2.87 days, respectively.

The above findings are in agreement with Gupta *et al.* (2015) who studied persistence of triazophos in cabbage head following spray application of Anaconda Plus (Triazophos 35% + Deltamethrin 1%). Studies indicated persistence of triazophos for 8 and 12 days at single and double dose, respectively. However half-life values calculated were lower i.e. 0.79 and 1.29 for single and double dose, respectively. In another studies on residues of triazophos and deltamethrin (Anaconda Plus) conducted by Gupta *et al.* (2013) in cauliflower, the half-life values calculated were 2.6 and 2.22 days for single and double dose, respectively. Further they suggested safe waiting period of 5 days for Anaconda Plus in cauiliflower at recommended dose.

Similarly, according to Paras Nath *et al.* (2005) mean initial residues of triazophos was 1.52 µg g^{-1} in okra which dissipated within 7 days (86.20 %) with a half-life of 2.55 days. Pradhan *et al.* (2011) reported initial residues of triazophos in brinjal as 0.49 mg kg^{-1} which dissipated within 10 days. Parmar *et al.* (2012) reported the mean initial residues of triazophos as 0.54 mg kg^{-1} in okra which persisted up to 7 days with a half-life value of 1.6 days. Similarly, Mukherjee *et al.* (2015) recorded initial residues of 0.52 mg kg^{-1} in brinjal after application of triazophos 35 EC (Anaconda Plus, combination product) @ 1 lit ha^{-1}. The residues persisted up to 10 days in brinjal after application. The half-life value calculated was 3.32 days. Further, they reported mean initial residue of triazophos as 1.12 mg kg^{-1} in tomato which dissipated within 10 days with a half-life value of 1.78 days. Raut *et al.* (2016) recorded mean initial residues of 1.12 mg kg^{-1} in chilli fruits after application of triazophos @ 500 g a.i. ha^{-1} which dissipated within 10 days with a half-life of 1.72 days. Brar *et al.* (2017) reported initial deposits of triazophos as 1.10 and 2.23 mg kg^{-1} at 500 and 1000 g a.i. ha^{-1} in brinjal. The residues persisted for 5 to 10 days with a half-life of 1.6 and 1.9 days. All these reports lend support to the present finding.

However, very low levels of residues of triazophos were recorded in brinjal by Raj *et al.* (1999). They reported mean initial residues of 0.17 mg kg^{-1} after application of triazophos @ 350 g. a.i. ha^{-1}. The residues persisted up to 10 days with a half-life of a day. According to Kumar *et al.* (2000) mean initial residues of triazophos was 0.43 mg kg^{-1} in chilli when triazophos applied @ 700 g a.i. ha^{-1}. The residues persisted up to 15 day with a half-life of 10.03 days. Mean initial residues of triazophos were 0.86 mg kg^{-1} in capsicum after application of triazophos @ 500 g a.i. ha^{-1} as reported by Shukla *et al.* (2016).

Banerji *et al.* (2008) reported 0.31 mg kg^{-1} as mean initial residues of triazophos in bitter gourd which dissipated within 7 days as observed in the present investigation. Cherukuri *et al.* (2015) studied the dissipation pattern of triazophos in tomato and registered mean initial residues of 1.108 mg kg^{-1}. The residues persisted up to 7 days with a half-life of 1.14 days.

Quinalphos

In the present investigation, the average initial residues of quinalphos were 0.48 mg kg^{-1} and dissipated to 0.21, 0.13, and 0.08 mg kg^{-1} at 1, 3 and 5 days, respectively. The corresponding per cent reduction in quinalphos residues were 56.25, 72.92 and 83.34 per cent at 1, 3 and 5 days, respectively (Fig. 22). While, at double the recommended dose average initial residues were 1.06 mg kg^{-1} which further dissipated to 0.55, 0.33, 0.16, and 0.08 mg kg^{-1} at 1, 3, 5 and 7 days with 48.11, 68.86, 84.90 and 92.45 per cent reduction at corresponding intervals.

Residues of quinalphos dissipated with a half-life of 2.10 and 1.97 days following application @ 250 and 500 g a.i. ha^{-1}, respectively.

The present findings are in agreement with Chahil *et al*. (2011) who reported initial residues of quinalphos as 0.41 and 0.75 mg kg^{-1} in cabbage following the application of 500 and 1000 g a.i. ha^{-1}, respectively. The residues of quinalphos dissipated below its determination limit of 0.01 mg kg^{-1} in 7 and 10 days and half-life was observed to be 3.02 and 2.70 days, at recommended and double the recommended dose, respectively. However, Aktar *et al*. (2010) reported initial residues of quinalphos as 4.42 and 9.75 mg kg^{-1} in cabbage at 500 and 1000 g a.i. ha^{-1}, respectively. The residues persisted up to 10 days with a half-life of 1.27 and 1.38 days, respectively.

Mohapatra and Deepa (2013) reported initial residues of quinalphos as 1.19 and 1.84 mg kg^{-1} which dissipated with a half-life of 4.8 and 5.3 days in cauliflower at 500 and 1000 g a. i. ha^{-1}, respectively. The residues persisted up to 15 days. Rajukkanu *et al.* (1979) studied the residues of quinalphos in tomato and suggested a waiting period of 2.01 days for safe consumption of tomato. Barooah and Yein (1996) reported mean initial residues of quinalphos in brinjal fruits ranging from 1.26 to 1.79 mg kg^{-1} with half-life values of 2.1 to 2.2 days at 500 and 1000 g a. i. ha^{-1}, respectively. Residues reached below detectable limits in 15 days after last spray. Safe waiting period of 4.9 and 6.1 days were suggested.

Bifenthrin

In the present investigation, the average initial residues of bifenthrin were 0.51 mg kg^{-1} and dissipated to 0.21, 0.10, 0.08 and 0.05 mg kg^{-1} at 1, 3, 5 and 7 days, respectively. The corresponding per cent reduction in bifenthrin residues were 58.82, 80.39, 84.31 and 90.19 per cent at 1, 3, 5 and 7 days, respectively (Fig. 23). While, at double the recommended dose average, initial residues were 1.08 mg kg^{-1} which further dissipated to 0.48, 0.23, 0.13, 0.09 and 0.06 mg kg^{-1} at 1, 3, 5, 7 and 10 days with 55.55, 78.70, 87.96, 91.44 and 94.44 per cent reduction at corresponding intervals.

Residues of bifenthrin persisted up to 7 and 10 days with a half-life of 2.30 and 2.52 days following application @ 50 and 100 g a.i. ha^{-1}, respectively.

The above findings are in corroboration with Reddy *et al*. (2012a) who reported initial deposit of bifenthrin as 1.03 mg kg^{-1} in cabbage. Residues persisted up to 7 days with a half-life value of 3.38 days. Reddy *et al*. (2014a) studied initial deposits of bifenthrin as 2.24 mg kg^{-1} which dissipated to 0.23 mg kg^{-1} at 7 days. Residues reached BDL on 10^{th} day with half-life value of 2.22 days. Further, Reddy *et al*. (2014b) studied initial deposit of bifenthrin as 1.21 mg kg^{-1} which dissipated to below detectable limit at 7 days in cabbage. The waiting period of a day was suggested. Sachin Kumari (2013) reported that initial deposits of bifenthrin residues as 0.36 and 0.58 mg kg^{-1} at 25 and 50 g a.i. ha^{-1}, respectively. Residue reached below detectable limit of 0.005 mg kg^{-1} on 15^{th} and 30^{th} day and half-life period were found to be 1.58 and 2.18 days at 25 and 50 g a.i. ha^{-1}, respectively. In chilli, initial deposit of bifenthrin residues was 1.33 mg kg^{-1} at 50 g a.i. ha^{-1} which persisted up to 7^{th} day by recording half-life value of 2.21 (Anon, 2015).

Babu *et al.* (2001) reported safe waiting period of 3 days for cabbage heads after application of cypermethrin in cabbage. Beta-cyfluthrin on cabbage dissipated to below detectable limits at 20 days after second spray when beta-cyfluthrin sprayed at 25.0 g a.i per ha (Singh *et al.,* 2003).

5.4 Impact of household processes on residues of insecticides in cabbage

Cabbage is the most popular vegetables in India. Insect pests and diseases are the major constraints in the production of cabbage. In order to protect the crop from the damage of insect pests and diseases farmers rely heavily on pesticides. Today, vegetables and fruits covering only 3 per cent cropped area, consume more than 14 per cent of the total pesticides used in the country. Indiscriminate use of pesticides has led to accumulation of pesticide residues in vegetables. The removal of these residues from the food commodities by utilizing different household processing methods is very important. In the present investigation, different household processes such as cooking, boiling, dipping in 2 per cent salt solution, dipping in 2 per cent tamarind solution and tap water washing were employed for the decontamination of triazophos, quinalphos and bifenthrin residues in cabbage.

In the present investigation, highest per cent reduction in residues of triazophos, quinalphos and bifenthrin was registered in the process of cooking (Fig. 24, 25 and 26). There was 85.18, 85.42 and 86.27 per cent reduction in residues of triazophos, quinalphos and bifenthrin, respectively in chopped cabbage sample. Boiling of chopped cabbage sample for 15 min. was the next best treatment to reduce the residues of triazophos, quinalphos and bifenthrin to the extent of 74.07, 81.25 and 80.39 per cent, respectively. Dipping of cabbage heads in 2 per cent salt solution for 15 min could remove residues of triazophos, quinalphos and bifenthrin to the extent of 51.85, 56.25 and 64.70 per cent, respectively. By dipping of cabbage heads in 2 per cent tamarind solution, there was reduction in the residues of triazophos, quinalphos and bifenthrin to 42.59, 41.67 and 56.86 per cent, respectively. Washing of cabbage heads with tap water also helped in reducing the residues of insecticides (up to 25.00 %).

In the present investigation, cooking process was the most effective in removing residues of triazophos, quinalphos and bifenthrin in cabbage. The present findings are in agreement with Aktar *et al.* (2010) who reported that cooking reduced 41.30 and 45.20 per cent and washing + cooking reduced 66.45 and 68.19 per cent reduction in quinalphos residues when applied at 500 and 1000 g.a.i.ha^{-1} in cabbage, respectively. Reduction of alphamethrin in the range of 25-32 per cent in brinjal and tomato and 12-17 per cent in cauliflower was reported by Gill *et al.* (2001) and Malik *et al.* (1999).

Reduction of fenvalerate residues by cooking process to an extent of 27-56 per cent in brinjal was reported by Sharma and Kumar (1993). Reddy *et al*. (2001) observed that washing with water followed by steam cooking removed triazophos to an extent of 64 to 68 per cent in brinjal. Kadian *et al*. (2001) reported that cypermethrin residues declined about 15 to 33 per cent in tomato, okra, bottle gourd and ridge gourd after cooking process. Similarly, Aktar *et al.* (2008) reported that quinalphos residues degraded to an extent of 71.55 per cent after okra fruits subjected to washing + cooking. According to Parmar *et al.* (2012) cooking was the best culinary process in which triazophos residues were dislodged from okra fruits up to 66.34 per cent. Thanki *et al*.

(2012) reported 22.84, 40.00 and 25 per cent reduction in quinalphos, cypermethrin and permethrin residues, respectively by the process of cooking. Effectiveness of cooking was also emphasized by Cherukuri *et al.* (2014) in brinjal where direct pressure cooking removed 39.40 and 48.70 per cent residues of quinalphos and lambda cyhalothrin, respectively. Harinathareddy *et al.* (2014) reported cooking as an effective decontamination process in tomato with 54.3 per cent reduction in residues of triazophos, 47.4 per cent of quinalphos and lambda cyhalothrin. Geetha (2015) reported reduction of triazophos and deltamethrin + triazophos residues in spinach by employing different household processes. Hot water cooking for 10 min. (54.52 and 90.71% +55.42 %) was found to be more effective than tap water treatment (19.88 and 54.59%+24.54%). Effectiveness of cooking was also endorsed by Shashi *et al.* (2015a) in brinjal where direct cooking removed 58.20 and 59.00 per cent residues of quinalphos and profenophos, respectively. Further, Shashi *et al.* (2016) reported 39.40, 52.90 and 48.70 per cent reduction in residues of quinalphos, profenophos and lambda cyhalothrin, respectively when tomato fruits were subjected to cooking.

Boiling was next best treatment in the removal of triazophos, quinalphos and bifenthrin residues from cabbage. These findings are in agreement with those of Beena Kumari (2008) who reported boiling to be comparatively more effective than washing in dislodging the residues of OPs insecticides. Boiling process reduces 100 per cent of OP insecticides in brinjal followed by 92 per cent in cauliflower and 75 per cent in okra. According to Chauhan *et al.* (2012) washing + boiling was most effective in tomato which reduced 42.10 and 45.23 per cent in bifenthrin after application at 25 and 50 g a.i.ha^{-1}, respectively. Satpathy *et al.* (2012) reported 97.60, 93.90 and 88.40 per cent reduction in chlorpyriphos, malathion and methyl parathion, respectively when cauiliflower, tomato, brinjal, okra and capsicum were subjected to boiling process. Sachin Kumari (2013) reported maximum reduction of bifenthrin after application of 25 and 50 g.a.i.ha^{-1} (64.58 to 68.42 %, respectively) by washing + boiling in okra. Almost 99 per cent monocrotophos, chlorpyriphos and cypermethrin residues were dislodged from treated brinjal and okra fruits by boiling in water (Subhash *et al.* 2015).

In the present study, 2 % salt solution was found to be the next effective treatment after boiling. Dipping of cabbage sample in 2 % salt solution reduced 66.45 and 68.19 per cent residues of quinalphos when applied at 500 and 1000 g.a.i.ha^{-1}, respectively in cabbage (Aktar *et al.* 2010). Satpathy *et al*. (2012) reported that washing of cauliflower with 0.9 % NaCl reduced the residues of organophosphorus insecticide by 51-95.3 per cent. Dipping the green chillies in 2 per cent salt solution for 10 min. followed by washing, removed the residues of triazophos to an extent of 32.56 and 84.21 per cent at 0 and 5 days, respectively as reported by Kumar *et al.* (2000). Klinhom *et al.* (2008) reported that 0.9 % NaCl was effective in residue reduction of methomyl and carbaryl residues by 39.33 and 91.18 per cent, respectively in chinese-Kale. Parmar *et al.* (2012) observed 2 % salt solution as the best culinary process in which greater level of triazophos residues were dislodged from okra fruits up to 54.69 per cent. Reddy *et al.* (2012b) reported that washing of brinjal fruits with 2 % salt water for 2 minutes removed residues of lambda-cyhalothrin to an extent of 69.11 to 70.65 per cent at 15 and 30 g a.i. ha^{-1}, respectively. While, dipping in 2 % salt solution led to highest (52.10 %) reduction in quinalphos residues in brinjal as reported by Cherukuri *et al.* (2014). Harinathareddy *et al.* (2014) reported that 2 % salt solution reduced the residues of quinalphos, lambda cyhalothrin and triazophos in the range of 44.3-69.8 per cent in tomato fruits. Shashi *et al*. (2014) reported that processing with 2 % salt water in tomato; residues of quinalphos dissipated to the level of 91.30 per cent. Subhash *et al*. (2015) reported that washing in 2 % salt solution was more effective in reducing 59.80-82.20 per cent of the pesticide (Chloropyriphos, cypermethrin and monocrotophos) residues from the brinjal fruits and 62-84.30 per cent from okra fruits. Geetha (2015) reported 46.87 and 43.78 per cent reduction in residues of cypermethrin and triazphos, respectively in spinach by employing 2 % salt solution.

Further, in the present study, 2 % tamarind solution was removed the insecticide residues. Cherukuri *et al.* (2014) reported that treatment of brinjal fruits with 2 % tamarind solution removed the residues of dimethoate, chlorpyriphos, quinolphos, profenophos, phosalone, lambda-cyhalothrin and malathion from 24-65 per cent. Similarly, Pallavi *et al*. (2014) reported that dipping okra fruits in 2 % tamarind solution for 15 min was more effective in removing the 54.46 to 68.92 per cent residues of malathion, chlorpyriphos quinalphos, profenophos and cypermethrin. Tamarind solution (2%) reduced the residues of quinalphos, lambda cyhalothrin and triazophos in tomato in the range of 46.1 to 80.4 per cent (Harinathareddy *et al.* 2015).

However, tap water washing was the least effective treatment among all the culinary processes as observed in the present investigation. Washing of cabbage sample with tap water reduced 27.72 and 32.48 per cent reduction in quinalphos residues when applied with single (500 g.a.i.ha^{-1}) and double (1000 g a.i.ha^{-1}) dose, respectively (Aktar *et al.* 2010). According to Dhiman (2003) washing of cauliflower treated with ch1orpyriphos, quinalphos, endosulfan, fenvalerate and deltamethrin reduced 28.92 to 78.64 per cent residues. Washing reduced the residues of OP insecticides by 20-77 per cent in brinjal, cauliflower and okra. Maximum (77 %) reduction of OP insecticides was observed in brinjal, followed by 74 per cent in cauliflower and 50 per cent in okra by washing (Beena Kumari, 2008). Singh *et al.* (2004) reported that washing of okra fruits with tap water removed cypermethrin residues to an extent of 41.2-48.3% in 0 day samples and 37.1-46.0 % in 5th day samples. Sood, (2006) reported percentage reduction of cypermethrin residues in okra at 0, 1, 3 and 7 days of spray were 39.88, 36.26, 35.79 and 47.69 per cent by employing water washing. Kwon *et al*. (2009) reported reduction rate of bifenthrin residues by washing was 58-64 per cent for spinach, chard and mellow. Parmar *et al.* (2012) reported that washing of okra fruits with normal tap water reduced the residues of deltamethrin, alphamethrin, triazophos, cypermethrin by 42.06, 26.32, 41.75, 26.32 and 93.72 per cent reduction, respectively. Sachin Kumari *et al.* (2013) reported that upon washing, residues were reduced in the range of 36.71 to 40.00 per cent in okra when bifenthrin was applied @ 25 and 50 g a.i. ha^{-1}, respectively. Similarly, Harinathareddy *et al.* (2014) reported reduction of quinalphos, lambda cyhalothrin and triazophos residues to the extent of 37, 49.6 and 62.3 per cent, respectively in tomato fruits after tap water washing. While, tap water washing led to (45.60 and 40.90 %) reduction in quinalphos and lambda cyhalothrin residues, respectively in brinjal as reported by Cherukuri *et al.* (2014).

6. SUMMARY AND CONCLUSIONS

Investigations on "Bio-efficacy of newer insecticides against diamondback moth (*Plutella xylostella* L.) and their residues in cabbage" were undertaken during the year 2015-16 and 2016-2017 at MPKV, Rahuri, Maharashtra. The survey on usage pattern of insecticides in cabbage was undertaken in Ahmednagar, Pune and Nasik districts of western Maharashtra. The field experiments on bio-efficacy were conducted on farmer's field at Nandur Madhyameshwar, Tq. Niphad, Dist. Nashik and at Khandgaon, Tq. Sangamner, Dist. Ahmednagar. Field experiment on dissipation was conducted at Research Farm, Post Graduate Institute, Department of Agril. Entomology, M.P.K.V., Rahuri. The laboratory studies on dissipation and decontamination of pesticide residues were carried out at the A.I.N.P. on Pesticide Residue Laboratory, Department of Agricultural Entomology, M.P.K.V, Rahuri. The experimental results obtained are summarized below.

6.1 Usage pattern of insecticides in cabbage

Insecticide usage pattern of selected farmers from Ahmednagar, Pune and Nashik district of western Maharashtra indicated that farmers relied mostly on chemical pesticides to control the insect pests of cabbage. Irrespective of location farmers from these locations used conventional insecticides.

Survey results revealed that total consumption of insecticides for the control of major insects of cabbage was to the extent of 1.52, 1.79 and 1.65 kg a.i. ha^{-1} $season^{-1}$ for Ahmednagar, Pune and Nashik, respectively.

Among three cabbage growing areas, the use of conventional insecticides was maximum by the farmers from Pune districts (1.43 kg a.i. ha^{-1} $season^{-1}$) followed by Ahmednagar (1.22 kg a.i. ha^{-1} $season^{-1}$) and Nashik districts (1.07 kg a.i. ha^{-1} $season^{-1}$). As regards, use of novel insecticides, farmers from Nashik district used 0.38 kg a.i.ha^{-1} $season^{-1}$ followed by Pune (0.24 kg a.i. ha^{-1} $season^{-1}$) and Ahmednagar district (0.20 kg a.i. ha^{-1} $season^{-1}$). Very few farmers from above locations used biopesticides i.e. Mycoinsecticides and neem based formulations. The most commonly used conventional insecticides were triazophos, quinalphos, dimethoate, dichlorvos, cypermethrin, profenophos and chlorpyriphos.

About 50 per cent farmers were aware of natural enemies. Nearly 60 per cent farmers know about the recommended insecticides and their doses on cabbage. Majority of the farmers indicated that they were aware of the residual effects of insecticides, but they did not follow any precautions to avoid harmful effects. It was also revealed that majority of the farmers did not know about safe waiting period for harvesting of cabbage after application of insecticides. Majority of the farmers sprayed at an interval of 7-10 days giving 5-7 rounds of spraying during cropping season of cabbage.

6.2 Bio-efficacy of newer insecticides against *P. xylostella* in cabbage

All the insecticides tested against *P. xylostella* on cabbage were found effective over untreated control in reducing the larval population. On the basis of per cent larval reduction of *P. xylostella*, chlorantraniliprole @ 10 g a.i. ha^{-1} was found to be the most effective with 91.30 per cent larval population followed by spinosad @ 17.5 g a.i. ha^{-1} (87.55 %) and flubendiamide @ 18.24 g a.i. ha^{-1} (86.61 %). Indoxacarb and emamectin benzoate were found moderately effective as they reported 82.95 and 79.88 per cent larval reduction, respectively. Bifenthrin was proved least effective. The maximum marketable yield of cabbage heads (238.15 q ha^{-1} with 129.23 % increase over control) was obtained from the plots treated with chlorantraniliprole @ 10 g a.i. ha^{-1} followed by spinosad @ 17.5 g a.i. ha^{-1} (233.83 q ha^{-1} with 125.07 % increase over control) and flubendiamide @ 18.24 g a.i. ha^{-1} (224.98 q ha^{-1} with 116.56 % increase over control). Next in the order of recording higher yields were indoxacarb (198.17 q ha^{-1} with 90.75 % increase over control) and emamectin benzoate (181.51 q ha^{-1} with 74.71 % increase over control). Whereas, lowest marketable yield was recorded from bifenthrin treated plots (120.74 q ha^{-1} with 16.21% increase over control). The highest cost: benefit ratio was registered in the treatment of chlorantraniliprole @ 10 g a.i. ha^{-1} (1:16.40) followed by flubendiamide @ 18.24 g a.i. ha^{-1} (1:14.98), spinosad @ 17.5 g a.i. ha^{-1} (1:12.22) and indoxacarb (1:10.92).Whereas, it was least in bifenthrin @ 50 g a.i. ha^{-1} (1:1.78) treatment.

6.3 Dissipation pattern of triazophos, quinalphos and bifenthrin in cabbage

Recovery studies

QuEChERS, a multiresidue analysis method was used for extraction and clean up of cabbage samples. Method was validated by spiking triazophos, quinalphos and bifenthrin standards (CRM) separately in cabbage matrix at different spiking levels *viz.*, 0.05, 0.25 and 0.5 mg kg^{-1}. The per cent recovery of triazophos (90.30-95.17 %), quinalphos (91.25-93.71 %) and bifenthrin (97.07-97.47 %) in cabbage matrix ranged between 70-120 per cent at different fortification levels *i.e.* 0.05, 0.25 and 0.5 mg kg^{-1}.

The residues of triazophos, quinalphos and bifenthrin were determined by using Gas Chromatography with Flame Photometric Detector and Electron Capture Detector. The data indicated that, initial residues were gradually declined with time and residues reached BQL in the cabbage samples collected at 10th and 15th days after last spray.

Triazophos

The initial residues of triazophos 40 EC @ 500 and 1000 g a.i ha^{-1} in cabbage were found to be 0.54 mg kg^{-1} and 1.09 mg kg^{-1}, respectively which dissipated to BQL on 10th and 15th day after second spray. The calculated half-life values were 2.66 and 2.87 days for recommended and double the recommended dose, respectively.

Quinalphos

The initial residues of quinalphos 35 EC @ 250 and 500 g a.i ha^{-1} in cabbage heads were found to be 0.48 mg kg^{-1} and 1.06 mg kg^{-1}, respectively which dissipated to BQL on 7th and 10th day after second spray. The calculated half-life values were 2.10 and 1.97 days for recommended and double the recommended dose, respectively.

Bifenthrin

The initial residues of bifenthrin 10 EC @ 50 and 100 g a.i ha^{-1} in cabbage were found to be 0.51 mg kg^{-1} and 1.08 mg kg^{-1}, respectively which gradually dissipated to BQL on 10th and 15th day after second spray. The calculated half-life values were 2.30 and 2.52 days for recommended and double the recommended dose, respectively.

6.4 Impact of household processes on residues of insecticides in cabbage

Different decontamination methods were evaluated for the removal of residues at Pesticide Residue Laboratory, AINP on Pesticide Residue, MPKV, Rahuri. Cooking in close pan was found to be the most effective method in removing triazophos, quinalphos and bifenthrin residues from chopped cabbage samples (85.18, 85.42 and 86.27 %, respectively). Boiling was the next effective treatment which removed the triazophos, quinalphos and bifenthrin residues to the extent of 74.07, 81.25 and 80.39 per cent from chopped cabbage samples, respectively.

Dipping of cabbage heads in 2 per cent salt solution reduced triazophos, quinalphos and bifenthrin residues to the extent of 51.85, 56.25 and 64.70 per cent, respectively. Reduction of residues due to dipping in 2 per cent tamarind solution was to the extent of 42.59, 41.67 and 56.86 per cent for triazophos, quinalphos and bifenthrin residues, respectively from cabbage heads. Washing of cabbage heads with tap water was observed to be the least effective in removing the residues of triazophos, quinalphos and bifenthrin residues (up to 25 %).

The descending order of effectiveness of various decontamination methods in removing residues of triazophos, quinalphos and bifenthrin was: cooking > boiling > salt solution (2 %) > tamarind solution (2 %) > washing with tap water.

CONCLUSIONS

- Irrespective of locations, use of conventional insecticides was predominant.
- Triazophos, quinalphos, dimethoate, dichlorvos, cypermethrin, profenophos and chlorpyriphos were the most commonly used insecticides by the farmers for the control of *P. xylostella* in cabbage.
- In addition, farmers also used newer insecticides to control *P. xylostella*. The descending order of usage was: Nashik > Pune > Ahmednagar.
- Survey revealed that, very few cabbage growers were aware of safe waiting period after application of insecticides for harvesting of cabbage. It was also revealed that large numbers of farmers were aware of toxic effects of pesticide residues but none of the farmers followed precautionary measures while spraying in field to avoid toxic effects of pesticides.
- Studies on bio-efficacy revealed that, chlorantraniliprole @ 10 g a.i. ha^{-1} was the most promising insecticide for effective and economic control of *P. xylostella* and recorded highest yield of cabbage. The next promising treatments were spinosad @17.5 g a.i. ha^{-1} and flubendiamide @18.24 g a.i. ha^{-1}.
- Triazophos persisted in cabbage up to 7th and 10th day with half-life of 2.66 and 2.87 days at recommended and double the recommended dose, respectively.
- Quinalphos persisted in cabbage up to 5th and 7th day with half-life of 2.10 and 1.97 days at recommended and double the recommended dose, respectively.
- Bifenthrin persisted in cabbage up to 7th and 10th day with half-life of 2.30 and 2.52 days at recommended and double the recommended dose, respectively.
- From safety point of view, consumption of cabbage may be considered safe after ten days for triazophos and bifenthrin and seven days for quinalphos at recommended dose.

- Pesticide residues were influenced by various decontamination methods. The reduction of selected pesticides ranged from 25 to 86.27 per cent by different methods.
- For safe consumption of cabbage, cooking for 15 minutes was found to be the most effective method of decontamination of pesticide residues. Whereas, boiling, dipping in 2 per cent salt solution, dipping in 2 per cent tamarind solution and washing with tap water were next effective methods.

Future lines of studies

- ✓ An effort may be made to explore possibility of utilization of biopesticides for the management of DBM.
- ✓ An effort may be made to determine the bio-intensive IPM module for management of DBM in Western Maharashtra.
- ✓ In the present investigation chlorantraniliprole, spinosad and flubendiamide proved most promising against *Plutella xylostella* L. These newer insecticides need to be evaluated for their dissipation behavior to work out safe waiting period under various climatic conditions.
- ✓ Studies on management of diamondback moth by safer insecticides be further explored.
- ✓ Chlorantraniliprole, spinosad and flubendiamide may be evaluated for their safety to natural enemies of DBM.
- ✓ It is necessary to determine effective methods to remove or minimize the residue levels of pesticides.

7. LITERATURE CITED

Aasia, Akbar, Panhwar and Saghir, Ahmed, Sheikh. 2013. Assessment of pesticide residues in cauliflower through gas chromatography-μECD and high performance liquid chromatography (HPLC) analysis. Int. J. Agric. Sci. Res., 3(1): 7-16.

Abhishek, Shukla. 2002. Bio-efficacy of some insecticides and development of ecosafe management technology against *Plutella xylastella* L. along with its population dynamics in cabbage (*Brassica aleracea* var. *capitata*). Ph.D Thesis submitted to Maharana Pratap Uni. Agric. Tech., Udaipur (RJ), India.

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

Afari-Sefa, V., Asare-Bediako, E., Kenyon, L. and Micah, J. A. 2015. Pesticide use practices and perceptions of vegetable farmers in the Cocoa Belts of the Ashanti and Western Region of Ghana. Adv. Crop. Sci. Tech., 3(3):174.

Agnihotri, N. D., Jain, H. K., Rai, S. and Gajbhiye, V. T. 1980. Relative toxicity and residues of synthetic pyrethroids on cabbage and cauliflower. Indian J. Entomol.,42:717-722.

Aktar, M. W., Sengupta, D., Purkait, S., Chowdhury, A. 2010. Risk assessment and decontamination of quinalphos under different culinary processes in/on cabbage.Environ. Monit. Assess.,163:369-377.

Aktar, Md. Wasim., Dwaipayan, Sengupta and Ashim, Chowdhury. 2008. Degradation dynamics and persistence of quinolphos and methomyl in/on okra (*Ablemoschus esculentus*) fruits and cropped soil. Bull. Environ. Contam. Toxicol., 80:74–77.

Al-Sayed, R., Ramlawi, A. and Salah, A. 2011. A national survey on the use of agricultural pesticides in Palestine. (special issue: Palestine.). Int. J. Environ. Stu., 68(4):519-529.

Ambule, A. T., Radadia, G. G., Shinde, C. U. and Patil, D. L. 2015. Relative efficacy of newer insecticides against *Helicoverpa armigera* (Hubner) in tomato under South Gujarat condition. Int.J. Pl. Protec., 8(2):250-255.

Ameta, O. P, Sarangdevot, S. S., Sharma and U. S., Swami. H. 2008. Bio-efficacy of bifenthrin against insect pests in brinjal. Indian J. Pl. Protec., 36(2):235-239.

Amoako, P. K., Kumah, P. and Appiah, F. 2012. Pesticide usage in cabbage (*Brassica oleracea*) cultivation in the Ejisu-Juaben Municipality of the Ashanti Region of Ghana. Int. J. Res. Chem. Environ., 2(3):26-31.

Ananta, Ghimire and Bed, Prasad, Khatiwada. 2001. Use of pesticides in commercial vegetable cultivation in Tandi, Eastern Chitwan, Nepal During 2001. A Survey Report submitted to Institute of Agriculture and Animal Science (IAAS) Rampur Campus, Chitwan, Nepal.

Andaloro, J. T., C. W. Hoy., K. B. Rose and A. M. Shelton. 1993. Evaluation of insecticide usage in the New York processing-cabbage pest management program. J. Econ. Entomol., 76:1121-1124.

Ankersmith, G. W. 1953. DDT resistance in *Plutella xylostella* (Curt.) in Java. Bull. Entomol. Res., 44:421-425.

Anastassiades, M. and Lehotay, S.J. 2003. Fast and easy multiresidue method employing acetonitrile/partitioning and 'dispersive solid-phase extraction' for the determination of pesticide residues in produce. J. Assoc. Off. Anal. Chem.,86(2):412-431.

Anonymous, 2015. Annual report, AINP on Pesticides Residues, MPKV, Rahuri.

Anonymous, 2015. Indian horticultural data base 2015. Oxford university press, pp.18.

Arun, Debbarma, K. I, Singh, M. K. Gupta and P. Sobitadevi. 2017. Bio-rational management of major lepidopterous pests and their influence on yield of cabbage crop under Manipur valley. J. Entomol. Zoo. Stu., 5(5):546-1551.

Askew, J., Mitchell, T. H., Thomson, J. and Wheals, B. B. 1968. The gas chromatographic examination of organophosphorous pesticides. J. Chromatography, 32:417-418.

Atwal, A. S. and Dhaliwal, G. S. 2002. Pests of vegetables In: Agricultural Pests of South Asia and Their Management. Kalyani Publishers, pp. 248-253.

Awasthi, M. D. 1993. Decontamination of insecticide residues on mango by washing and peeling. J. Food Sci. Tech., 30(2):132–133.

Awasthi, M. D. 1986. Chemical treatments for the decontamination on brinjal fruits from the residues of synthetic pyrethroids. Pest. Sci., 17:89-92.

Babu, T. R., Sultan, M. A., Reddy, K. N. and Reddy, D. J. 2001. Dissipation of quinalphos and cypermethrin residues in cabbage. Indian J. Pl. Protec., 29:(1/2):144-145.

Balakrishnan, N., Kumar and B. V., Sivasubramanian, P. 2009. Bioefficacy of bifenthrin 10 EC against sucking insects, bollworms and natural enemies in cotton. Madras Agric. J., 96 (1/6):225-229.

Banerjee, I., Tripathi, S. K. Sinha, Roy, A. and Sengupta, P. 2014. Pesticide use pattern among farmers in rural district of West Bengal, India. J. Natural. Sci. Biol. Medi., 5(2):313-316.

Banerjee, T., Banerjee, D., Roy, S., Banerjee, H. and Pal, S. 2012. A comparative study on the persistence of imidacloprid and beta-cyfluthrin in vegetables. Bull. Environ. Contam. Toxicol., 89:193-196.

Banerji, R., Sahoo, S. K., Jha, S. and Banerjee, H. 2008. Persistence and dissipation of triazophos in bittergourd. J. Horti. Sci., 3(1):82-83.

Baral, K., B. C. Roy., K. M. B. Rahim., H. Chatterjee., P. Mondal., D. Mondal and D. Ghosh. 2006. Socio-economic parameters of pesticide use and assessment of impact of an IPM strategy for the control of eggplant fruit and shoot borer in West Bengal,India., Technical Bulletin No. 37. AVRDC 06-673. The World Vegetable Center, Shanhua, Taiwan, pp. 36.

Barooah, A. K. and Yein, B. R. 1996. Residues of Quinalphos in/on Brinjal (*Solanum melongena*). Fruits Pest. Res. J., 8(1):43- 48.

Bassi, Andrea, J. L. Rison and J. A. Wiles. 2009. Chlorantraniliprole (DPX-E2Y45, Rynaxypyr®, Coragen®), A new diamide insecticide for control of Codling moth (*Cydia pomonella*), Colorado potato beetle (*Leptinotarsa decemlineata*) and European grapevine moth (*Lobesia botrana*).

Proce. 9th Slovenian Conference on Pl. Protec. Inter. Partic., 39 Nova Gorica, pp.39-45.

Beena, Kumari. 2008. Effect of household processing on reduction of pesticide residues in vegetable, ARPN J. of Agric. Bio. Sci., 3(4):46-57.

Beltran, J., Peruga, A., Pitarch, E., Lopez, F. J. and Hernandez, F. 2003. Application of solid-phase micro-extraction for the determination of pyrethroid residues in vegetable samples by GC-MS. Anal. Bioanal. Chem., 376(4):502-511.

Bonnachere, A., Hanot, V., Jolie, R., Hendrickx, M., Bragard, C., Bedoret, T. and Loco, J. Van. 2012. Effect of household and industrial processing on levels of five pesticide residues and two degradation products in spinach. Food control, 25(1): 397-406.

Boopathi, T., Pathak, K. A., Ngachan, S. V. and Nabajyoti, Das. 2010. Evaluation of insecticides and biopesticides against diamondback moth, *Plutella xylostella* (L.) on broccoli. Pest Manag. Hort. Ecosys., 16(1):69-72.

Bordia, J. S. and Gupta, H. C. L. 1992. Residues of monocrotophos, carbaryl and fenitrothion in cauliflower. Indian J. Entomol., 54: 230-232.

Borjan, M., Robson, M. G., Hamilton, G., Brown, C. and Mayer, R. 2006. Trends indicated by the New Jersey pesticide use survey. Outlooks on Pest Management, 17(4):157-163.

Brar, G. S., Patyal, S. K. and Banshtu, T. 2017. Persistence of acephate, profenofos and triazophos residues in brinjal fruits and soil. The Bioscan, 12 (1):33-37.

Calderon, J. I. and G. J. Hare. 1986. Control of diamondback moth in Southeast Asia by Profenophos. In: Talekar, N.S. and Griggs, T., Diamondback Moth Management:- Proc. I International Workshop, AVRDC, Taiwan, pp:347-357.

Chahal, K. K., Joia, B. S., Battu, R. S., and Kang, B. K. 2000. Dissipation of triazophos on cauliflower. Ann. of Pl. Protec. Sci., 8:278-280.

Chahil, Gurminder, S., Gurmail Singh, Urvashi Bhardwaj, Reenu Takkar, Raminderjit S. Battu and Balwinder Singh. 2011. Degradation dynamics of quinalphos on cabbage under subtropical conditions of Ludhiana, Punjab, India. Orbital Elec. J. Chem., Campo Grande., 3(2): 104-111.

Chand, P. and Choudhary, R. 1977. Patterns of insect plant relationships determining susceptibility of food plants in the diamondback moth, *Plutella xylostella* (L.) Curtis. Mysore. J. Agric. Sci., 11:547-549.

Chandi, R. S., Chandi, A. K., Singh, G. and Suri, K. S. 2012. Insecticide use pattern on cole crops in Punjab. J. Insect Sci., 25(2):210-213.

Chatterjee, M. L. and Shanowly, Mondal. 2017. Sustainable Management of Some Key Lepidopteran Insect Pests of Vegetables. A thesis submitted to Bidhan Chandra Agric. Uni., Kolkata (WB), India.

Chauhan, Reena., Monga, Samriti and Kumari, Beena. 2012. Dissipation and decontamination of bifenthrin residues in tomato (*Lycopersicon esculentum* Mill). Bull. Environ. Contam. Toxicol., 89:181-186.

Chauhan, S. K., S. V. S. Raju., B. M. Meena., R. Nagar, V. S. Kirar and S. C. Meena. 2014. Bio-efficacy of newer molecular insecticides against diamondback moth (*Plutella xylostella* L.) on cauliflower. Agric. for Sustainable Devel., 2(1):22-26.

Chauhan, Reena., Monga, Samriti and Kumari, Beena. 2012a. Effect of processing on reduction of lambda-cyhalothrin residues in tomato fruits. Bull. Environ. Contam. Toxicol., 88(3):352-357.

Cherukuri, S. R., Shashi, B. V., Reddy A. H., Darsi, R., Aruna, M. and Ramesh, B. 2014. Risk Mitigation Methods for Removal of Pesticide Residues in Brinjal for Food Safety. Univ. J. Agric. Res., 2(8):279-283.

Cherukuri, S. R., Shashi, B. V., Reddy H. A., Hymavathy, M., Ravindranath, D., Aruna, M. and Swarupa, R. S. 2015. Dissipation dynamics and risk assessment of profenophos, triazophos and cypermethrin residues on tomato for food safety. Int. J. Agric. Forest, 5(1):60-67.

Chowdary, L. R., Kumar, L. R. and Ghante, V. K. 2015. Rynaxypyr 20 SC (Coragen) green labeled insecticide for the management of head borer (*Hellula undalis* Fab.) in cabbage. J. Expt. Zoo., 18(2):803-805.

Deepak, S., Narasa, Reddy., Gaikwad, S. M. and Shashibhushan, V. 2017. Bio-efficacy and dissipation of flubendiamide against shoot and fruit borer (*Earias vittella* Fab.) of okra. J. Entomol. Zoo.Stu.,5(4):1825-1829.

Devendran, A., Beena, Kumari and Yadav, G. S. 2006. Dissipation of endosulfan and dichlorvos residues in/on cauliflower curds. Environ. Monit. Assess., 116:307-313.

Devi, I. 2010. Pesticides in Agriculture: A boon or a curse. A case study of Kerala. Economic and Political Weekly, 14(26&27): 199-207.

Deviprasad, A. G., Radha, S. and Manonmani, H. K. 2015. Pesticide use pattern in four district of Karnataka: A survey. J. Environ. Sci. Toxicol. Food Tech., 9(10):48-51.

Dey, K. R., Choudhury, P. and Dutta, B. K. 2013. Impact of pesticide use on the health of farmers: A study in Barak Valley, Assam (India). J. Adv. Chem. Exotoxicol., 5(10):269-277.

Dey, P. K. and Somchoudhary, A. K. 2001. Evaluation of spinosad against lepidopteran pest complex of cabbage and its effect on natural enemies of diamondback moth under field conditions of West Bengal. Pestology, 25(1):54-58.

Dhaka, S. S., M. K. Rai and Arvind, Kumar. 2016. Relative efficacy of novel insecticides and biopesticides against *Earias vittella* (Fab.) in Okra. Ann. Pl. Protec. Sci., 24(2):271-275.

Dhas, S. and Srivastava, M. 2010. An assessment of carbaryl residues on brinjal crop in an agricultural field in Bikaner, Rajasthan (India). Asian J. Agril. Sci., 2(1):15-17.

Dhiman, N. 2003. Effect of processing on the pesticide residues in milk, selected cereals and vegetables. M.Sc. Thesis submitted to Punjab Agricultural University, Ludhiana, India.

Dhiman, N., Jyot, G., Bakhshi, A. K. 2006. Decontamination of various insecticides in cauliflower and tomato by different processing methods. J. Food Sci. Tech., 43:171–178.

Dhore, S. B. 2016. Persistence of quinalphos, ethion and imidacloprid in/on brinjal and cropped soil. M.Sc. Thesis submitted to MPKV, Rahuri, India.

Dinabandhoo, C.L. and Sharma, I.D.1994. Effect of decontamination processes on insecticide residues on cauliflower. Indian J. Pl. Path., 22:77–82.

Dinter, A., Brugger, K., Bassi, A., Frost, N. M. and Woodward, M. D. 2008. Chlorantraniliprole (DPX-E2Y45, Rynaxypyr®) (Coragen® 20 SC and Altacor® 35WG)- A novel DuPont anthranilic diamide insecticide–demonstrating low toxicity and low risk for beneficial insects and predatory mites. IOBC WPRS Bulletin, 35:128-135.

Dotasara, S.K., Agrawal, N. Singh and Dinesh, Swami. 2017. Efficacy of some new insecticides against Diamondback moth (*Plutella xylostella* L.) on cauliflower. Int. J. Curr. Microbiol. App. Sci., 6(5):1958-1963.

Duhan, Anil., Duhan, Saroj and Beena, Kumari. 2011. Behavior of endosulfan in cabbage (*Brassica oleracea* L.). Toxicol. Environ. chem., 93(10):1960-1970.

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

Epstein, L. and Bassein, S., 2003. Patterns of pesticide use in California and the implications for strategies for reduction of pesticides (Review). Ann. Rev. Phytopathol., 41: 351–375.

Eziah, V. Y., Rose, H. A., Wilkes, M. and Clift, A. D. 2009. Biochemical mechanisms of insecticide resistance in the diamondback moth (DBM) *Plutella xylostella* (Lepidoptera: Ypnomentidae) in the Sydney region, Australia. Aust. J. Entomol., 48:321-327.

Fletcher, T. B. 1914. Some South Indian Insects. Superintendent Government Press, Madras. pp. 565.

Gbewonyo, W. S. K. and Ninsin, K. D.1997. Insecticide Use Patterns and Residue Levels on Cabbage, *Brassica Olerecea* Var. *Capitata* L. Cultivated Within the Accra-Tema Metropolitan Area of Ghana. M.Phil. Thesis dissertation, University of Ghana.

Geetha, P. 2015. Survey on pesticide usage, monitoring of pesticide residues and decontamination methods in spinach (*Spinacia oleracea* l.). M.Sc. Thesis submitted to Professor Jayashankar Telangana State Agric. Uni., Hyderabad.

Geisman, J. R., Gunther, F. A. and Gunther, J. D.1975. Reduction of pesticide residues in food crops by processing. Residue reviews of pesticides and other contaminants in the total environment, 54:43-54.

Gill, K, Kumari, Beena and Kathpal, T. S. 2001. Dissipation of Alpha-methrin residues in/on brinjal and tomato during storage and processing conditions. J. Food Sci. and Technol., 38(1):43-46.

Gill, C. K., Sandeep, Kaur and Joia, B. S. 2008. Efficacy of new insecticides for the management of diamondback moth, *Plutella xylostella* (L.) on cauliflower and cabbage. J. Insect Sci., 21(2): 171-177.

Gill, C. K., Sharma, Sudhendu and Singh, Ravinder. 2010. Bioefficacy of flubendiamide against diamondback moth (*Plutella xylostella* L.) in cabbage Indian J. Entomol., 72(2):99-103.

Gupta, A. 2006. Pesticide Residues in Food Commodities. Agribios, (India).pp- 95.

Gupta, A. and Singh, B. 2001. Dissipation of fenvalerate residues in cauliflower. Bull. Environ. Contam. Toxicol., 66:24-28.

Gupta, S., Gajbhiye, V. T., Sharma, R. K. and Gupta, R. K. 2011. Dissipation of cypermethrin, chlorpyriphos and profenophos in tomato fruits and soil following application of pre-mix formulations. Environ. Monit. Assess., 174:337-345.

Gupta, S., Gajbhiye, V. T., Sharma, R. K. and Gupta, R. K. 2015. Residue behavior of combination formulations of insecticides in/on cabbage and their efficacy against aphids and diamondback moth. Environ. Monit. Assess., 187:4076.

Gupta, S., Sharma, R. K., Gajbhiye, V. T., and Gupta, R. K. 2012. Residue behavior of combination mix formulations in/on bitter gourd and their efficacy against melon fruit fly. Bull. Environ. Contam. Toxicol., 89:1258-1263.

Gupta, S., Sharma, R. K., Gajbhiye, V. T. and Gupta, R. K. 2013. Persistence of insecticides in ready-mix formulations and their efficacy against Lipaphis erysimi (Kalt) in cauliflower. Environ. Monit. Assess., 185(3):2107-14.

Gupta, S., Sharma, R. K., Gupta, R. K., Sinha, S. R., Rai, Singh and Gajbhiye, V. T. 2009.Persistence of new insecticides and their efficacy against insect pests of okra. Bull. Environ. Contam. Toxicol., 82:243-247.

Halimatunsadiah, A. B., Norida, M., Omar, D. and Kamarulzaman, N. H. 2016. Application of pesticide in pest management-The case of lowland vegetable growers. Int. Food Res. J., 23(1):85-94.

Han, W., S. Zhang, F. Shen, M. Liu, C. Ren, X. Gao 2012. Residual toxicity and sublethal effects of chlorantraniliprole on *Plutella xylostella.* Pest. Manage. Sci., 10:1002 pp.3282.

Harinathareddy, A., N. B. L. Prasad., K. Lakshmi, Devi., D. Raveendranath and B. Ramesh. 2015. Risk mitigation methods on the removal of pesticide residues in grapes fruits for food safety. Res. J. Pharm. Chem. Sci., 6(2):1568-1572.

Harinathareddy, A., Prasad, N. B. L and Devi, K. L. 2014. Effect of household processing methods on the removal of pesticide residues in tomato vegetable. J. Environ. Res. Devel., 9(1):50-57.

Head, G., Hoy, C. W. and Hall, F. R. 1995. Influence of permethrin droplets on movement of larval *Plutella xylostella* (Lepidoptera: Plutellidae). Pesti. Sci., 45:271-278.

Hiramoto, Matthew. 2007. Evaluation of chlorantraniliprole, flubendiamide, indoxacarb, metaflumizone and pyridalyl for diamondback moth, *Plutella xylostealla*, (Linnaeus) in Hawaii. Annual meeting, University of Hawaii, D0167.

Hotellier M.L. 1982. Deltamethrin residues in food crops and some animal products. Deltamethrin Momograph Roussel Vcalf: 285-315.

Jagginavar, S. B., Sunitha, D. and Biradar, A. P. 2009. Bioefficacy of flubendiamide 480 SC against brinjal fruit and shoot borer, *L. orbonalis* (G.). Karnataka J.Agric.Sci., 22:712-713.

Jain, H. K., Agnihotri, N. P. and Srivastava, K. P. 1979. Toxicity of fenvalerate and estimation of its residues on some vegetables. J. Entomol. Res., 3(2):212-216.

Jat, S. K. and Ameta, O. P. 2013. Relative efficacy of biopesticides and newer insecticides against *Helicoverpa armigera* (Hub.) in tomato. The Bioscan, 8(2):579-582.

Jeyanthi, H. and Kombairaju, S. 2005. Pesticide use in vegetable crops: frequency, intensity and determinant factors. Agric. Econ. Res. Rev., 18:209-221.

Jugal, Kishor, Bana. 2011. Seasonal incidence and management of major insect pests of cabbage, *Brassica oleracea* var. *capitata* L in semi-arid region of Rajasthan. Ph.D Thesis submitted to SKRAU, Bikaner (Rajasthan), India.

Kadian, S, Kumar R, Grewal R. K. and Shrivastava S. P. 2001. Effect of household processing on cypermethrin residues in commonly used vegetables. Pestology, 25:10-13.

Kamarulzaman, N. H., Mazlan, N., Rajendran, S. D. and Mohayidin, M. G. 2012. Role of biopesticides in developing a sustainable vegetable industry in Malaysia. Int. J. Gr. Econ., 6(3):243-259.

Kanna, S. S., Chandrashekaran, S., Regupathy, A. and Stanly, S. 2005. Field efficacy of emamectin 5 SG against tomato fruit borer *Helicoverpa armigera* (H.) Pestology, 29 (4): 21-24.

Katinka, Weinberger and R. Srinivasan. 2009. Farmers management of cabbage and cauliflower pests in India and their approaches to crop protection. J. Asia-Pacific Entomol.,12: 253-259.

Khan, M. F. R., Griffin, R. P., Carner, G. R. and Gorsuch, C. S. 2008. Evaluating biological based insecticides for managing diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). J. Entomol.,5(4):252-261.

Khan, M. A. M., Reddy, D. J. and Rao, S. V. 1999. Dissipation of dichlorvos and dimethoate residues in okra, Pest. Res. J., 11(2):204-206.

Khuhro, R. D. and Nizamani, S. M. 2000. Monitoring pesticide residues in fruits and vegetables. Report submitted to EPA, Karachi, pp .51.

Klinhom, P., Halee, A and Methawiwat, S. 2008. The effectiveness of household chemicals in residue removal of methomyl and carbaryl pesticides on Chinese kale. Kasetsart J. Nat. Sci., 42: 136-143.

Koushik, Sen., Arka, Samanta., S. K. Fashi, Alam., Partha, Protim, Dhar and Arunava. Samanta. 2017. Field evaluation of a new ready mix formulation Ampligo 150 ZC (chlorantraniliprole 9.3%+ lambda cyhalothrin 4.6% ZC) against Shoot and fruit borer (*L. orbonalis* Guen.) infestation in brinjal. J. Pharm. Phytochem., 6(5):1674-1678.

Kranthi, K. R., Jadhav, D. R., Kranthi, S., Wanjara, R. R. and Ali, S. S. 2002. Insecticide resistance in five major insect pests of cotton in India. Crop protec., 21:449-460.

Krishnaiah, K. and N. Jagan Mohan. 1977. Control of cabbage pests by new insecticides. In Paper presented at the Second Oriental Entomology Symposium, Loyola College, Madras, India., pp.88-89.

Krishnakumar, N. K., Srinivasan, K., Ramachander, P. R. and Suman. C. L.1984. Optimum control strategy of cabbage pests from a chemical control trial. Singapore J. Pri. Ind. (In Press).

Kumar, K. P., Reddy, D. J., Reddy, K. N., Babu, T. R. and Narendranath, V. V. 2000. Dissipation and decontamination of triazophos and acephate residues in chilly (*Capsicum annuum* Linn). Pest. Res. J.,12(1):26-29.

Kumar, P. and Devappa, U. 2006. Bio-efficacy of emamectin benzoate 5 % SG (proclaim) against diamondback moth in cabbage. Pestology, 30 (2):23-25.

Kumar, P., Prasad, C. S. and Tiwari, G. N. 2007. Population intensity of insect pests of cabbage in relation to weather parameters. Ann. Pl. Protec. Sci.,15(1):245-246.

Kumar, S. S. R. 1997. Insecticide residues in market samples of vegetables and methods of their decontamination. M.Sc Thesis, Kerala Agricultural University, Thrissur, India.

Kwon, H. Y., Lee, H. D., Kim, J. B., Jin, Y. D., Moon, B. C., Park, B. C., Son, K. A., Kwon, O. K and Hong M. K. 2009. Reduction of pesticide residues in field sprayed leafy vegetables by washing and boiling. J.Fd. Hyg. and Safety, 24(2):182-187.

Lal, K. M., Singh, S. P., Kumari, K and Singh, S. N. 2008. Effect of washing on decontamination of insecticide residues in okra fruits. Ann. Pl. Protec. Sci., 16(1):236-237.

Lee, Mi-Gyung and Lee, Su-Rae.1997. Reduction factors and risk assessment of organophosphorus pesticides in korean foods. Korean J. Food Sci. Tech., 29(2):240-248.

Lehotay, S. J. 2000. Analysis of pesticide residues in mixed fruit and vegetable extracts by direct sample introduction/Gas Chromatography/Tandem Mass spectrometry. Assoc. Off. Anal. Chem., 83(3):680-697.

Lehotay, S. J. 2005. Validation of a fast and easy method for the determination of residues from 229 pesticides in fruits and vegetables and using Gas and Liquid chromatography and Mass Spectrometric detection. J. Assoc. Off. Anal. Chem., 88 (2):559-614.

Lehotay, S. J. 2007. Determination of pesticide residues in foods by acetonitrile extraction and partitioning with magnesium sulfate: Collaborative Study. J. Assoc. Off. Anal. Chem., 90 (2):485-520.

Leibee, G. L. and K. E. Savage. 1992. Toxicity of selected insecticides to two laboratory strains of insecticide resistant diamondback moth (Lepidoptrea: Plutellidae) from Central Florida. J. Econ. Entomol., 85:2073-2076.

Li, X. S., Lu, Z. X., Lin, M. Z. and Huang, H. Y. 2005. Degradation dynamics of triazophos residues in litchi and soil. South west China J. Agric. Sci., 18(6):758-763.

Liang, Y., Wanga, W. and Shen, T. 2012. Effects of home preparation on organophosphorus pesticide residues in raw cucumber. Food Chem., 133: 636-640.

Liang, Yan-po., XIE, Sheng-hua., JI, Xun-cong and QIN, Shuang. 2011. Prevention and Control of Plant Diseases and Insect Pests. Guangdong Agric. Sci., 2011-23.

Liu, Congyun., Dahai, Lu.,Youcheng, Wang., Jian xiang, Huang., Kai, Wan and Fuhua, Wang. 2013. Residue and risk assessment of pyridaben in cabbage. Food Chemistry, 149:233-236.

Magdoleen, Ali. and Ahmed, Saeed, 2007.Seasonal Variation of pesticide residues in some salad vegetables in Khartoum State-Sudan. Thesis submitted to Faculty of Agriculture, University of Khartoum.

Mahantesh, N and Singh, A. 2009. A study on farmer's knowledge, perception and intensity of pesticide use in vegetable cultivation in western Uttar Pradesh. Pusa Agric. Sci., 32: 63-69.

Mahla, R.S., Singh, S. and Chaudhary, P. 2005. Management of diamondback moth, *Plutella xylostella* (L.) larvae by entomopathogenic fungus, *Metarhizium anisopliae.* Indian. J. Entomol., 67:342-344.

Malik, K., Kumari. Beena and Kathpal, T.S. 1999. Persistence and decontamination of alphamethrin residues in/on cauliflower at two different temperatures. Pesti. Res. J., 10(2):246-250.

Mandal, S. K., Randhir, Kumar., Sudhir, Das and Vinod, Kumar. 2009. Field evaluation of some newer insecticides against the diamondback moth, *Plutella xylostella* (L.) on cauliflower. Pest Mang. Econ. Zool., 17(1):105-108.

Marmat, Charansing, Sureshsing and Anoorag, R. Tayde. 2017. Efficacy of certain biorationals against shoot and fruit borer (*Leucinodes orbonalis* Guenee) of brinjal (*Solanum melongena* L.).J. Pharma.Phytochem., 6(4):1857-1859.

Meena, Sugan, Chand and Veer, Singh. 2013. Bio-efficacy of different insecticides/biopesticides against *Plutella xylostella* in cabbage. Indian J. Pl. Protec., 41(4):290-295.

Meena, U. Patil., A. V. Kulkarni and Omkar, Gavkare. 2013. Bio-efficacy of flubendiamide 39.35 % SC against chilli fruit borer (*Spodoptera litura* Fb). Asian J Biosci., 8(2):241-244.

Midmore, D. J., Jansen, H. G. P. and Dumsday, R. G. 1996. Soil erosion and environmental impact of vegetable production in the Cameron Highlands, Malaysia. Agri. Ecosys. Environ., 60:29-46.

Mishra, H. P. 2008. New promising insecticides for the management of Brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. Pest Mange. in Hort. Eco., 14(2):140-147

Mohamed, Braham and Lobna, Hajji. 2012. Management of *Tuta absoluta* (Lepidoptera, Gelechiidae) with Insecticides on Tomatoes. Insecticides-Pest Engineering, Intech Publication, pp. 333-354.

Mohapatra, S and Ahuja, A. K. 2007. Effect of moisture and soil type on the degradation of bifenthrin in soil. Pest. Res. J., 21(2):19-194.

Mohapatra, S. and Deepa, M. 2013. Persistence and dissipation of quinalphos in/on cauliflower and soil under the semi arid climatic condition of Karnataka, India. Bull. Environ. Contam. Toxicol., 90(4):489-493.

Mohayidin, M. G., Shamsudin, M. N., Chiew, E. F. C., Mohamed, Z. A., and Taylor, D. C. 1994. Sustainability of English cabbage production practices in Cameron Highlands, Malaysia. University of Putra, Malaysia., Serdang Malaysia., pp. 99.

Mohite, P. B and Patil, S. A. 2005. Evaluation of a new molecule, spinosad 2.5 SC for the management of diamondback moth *Plutella xylostella* on cauliflower. J. Pl. Protec. Environ., 2 (2):17-19.

Moore, A. and Tabasink, B. E., 1989. Leg autotomy of adult diamondback moth (Lepidoptera: Plutellidae) in response to tarsal contact with insecticide residues. J. Econ. Entomol.82: 381-384.

Mukherjee, I., Kumar, A. and Kumar, A. 2015. Dissipation of deltamethrin, triazophos and endosulfan in ready mix formulations in tomato (*Lycopersicum esculentus* L.) and Egg plant (*Solanum melongena* L.). Environ. Sci. Pollu. Res., 22:14169–14177.

Mukherjee, P., Kole, R. K., Bhattacharya, A. and Banerjee, H. 2006 of chlorpyriphos residues from cauliflower by culinary processes. Pest. Res. J., 18:101-103.

Mukherjee, U. and Singh, H. N. 2005. Pesticide use pattern on cabbage and cauliflower against diamondback moth, *Plutella xylostella* Curt in Varanasi (Uttar Pradesh). J. Res., Birsa Agric. Uni., 17(1):69-75.

Muthukumar, M, Sharma, R. K and Sinha, S. R. 2007.Field efficacy of biopesticides and new insecticides against major insect pests and their effect on natural enemies in cauliflower. Pest. Res. J., 19 (2):190-196.

Muzlon, Norida and John, Mumford. 2005. Insecticide use in cabbage pest management in the Cameron Highlands, Malaysia. Crop Protec., 24:31–39.

Nagendra. 2009. Economic consequences of pesticide use in cabbage production in Belgaum district of Karnataka. M.Sc Thesis. University of Agricultural Sciences, Dharwad, India.

Nagenthirajah, S. and Thiruchelvam, S. 2008. Knowledge of farmers about pest management practices in pambaimadu, Vavuniya district: an ordered probit model approach. Sabaramuwa Uni. J., 8 (1): 79-89.

Nagesh, M and Varma, S.1997. Bioefficacy of certain insecticides against diamondback moth, *Plutella xylostella* L. on cabbage. Indian J. Entomol., 59(4):411-414.

Nagesh, M, Verma, S.1997a. Decontamination of cabbage treated with chlorpyriphos and quinalphos. Indian J. Entomol., 59:404-410.

Narendra, P.K. 2017.Bio-efficacy of newly evolved novel insecticides against cabbage insect pests. M.Sc. Thesis submitted to Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.), India.

Narendra, Singh., S.K. Dotasara., Bhoopender, Kherwa and Swaroop, Singh. 2017. Management of tomato fruit borer by incorporating newer and biorational insecticides. J. Entomol. Zoo. Stu., 5(2):1403-1408.

Nath, G. and Agnihotri, S.1984. Removal of endosulfan from bitter gourds by home processing. Pesticides., 18(8):13-15.

Natwick, Eric T. and Martin, I. Lopez. 2016. Cabbage worm pest insecticide efficacy evaluation in 2016. Arthropod Manage. Tests, 41(1):1-2.

Ngowi, A. V. F. 2003. A study of farmers knowledge, attitude and experience in the use of pesticides in coffee farming. African. Newsletter on Occupation and Health Safety., 13: 62.

Ngowi, A. V. F., Mbise,T. J., Ijani, A. S. M., London, L., and O. C. Ajayi. 2007. Smallholder vegetable farmers in Northern Tanzania: Pesticides use practices, perceptions, cost and health effects. Crop Protec., 26:1617-1624.

Nikam, T. A., A. G. Chandele and Nikita, S. Awasthi. 2015. Relative toxicity of some newer insecticides to Diamondback moth, *Plutella xylostella* L. The Ecoscan, special issue, (7):105-108.

Nikam.T. A. 2013.Bio-efficacy of chemical insecticides against diamondback moth (*P. xylostella*) on cabbage. M. Sc. Thesis submitted to MPKV, Rahuri.

Nyakundi, W. O., Magoma, G., Ochora, J. and Nyende, A. B. 2011. A survey of pesticide use and application pattern among farmers in Rift Valley Central Provinca, Kenya. J. Entomol. Acarol. Res., 10(2):161-166.

Odhiambo, J. A. A., Winfred, S. K. G. and Daniel, O. 2014a. Insecticide use pattern and residue levels in cabbage (*Brassica oleracea* var. *capitata* L.) within selected farms in Southern Ghana. JENRM, 1(1):44-45.

Odhiambo, J. A. O., Winfred, S. K. Gbeworryo and Danial, O. O. 2014b. Insecticide use pattern and residue levels in cabbage (*Brassica oleracea var. Capitata* L.) within selected farms in Southern Ghana. JENRM., 1(1): 44-55.

Ong, K. C., Cash, J. N., Zabik, M. J., Saddiq, M. and Jones A.L., 1996. Chlorine and ozone washes for pesticide removal from apples and processed apple sauce. Food Chemistry, 55(2):153-160.

Pallavi, Nair, K., Thomas, Biju, Mathew, S., Naseema, Beevi and Thomas, George. 2014. Monitoring and decontamination of pesticide residues in okra (*Abelmoschus esculentum* Moench). Int. J. of Interdisc. Sci. Multidisci. Stu., 1(5):242-248.

Pandit, G. K., Bhattacharya, A., Bose, A. K., Bandyopadhyay, D., Das, A. K. and Adityachaudhury, N. 1996. Persistence of α-cypermethrin in cabbage and monocrotophos in three soils of West Bengal. Pesticide Res. J., 8(2):132-138.

Panhwar, A. A and Sheikh, S. A. 2013. Assessment of pesticide residues in cauliflower through gas chromatography-μ ECD and high performance liquid chromatography(HPLC) analysis. Int. J .Agric. Sci. Res., 3(1):7-16.

Paramasivam, S. M., Chandrasekaran, S., Karthik, P., Naik, R. H., Thangachamy, P. and Mahalingam, C. A. 2011. Persistence and dissipation of dichlorvos and profenophos on mulberry leaves. Madras Agric. J., 99(7/9):583-585.

Paras, Nath., Kumari, B., Yadav, P. R. and Kathpal, T. S. 2005. Persistance and dissipation of ready-mix formulations of insecticides in okra fruits. Environ. Monit. Assess., 107(13):173-179.

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

Patel, R. D., V. R. Parmar and N. B. Patel. 2016. Bio-efficacy of chlorantraniliprole 35 WG against *Helicoverpa armigera* (Hubner) Hardwick in tomato. Trends in Biosci., 9(15):793-798.

Patil, B. A., Shah, P. G., Raj, M. F., Patel, B. K., Patel, J. A. and Talathi, J.G.1999. Chlorpyriphos residues in/on cabbage and brinjal. Pest. Res. J., 11(2):195-195.

Patil, R. V. 2017. Survey on pesticide usage, dissipation and decontamination of profenophos and triazophos in brinjal and tomato. Ph.D Thesis submitted to MPKV, Rahuri, India. (Unpublished).

Patil, S. K. 2012. Assessment of insecticide resistance in *Spodoptera litura* (Fabricus) in western Maharashtra. Ph.D thesis submitted to MPKV, Rahuri, India.

Patra, B., Das, B. C., Alam, S. K. F., Dhote, V., Patra, S., Chatterjee, M. L. and Samanta, A. 2015. Evaluation of new insecticides against Diamondback moth, *Plutella xylostella* (L.) on red cabbage. Int. J. Bio-Res. Stre. Manag., 6(2):280-284.

Patrick, Holland and Anis, Rahman. 1999. Review of trends in agricultural pesticide use in New Zealand. MAF Policy Technical Paper, 99/11. pp.28.

Patyal, S. K., Dubey J. K., Sharma, I. D and Gupta, Divender. 2010. Persistence of bifenthrin residues on Apple (*Malus domestica*) fruit and soil. Pest. Res. J., 22:116-119.

Pawar, S. A., Wagh, B. M., Datkhile, R. V. and Bhalekar, M. N. 2016. Evaluation of newer insecticide molecules against pests of Tomato. Ann. Pl. Protec. Sci., 24(2):303-306.

Peter, John, A., Srinivasan, K. and Chelliah, S. 2000. Bioefficacy of spinosad: A new class of insecticide against cabbage pests. Pest Mang. Hort. Ecosys., 6(1):40-46.

Plianbangchang, P., Kanchalee, J. and Sakchai, W. 2009. Pesticide use patterns among small-scale farmers: a case study from phitsanulok, Thailand. Southeast Asian J. Trop. Medi. Public Health, 40(2):401-410.

Pradhan, S., Chowdhury, A., Manabendra, N. S. and Aktar, M. W. 2011. Environmental fate and persistence behaviour of a combination product of deltamethrin and triazophos in and on brinjal under eastern Indian climatic condition. Environ.Monit. Assess., 3 (1):111-117.

Pramanik, P. and Chatterjee, M. L. 2003. Efficacy of some new insecticides in the management of diamondback moth *Plutella xylostella* (L.) in cabbage. Indian J. Pl. Protec., 31(2):42-44.

Prashanthi, S. J., M. K. Chakravarty and Rajesh, Kumar. 2017. Field efficacy of newer insecticides against *Helicoverpa armigera* Hubner in Chick pea (*Cicer arietinum* L.). Ann. Pl. Protec. Sci., 25(1):49-52.

Prashant, Kumar, C. S. Prasad and Lok, Nath, Patel. 2007. Efficacy and economics of insecticides and bio-pesticides against *Plutella xylostella* (L.) on cabbage. Ann. Pl. Protec. Sci., 15(2):342-344.

Prashar, P., Tyagi, H. and Gautam, T. 2015. Survey of pesticide use patterns and farmers' perceptions: A case study from cauliflower and tomato cultivating areas of district Faridabad, Haryana, India. Inter. J. Medi. Pharm. Res., 1(3):139-146.

Puja, Rani and Jandial, V. K. 2010. Bioefficacy of biological based insecticides against diamondback moth (*Plutella xylostella*) on cabbage (*Brassica oleracea*). Indian J. Agric. Sci., 80(4):345-347.

Purushotam, Sharma. 2016. Seasonal abundance and management of Diamondback Moth, *Plutella xylostella* (L.) on cabbage, *Brassica oleracea* var. *capitata* L. M.Sc. Thesis submitted to Sri Karan Narendra Agric. Uni., Jabaner, India.

Purushotam, Sharma., K.C. Kumawat., S.K. Khinchi, Virendra Kumar and Baddhri, Prasad. 2017. Bioefficacy of different insecticides against diamondback moth. Int. J. Chem. Stu., 5(3): 891-893.

Rahimgul, Stanikzi and Sasya, Thakur. 2016. Efficacy of chemical insecticides and botanicals in the management of diamondback moth (*Plutella xylostella*) in cabbage (*Brassica oleracea* var. *capitata* L.). Int. J. Multidisc. Res. Devel., 3(6):101-104.

Raj, M. F., Shah, P. G., Patel, B. K., Patel, B. A. and Patel, J. A. 1999. Dissipation of triazophos in brinjal and okra fruits. Pest. Res.J., 11(1):102-105.

Rajukkannu, K., Saivaraj, K., Vasudevan, P. and Balasubramanian, M. 1979. Residues of phosalone, quinalphos, methyl parathion and fenitrothion in on tomato. Indian J. Pl. Protec., 7(1):19-22.

Ram, K. Thulasi and Kumar, K. 2015. Bio-efficacy of bifenthrin 8 SC against the shoot and fruit borer, *Earias vittella* on okra. Indian J. Pl. Protec., 43(4):416-419.

Ram, Prasad, Mainali., Ram, Babu, Peneru., Padma, Pokhrel and Yagya, Prasad, Giri. 2015. Field bio-efficacy of newer insecticides against eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee. Int. J. Appl. Sci. Biotech., 3(4):727-730.

Ramakrishnan, N. Sridharan, S. and Chandrasekaran, S. 2015. Insecticide Usage Patterns on Curry Leaf. Int. J. Vegetable Sci., 21(4):318-322.

Randhawa, M. A., Anjum, F. M., Asi, M. R. Butt, M. S., Ahmed, A. and Randhawa, M.S. 2007. Removal of endosulfan residues from vegetables by household processing. J.Sci. Indus.Res., 66:17.

Rao, S. R. K. and Lal, O. P. 2001. Efficacy of different insecticides against diamondback moth, *Plutella xylostella* L. on cabbage. J. Entomol.Res., 25(2):161-164.

Ratnsari, K. 2012. Survey and management of defoliator pests of cabbage.M.Sc. Thesis submitted to University of Agricultural Sciences, Dharwad, India.

Raut, A. N. 2016. Persistence of triazophos, chlorpyriphos and quinalphos in/on chilli and cropped soil. M.Sc. Thesis submitted to MPKV, Rahuri, India.

Raut, A. N., Patil, C. S., Saindane, Y. S., Deore, B. V. and Landge, S. A. 2016. Persistence of triazophos and chlorpyriphos in/on chilli and cropped soil. Adv. Life Sci.,5(20):8985-8989.

Ravi, Kumar, Katroju., Sreenivasa, Rao., Cherukuri, Shashi, Bushan, Vemuri and Narasimha, Reddy, K. 2014.Bio-efficacy of insecticides against fruit borer (*Helicoverpa armigera*) in tomato(*L.esculentum*).Int.J.Appli.Bio.Pharma.Tech.,5(1):239-243.

Reddy, A. A., Vemuri, S. and Cherukuri, S. R. 2014a. Dissipation pattern of bifenthrin in Cabbage (*Brassica Oleracea* Var.*Capitata*), Indian. J. Adv. Pl. Res., 1(3):51-56.

Reddy, Anil A., Shashi Bhushan, V., Sreenivasa Rao, Ch. and Harinathareddy, A. 2014b. Persistence of profenophos and bifenthrin residues in cabbage. Int. J. Curr. Res., 6(10):9167-9169.

Reddy, Anugu, Anil., Shashi, Vemuri., and Ch. S. Rao. 2014c. Bio efficacy of insecticides against Diamondback moth *Plutella xylostella* (L.) in cabbage (*Brassica oleracea* var. capitata). Int. J. Sci. Tech., 6(6):222-224.

Reddy, Anugu, Anil., Shashi, Vemuri., Ch. S. Rao and M. Aruna. 2017. Bio-Efficacy of insecticides against DiamondBack moth *Plutella xylostella* (L.) in cabbage (*Brassica oleracea* var. Capitata). Int. J. Curr. Microbiol. Appl. Sci., 6(6):1121-1125.

Reddy, C. N., Reddy, D. J and Rahman, S. M. A. S. 2012b. Dissipation and effect of processing of lambda-cyhalothrin residues in brinjal. Int. J. Bio-res. Stress Manag., 3(2):242-244.

Reddy, C. Narendra., Reddy, Jagdishwar, D. and Rahman S. M. A. S. 2012a. Persistence of Fipronil and Bifenthrin Residues in Cabbage. Int. J. Bio-res. Str. Manage.,3(1):73-75.

Reddy, J.D. and Rao, N. 2001. Dissipation of bifenthrin residues on grapes. Pestology, 25(8):33-35.

Reddy, K. Narsimha., M. A. Sultan., D. Jagdishwar, Reddy and T. Ramesh Babu. 2001. Dissipation and decontamination of triazophos and lindane in brinjal. https://www.researchgate.net/publication/286703622.

Ripley, Brian, D., Gwen, M. Ritcey, C., Ronald, Harris., Mary, Anne, Denommé and Pamela, D. Brown. 2001. Pyrethroid insecticide residues on vegetable crops. Pest Manage. Sci., 57(8):683-687.

Restrepo, A. R., Ortiz, A. F. G., Ossa, D. E. H. and Mesa, G. A. P. 2014.QuEChERS GC–MS validation and monitoring of pesticide residues in different foods in the tomato classification group. Food Chem., 158:153-161.

Rosli B. Mohamad., Yusof, B. Ibrahim and Chong, Wei. Cheong.1979. Field Efficacy of Several Selected Insecticides against the Diamondback moth, *Plutella xylostella* (L) on Cabbage, *Brassica oleracea* var. *capitata* (L) in the Lowland of Malaysia. Pertanika, 2(2):84-88.

Sable, Y. R., M. B. Sarkate, S. V. Sarode, P. O. Sangle and B. D. Shinde. 2007. Efficacy of newer molecules against *Plutella xylostella* Linn. Pest Manage. Horti. Eco., 13(2):139-145.

Sachin, Kumari, Reena, C., Ramprakash and Beena Kumari. 2013. Persistence and decontamination of bifenthrin residues in okra fruits. African J. Agric. Res., 8(38):4833-4838.

Sali, A. A. 2016. Persistence of quinalphos, ethion and carbendazim in/on tomato and cropped soil. M.Sc. Thesis submitted to MPKV, Rahuri, India.

Sapahin, H. A., Makahleh A. and Saad, B. 2014. Determination of organophosphorus pesticide residues in vegetables using solid phase micro-extraction coupled with gas chromatography-flame photometric detector. Arab J. Chem., pp-12.

Sarnabati, L. and Ray, D. C. 2017. Efficacy of newer insecticides against brinjal shoot and fruit borer *Leucinodes orbonalis* Guen. in Manipur. Indian J. Entomol., 79(1):55-58.

Satpathy, G., Tyagi, Y. K. and Gupta, R. K.2012. Removal of organophosphorus (OPs) pesticide residues from vegetables using washing solutions and boiling. J. Agric. Sci., (2):69-78.

Schenck, F. J., Brown, A. N., Podhorniak, L. V., Parker, A., Reliford, M. and Wong, J. W. 2008. A rapid multiresidue method for determination of pesticides in fruits and vegetables by using acetonitrile extraction/partitioning and solid-phase extraction column cleanup. J. Assoc. Off. Anal. Chem., 91(2):422-438.

Selvaraj, C. and Kennedy, J. S. 2017. Bio-efficacy of some new generation insecticides on *Plutella xylostella* L and toxicity on two natural enemies. Int. J. Agric. Sci., 9(3):3680-3682.

Setiawati, W. K. 2000. Controlling of diamondback moth (*Plutella xylostella* L.) and cabbage head caterpillar by using spinosad 2.5 SC and its effect on *semiclausum* Hellen. J. Hort. Indonesia, 10(1):30-39.

Shah, K.D., Bharpoda, T.M. and Jhala, R.C. 2012. Bio-efficacy of newer molecules of insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae). AGRES-An international *e*-Journal, 1(2):186-200.

Shalaby, S. E. M, Soliman, M. M. M. and A. E. M. Abd, El-Mageed. 2012. Evaluation of some insecticides against tomato leaf miner (*Tuta absoluta*) and determination of their residues in tomato fruits. Appl.Bio. Res., 14(2):113-119.

Sharaniya, S. and Loganathan, P. 2015. Vegetable growers perception of pesticide use practices and health effects in Vavuniya District. American-Eurasian J. Agric. Environ. Sci., 15(7):1479-1485.

Sharma, K.K. 2014. Pesticide Residue Analysis Manual. ICAR, New Delhi

Sharma, P. L. and Kumar, N. R. 1993. Dissipation pattern of fenvalerate in/on brinjal fruits under midhill conditions. Pestology., 17(10):20-21.

Sharma, Saurabh and Saika, D. K. 2009. Efficacy of certain eco-friendly pesticides against lepidopteran pests of cabbage in mid hills of Himachal Pradesh. Indian J. Entomol., 71(2):176-178.

Shashi, B. V., Cherukuri. S. R., Reddy H. A., Hymavathy, M., Ravindranath, D., Aruna, M. and Swarupa, R. S. 2015. Dissipation dynamics and risk assessment of profenophos, triazophos and cypermethrin residues on tomato for food safety. Int. J. Agric. Forest, 5(1):60-67.

Shashi, Bhushan, Vemuri., Cherukuri, Sreenivasa, Rao., S. Swarupa., Ravindranath, Darsi., Harinatha, Reddy, A. and Aruna, M. 2015a. Simple decontamination methods for removal of pesticide residues in brinjal. J Agric. Vet. Sci., 2 (1A):27-30.

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

Shashi, Vemuri., Cherukuri, Sreenivasa, Rao., Harinathareddy, A., S. Swarupa, K., Kavitha and V. Anitha. 2016. Risk mitigation methods for removal of pesticide residues in tomato for food Safety. Int. J. Forestry Horti., 2(1):19-24.

Shasikumar, K. and K. Kumar. 2015. Bio-efficacy of insecticide against shoot and leaf webber, *Antigastra catalaunalis* Duponchel on leaf damage basis in Sesame. Ann. Pl. Protec. Sci., 23(2):237-240.

Shelton, A. M., Robertson, J. L., Tang, J. D., Perez, C., Eigenbrode, S.D., Preisler, H.K., Wilsey, W.T. and Cooley, R.J., 1993. Resistance of diamondback moth (Lepidoptera: Plutellidae) to *Bacillus thuringiensis* subspecies in the field. J. Econ. Entomol., 86:697-705.

Shetty, P. K., Murugan, M., Hiremath, M. B. and Sreeja, K.G. 2010. Farmers education and perception on pesticide use and crop economies in Indian agriculture. J. Expt. Sci., 1(1): 03-08.

Shivalingaswamy, T. M., Akhilesh, Kumar., Satpathy, S., Rai, A. B. and Mathura, Rai. 2006. Spinosad a new molecule for management of diamondback moth (*Plutella xylostella* L.) in cauliflower. Veg. Sci., 2 (33):155-57.

Shukla, V. R., Parmar, K. D., Vaghela, K. M., Patel, J. S., Chawla, S., Patel, A. R., Upadhyay, P. A., Pathan, F. and Shah, P. G. 2016. Persistence of pesticides in capsicum (*Capsicum annuum* L.) under greenhouse and open field. Pest. Res. J., 28(2):159-167.

Sibanda, T., Dobson, H. M., Cooper, J. F., Manyangarirwa, W. and Chiimba, W. 2000. Pest management challenges for smallholder vegetable farmers in Zimbabwe. Crop Protec., 19 (8-10):807-815.

Singh, B and Dhaliwal G. S. 2000. Pesticides and Environment Commenwealth Publishers, New Delhi.

Singh, B., Singh, P., Battu, R. S. and Kalra, R. L. 1988. Residues of quinalphos in different parts of cauliflower crops. J. Insect Sci., 1:178–181.

Singh, D., G. C. Verma and M. Ramzan. 1976. A field evaluation of some new insecticides against the diamondback moth, *P. xylostella* L. Indian J. Pl. Protec., 4:117-119.

Singh, G., R. S. Battu, G. Jyot., B. Singh and B. S. Joia. 2007. Persistence of ethion residues on cucumber and *Cucumis sativus* (Linn) using Gas Chromatography with nitrogen phosphorus detector. Bull. Environ. Contam. Toxicol., 79:437-439.

Singh, K. I., A. Debbarma and H. R. Singh. 2015. Field efficacy of certain microbial insecticides against *Plutella xylostella* Linnaeus and *Pieris brassicae* Linnaeus under cabbage-crop ecosystem of Manipur. J. Biological Control, 29(4):194-202.

Singh, R., Patyal, S. K., Dubey, J. K. and Nath, A. 2003. Persistence of beta-cyfluthrin on cabbage and cauliflower. Pestology, 27: 26-28.

Singh, S. P., Kiran, Sanjay, Kumar and Tanwar, R. S. 2004. Dissipation and decontamination of cypermethrin and fluvalinate residues in okra. Pest. Res. J., 16(2):65-67.

Singh, Y., Mandal K. and Singh B. 2015. Dissipation pattern and risk assessment studies of triazophos residues on capsicum (*Capsicum annuum* L.) using GLC-FPD and GC-MS. Environ. Monit. Assess., 187-637.

Sinha, S. R. and Sharma, R. K. 2010. Effect of insecticides on insect pests of brinjal. Ann.Pl. Protec. Sci., 18(1): 82-85.

Smith, K. and Usher, K. 2012. Analysis of pesticide residues in lettuce and samples using Agilent bond elute QuEChERs AOAC extraction kit with universal dispersive SPE, www. Agilent. com/chem.

Sneha, D., Kumar, A., Rao, J. and Sunitha, Devi, R. 2017. Survey on plant protection practices in blackgram (*Vigna mungo*). Int. J. Sci. Environ. Tech., 6(1):288–294.

Sood, Nitin. 2006. Persistence and residue dynamics of some insecticides on summer cabbage, *Brassica oleracea* var. *capitata* L. Ph.D Thesis submitted to Haudhary Sarwan Kumar Himachal Pradesh Krishi Vishwvidyalaya, Palampur -176 062 (H.P.), INDIA.

Sridhar, V., S. Onkaranaik and K. S. Nitin. 2016. Efficacy of new molecules of insecticides against South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Pest Manage. Horti. Ecosys., 22(2):137-145.

Street, J. C. 1969. Methods of removal of pesticide residues. Canadian Medi. Assoc. J., 100:154-160.

Subhash, Chandra., Mukesh, Kumar., Anil, N. Mahindrakar and L.P. Shinde. 2015. Effects of household processing on reduction of pesticide residues in brinjal and okra. Int. J. Adv. Pharm. Bio.Chem., 4(1):98-102.

Sudhendu, Sharma., Ravinder, Singh., and C. K. Gill. 2016. Efficacy of anthranilic insecticide E2Y45 20 SC (Chlorantraniliprole) against *Plutella xylostella* L. in cabbage, *Brassica oleracea* var. *capitata*..J. Appli. Nat. Sci., 8(3):1584-1588.

Suganyakanna, S., Chandrasekaran, S., Regupathy,A. and Lavanya, D. 2005. Emamectin SG (Proclaim)-A newer insecticide for diamondback moth, (*P.xylostella*) management in cabbage. Pestology, 29:24-27.

Sunitha K. 2014. Bio-efficacy and relative toxicity of newer insecticides against diamondback moth (*Plutella xylostella*) on cabbage. M.Sc. Thesis submitted to MPKV, Rahuri.

Sunitha K. and Mohite P. B. 2016. Relative toxicity of new molecules of insecticides against Diamondback moth, *P.xylostella* L. infesting cabbage. Indian J. Appl. Res., 6(2):35-37.

Sunitha, Kurakula and Pandurang, B. Mohite. 2015. Toxicity of new molecules of insecticides against diamondback moth, *P. xylostella* L. infesting cabbage. Int. J. Inn. Res. Review, 2(12):1530-1532.

Sutharsan, S., Sivakumar, K. and Srikrishnah, S. 2014. Pesticide usage pattern for vegetable cultivation in Manmunai South & Eruvilpattu divisional secretariat, Division of Batticaloa district, Sri Lanka. Int. J. Agric. Res. Inn. Technol., 4(1): 53- 56.

Tabashnik, B. E., Cushing, N. L., Finson, N. and Johnson, M. W., 1990. Field development of resistance to *Bacillus thuringiensis* in diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol., 83:1671-1676.

Talekar, N. S., Sun, L. T., Lee, E. M., Chen, J. S. and Lee, Lu, T. M. S. 2016. Residual Behavior of Several Insecticides on Chinese Cabbage. J. Econ. Entomol.,6:689-692.

Talekar, N. S. and Shelton, A. M. 1993. Biology, ecology and management of the Diamondback moth. Ann. Rev. Entomol., 38:275-301.

Tambe, A. B. and Mote, U. N. 2003. Effectiveness of new molecule, spinosad 2.5 SC against diamondback moth, *Plutella xylostella* L. on cabbage. J. Appl. Zool. Res., 14(1):44-45.

Tandi, T. E., Wook, C. J., Shendeh, T. T., Eko, E. A. and Afoh, C. O. 2014. Small-scale tomato cultivators perception on pesticides usage and practices in Buea Cameroon. Health, 6:2945-2958.

Tarun, Kumar, Kushwaha and Gopal, P. D. Painkra. 2016. Efficacy of certain insecticides against shoot and fruit borer (*Leucinodes orbonalis* Gune.) on *kharif* season brinjal (*Solanum melongena* L.) under field condition. Int. J. Agric. Sci. Res., 6(2):383-388.

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

Tewary, D.K., Kumar, V., Rabindranath, S.D. and Shanker, A. 2009. Dissipation behaviour of bifenthrin residues in tea and its brew. Food Chem. Toxicol., 47(2):502-505.

Thanki, Neha., Praful, Joshi and Hasmukh, Joshi. 2012. Effect of household processing on reduction of pesticide residues in Cauliflower (*Brassica oleraceae var. botrytis*). European J. of Expt. Bio., 2(5):1639-1645.

Tibugari, H., Jowah, P., Mandumbu, R. and Karavina, C. 2012. Tackling diamondback moth, *P. xylostella* (L.) resistance: a review on the current research on vegetable integrated pest management in Zimbabwe. Arc. Phytopath. Pl. Protec., 45(20):2445-2453.

Umeda K., D. Macneil and D. Roberts. 2000. New insecticides for diamondback moth control in cabbage. Vegetable report, index at http://ag.arizona.edu/pubs /crops/ az1177/.

Varghese, T. S. and Mathew, T. B. 2013. Pesticide residues-Home remedies for eliminating pesticide residues from green chilli fruits. In: Chaudhary AK (Ed.) Contributory Paper, International Conference on Insect Science, pp.120.

Vaseem, Mohd., Singh, Hem., Kumar, Kaushlendra and Ali, Mohd. 2014. Efficacy of newer insecticides against diamondback moth (*Plutella xylostella* Linn.) on cabbage under poly house condition. J. Expt. Zool.,17(2): 487-489.

Venkate, Shalu and Mahesh, Math. 2017. Management of insect pests of cabbage with a newer anthranilic diamide insecticide, cyantraniliprole 10% OD. The Bioscan, 12(2):703-708.

Venkateswarlu, V., Sharma R. K. and Sharma Kirti. 2011. Evaluation of eco-friendly insecticides against major insect pests of cabbage. Pest. Res. J., 23 (2):172-180.

Vishwakarma, R., P. H. Prasad and S. S. Ghatak. 2009. Bio-efficacy of botanicals and bio-pesticide against diamondback moth (*Plutella xylostella* L.) infesting red cabbage (*Brassica oleracea* L. *var. capitata f. rubra* L.) Int. Conference on Horti., pp.1149-1151.

Waghulde, P. N., Khatik, M. K., Patil, V. T. and Patil, P. R. 2011. Dissipation of chlorpyriphos, endosulfan, dimethoate and malathion residues were studied in/on chilli (*Capsicum annum* L) and okra (*Abelmoschus esculentus* L) fruits at North Maharashtra region (India). Environ. Monit. Assess., 174(1-4):337-45.

Waibel, H. and Schmidt, E. 2000. Feeding Asian cities: food production and processing issues. Paper presented at the AFMA/FAO Regional Seminar, ‘Feeding Asian Cities’: 26–30th November,Bangkok,http://www.fao.org/fcit/mark.asp(accessed on 27/5/04).

Watts, M. 1997. Proposal for a pesticide risk reduction policy for New Zealand. Proceedings 50th New Zealand Pl. Protec. Conference, 498-505.

Weinberger, K. and Srinivasan, R. 2009. Farmers management of cabbage and cauliflower pests in India and their approaches to crop protection. J. Asia-Pacific Entomol., 12:253-259.

Willam, J. N., Hub, J. G., Peter, K. and Pay, D. 2006. Farmer's perception and pesticides in vegetables production in Ghana. Pest Manage. Sci., 62:356-365.

Xie, X. C., Zhang, S. H. and Wang, D. S. 2005. Study on multi-residue analysis of OPs insecticides in cabbage. Acta Agriculturae Shanghai, 21:118-121.

Xu, R., Kuang, R., Pay, E., Dou, H. and de, Snoo, G. R. 2008. Factors contributing to overuse of pesticides in western China. Environ. Sci., 5(4):235-249.

Yadav, S. K., S. V. S. Raju, M. K. Yadav, A. K. Srivastava and P. K. Dwivedi. 2017. Bio-efficacy of new insecticidal molecules against the Diamondback moth (*Plutella xylostella* L.) on cauliflower. J. Exp. Zool. India, 20(1):465-469.

Yen, I., Chang., I.B. and Kalloo, C. 1999. Use patterns and residual levels of organophosphate pesticides on vegetables in Trinidad, West Indies. J. AOAC. Inter., 2(4):991-995.

Zhao, J. Z., Collins, H. L., Li, Y. X., Mau, R. F. L., Thompson, G. D., Hertlein, M., Andaloro, J. T., Boykin, R. and Shelton, A. M., 2006. Monitoring diamondback moth (Lepidoptera: Plutellidae) resistance to spinosad, indoxacarb and emamectin benzoate. J. Econ. Entomol., 99:176-181.

Zhen-di, H. U., Xia F., Qing-shen, L., Huan-yu, C., Zhen-yu, L., Fei Y., Pei L. and Xi-wu, G. 2014. Biochemical mechanism of chlorantraniliprole resistance in the diamondback moth, *Plutella xylostella* Linnaeus. J. Integ. Agric., 8(2):205-209.

Zhi, Hua, Wang., Tong, Yang., Dong, Mei, Qin., Yong, Gong and Ying, Ji. 2008.Determination and dynamics of difenoconazole residues in Chinese cabbage and soil. Chinese Chemical Letters. 9(8):969-972.

Zhi-Yong, Zhang., Cun-Zheng, Zhang., Xian-Jin, Liu and Xiao-Yue, Hong. 2006. Dynamics of pesticide residues in the autumn Chinese cabbage (*Brassica chinensis* L.) grown in open fields. Pest Manage. Sci., 62(4):350-355.

Zhi-Yong, Zhang., Xian-Jin, Liu., Xiang-Yang, Yu., Cun-Zheng, Zhang and Xiao-Yue, Hong. 2007. Pesticide residues in the spring cabbage (*Brassica oleracea* L. *var. capitata*) grown in open field. Food Control.18:723-730.

Zohair, A. 2001. Behavior of some organophosphorous and organochlorinepesticides in potatoes during soaking in different solutions. Food Chem. Toxicol., 39:751-755.

8. APPENDICES
8.1 APPENDIX-I
Questionnaire of insecticides usage pattern in cabbage

Department of Agril. Entomology Post Graduate Institute Mahatma Phule Krishi Vidyapeeth, Rahuri (MS), INDIA		
SN	**Particulars**	**Answers**
1	Name of Farmer	
2	Address	
3	Year	
4	Total cultivable land	
5	Area under cabbage	
6	Area under other crop	
7	Pest occurrence	
	Aphids	
	Diamondback moth	
	Leaf Webber	
	Other pests	
8	Bio-agents observed	
9	Insecticides used against aphids	
10	Insecticides used against Diamondback moth	
11	Yield q/ha	
12	Volume of spray	
15	Information on application of bio-pesticides (if any)	
16	Do you know about natural enemies?	
17	Do you know about recommended pesticides in cabbage?	
18	How do you measure pesticides (bottle/ top approximately)?	
19	How do you mix the pesticides in the water-bare hand/sticks?	
20	Source of information for recommended pesticides-Agril. Dept /Neighbour /Media/Dealers/Scientists/ University	
21	Do you know safe waiting period ?	
22	Do you know about effects of pesticide residues?	
23	Signature of farmer	
24	Signature of Surveyor	

8.2 APPENDIX-II

METEOROLOGICAL DATA-2015-16

Month	Met. Week	Temperature (^0C)		Relative Humidity (%)		Wind Velocity (Km/hr)	Sunshine hrs.	Rainfall (mm)	Rainy days
		Max.	Min.	Morn.	Even.				
January	1	24.9	12.7	74	55	0.4	0.3	1.2	0.0
	2	27.2	06.8	48	26	0.8	9.7	0.0	0.0
	3	28.6	10.5	54	33	0.5	9.1	0.0	0.0
	4	29.4	14.0	62	37	0.9	6.9	0.0	0.0
	5	30.1	12.9	52	35	1.2	9.2	0.0	0.0
February	6	31.3	12.3	51	24	1.8	9.0	0.0	0.0
	7	33.0	13.0	53	23	0.8	10.3	0.0	0.0
	8	33.2	13.7	54	23	1.2	10.2	0.0	0.0
	9	28.9	13.0	65	37	2.4	7.5	42.4	2.0
March	10	31.9	14.8	52	37	1.2	8.9	65.2	3.0
	11	31.0	16.8	67	39	1.5	9.1	11.0	2.0
	12	35.3	19.2	45	23	1.0	9.0	0.0	0.0
	13	36.4	19.4	54	20	1.2	7.6	0.0	0.0
April	14	35.8	16.1	51	20	1.7	9.5	0.0	0.0
	15	33.9	19.5	35	37	1.2	6.8	7.2	1.0
	16	37.2	21.5	48	22	1.0	9.5	0.0	0.0
	17	39.1	20.5	40	14	2.9	10.2	0.0	0.0
	18	40.4	21.0	36	16	3.4	10.0	0.0	0.0
May	19	39.6	24.4	41	19	1.7	10.0	0.0	0.0
	20	38.6	23.5	48	28	2.8	8.5	8.0	1.0
	21	40.1	23.6	49	22	7.2	11.1	0.0	0.0
	22	39.3	23.3	56	25	4.7	7.7	3.0	1.0
June	23	36.0	22.8	68	52	2.6	7.8	36.4	4.0
	24	32.3	23.2	72	64	2.9	4.0	25.8	2.0
	25	31.6	23.6	71	60	9.4	2.8	11.6	2.0
	26	33.8	23.3	66	45	9.8	7.8	0.0	0.0
July	27	34.7	23.3	66	43	9.7	9.1	0.0	0.0
	28	34.5	23.4	68	41	7.5	7.7	0.0	0.0
	29	32.5	23.7	74	57	8.0	2.9	17.4	1.0
	30	30.8	23.5	71	60	11.4	2.1	8.4	1.0
	31	30.8	22.4	77	59	6.7	3.3	7.4	1.0
August	32	30.4	22.2	76	60	2.6	2.3	4.0	1.0
	33	31.8	23.1	71	49	4.1	3.8	0.0	0.0
	34	33.0	21.9	69	49	4.4	5.9	1.0	0.0
	35	33.1	21.4	71	47	4.0	6.6	3.0	0.0
September	36	33.3	23.9	81	55	0.9	6.0	20.6	2.0
	37	31.8	22.9	79	58	1.3	4.6	48.4	3.0
	38	30.2	22.6	79	58	6.8	4.3	54.6	3.0
	39	33.5	19.7	68	40	0.6	8.7	0.0	0.0
October	40	32.8	21.0	76	50	1.2	7.1	20.6	3.0
	41	34.2	20.9	71	39	0.4	7.4	0.0	0.0
	42	35.0	19.1	56	30	0.8	9.5	0.0	0.0

	43	34.7	20.3	57	36	0.5	6.9	0.0	0.0
	44	32.2	17.4	57	37	0.6	7.9	0.0	0.0
November	45	32.9	17.2	58	36	0.6	8.2	0.0	0.0
	46	32.4	14.5	50	30	1.8	9.5	0.0	0.0
	47	30.1	17.9	71	59	1.5	5.1	26.0	2.0
	48	31.6	17.8	70	44	0.2	7.6	0.0	0.0
December	49	31.6	13.9	57	32	0.4	9.4	0.0	0.0
	50	32.3	16.0	49	33	0.7	9.0	0.0	0.0
	51	31.1	13.7	64	35	0.4	8.6	0.0	0.0
	52	28.3	07.8	37	22	1.2	9.7	0.0	0.0
January	1	31.4	11.6	47	26	0.4	9.5	0.0	0.0
	2	30.3	11.8	47	27	0.2	8.4	0.0	0.0
	3	28.7	11.8	59	30	1.6	9.1	0.0	0.0
	4	29.4	09.3	46	22	0.6	9.9	0.0	0.0
	5	33.5	12.0	47	25	0.2	10.3	0.0	0.0
February	6	32.4	13.4	53	24	1.0	9.7	0.0	0.0
	7	32.8	14.9	64	27	1.3	8.3	0.0	0.0
	8	35.0	17.5	52	23	0.7	9.4	10.2	2.0
	9	35.3	18.6	56	28	0.9	7.8	0.0	0.0
March	10	34.5	17.1	51	22	0.8	8.1	0.0	0.0
	11	35.8	17.3	40	20	1.5	9.2	0.0	0.0
	12	37.1	18.7	35	17	2.7	9.1	0.0	0.0
	13	39.0	19.3	34	18	1.2	8.6	0.0	0.0
April	14	39.0	21.5	40	22	1.3	8.2	0.0	0.0
	15	39.0	20.6	37	20	1.6	9.8	0.0	0.0
	16	39.9	22.7	38	22	1.5	9.0	0.0	0.0
	17	39.0	20.6	41	19	2.2	10.6	0.0	0.0
	18	39.9	21.8	30	17	1.7	10.4	0.0	0.0
May	19	39.0	24.2	47	27	1.9	9.3	1.4	0.0
	20	41.2	25.3	44	25	3.0	8.5	5.8	1.0
	21	38.6	24.2	55	34	5.9	10.6	46.0	1.0
	22	37.9	25.7	58	30	4.2	10.0	1.8	0.0

9. VITA

SAWANT CHANDRAKANT GYANOBA
A candidate for the degree
of
DOCTOR OF PHILOSOPHY (AGRICULTURE)
in
AGRICULTURAL ENTOMOLOGY
2018

Title of thesis	:	"Bio-efficacy of newer insecticides against diamondback moth (*Pluttella xylostella* L.) and their residues in cabbage"
Major field	:	Agricultural Entomology
Personal information	:	Born on 24th October,1990 At.Kauthali, Tq. Parli Vijnath, Dist. Beed, State.Maharashtra S/O Gyanoba Sopanrao Sawant and Smt. Sanjivani Gynaoba Sawant
Educational qualifications	:	Passed S.S.C. examination from Vidyavardhini Vidyalaya, Parli Vaijnath in 2006. Passed H.S.C. examination from Mamata Junior College, Palam in 2008. Received B. Sc (Agri) from Rajiv Gandhi College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in 2012. Received M. Sc (Agri) in Agricultural Entomology from College of Agriculture,Latur, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in 2014.
Awards	:	Awared with Certificate of Merit and Late Gopal Kishan Kale Prize for securing highest CGPA in discipline of Agricultural Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani for batch 2012-14.
Fellowship	:	Recipient of INSPIRE Fellowship from Department of Science and Technology, Ministery of Science and Technology, Delhi (2015- 2017) for Ph.D program in the discipline Agricultural Entomology.
Permanent Address	:	Mr. Sawant Chandrakant Gyanoba, S/O. Gyanoba Sopanrao Sawant At.Post.Kauthali, Tq.Parli Vaijnath, Dist.Beed, Maharashtra, India. Pin: 431 530, Mob: 9421378109 E-mail: cgsk123456@gmailmail.com