EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE

by

Mr. Mali Audumber Sumant
(Reg. No. K-16/165)

AGRICULTURAL ENTOMOLOGY SECTION

COLLEGE OF AGRICULTURE, KOLHAPUR

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413722, DIST-AHMEDNAGAR
MAHARASHTRA, INDIA

2018

EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE

by

Mr. Mali Audumber Sumant
(Reg. No. K-16/165)

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

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

AGRICULTURAL ENTOMOLOGY SECTION

COLLEGE OF AGRICULTURE, KOLHAPUR

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413722, DIST-AHMEDNAGAR
MAHARASHTRA, INDIA
2018

EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE

by

Mr. Mali Audumber Sumant
(Reg. No. K-16/165)

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

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

APPROVED BY

Dr. A. S. Bagde
(Chairman and Research Guide)

Dr. Pandurang B. Mohite
(Committee Member)

Prof. D. R. Patgaonkar
(Committee Member)

Prof. R. M. Khadtare
(Committee Member)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE, KOLHAPUR

**MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413722, DIST-AHMEDNAGAR
MAHARASHTRA, INDIA**
2018

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

Place: (Mali A. S.)
Date:

Dr. A. S. Bagde
Assistant Professor
Agricultural Entomology
College of Agriculture,
Kolhapur –416 004, Dist. Kolhapur
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled. **"EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **MR. MALI AUDUMBER SUMANT** under my guidance and supervision and that no part of the 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: Kolhapur (Dr. A. S. Bagde)
Date:

Dr. Pandurang B. Mohite
Professor of Agril. Entomology,
College of agriculture, Kolhapur.
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413722, Dist- Ahmednagar,
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled. **“EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE”** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **MR. MALI AUDUMBER SUMANT** under my guidance and supervision of **DR. A. S. BAGDE,** Assistant Professor of Agricultural Entomology, College of Agriculture, Kolhapur 416 004. Dist. Kolhapur, Maharashtra, India and that no part of the 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: Kolhapur (Dr. Pandurang B. Mohite)
Date:

Dr. G. G. Khot
Associate Dean,
College of agriculture, Kolhapur.
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413722, Dist- Ahmednagar,
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled. **“EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE”** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **MR. MALI AUDUMBER SUMANT** under my guidance and supervision of **DR. A. S. BAGDE,** Assistant Professor of Agricultural Entomology, College of Agriculture, Kolhapur 416 004. Dist. Kolhapur, Maharashtra, India and that no part of the 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: Kolhapur (Dr. G. G. Khot)
Date:

ACKNOWLEDGEMENTS

I avail this opportunity to acknowledge my sincere, humble indebtedness and deepest sense of gratitude to my honourable guide ***Dr. A. S. Bagde****, Asstt. Professor of Agril. Entomology, College of Agriculture, Kolhapur, whose insight, unfailing interest, constructive critism, inspiring guidance, infinite patience were as asset throughout the course of investigation, providing necessary facilities and valuable help in conducting the studies. The words are inadequate to thank him for the painstaking efforts; he has taken during the research work, in the preparation of manuscript and final shaping of the thesis in present form.*

I enroll my esteem and inestimable gratitude with great respect to the Advisory Committee Dr. P. B. Mohite, Professor of Entomology, Prof. D. R. Patgaonkar, Asstt. Professor of Horticulture, and Prof. R. M. Khadtare, Asstt. Professor of plant pathology, College of Agriculture, Kolhapur for their valuable suggestions during the course of present investigation.

I sincerely thanks to Dr. G. G. Khot, Associate Dean, College of Agriculture, Kolhapur for providing necessary facilities for successful completion of research work.

I wish to place on record my heartful thanks to, Prof. S. A. Patil, Asso. Professor of Entomology, College of Agriculture, Kolhapur for their valuable support, help and co-operation throughout the course of study.

I owe my heartful gratitude to, Mr. Atul Pandav, Mrs. Sheetal N. Deshmukh, Agril. Assistant of Entomology Section, College of Agriculture, Kolhapur for their kind co-operation.

I wish to express my cordial thanks to Dr. P. N. Sonvane, Mr. Tanaji mama, Sattappa Suhas, Deepak, Shivajimama, Mane mavashi for rendering assistance during different times of this experiment.

I would like to express my sincere appreciation to my colleagues Rohan, Tejaswini,Vilas and Chetan sir, Pankaj and all M.sc Agri 2016 batch, for their co-operation during course of time.

I also thank to my seniors Vijay sir, Jafar sir for their kind co-operation. My heart is filled with sweet memories of my sweet Raghu sir, Datta, Dnyaneshwar, Amit, Mangesh, Vikas and all friends.

Everlasting, words seems to be inadequate to express my indebtedness to my Father Shri. Sumant Mali, Mother Smt. Surekha, Aunt Chandrabhaga and my brother Keshav & Ashok bhau, Shital vahini & Varsha vahini, Kaka and Mavshi for their exemplary enthusiasm, supreme sacrifice, immense care, moral courage, constant motivation and support through ramifying paths of thick and thin, throughout my career.

Place: Kolhapur *(Mr. Mali A. S.)*

CONTENTS

Chapter No.	Title	Page No.
	CANDIDATES DECLARATION	I
	CERTIFICATE OF RESEARCH GUIDE	II
	CERTIFICATE OF HEAD OF THE DEPARTMENT	III
	CERTIFICATE OF ASSOCIATE DEAN	IV
	ACKNOWLEDGEMENT	V
	CONTENTS	VI
	LIST OF TABLES	VIII
	LIST OF FIGURES	VIII
	LIST OF PLATES	VIII
	LIST OF ABBREVIATIONS AND SYMBOLS	IX
	ABSTRACT	XII
1	**INTRODUCTION**	1
2	**REVIEW OF LITERATURE**	5
	2.1 Seasonal Incidence of Pests on Cabbage.	5
	2.1.1 Aphid.	5
	2.1.2 Diamondback Moth.	7
	2.1.3 Tobacco Caterpillar.	8
	2.2 Different Integrated Pest Management Modules for Control Pests of Cabbage.	10
	2.2.1 Pheromone Traps.	10
	2.2.2 Entomopathogenic Fungus.	10
	2.2.3 Utilisation of Insecticides Against Pests of Cabbage.	11
	2.2.3.1 *Bacillus thuringiensis* (Berliner)	11
	2.2.3.2 Neem based pesticides.	12
	2.2.3.3 Insect growth regulators.	14
	2.2.3.4 Chemical control.	14
	2.3 Natural Enemies.	18
3	**MATERIALS AND METHODS**	21
	3.1 Location of The Experiments.	21
	3.2 Climatic Conditions.	21
	3.3 Soil Type.	21
	3.4 Seasonal Incidence.	21
	3.5 Efficacy of Different Modules Against Pest Complex of Cabbage.	21
	3.5.1 Experimental details.	22
	3.5.2 Application of insecticides.	25
	3.5.3 Methods of Recording Observations.	26
	3.6. Statistical Analysis.	26
4	**RESULTS AND DISCUSSION**	27
	4.1 The Seasonal Incidence of Pests.	27
	4.1.1 Seasonal incidence of Aphids.	27

Chapter No.	Title	Page No.
	4.1.2 Seasonal incidence of Diamondback moth.	27
	4.1.3 Seasonal incidence of *Spodoptera litura*.	28
	4.2 Efficacy of Different Modules Against Pest Complex of Cabbage.	32
	4.2.1 Efficacy of Different Modules Against Aphid (*B. Brassicae)* of Cabbage.	32
	4.2.2 Efficacy of Different Modules Against Diamondback Moth (*P. xylostella)* of Cabbage.	34
	4.2.3 Efficacy of Different Modules Against *S. litura* of Cabbage.	37
	4.3 Effect of Different Modules on Natural Enemies of Cabbage.	40
	4.3.1 Effect of Different Modules on Predatory Coccinellids Population in Cabbage.	40
	4.4 Cost Benefit Ratio for Pests of Cabbage.	43
	4.4.1 Cost Benefit Analysis of Modules for Pests of Cabbage.	43
5	**SUMMARY AND CONCLUSION**	45
	5.1 Summary.	45
	5.1.1 Seasonal Incidence of Pests on Cabbage.	45
	5.1.1.1 Aphid.	45
	5.1.1.2 Diamondback moth.	45
	5.1.1.3 *Spodoptera litura.*	45
	5.1.2 Efficacy of Different Modules Against Pests Infesting Cabbage.	45
	5.1.2.1 Aphid.	45
	5.1.2.2 Diamondback moth.	46
	5.1.2.3 Tobacco caterpiller.	46
	5.1.3 Effect of Different Modules on Natural Enemies of Cabbage.	46
	5.1.3.1 Coccinellid beetle.	46
	5.2 Conclusion.	46
6	**LITERATURE CITED**	49
7	**VITAE**	59
8	**APPENDICES**	

LIST OF TABLES

Table No.	Description	Page No.
1	Module detail for pest complex of cabbage.	24
2	Details of insecticidal treatments for pests on cabbage.	25
3	Seasonal incidence of pests infesting cabbage during *Rabi*: 2016 – 2017	30
4	Correlation between pests of cabbage. Incidence with weather parameters.	31
5	Efficacy of different modules on aphid (*B. brassicae)* of cabbage.	33
6	Efficacy of different modules against diamondback moth (*P. xylostella)* of cabbage.	36
7	Efficacy of different modules against *S. litura of* cabbage.	39
8	Effect of different modules on coccinellids population in cabbage.	42
9	Cost Benefit ratio of module application for pests of cabbage.	44

LIST OF FIGURES

Table No.	Description	Page No.
1	Layout of research experiment.	23
2	Seasonal incidence of pests infesting cabbage during *Rabi*: 2016 – 2017	30-31
3	Correlation between abiotic factors and pests of cabbage during *Rabi* 2016.	32-33
4	Efficacy of different modules on aphid (*B. brassicae)* of cabbage.	34-35
5	Efficacy of different modules against diamondback moth (*P. xylostella)* of cabbage.	36-37
6	Efficacy of different modules against *S. litura of* cabbage.	40-41
7	Effect of different modules on Coccinellids population in cabbage.	42-43

LIST OF PLATES

Table No.	Description	Page No.
1	Overall View of Experimental Plot.	22-23
2	Cabbage Aphid (*B. brassicae)* Infesting cabbage.	26-27
3	Larvae of (*P. xylostella)* Infesting cabbage.	26-27
4	Larvae of *S. litua* Infesting cabbage.	26-27
5	Coccinellid Beetle.	26-27

LIST OF ABBREVIATIONS AND SYMBOLS

a. i.	:	Active Ingradient
Bt.	:	*Bacillus thuringiensis*
C.D.	:	Critical Difference
^{o}C	:	Degree Celcius
cm	:	Centimeter
C. V.	:	Coefficient of Varience
cv.	:	Cultivar
DAP	:	Days After Planting
DAT	:	Days After Transplanting
DBM	:	Diamondback Moth
EC	:	Emulsifiable Concentrate
et al.	:	and others
etc.	:	Etcetera
Fig.	:	Figure
g	:	Gram
G	:	Granule
h	:	Hour
ha	:	Hectare
i.e.	:	That is
ICBR	:	Incremental cost benefit ratio
IPM	:	Integrated Pest Management
IU	:	International Unit
L	:	Liter
LC	:	Lethal concentration
kg	:	Kilogram
km	:	Kilometer
Max	:	Maximum
mg	:	Milligram

Min.	:	Minimum
ml	:	Milliliter
MSW	:	Meteorological Standard Week
MT	:	Metric Ton
M.W.	:	Meteorological Week
No.	:	Number
nos.	:	Numbers
NSE	:	Neem Seed Extract
NSKE	:	Neem Seed Kernel Extract
NSKP	:	Neem Seed Kernel Powder
ppm	:	Patrs per million
q	:	Quintal
RH	:	Relative Humidity
Rs	:	Rupees
SC	:	Soluble Concentrate
SG	:	Soluble Granule
SL	:	Soluble Liquid
S*l*NPV	:	*Spodoptera litura* Nuclear Polyhedral Virus
SP	:	Soluble Powder
SW	:	Standard Week
t	:	Ton
V	:	Volume
Var.	:	Variety
Viz	:	Namely
%	:	Per cent
S.E.	:	Standard Error
EDC	:	Emulsifiable Dispersible Concentrate
WG	:	Wettable Granule
WSC	:	Water Soluble Concentrate

WP	:	Wettable Powder
/	:	Per
@	:	At the rate of
<	:	Less than
>	:	Greater than

ABSTRACT

EFFICACY OF DIFFERENT MODULES AGAINST PEST COMPLEX OF CABBAGE

by

Mr. Mali Audumber Sumant

(Reg. No. K-16/165)

A candidate for the Degree of

MASTER OF SCIENCE (AGRICULTURE)
In
AGRICULTURAL ENTOMOLOGY
Department of Agricultural Entomology,
College of Agriculture, Kolhapur,
Mahatma Phule Krishi Vidyapeeth, Rahuri-413 722

2018

Research guide	:	Dr. A. S. Bagde
Department	:	Agricultural Entomology

Field experiment entitled "Efficacy of different modules against pest complex of cabbage'' was conducted during *Rabi* season of 2016-17 with nine modules, replicated thrice, in the 'Randomized Block Design' with gross plot size 3.00 m x 2.00 m and net plot size 2.40 m x 1.10 m at the farm of Horticulture section, College of Agriculture, Kolhapur (Maharashtra) with the objectives *viz.*, to study the seasonal incidence of pests infesting cabbage and to evaluate the efficacy of different modules against them.

The modules comprised for pests were module M1 (Soil application of phorate 10 G @ 15 kg ha^{-1} + Erecting sticky traps + *Lecanicillium lecanni* @ 6g lit.$^{-1}$ + *Beauveria bassiana* @ 6g lit.$^{-1}$ + pyriproxifen 10 EC @ 2ml lit.$^{-1}$), module M2 (Dipping of seedling in thiamethoxam 25 WG @ 7 ml lit.$^{-1}$ + Pheromone traps 5 ha^{-1} + NSE 5% @ 5 ml lit.$^{-1}$ + *Metarhizium anisopliae* @ 6 g lit.$^{-1}$ + indoxacarb 14.5 EC @ 0.5 ml lit.$^{-1}$), module M3 (Dipping of seedling in imidachloprid 17.8 SL @ 1ml lit.$^{-1}$ + *Lecanicillium lecanni* @ 6 g lit.$^{-1}$ + *Beauveria bassiana* @ 6 g lit.$^{-1}$ + NSE 5 % @ 5 ml lit^{-1}. + emamectin benzoate 5 SG @ 0.30 gm lit.$^{-1}$), module M4 (Soil application of carbofuron 3 CG @ 50 kg ha^{-1} + Erecting sticky traps + *B. thuringiensis* @ 1 g lit.$^{-1}$ + *Metarhizium anisopliae* @ 6 g lit.$^{-1}$ + chlorantraniliprole 18.5 SC @ 0.30 ml lit.$^{-1}$), module M5 (Dipping of seedling in thiamethoxam 25 WG @ 1gm lit.$^{-1}$ + Mustard (20:1) + *Lecanicillium lecanni* @ 6g lit.$^{-1}$ + NSE 5% @ 5ml lit.$^{-1}$ + cartap hydrochloride 50 SP @ 1gm lit.$^{-1}$), module M6 (Dipping of seedling in acetamiprid 20 SC @ 7 ml lit.$^{-1}$ + Pheromone traps 5 ha^{-1} +*Metarhizium anisopliae* 6 @ g lit.$^{-1}$ + chorfluazuron 5 EC @ 0.75 ml lit.$^{-1}$ + cypermethrin 25 EC @ 0.5 ml lit.$^{-1}$), module M7 (Soil application of phorate 10 G @ 15 kg ha^{-1} + NSE 5% @ 5 ml lit.$^{-1}$ + diflubenzuron 25 WP @ 0.10 gm lit.$^{-1}$ + fipronil 5 SC @ 1.5 ml lit.$^{-1}$ + lamda cyhalothrin 5 EC @ 2 ml lit.$^{-1}$), module M8 (Soil application of *Trichoderma viridi* @ 5

kg ha^{-1} + Pheromone traps 5 ha^{-1} + NSE 5% @ 5 ml lit.$^{-1}$ + *Metarhizium anisopliae* 6 @ g lit.$^{-1}$ + *Beauveria bassiana* @ 6 g lit.$^{-1}$), and untreated control.

The study revealed that low incidence of Diamondback moth and *Spodoptera litura* was observed as compared to incidence of aphid. The incidence of aphid was negatively nonsignificant with maximum temperature (-0.635), and positively significant with relative humidity (0.324). Diamondback moth population was positively significant with maximum temperature (0.057), and relative humidity (0.259). *S. litura* population was negatively nonsignificant with maximum temperature (-0.296) and positively significant with relative humidity (0.745).

The module M7 (3.54 aphids plant-^{1}) was found most superior in reducing population aphid at 30, 45, 60 and 75 days after planting. The next best module M3 (4.87 aphids plant-^{1}) and M2 (5.28 aphids plant-^{1}).

The module M7 (0.88 larvae plant-^{1}) was found most superior in reducing population of DBM at 45, 60 and 75 days after planting. The next best module were M2 (1.16 larvae plant-^{1}) and M3 (1.37 larvae plant-^{1}).

As regards with *S. litura*, the module M7 (1.41 larvae plant-^{1}) was most effective at 30, 45, 60 and 75 days after planting. The next best modules M2 (1.04 larvae plant-^{1}) and M3 (1.05 larvae plant-^{1}).

The module M8 showed highest average number of coccinellid population i.e. 1.85 beetles plant-^{1}, followed by module M2 (1.67 beetles plant-^{1}) and M5 (1.61 beetles plant-^{1}).

Considering from the above, module M3 for aphid, and module M7 for DBM and *S. litura* were found to be the most effective module for the management of pests of cabbage.

The module M7 showed maximum B:C ratio (5.64) followed by module M2 (5.44). While regarding ICBR ratio, module M5 showed maximum (67.44) followed by module M2 (48.83) for the pests of cabbage.

Mali A. S. 1-58

INTRODUCTION

The word "Cabbage" is derived from the French word Cobache, meaning head. The cabbage belongs to the family Cruciferae, genus *Brassica,* and species *oleracea* and variety *capitata.* It is one of the oldest biennial vegetable cole crops cultivated throughout India. It is also grown in kitchen gardens and truck gardens. Cole vegetables grown mostly in winter season occupy an important position in meeting the dietary requirements of most of the people all over the world. Among the winter vegetables cabbage, *Brassica oleracea var. capitata* L. is a popular and extensively cultivated crop because of its nutritional and economical values.

Cabbage is one of the most widely cultivated vegetables of the temperate zone. In world, the area under cabbage cultivation is around 24.7 lakh ha. with 717.8 lakh MT production and average yield of 29.06 MT/ha (Anonymous 2017). In India, the area under cabbage cultivation is around 4.07 lakh ha. with 89.71 lakh MT production and average yield of 22 MT/ha during 2016-17 (Anonymous 2017). In Maharashtra, the area under cabbage cultivation is around 89.2 thousand ha with 189.31 thousand MT production and average yield of 22.1 MT/ha during 2016-17 (Anonymous 2017).

Cabbage is rich in mineral contents and vitamins. It is a rich source of vitamin A and C and it contain mineral like Calcium, Sodium, Potassium, Phosphorus and Iron. Cole crops are used against gouts, diarrhoea, colic trouble, deafness and headache. The leaves are used to cure wounds and ulcers. Cabbage is mostly used as culinary and dietic articles, salad, pickles, boiled vegetable and can also be used for feeding livestock. Cabbage juice is said to be remedy against poisonous mushrooms.

One of the major constraints of not attaining higher yields of crucifers is the damage caused by insect pests those, which attack at various stages of growth to the crop (Bhavani *et al*.2009). As compared to other countries the yield is very low and the losses in the yield have been reported to the extent of 57 to 97 per cent due to insect pest alone (Prasad, 1963).

The predominant pest species attacking the crops are Diamondback moth, (*Plutella xylostella* Linn.), Cabbage aphid, (*Brevicoryne brassicae* Linn.), Cabbage borer, (*Hellula undalis* Fab.), and Tobacco caterpillar, (*Spodoptera litura* Fab.).

Among the pest complex of cabbage, diamondback moth (DBM), *P. xylostella* is the most destructive and dreaded pest. Fletcher (1914) recorded this pest for the first time in India on cruciferous vegetables and perusal of literature revealed that the pest is distributed all over India. Several crores of rupees are lost due to direct crop loss. Further, farmers spend large amount of money towards insecticides. Krishna Kumar *et al*., 1983 reported 52 per cent loss in marketable yield of cabbage due to the attack of *P. xylostella*.

The *S. litura* (Fab.) is one of the most important insect pest of agricultural crops in the Asian tropics. This species is widely distributed throughout tropical and temperate Asia, Australia and the Pacific Island (Feakin, 1973; Kranz *et al*., 1977). It is polyphagous pest reported on more than 120 host plants belonging to 44 families (Pogue, 2003). The major host plants include tobacco, cotton, groundnut, castor, chilli, potato, soybean, cauliflower, cabbage, tomato, beans and sunflower. It is next to *Helicoverpa armigera* in terms of economic importance at national level.

The aphids, due to their sucking propensities devitalise the plant tissues leading to yield reduction and their presence reduce the quality of cabbage heads. The young caterpillars of diamondback moth feed by scraping epidermal leaf tissues, producing typical whitish patches and advanced stage larvae bite holes in the leaves. It causes retardation of growth resulting in under sized cabbage heads.

Since cabbage is a highly remunerative vegetable crop, intensive plant protection measures involving use of a number of insecticides was common practice. In spite of large scale and repeated application of insecticide, the pest has been found to occur in severe form in all cabbage growing areas. In addition to the development of resistance in pests, indiscriminate and injudicious use of pesticides has grossly poisoned almost each component of the biosphere, caused resurgence of pests and reduction of natural enemies in ago-ecosystems allowing rapid rebound of target and minor pests. In the last few years *P. xylostella* has been reported to have expressed resistance to conventional insecticides including organophosphates and pyrethrins (Tabashnik and Cushing 1987; Magaro and Edelson, l992), Carbamates (Sun *et al*., 1978) Synthetic pyrethriods (Liu *et al*., 1981 and l982). Unfortunately, the *S. litura* has developed resistance to many insecticides, including the new chemistry insecticides lufenuron (Sudhakaran, 2002). Field strain of *S. litura* which showed resistance to almost all classes of insecticides have been reported from different parts of the world (Armes *et al*., 1997; Kranthi *et al*., 2002 and Ahmad *et al*., 2007). The populations of many pests including *S. litura* have developed resistance to many commercially available pesticides (Ramakrishna *et al*., 1984; Rame Gowda, 1999). So, there is need to test the efficacy of chemical molecules with higher insecticidal property, lower mammalian toxicity and lower dosage application to monitor the resistance levels.

Hence the knowledge of seasonal incidence of insect pests at different growth stages of cabbage crop will be helpful in evolving proper management schedule for effective control of insect pests. The information on seasonal incidence was however, generated by many workers (Sachan and Srivastava, 1972, Sharma, 2004, Shukla and Kumar, 2004 and Wagle *et al*., 2005) in different regions of India. Further climatic conditions were also changed frequently. Hence, the investigation on seasonal incidence of major insect pests of cabbage and their natural enemies in relation to weather parameters was undertaken, which can effectively be utilized in formulating pest management programme.

Conventional insecticides continue to be one of the most powerful weapons available for the control of pests, but their wide scale and indiscriminate application creates problems like, development of resistance and resurgence of pests; besides, leaving excessive residue on edible portions (Tandon and Bhalla, 1982, Lal and Meena, 2001, Ram *et al*., 2001 and Patel *et al*., 2005). Consequently, the use of eco-friendly materials such as botanicals, biopesticides, insect growth regulators and some newer molecules, emerged as a superior alternative to the synthetic insecticides. Moreover, these were also reported to be compatible with other pest control measures to solve the pest problems. Keeping these view in mind, the investigations were undertaken to test the bio-efficacy of newer insecticides, chitin inhibitors, neem products and biopesticides, we made some IPM modules i.e. sequential application of insecticides against major insect pests of cabbage.

So there is need to develop different modules against pest which could feasible and effective for pest management of cabbage. So the research work was taken with following objectives.

1) Seasonal incidence of pests infesting cabbage.
2) To study the efficacy of different modules against cabbage pests.
3) To study the effect of different modules on natural enemies.

2. Review of Literature

The available literature indicated that not much attention has been paid on the management of major insect pests of cabbage through cultural practices, bio-pesticides and IPM modules in maharashtra. However, an attempt has been made to review some of the available and pertinent literature. For the sake of convenience, the entire review of the work done has been presented in the following heads:

2.1 Seasonal Incidence of Pests on Cabbage.

2.1.1 Aphid

Patidar and Dadheech (2000) observed that aphid, *L. erysimi* appeared in the last week of November on cabbage with its peak in second week of January.

Malik *et al.*, (2000) reported that the population of cauliflower aphid, *B. brassicae* fluctuated from 51^{st} metrological week to 4^{th} meteorological week. The correlation between aphid population and maximum-minimum temperatures were negative and with morning relative humidity it was positive.

Nayak *et al*., (2001) studied the seasonal abundance of the aphid, *L. erysimi* on different cruciferous crops at weekly intervals from the first week of December to second week of February. The population of aphid $plant^{-1}$ was lowest (3.51) on turnip and highest (6.08) on cabbage. The maximum aphid population was recorded in the second week of January, i.e., 42.95, 22.95, 22.30, 17.35, 16.32 and 11.72 aphids $plant^{-1}$, on Indian mustard, cabbage, cauliflower, knoll-khol, radish and turnip, respectively, thereafter, the aphid number declined. Overall, the mean aphid population during the season was highest (10.59) on radish and lowest (6.97) on turnip.

Badjena and Mandal (2005) reported that the aphids made their appearance in the second week of November, gradually increased in number and reached the peak (216.3 aphids/3 leaves) in the fourth week of January.

Rao and Lal (2005) studied the seasonal incidence of mustard aphid, *L. erysimi* and diamondback moth, *P. xylostella* on cabbage a Division of Entomology IARI, New Delhi, during 1997-98 and 1998-99. The peak population of *L. erysimi* was observed during fourth week of January, while that of *P. xylostella* was recorded in the first and second weeks of February during both the years. Maximum and minimum temperatures and relative humidity did not showed any significant correlation with the incidence of *L erysimi* whereas, maximum temperature showed a positive correlation with the population build up of *P. xylostella.*

Singh *et al*., (2010) observed the aphid during 2^{nd} standard week with intensity of 4.59 aphids $leaf^{-1}$ on cauliflower and 4.49 aphids $leaf^{-1}$ on cabbage, when maximum and minimum temperature were 22.57 and 9.47°C with relative humidity (morning and evening) 94.0 and 56.42 per cent. The population of aphids reached its peak of 78.87 aphids leaf^{-1} on cauliflower and 80.96 aphids leaf^{-1} on cabbage during 5th standard week at maximum and minimum temperature 24.32 and 7.96°C along with relative humidity (morning and evening) 89.0 and 40.14 per cent, respectively. The correlation coefficient analysis of aphid population on cauliflower and cabbage with prevailing environmental conditions indicated a negative relationship with maximum, minimum and mean temperature evening and average relative humidity, wind velocity evaporation and age of crop were conducive with significant positive correlation.

Patra *et al*., (2013) observed that cabbage aphid reached its peak on 9th February (14.17 aphids/inch^2 leaf) and 16th February (11.03 aphids/inch^2 leaf) of 2011-12 and 2012- 13, respectively. Aphid population was enhanced by maximum temperature.

Shah *et al*., (2013) recorded seasonal dynamics of insect pests and their natural enemies in cabbage and cauliflower ecosystems in Balochistan (Pakistan). *M. persicae* and *B. brassicae* on cabbage had a peak at the end of July and October, respectively.

Aggrawal *et al*., (2014) observed that the incidence of cabbage aphid varied from 20 to 410/3 leaves plant^{-1}. The incidence was highest during 12th SW. These insects showed significantly negative correlation with maximum relative humidity while non-significant positive correlation was observed with maximum and minimum temperature.

Raja *et al*., (2014) revealed that the population of *B. brassicae* was positively influenced by temperature (maximum and minimum) and relative humidity and negatively influenced by rainfall, wind speed in Theni. Maximum and minimum temperature and wind speed were positively influenced in *B. brassicae* populations in Hosur. The population was positively influenced by maximum temperature and minimum temperature, rainfall and wind speed in Ooty.

Mishra and Singh (2015) carried out studies on the seasonal incidence of some insect pests associated with the cabbage during December 2010 - April 2011. These crops were severely attacked by the different insect pests, mainly cabbage aphid, *B. brassicae* (L.), diamondback moth, *P. xylostella* and their natural enemies. The cabbage aphid, *B. brassicae* (L.) appeared on the second fortnight of January and gradually increased and reached a peak level of 41.82 aphids leaf^{-1} during the first fortnight of March. It was found that aphid population increased with increasing maximum and minimum temperature, relative humidity, rainfall and sunshine hours but decreased with increasing wind velocity, whereas predators were very much seasonal and their numerical abundance coincide with the pest.

Patel *et al*., (2015) conducted an experiment to find out seasonal appearance of diamond back moth (DBM) and aphid in broccoli. The incidence of aphid on broccoli started from early December that reached its peak at end of February. The temperature (max.) around 30^0C and relative humidity (max.) 90 to 95 % favoured its multiplication.

Dewanda and Khan (2016) conducted studies on the incidence and population dynamics of major insect pests and their natural enemies on cauliflower during August 2014 – November 2014 and January 2015 – April 2015. Severity of aphid incidence was found to be higher in winter season as compared to monsoon season.

Shalini *et al*., (2016) reported that the maximum population of *B. brassicae* was recorded 348 aphids plant^{-1} in 47th SW of year 2013-14 when the temperature range were 10.7- 25.1^0C and RH 38-78% and 332 aphids plant^{-1} in 9th SW in year 2014-15 when the temperature ranged and RH observed 10.1-25.8^0C and RH 40- 80%, respectively. The population of *B. brassicae* had significant positive influence of maximum temperature, minimum temperature and wind speed while RH morning and RH evening showed negative influence on them. Rainfall did not show any influence on aphid populations during both observed seasons 2013-2015.

2.1.2 Diamondback Moth

Meena and Sharma (2003) reported that *P. xylostella* started attacking the cabbage crop initially in the last week of November (1.00 larva plant^{-1}) and attained its peak (8.06 larvae plant^{-1}) in the fourth week of January.

Shukla and Kumar (2004) reported that in Rajasthan, the diamondback moth appeared in the beginning of September and the population reached it is peak by the end of November followed by a declined phase from the last week of December to the last week of January, but this difference may probably be due to the difference in transplanting time and the prevailing climatic conditions of the region.

Ayalew *et al*., (2006) reported that rainfall and maximum temperature significantly influenced DBM numbers and parasitoid activity.

Campos *et al*., (2006) suggested that seasonal growth in tropical population of *P. xylostella* may be largely dependent on annual pattern of atmospheric circulation.

Goud *et al*., (2006) studied the seasonal incidence of diamondback moth, *P. xylostella* on cabbage during Rabi 2003-04 at Rajendranagar, Hyderabad. They observed that *P. xylostella* appeared in third week of November (46th standard week) with mean population of 0.38 larva plant^{-1} and peak larval incidence continued till the end of first week of February (5th standard week). Thereafter, there was a sudden decline and population of 0.4 and 0.1 larvae plant^{-1} were recording during second and third week of February (6th and 7th standard week), respectively.

Singh *et al*., (2010) observed the incidence of DBM on cauliflower and cabbage started in the 3rd standard week with 0.20 and 0.10 larvae head^{-1}, respectively, when maximum and minimum temperature were 24.31 and 10.30°C, relative humidity (morning and evening) 89.0 and 46.0 per cent. Its population increased gradually on respective crops upto 5.67 and 7.67 larvae head^{-1} in end of February and had significant positive correlation with maximum temperature, average temperature, wind velocity, evaporation rate and age of crop, while it had significant negative correlation with relative humidity.

Tufail and Ansari (2010) reported that when temperature ranged from 25.20 to 35.00C and humidity 64.2 to 80.8 per cent significantly increase in population of *P. xylostella* larvae from 8.93 to 22.4 larvae plant^{-1}.

Venkateswarlu *et al*., (2011) reported that the significant positive correlation of diamondback moth population with the maximum and minimum temperatures.

Bana *et al.*, (2012) reported that, the cabbage crop was found to be infested by two major pests i.e., aphid (A*phis erysimi* (Kalt.)) and diamondback moth. The infestation of aphid started in the last week of November and reached peak in third and fourth week of January during *Rabi* 2008-09 and 2009-10, respectively. Whereas, the infestation of diamondback moth started from the third week of November and reached peak in the first week of January. The maximum and minimum temperatures showed significant negative correlation with aphid and larval population of diamondback moth, whereas, relative humidity and sunshine hours showed non-significant correlation.

Meena and Singh (2012) reported that the minimum temperature showed positive and significant relation with the larval population of diamondback moth**.**

2.1.3 Tobacco Caterpillar

Monobrullah *et al*., (2007) conducted an experiment to determine the seasonal Incidence of *S. litura* on cauliflower (cv. selection-4) and tomato (cv. Pusa Ruby) using trap catches. The earliest moth catch was obtained during the 6th standard week, immediately after appearance of overwinterd moths a gradual increase was observed up to the 19th standard week with the peak activity of 11.43 moths trap^{-1} week^{-1} corresponding to the maximum temperature of 39.5°C and minimum temperature of 20.7°C. Moth activity started declining after the 42nd standard week and at the 48th standard week ceased completely. The adult population fluctuated between 20th and 43rd standard week. Thereafter, a sharp decline was observed and no moth could be trapped from 49th standard week onwards up to 5th standard week. The larval activity of *S. litura* on tomato was recorded from the 14th standard week but no larvae were found during that period on tomato. The larvae started appearing from the 17th standard week. A gradual increase in the larval population was recorded until the 25th standard week. Larval population declined gradually after the 27th standard week at the time of crop harvest. The peak population also observed during the 25th standard week. However, in the case of cauliflower the larvae could be seen from 36th standard week onwards in a fluctuating manner and the larval populatation attained its peak during the 43rd standard week. Thereafter it declined gradually after 46th standard week and no larvae were recorded at 49th standard week and onwards until crop harvest. Among the meteorological variables correlated with pest activity, only temperature showed significant influence on the moth catch and larval population of cauliflower. The number of moths trap^{-1} week^{-1} exhibited significant positive correlation with maximum and minimum temperature, whereas the larval population on cauliflower showed positive correlation with mean minimum temperature.

Kumar *et al.,* (2007) conducted a study in Meerut, Uttar Pradesh, India, in the Spring season of 2006 to determine the population intensity of insect pest on cabbage cv. Golden Acre. Sampling of various insect pest was done at weekly intervals from the date of transplanting until harvest. *P. xylostella* appeared from the 3rd week of January and reached its maximum (8.2 larvae plant^{-1}) on the first week of March when the temperature and relative humidity were 12.4-29.4°C and 29.8-79.4%, respectively. The population was positively correlated with the mean temperature but negatively correlated with relative humidity. *S. litura* population was first recorded on the last week of January in late season cabbage. Thereafter, it gradually reached its maximum level (4.2 larvae plant^{-1}). The population was positively correlated with the mean temperature but negatively correlated with relative humidity.

Selvaraj *et al*., (2010) conducted an experiment to ascertain the effect of ecological factors on incidence and development of *S. litura* at five different date of sowing on three varieties of cotton. Sowing dates commenced on 1st February and went up to 1st March with an interval of seven days. The *S. litura* population was built up progressively from April (1st week) and acquired its peak in the month of May (1st week). Maximum *S. litura* (25.46%) was built up at temperature ranges from 26.0°C to 35.1°C, relative humidity ranges from 89 and 62 per cent, zero rainfall, wind velocity 62 km hr^{-1}., total sunshine hours (64.6 hrs. week^{-1}), evaporation (53.20 mm) and dewfall (O.161 mm). This built up *S. litura* showed a positive correlation with relative humidity, determination of the effects of different weather factors on population and incidence of *S. litura* in cotton is essential for effective pest management. This study helps not only in forecasting outbreaks of *S. litura* but also in formulating effective pest management strategies.

Manoharan *et al*., (2010) assessed the seasonal incidence of Sugar beet pests and natural enemies in Coimbatore during 2006-2007 and the predominant pests were *Spoladea recurvalis* (F.). *S. litura* (F.) and *Tetranychus urticae* Koch. *S. recurvalis* incidence was noticed from August 2006 to February 2007 and the maximum larval population was observed during the second fortnight of October 2006. Peak incidence of *S. litura* occurred during the first fortnight of November (3.9 larvae/3 leaves plant^{-1}).

Satyanarayana, *et al*., (2010) studied on incidence and management of *S. litura* (Fab.) on post rainy season groundnut reported that incidence of *S. litura* in terms of larval population showed no significant relationship with maximum temperature, relative humidity, wind speed, spiders and coccinellid predatory beetles, but significant relationship with minimum temperature. The result of chemical control trials indicated that emamectin benzoate 0.00725% + were the most effective treatment followed by indoxacarb 0.0145% and indoxacarb 0.00725% + novaluron 0.005% in reducing the larval population of *S. litura*.

Gadad *et al*., (2013) studied seasonal incidence of *S. litura* (F.) in summer groundnut crop. Observed Spodoptera incidence started from 6th meteorological standard week (MSW) and reached its peak during the 11th MSW with 19.50 per cent leaf damage and decline thereafter.

Radhika (2013) stated that the correlation analysis with weather parameters revealed that, max temp. and min temp. have significant positive correlation with *S. litura* trap catch and the RH-I showed significant negative correlation.

2.2 Different Integrated Pest Management Modules for Control Pests of Cabbage

2.2.1 Pheromone Traps

Walker *et al*., (2003) showed that increases in moth trap catches predicted increases in larval infestations in three of four commercial crops in spring by 2-3 weeks and gave 2 weeks warning in four of five summer crops.

Xiang-Ping Wang *et al*., (2004) studied the lures in plastic basin traps with water containing detergent (5%) had the most captures. Both Chinese lures and Japanese lures could effectively attract DBM male. The captures of the two types of lures were not significantly different. Mass trapping of DBM with Chinese lures in plastic basin traps in cabbage fields could decrease the population densities of DBM.

Dai *et al*., (2008) resulted that traps baited with pheromone (Z)-3-hexenyl acetate (Z)-3-hexen-1-ol allyl isothiocyanate have a stronger attraction to both male and female DBM and may provide more effective tools for monitoring and controlling this insect pest.

2.2.2 Entomopathogenic Fungus

Thuy *et al*., (2001) studied that direct conidial application *B. bassiana* at the dose of $9x10^8$ conidia ml^{-1} gave effective control of DBM 8 days after treatment and recorded 81.25 per cent reduction of DBM.

Shivankar and Rao (2003) reported that mortality rate increased with increase in time period viz., 24, 48 and 72h.

Valda *et al*., (2003) reported that five isolates of the entomopathogenic fungi *B. bassiana* and *M. anisopliae* tested against DBM caused larval mortality ranging from 26%- 96%.

Furlong (2004) reported that *B. bassiana* applied at the rate of $3x10^6$ conidia ml^{-1} gives 100% DBM mortality after 3- 7 days.

Kirk *et al*., (2004) suggested that *M. anisopliae* isolated from DBM collected in eastern Romania was also very virulent.

According to SP-IPM, (2006) *B. bassiana* and *M. anisopliae* are ubiquitous in nature, specific to target pests, persist in the environment and easy to mass produce and are increasingly gaining attention as commercial microbial pesticides.

Thungrabeab and Tongma (2007) reported that *B. bassiana* Bb. 5335 and *M. anisopliae* Ma.7965 have the potential use as biological control agents against insect pests because they were relatively safe on non-target insects, such as natural enemies and beneficial soil insects.

Vanlaldiki *et al*., (2013) reported that *B. bassiana* provided significant effect in suppressing the larval population as compared with the untreated control.

Correa-Cuadros *et al*., (2014) reported that higher mortality was produced by *B. bassiana* Bb9205 (95.33%) in *P. xylostella* at a dose of $1x10^5$ con/cm^2.

2.2.3 Utilisation of Insecticides Against Pests of Cabbage.

2.2.3.1 *Bacillus thuringiensis* (Berliner):

Kandoria *et al*., (2000) studied the efficacy of different formulations of *B. thuringiensis* against diamondback moth, *P. xylostella* on cauliflower and found that Dipel 8 L @ 1.5 l ha-1 resulted in maximum mortality (72.42%) of *P. xylostella* after 10 days of treatment.

Rao *et al*., (2000) conducted a field experiment to control of cauliflower pests in Andhra Pradesh, India. The result revealed that creoyolite (2000, 6000 and 1000 ppm) alone or combination with *B. thuringiensis* var. *Kurstaki* or with chloropyriphos 0.03 or 0.06 per cent gave better control of *S. litura*, *P. xylostella* and *Crocidolomia binotalis* on cauliflower.

Birader and Dhanorkar (2001) evaluated efficacy of twelve insecticides against diamondback moth infesting cauliflower. All the insecticidal treatments and combinations were significantly superior over untreated control in controlling the DBM population. The treatment of *B. thuringiensis kurstaki* (Delfin) at 500 g ai ha^{-1}. Was most effective three days after each application and significantly superior over flufenoxuron (Cascade 80 gm ai ha^{-1}.) and cypermethrin (Ralo 60 gm ai ha^{-1}). However, *Bt*. was at par with the remaining treatments. Further, at seven and fourteen days after each application *Bt* + flufenoxuron, flufenoxuron alone and *Bt* were at par and performed well over the remaining treatments in reducing DBM population.

Pokharkar *et al*., (2002) determined the LC_{50} value and persistence of *B. thuringiensis* on cabbage leaves under field condition. The LC_{50} of the five formulations Delfin, Dipel, Halt, Biobit and Biolep ranged between 0.0100 and 0.0173 per cent and the differences were non-significant. All the formulations persisted on the leaves for at least 120 hours. These *Bt* formulations, thus, can provide high protection against DBM for at least five days and can be utilized as critical component of IPM.

Wo *et al*., (2002) reported that pakchoi cabbage (*Brassica pekenensis*) when spray with *B.t*. H 3136, omethoate or water gave better control of the two pests. *Bt* H 3136 resulted in 97.5 and 79.8 per cent mortality of *Pieris rapae* and *P. xylostella*, respectively, occurring 5 to 7 and 2 to 5 days after treatment.

Shukla and Kumar (2003) studied the efficacy of some newer eco-safe insecticide against diamondback moth on cabbage. Betacyfluthrin was found most effective. Among biopesticides, *B.t.k*. (1.25 kg ha^{-1}.) was most effective, but other biopesticides were less effective as compared to standard check endosulfan.

2.2.3.2 Neem based pesticides:

Chatterjee and Senapati (2000) reported the reduction in larval population with gradual increase in toxicity of azadirachtin and effects as 71.36 per cent reduction in larval population of *P. xylostella* after 14 DAS.

Javaid *et al*., (2000) tested the effectiveness of neem leaf and seed extracts for the control of *P. xylostella* on cabbage in field conditions compared with dimethoate + cypermethrin treatments. All the neem treatments recorded significantly higher yield of marketable heads of cabbage and significantly better control of the pest than the commonly used mixture of pyrethroids or the untreated control.

Krishnamoorthy and Kumar (2000) used neem seed kernel extract (NSKE), 4.0 per cent for managing insecticides resistant diamondback moth, *P. xylostella*. As an alternative of this, neem seed kernel powder extract (NSKP) 4.0 per cent was also evaluated and found effective against diamondback moth, *P. xylostella* and leaf webber, *C. binotalis.*

Manjunatha *et al.*, (2000) evaluated the efficacy of neem based pesticide, nivaar and other conventional pesticides against *P. xylostella* and aphid, *M. persicae* on cabbage. Treatments consisted of 0.2, 0.3 and 0.4 per cent nivaar, 0.1 per cent malathion, 0.05 per cent monocrotophos and water spray (control). Nivaar at all concentrations was superior over the control. It was at par with malathion and monocrotophos after the first and second spray and superior to both after the third spray. All Nivaar treatments reduced *P. xylostella* effectively and were at par with malathion and monocrotophos. Yields resulting from the Nivaar treatments were at par with those from malathion.

Reddy and Mohan (2001) carried out a field trial, to evaluate the efficacy of fortune aze (a neem based pesticides) and monocrotophos against diamond back moth *(P. xylostella* L.) infesting cauliflower. The results of the experiment revealed that application of fortune aze at all the concentrations effectively controlled larval population, leaf infestation of diamond back moth compared to control and most pronounced effect was observed at 10 ml litre^{-1}. It was also found that fortune aze @ 7.5 or 10 ml lit.$^{-1}$ was as effective as monocrotophos @ l.5 ml lit.$^{-1}$ in controlling diamondback moth.

Kamala *et al*., (2003) studied the efficacy of some biopesticides against diamondback moth on cabbage, with standard check (NSKE) and untreated control. Five sprays were given at ten days interval. Abamectin, NSKE and Spinosad gave highest number of marketable heads as well as yield, while Dipel and Neemazal were on par but superior to neem oil soap, pongania oil soap and control. *Bt* product Dipel, Neemazal, neem oil soap and pongania oil soap failed to give satisfactory results.

Patil *et al*., (2003) evaluated the efficacy of plant extracts and new insecticides against DBM on cabbage. Treatment of Azadirachtin, Carina (profenofos), Rocket (profenophos + cypermethrin) showed 100 per cent efficacy in the fourth spray at seven days after spraying.

Murthy *et al*., (2006) evaluated four commercial neem formulations viz., Soluneeem (0.15%), Econeem plus (0.3%), Vijayneem (0.3%), Neemark (0.6%), two plant extracts viz., leaf extracts of *Vitex negundo* and rhizome extracts of *Acorns calamus* (both at 10%), two new insecticide molecules viz., indoxacarb (0.0075%) and fipronil (0.01%) and a standard check, neem seed kernel extracts (NSKE 4%) for their efficacy against diamondback moth (DBM), *P. xylostella* on cabbage. Among the treatments, indoxacarb, fipronil and NSKE were found to be effective in reducing the DBM population and recorded significantly higher marketable cabbage heads followed by Soluneeem, Econeem plus, Vijayneem and Neemark.

Sewak *et al*., (2008) evaluated the efficacy of certain indigenous products along with three chemical insecticides and their combinations against the diamondback moth, *P. xylostella*. Amongst the indigenous products, the extract of NSKE (5%) was most effective in causing larval mortality (58.02%) which was at par with extract of chilli + garlic 5 per cent (54.31%). While, the chemical insecticide dichlorvos (0.05%) proved to be highly toxic (96.91%) which was at par with endosulfan 0.07 per cent (85.79%). Further, the efficacy of least effective indigenous products, viz., chilli 3 per cent, garlic 2 per cent and cow dung + cattle urine 10 per cent in combination with half dose of dichlorvos 0.25 per cent and endosulfan 0.035 per cent proved to be as effective as that of the chemical insecticides alone. Thus, the finding highlighted an eco-friendly approach for the management of notorious pest, diamondback moth.

Chauhan *et al*., (2014) conducted a study at Vegetable Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi on bio-efficacy of biopesticides i.e. NSKE 5% @ 3250 g a.i. ha^{-1} against diamondback moth (*P. xylostella* L.) on cauliflower crop during 2008-09 revealed that all the insecticide treatments were significantly superior over the control in term of higher yield and less infestation of diamondback moth.

Pritin Sontakke (2014) evaluated the *in vitro* toxicity and co-toxicity of different groups of microbial and botanicals pesticides on the field derived population of *P. xylostella* using leaf dip bioassay. Among microbial pesticides Lipel® (*Bacillus thuringiensis* sub sp. *kurstaki)* was found to be very effective than MVP II (Cry1Ac) and XenTari® (*Bacillus thuringiensis* subsp. *aizawai*). Anosom® (1% EC) was found to be most effective against *P. xylostella* among botanicals as evidenced from lowest LC_{50} value of only 0.1 ppm. Being a botanical pesticide, Anosom® (1% EC) could be used as a substitute to synthetic insecticides in integrated management of *P. xylostella*.

2.2.3.3 Insect growth regulators

Kadam *et al.,* (1995) determined that per cent larval mortality of *P. xylostella* ranged from 41.67 to 100.00, 66.66 to 100.00, 0.00 to 66.66 for first to fourth instars respectively as compared to 6.66, 0.00, 0.00 and 0.00 for the untreated control. Affected larvae failed to moults, turned black and displayed morphological deformities. It was concluded that diflubenzuron adversely affected larval growth and weight. The duration of each instar following treatments increased.

Somchoudhary *et al.,* (1996) tested the bioefficacy of cascade (flufenoxuron) 10 WDC against diamond back moth on cabbage. Cascade was highly effective against the pest at 40 and 80 g a.i. ha^{-1}. Its performance was superior to dimlin (diflubenzuron) in suppressing the pest infestation and in increasing the yield.

Lokare *et al.,* (1999) conducted laboratory studies on the relative toxicity of lufenuron 5 SC and diflubenzuron 25 WP against the larvae of diamond back moth *P. xylostella.* Studies revealed that both the insect growth regulators were highly effective against the pest. The treatment with lufenuron 5 SC recorded the LC_{50} value 0.0075 per cent with the maximum mortality of 94.74 per cent whereas, diflubenzuron 25 WP recorded the LC_{50}, 0.0163 per cent larval mortality.

2.2.3.4 Chemical control

Joshi and Jhala (2000) evaluated nine synthetic insecticides (dichlorovos @ 0.05%, endosulfan @ 0.07%, monocrotophos @ 0.04%, triazophos @ 0.05%, quinalphos @ 0.05%, chloropyrifos @ 0.04%, Spark @ 0.036%; deltamethrin @ 0.0014% and cartap hydrochloride @ 0.05%), six neem formulations and thuricide *(Btk)* against diamond back moth) *P. xylostella* in cress *(Lepidium satiuum* L.). Cartap hydrochloride, Spark, deltamethrin and *Btk* recorded significantly lower, larval population and per cent infested capsules as well as high seed yield.

Lal and Meena (2001) investigated the efficacy of different insecticides against *P. xylostella* on cabbage. The treatments comprised beta-cyfluthrin (0.0125%), cartap hydrochloride (0.05%), endosulfan (0.07%), imidacloprid (0.01%), ethofenprox (0.01%), lambda cyhalothrin (0.01%) and an untreated control. The efficacy of the insecticides in a descending order was cartap hydrochloride > lambda-cyhalothrin > betacyfluthrin> etofenprox > endosulfan > imidacloprid.

Ram *et al*., (2001) evaluated the comparative efficacy of some insecticides against diamondback moth on cabbage. Quinalphos followed by endosulfan, biobit, biolep, cypermethrin and fenvalerate were found most effective in controlling the diamondback moth, whereas, cartap hydrochloride, NSKE and neem oil were found less effective.

Sreekant and Babu (2001) tested the efficacy of imidacloprid 20 EC (0.08 and 0.2%), silafluofen 20 EC (0.02%), deltamethrin + triazophos 36EC (0.075%), profenofos 50 EC (0.05%), diafenthiuron 50 WP (0.025%), dichlorvos 76 EC (0.1%) and monocrotophos 36 WSC (0.05%) against aphid, *L. erysimi* on cabbage cultivar Golden Acre. Based on overall efficacy, imidacloprid was found to be the most effective, registered 99.06 per cent suppression of aphid population.

Pramanik and Chatterjee (2003) studied the efficacy of some new insecticides in the management of diamondback moth, *P. xylostella* on cabbage and found that spinosad (0.005%) was most effective on the basic of pest population plant^{-1} and increase in yield over untreated check. Average data analysis showed the order of efficacy of different insecticides was spinosad > *Bt* > abamectin > cartap hydrochloride > acetamiprid > novaluron.

Purwar and Yadav (2003) tested the efficacy of pesticides from different origin against tobacco caterpillar, *S. litura* (Fab.) on two cultivars of soybean crop, i.e. PK-1029 and PK-416. These included synthetic chemical insecticide, plant extract, animal origin, insect growth regulator and entomopathogenic fungi. The chitin inhibitor i.e. Dimilin (diflubenzuron), Entomopathogenic Fungi, *Beauveria bassiana* (Dispel) showed more effectiveness than botanicals.

Sannaveerappanavar *et al*., (2003) studied the efficacy of five new chemical insecticides against diamondback moth on cabbage. Five sprays were given at ten days interval. Novaluron, flufenoxuron and indoxcarb had significantly low population as compared to other. From second spray to fourth spray NSKE, novaluron and indoxcarb performed better as compared to fipronil. At the end of fifth spray NSKE and indoxacarb were superior followed by novaluron and flufenoxuron. They recommended that novaluron can be effectively rotated with NSKE for the management of diamondback moth.

Sakthi *et al*., (2003) evaluated bio-efficacy of new insecticides against diamondback moth, *P. xylostella*, lufenuron (Mateh 5 EC) @ 30 and 40 g a.i. ha^{-1} was found to be the most effective followed by *B. thuringiensis* (400 g ha^{-1}), while, cypermethrin and quinalphos were proved moderately effective.

Haruka oouchi (2005) reported that a device treated with an appropriate formulation of pyriproxyfen to contaminate both sexes of *P. xylostella* adults and their eggs would be superior to methods of targeting larvae in control operations.

Sharma (2004) tested the bio-efficacy of various insecticides against diamondback moth and reported that lufenuron (0.006%) was the most promising insecticide followed by cartap (0.05%) and *Btk* (0.01%), while, NSKE (5.0%) was proved less effective. Further, when insecticides applied at 10 days interval registered significantly higher per cent reduction in comparison to 15 days interval except cartap hydrochloride. Highest yield and net monetary return was also obtained with the treatment of lufenuron followed by cartap hydrochloride, while, minimum was with endosulfan. He suggested that lufenuron and cartap hydrochloride can be applied at much longer interval (15 days), owing to their higher efficacy at low doses, while, *B.t.k.* and NSKE be applied at shorter interval (10 days).

Patel *et al*., (2005) reported significant effectiveness of indoxacarb against larval population of diamondback moth on cabbage. Among the tested doses of indoxacarb, the highest dose (40 g a.i. ha^{-1}) was significantly effective in reducing the larval population of diamondback moth. Further, the second higher dose (30 g a.i.ha^{-1}) was found superior than methyl demeton (100 g a.i. ha^{-1}) but at par with monocrotophos (144 g a.i. ha^{-1}) and lower dose of indoxacarb (20 g a.i. ha^{-1}) was also found as effective as monocrotophos. The higher yield of cabbage heads (176.19 q ha^{-1}) was obtained in the treatment of indoxacarb at higher dose. The remaining two doses (20 and 30 g a.i. ha^{-1}) were at par with monocrotophos and methyl-o-demeton. Indoxacarb showed less adverse effect on the population of parasitoid, *Apanteles plutellae* (Kurdyumov).

Goud *et al*., (2006) determined the effect of chitin synthesis inhibitors alone and in combination with cartap hydrochloride (CH) against diamond moth, *P. xylostella* infesting cabbage. The treatments comprised, novaluron (0.01%), lufenuron (0.01%), flufenoxuron (0.005%), nuvaluron (0.005%) + CH (0.025%), lufenuron (0.005%) + CH (0.025%), flufenoxuron (0.005%) + CH (0.025%), neem (0.2%), CH (0.05%). Promising control of *P. xylostella* could be obtained with novaluron (0.005%) + CH (0.025%).

Ameta and Bunker (2007) evaluated the relative efficacy of different doses of UNI 001 (flubendiamide) 480 SC @ 25, 37.5 and 50 ml ha^{-1} along with indoxacarb 14.5 SC @ 167 ml ha^{-1} and spinosad 2.5 SC @ 750 ml ha^{-1} against *P. xylostella* on cabbage and found that flubendiamide, indoxacarb and spinosad were significantly superior to untreated control in reducing the larval population of diamondback moth. The marketable yield of cabbage recorded in flubendiamide (50 ml ha^{-1}) was significantly higher than rest of the treatments. It did not cause adverse effect on the population of natural enemies and phytotoxicity in cabbage.

Deivendran *et al*., (2007) evaluated the efficacy of new insecticides against *P. xylostella* on cauliflower, revealed that indoxacarb at 90 g a.i. ha^{-1} gave the highest mean larval mortality

(67.0%) followed by spinosad at 75 g a.i. ha^{-1} (62.0%), fipronil at 75 g a.i. ha^{-1} (65.0%), thiodicarb at 750 g a.i. ha^{-1} (57.0%), dichlorvos at 115 g a.i. ha^{-1} (44.0%), endosulfan at 350 g a.i. ha^{-1}, Nimbecidine at 75 g a.i. ha^{-1} (37.0%) and *Bt* at 1000 g ha^{-1} (14.0%) one day after the spray and all were significantly better than control. The overall order of efficacy recorded was: Indoxacarb > spinosad > fipronil > thiodicarb > *Bt* > dichlorvos > endosulfan > nimbecidine.

Kumar *et al*., (2007) evaluated the efficacy of indoxacarb 15 SC in different doses (20, 25 and 30 g a.i. ha^{-1}) against diamondback moth, *P. xylostella* on cabbage. Indoxacarb was found effective in all the doses followed by *Bt* (500 g a.i. ha^{-1}). However, indoxacarb @ 30 g a.i. ha^{-1} recorded lowest larval population. Comparing the larval population in control (7.76 and 5.40 larvae $plant^{-1}$) during 2000-01 to 2001-02, the treatments were found to be persistent upto 10 DAT. Relative diamondback moth population in indoxcarb (1.71, 1.50, 1.50 and 1.21, 0.96, 0.79 larvae $plant^{-1}$) and *Bt* (4.97 and 1.33 larvae $plant^{-1}$) after 10 DAT showed similar efficacy of these treatments.

Muthukumar *et al*., (2007) conducted field studies in New Delhi, India, during the 2005/06 and 2006/07 *rabi* seasons, to determine the efficacy of botanical pesticides and new insecticides against major insect pests and their effect on natural enemies in cauliflower. Higher mean per cent reduction over the control (PROC) was recorded against aphids (78.8 and 61.6 for imidacloprid at 20 g ai ha^{-1}), 80.8 and 58.5 (thiamethoxam at 75 g ai ha^{-1}) and 77.8 and 51.8 (cartap hydrochloride at 250 g ai ha^{-1}) after the first and second spraying, respectively, during 2005/06 and 80.8 and 68.2 for imidacloprid at 20 g ai ha^{-1}, 79.8 and 61.2 (thiamethoxam at 75 g ai ha^{-1}) and 78.5 and 50.9 (cartap hydrochloride at 250 g ai ha^{-1}) after the first and second spraying, respectively, during 2006-07.

Meena and Singh (2010) tested the efficacy of spinosad 45 SC (0.002%), indoxacarb 15 SC (0.01%), endosulfan 35 EC (0.07%), malathion 50 EC (0.05%), oxydemeton methyl 35 EC (0.025%), NSKE (30 g l^{-1}), *B. bassiana* (4 g l^{-1}), *B. thuringiensis* (2 ml l^{-1}) and azadirachtin (5 ml l^{-1}) against diamondback moth, *P. xylostella* on cabbage cultivar Golden Acre based on overall efficacy spinosad 45 SC proved to be most effective in reducing the larval population (2.99 larvae $plant^{-1}$) of *P. xylostella*. The highest yield was obtained from the treatment of spinosad (233.5 q ha^{-1}) followed by indoxacarb (226.8 q ha^{-1}) and *B. thuringiensis* (224.9 q ha^{-1}). The highest gross return (1, 16, 76 Rs ha^{-1}) and B:C ratio of (17.51) recorded from the treatment of spinosad.

Wensu Han *et al*., (2012) resulted that chlorantraniliprole is effective against *P. xylostella*. The sublethal concentrations of chlorantraniliprole may reduce the population growth of *P. xylostella* by decreasing its survival and reproduction, and by delaying its development.

Dotasara *et al*., (2017) studied that the efficacy of different insecticides against the diamondback moth (DBM) on cauliflower at CSAUA&T, Kanpur. Among the various insecticides evaluated against the DBM, spinosad (45 SC @ 0.5ml lit.$^{-1}$) treated cauliflower plot showed highest per cent reduction over control (89.97%) with less number of larvae (0.58 larvae plant^{-1}). The larval count and per cent reduction over control in the different treated plots ranged from 0.58 to 3.94 and 89.97 to 41.37 respectively as against 8.79 numbers of larvae in untreated control. Flubendiamide 48 SC @ 0.3 ml lit.$^{-1}$ and chlorantriniliprole 18.5 SC @ 0.3 g lit.$^{-1}$ were next effective pesticides to reduce the pest incidence significantly. All the treatments were also observed to be significantly superior over control.

2.3 Natural Enemies

Srivastava *et al*., (1978) reported that the lady bird beetle, *Coccinella septempunctata* L. predated on all the species of aphid.

Chandra and Kushwaha (1987) reported that *C. septempunctata* appeared within two to three weeks after transplanting of cabbage and peaked during March (34-54 per 100 plants). The population of *C. septempunctata* was found positively correlated with the population of aphid, *L. erysimi*.

Bhaskar and Virakatamath (2002) investigated the diversity and abundance of aphidophagous coccinellids in cabbage field. Three species of coccinellids were found predating on aphids, i.e., *Coccinella transversalis*, *Menochilus sexmaculatus* and *Harmonia octomaculata*, which accounted for 52, 41 and 7 per cent of the total coccinellid population, respectively, *H. octomaculata* alone showed significant positive correlation with aphid population, while the other species fluctuated considerably.

Mandal and Patnaik (2006) studied the predatory potential of aphidophagous predators associated with cabbage crop during 2001-2002 at Bhubaneswar, Orisa. Four species of coccinellids, two species of surphids and a chrysopid were found feeding on all the three species of aphid, viz.; *L. erysimi*, *M. persicae* and *B. brassicae* that attacked the cabbage crop. Predation of *L. erysimi* was the highest followed by *M. persicae* and *B. brassicae* for all the species of predators.

Bana *et al.,* (2012) reported that the coccinellid beetle was recorded as an important predator of aphid, which was maximum in the second and third week of January during 2008-09 and 2009-10, respectively.

Akmal *et al*. (2013) reported that the entomopathogenic fungus, *B. bassiana* showed little or no detrimental effects to coccinellids.

Bala (2015) among the various insecticides *viz.* dimethoate, cypermethrin, imidacloprid, beta-cyfluthrin, acetamprid, lambda-cyhalothrin, thiacloprid, fipronil, thiamethoxam, spinosad, difenthiouron and triazophos population of natural enemies i.e. coccinellid was observed and no significant difference was noted in natural enemies population in treatments and untreated check. The finding also explained that there was no adverse effect of treatments on natural enemies. The mean population of natural enemies ranged from 5.85 to 10.81.

Sabry *et al.* (2015) reported that the second instar larvae of seven-spotted ladybird beetle *Coccinella septempunctata* are more susceptible to the tested insecticides especially thiamethoxam and chlorantraniliprole. With lower concentrations chlorantraniliprole is more toxic than thiamethoxam.

Gosalwad and Tikotkar (2016) reported that the insecticides *Bt* @ 500g ha^{-1} and HaNPV @ 500 LE ha^{-1} were safe, which were followed by NSE @ 5 %, azadirachtin 15 EC @ 150 g a.i./ha and spinosad 45 SC @ 75 g a.i ha^{-1}.

Patil *et al.* (2016) found that treatment with acetamiprid 20 SP and emamectin benzoate 5 EC was safer to the coccinallids than thiamethoxam 25 WG and lambda-cyhalothrin 3 EC. In the study population of natural enemies in insecticides treated plots was low as compared to untreated control.

Sumalatha *et al.* (2017) the overall efficacy data indicated that the plants treated with lambda-cyhalothrin 5 EC @ 50 g a.i ha^{-1} (1.47 beetles $plant^{-1}$), fipronil 5 SC @ 50 g a.i. ha^{-1} (1.58 beetles $plant^{-1}$) and imidacloprid 17.8 SL @ 50 g a.i. ha^{-1} (1.68 beetles $plant^{-1}$) recorded minimum predator population as compared to other treatments at 14 days after spray.

Sangamithra *et al.* (2018) reported the lowest survival population of ladybird beetle in plots treated with fipronil 200 SC @ 50 g a.i. ha^{-1} followed by lambda-cyhalothrin 5 EC. The highest number of ladybird beetle was observed in imidacloprid 17.8 SL treated plots.

3. MATERIAL AND METHODS

The details of the material used and methods adopted in the present investigations are described in this chapter.

3.1 Location of The Experiments.

Field experiment was conducted during *Rabi* season of 2016 on the farm of Horticulture Section, College of Agriculture, Kolhapur (Maharashtra), which is situated on 16^0 16’ North latitude and 73^0 85’ East longitude with an altitude of 511 meters above mean sea level.

3.2 Climatic Conditions.

The mean annual rainfall of Kolhapur is about 1050-1100 mm, receiving mostly during June to October. The rainfall is assured for *kharif* season. Summer is dry, while winter is cool. The maximum temperature varies from 25.4 ^{0}C in December to 35 ^{0}C in May. The minimum temperature varies from 11.32 ^{0}C and 25.77 ^{0}C in winter and summer, respectively. The mean relative humidity ranges from 50 to 90 per cent. The climate is subtropical. The meteorological data of year 2016-17, is used for obtain correlation coefficients.

3.3 Soil Type

The field selected for experiment was uniform with sandy loam soil having medium fertility and fairly good drainage.

Agronomic practices and transplanting

All the agronomical practices like field preparation, transplanting of seedling, application of fertilizers, irrigation and intercultivation operations were carried out as per recommended cultivation practices except plant protection measures. Local popular variety 'Sukirti' seedlings were raised in nursery and transplanted in main field at research farm during *Rabi*- 2016.

The experimental land was prepared by giving one deep ploughing followed by harrowing and rotavating. Recommended dose of fertilizers, 160 kg N, 80 kg P and 80 kg K per hectare, half dose of N and full dose of P and K was applied at the time of transplanting and remaining dose of N was applied after 30 and 45 days after transplanting. Two hand weedings were done to keep the plots free from weeds.

3.4 Seasonal Incidence

Weekly observations on five randomly selected plants were recorded for pests infesting cabbage crop and compared with weather parameters.

3.5 Efficacy of Different Modules Against Pest Complex of Cabbage.

A field experiment was conducted to study the efficacy of different modules against pest complex of cabbage during *rabi* 2016.

3.5.1 Experimental details.

The details of the experiment are as under:

Design	: RBD
Replications	: Three
Treatments	: Nine
Plot size	: 3.00 m x 2.00 m
Spacing	: 45 cm x 30 cm
Crop	: Cabbage
Variety	: Sukirti
Date of planting	: 20/10/2016
Date of 1st spraying	: 11/11/2016
Date of 2nd spraying	: 25/11/2016
Date of 3rd spraying	: 09/12/2016
Date of 4th spraying	: 23/12/2016
Date of harvesting	: 02/01/2017

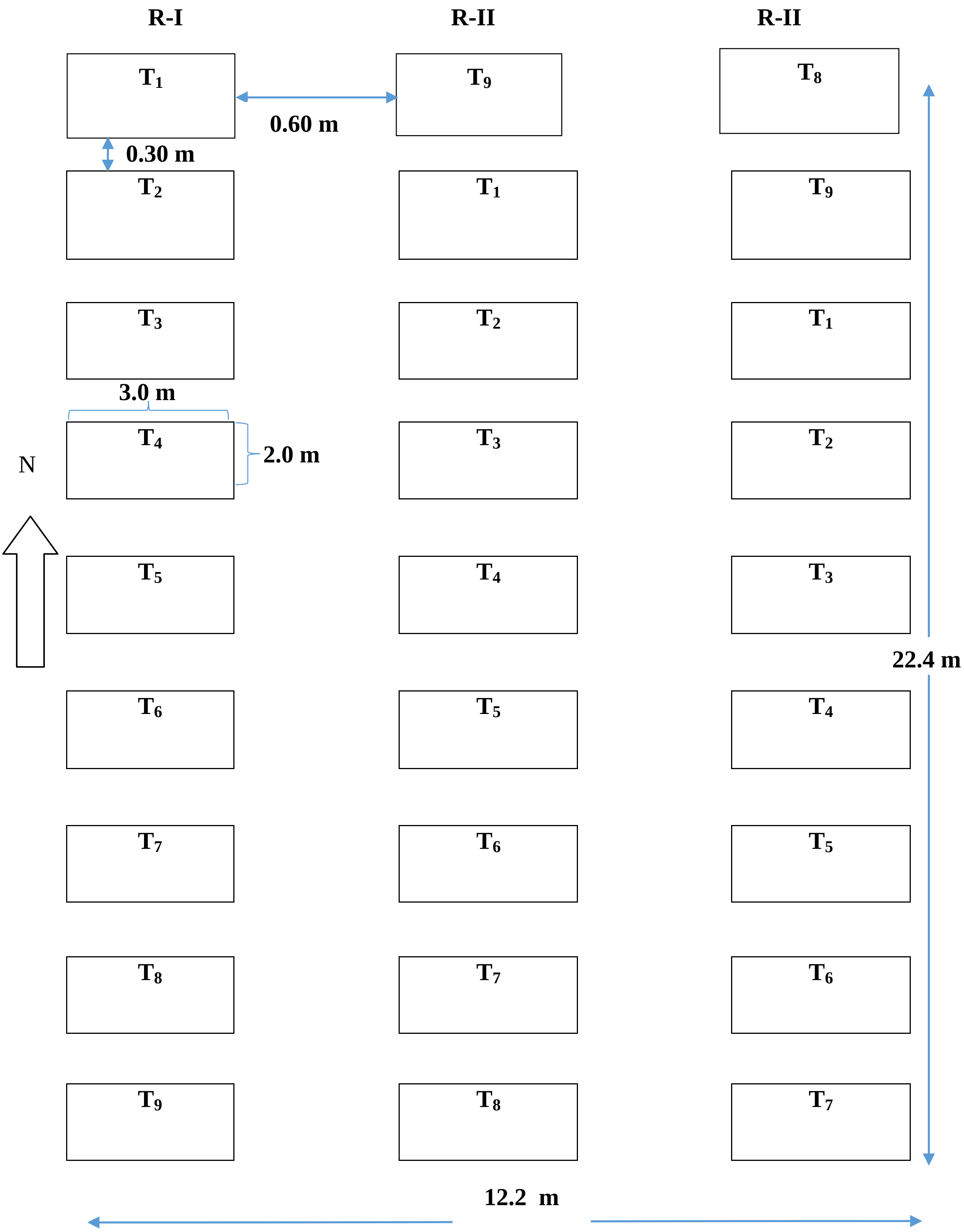

Fig. 1: Layout of Research Experiment

Table 1: Module Detail for Pest Complex of Cabbage.

Sr. No.	Module Details
M1	Soil application of phorate 10 G @ 15 kg ha^{-1} + Erecting sticky traps + *Lecanicillium lecanni* @ 6g $lit.^{-1}$ + *Beauveria bassiana* @ 6g $lit.^{-1}$ + pyriproxifen 10 EC @ 2ml $lit.^{-1}$
M2	Dipping of seedling in thiamethoxam 25 WG @ 7 ml $lit.^{-1}$ + Pheromone traps 5 ha^{-1} + NSE 5% @ 5 ml $lit.^{-1}$ + *Metarhizium anisopliae* @ 6 g $lit.^{-1}$ + indoxacarb 14.5 EC @ 0.5 ml $lit.^{-1}$
M3	Dipping of seedling in imidachloprid 17.8 SL @ 1ml $lit.^{-1}$ + *Lecanicillium lecanni* @ 6 g $lit.^{-1}$ + *Beauveria bassiana* @ 6 g $lit.^{-1}$ + NSE 5 % @ 5 ml $lit.^{-1}$ + emamectin benzoate 5 SG @ 0.30 g $lit.^{-1}$
M4	Soil application of carbofuron 3 CG @ 50 kg ha^{-1} + Erecting sticky traps + *B. thuringiensis* @ 1 g $lit.^{-1}$ + *Metarhizium anisopliae* @ 6 g $lit.^{-1}$ + chlorantraniliprole 18.5 SC @ 0.30 ml $lit.^{-1}$
M5	Dipping of seedling in thiamethoxam 25 WG @ 1g $lit.^{-1}$ + Mustard (20:1) + *Lecanicillium lecanni* @ 6g $lit.^{-1}$ + NSE 5% @ 5ml $lit.^{-1}$ + cartap hydrochloride 50 SP @ 1g $lit.^{-1}$
M6	Dipping of seedling in acetamiprid 20 SC @ 7 ml $lit.^{-1}$ + Pheromone traps 5 ha^{-1} +*Metarhizium anisopliae* 6 @ g $lit.^{-1}$ + chorfluazuron 5 EC @ 0.75 ml $lit.^{-1}$ + cypermethrin 25 EC @ 0.5 ml $lit.^{-1}$
M7	Soil application of Phorate10 G @ 15 kg ha^{-1} + NSE 5% @ 5 ml $lit.^{-1}$ + diflubenzuron 25 WP @ 0.10 g $lit.^{-1}$ + fipronil 5 SC @ 1.5 ml $lit.^{-1}$ + lamda cyhalothrin 5 EC @ 2 ml $lit.^{-1}$
M8	Soil application of *Trichoderma viridi* @ 5 kg ha $lit.^{-1}$ + Pheromone traps 5 ha $lit.^{-1}$ + NSE 5% @ 5 ml $lit.^{-1}$ + *Metarhizium anisopliae* 6 @ g $lit.^{-1}$ + *Beauveria bassiana* @ 6 g $lit.^{-1}$
M9	Untreated control

Table 2. Details of Insecticidal Treatments for Pests on Cabbage.

Sr. no.	Treatments	Trade name	Concentration	Dose g/l or ml/l
1	*Metarhizium anisopliae*	Phule metarhizium	$1x10^8$ Spores ml^{-1}	6 g
2	*Beauveria bassiana*	Phule *Beauveria*	$2x10^8$ Spores ml^{-1}	6 g
3	*Lecanicillium lecanni*	Phule verticillium	$2x10^8$ Spores ml^{-1}	6 g
4	Neem seed extract	Neemraz	5% V/V	5 ml
5	*Bacillus thuringiensis*	Dipel	5WP	1 g
6	Diflubenzuron	Bi-Larv	25 WP	0.10 g
7	Pyriproxifen	Admiral	10 EC	2 ml
8	Indoxacarb	Kingdoxa	14.5 EC	0.5 ml
9	Cartap hydrochloride	Cargo	50 SP	1 g
10	Cypermethrin	Cymbush	25 EC	0.5 ml
11	Lamda cyhalothrin	Karate	5 EC	2 ml
12	Fipronil	Regent	5 SC	1.5 ml
13	Chlorfluazuron	Atabron	5 EC	0.75 ml
14	Chlorantraniliprole	Coragen	18.5 SC	0.3 ml
15	Emamectin benzoate	Proclaim	5 SG	0.3 g
16	Thiamethoxam	Actara	25 WG	7 ml
17	Carbofuran	Fury	3 G	50 kg ha^{-1}
18	Imidachloprid	Confidor	17.8 SL	7 ml
19	Acetamiprid	Tata manic	20 SC	7 ml
20	Phorate	Thimete	10 G	15 kg ha^{-1}
21	Spodolure	-	-	5 ha^{-1}
22	DBM lure	-	-	5 ha^{-1}

3.5.2 Application of Insecticides

The insecticidal solutions were prepared by thoroughly mixing of required quantity of insecticides in known quantity of water and insecticidal spray solution was used for spraying. Knapsack sprayer was used for spraying. The spraying was done in the evening hours from 4 p.m. to 6 p.m. Total four sprayings were given. First spraying was given 20 DAP second 35 DAP, third 50DAP, and last spraying was given 65 DAP.

3.5.3 Methods of Recording Observations.

Observations were recorded one day before spray and after 30, 45, 60, and 75 days after planting on all pests infesting cabbage.

1. Cabbage Aphid, *Brevicoryne brassicae* (Linn.).

The observation of aphid population will be taken as per the method given by Lal, (1998). The five plants of cabbage randomly selected from each plot and tagged, total no of aphid will be recorded and converted into no. of aphids plant^{-1}.

2. Diamondback Moth, *Plutella xylostella* (Linn.).

The observation on the population of diamondback moth was recorded as per the method suggested by Lal (1998). Five plants per plot were selected randomly for recording observations. Mean survival populations of larvae plant^{-1} were recorded.

3. Toacco Caterpillar, *Spodoptera litura* (Fab.).

The observation on the population of tobacco caterpillar was recorded as per the five plant from each plot were selected randomly for recording observations. Mean survival populations of larvae plant^{-1} were recorded.

4. Coccinellid, *Coccinella septempunctata* (Linn.).

The observation of natural enemy coccinellid beetle population will be taken as per the method given by Lal, (1998). The five plants of cabbage randomly selected from each plot and tagged, total no of coccinellid beetle will be recorded and converted into no. of coccinellid plant^{-1}.

3.6. Statistical Analysis

The average number of aphid, diamondback moth larvae, tobacco caterpillar larvae, and average number of coccinellid beetle per plants were worked out and transferred by using Poisson formula $\sqrt{x + 0.5}$ before analysis.

Where,

X = average number of pest population.

The data pertaining to infestation, larval count, after their transformation, were statistically analyzed as per the standard analysis of variance (Panse and Sukhatme, 1967).

4. RESULTS AND DISCUSSION

The present investigations were carried out to study the seasonal incidence of pests of cabbage, evaluate the efficacy of different modules against the pests infesting cabbage and to study their effect on natural enemies.

The results obtained during the course of these investigations are described under following heads:

1. Seasonal incidence of pests infesting cabbage.
2. To study the efficacy of different modules against cabbage pests.
3. To study the effect of different modules on natural enemies.

4.1 The Seasonal Incidence of Pests.

The data on seasonal incidence of pests of cabbage are presented in Table 3.

4.1.1 Seasonal Incidence of Aphids (Linn.).

The data presented in the Table 3 and depicted in Fig. 2 clearly indicated that the infestation of aphid was recorded throughout the cropping season. The aphid incidence first appeared in the 44^{th} MW corresponding to the October last week with mean population 3.5 aphids/plant. The population steadily increased and reached to its peak in the 50^{th} MW corresponding to December 2^{nd} week (22.13 aphids $plant^{-1}$) when the maximum temperature was $30.6^{0}C$, morning relative humidity 81 per cent. The population of the aphids declined thereafter from 21.33 at 51^{st} MW corresponding to December 3^{rd} week to 20.18 aphids $plant^{-1}$ at 2^{nd} MW corresponding to January 2^{nd} week.

The correlation coefficient was compared between the aphid population and weather parameters. The analysis in the Table 4 revealed that aphids population was negatively nonsignificant with maximum temperature (-0.635), and positively significant with average relative humidity (0.324).

These findings are in harmony with the results of Bana *et al*. (2012) who reported that the incidence of aphids started in last week of November, increased slowly and attained the peak in the third week of January. Similar results were also reported by Malik *et al.* (2000) the correlation between aphid population and maximum-minimum temperatures were negative and with morning relative humidity it was positive.

4.1.2 Seasonal Incidence of Diamondback Moth (Linn.).

Seasonal incidence of *P. xylostella* per five plants was determined randomly on cabbage under field conditions and compared along with weather parameters. The data on seasonal incidence and weather parameters are depicted in Table 3 and graphically depicted in Fig. 2. The observations on the seasonal incidence on the DBM revealed that the larval population density of DBM in cabbage was initially started during 48^{th} meteorological week correspond to last week of November with an average number of 0.26 larvae plant^{-1} at 31.4^{0}C maximum temperature and relative morning humidity 86 per cent .

The incidence of the diamondback moth larvae steadily increased with passage of time and showed population 2.60 larvae plant^{-1} at 30.7^{0}C with relative morning humidity 84 per cent and 5.80 larvae plant^{-1} at 30.8^{0}C with relative morning humidity 80 per cent on 51st and 52nd MW correspond with 1st and 3rd week of December lasted to the harvesting of crop in 2nd week of January. The peak incidence of larvae recorded on 1st MW corresponds with 1st week of January with mean number of 6.40 larvae plant^{-1} when the maximum temperature and relative morning humidity was 31.4^{0}C and 80 per cent, respectively.

The correlation coefficient was compared between the diamondback moth population and weather parameters. The analysis in the Table 4 revealed that diamondback moth population was positively significant with maximum temperature (0.057), and average relative humidity (0.259).

Hence, the present results are discussed in the light of the following findings of previous workers. Tufail and Ansari (2010) reported that when temperature ranged from 25.2 to 35.0^{0}C and humidity 64.2 to 80.8 per cent significantly increase in population of *P. xylostella* larvae from 3.05 to 9.02 larvae per plant. Venkateswarlu *et al*. (2011) reported that the significant positive correlation of diamondback moth population with the maximum and minimum temperatures. Meena and Singh (2012) reported positive and significant relation of minimum temperature with larval population of diamondback moth.

4.1.3 Seasonal Incidence of *Spodoptera litura* (Fab.).

The data presented in the Table 3 and depicted in Fig. 2 clearly indicated that the *S. litura* incidence was first appeared in the 46th MW corresponding to the November 2nd week with mean population of 0.80 larvae plant^{-1}. The population started increasing slowly and reached to its peak in the 49th MW corresponding to December 1st week (1.40 larvae plant^{-1}) when the maximum temperature was 30.5^{0}C, morning relative humidity 85 per cent. The population of the *S. litura* declined thereafter from 1.40 larvae plant^{-1} at 51st MW corresponding to December 3rd week.

The correlation coefficient was compared between the *S. litura* population and weather parameters. The analysis indicated in the Table 4 revealed that *S. litura* population was negatively nonsignificant with maximum temperature (-0.296) and positively significant with average relative humidity (0.745).

These results are in line with the findings of Sai Reddy *et al.* (2015) who reported that, the larval population of *S. litura* had significant negative correlation with maximum and non-significant negative correlation with minimum temperatures (r = -0.867 and r = -0.437) and significant positive correlation with relative humidity and non-significant negative with sunshine hours (r = 0.601 and r = -0.336). The correlation studies clearly demonstrated that the incidence of *S. litura* was affected only by temperature, which indicated that the rise in temperature lead to reduction of the *S. litura* population.

Table: 3 Seasonal incidence of pests infesting cabbage during *Rabi*: 2016
Variety: Sukirti Transplanting Date: 20/10/2016

Meteorological Week (MW)	Temperature (^oC)		Relative Humidity (%)		No. of Aphids Plant^{-1}	No. of DBM Larvae Plant^{-1}	No. of *S. litura* Larvae Plant^{-1}
	Max.	Min.	Morning	Evening			
43	31.7	14.9	79	50	0.00	0.00	0.00
44	31.8	14.2	70	58	3.5	0.00	0.00
45	31.2	10.6	68	48	10.2	0.00	0.00
46	30.8	12.3	73	57	15.46	0.00	0.80
47	30.4	9.5	76	51	19.53	0.00	1.06
48	31.4	8.7	86	54	22.06	0.26	1.33
49	30.5	11.8	85	51	21.86	1.50	1.40
50	30.6	16.9	81	52	22.13	1.88	1.13
51	30.7	10.2	84	54	21.33	2.60	1.40
52	30.8	8.2	80	50	20.16	5.80	0.60
01	31.4	9.9	80	50	20.26	6.40	0.00
02	29.6	8.1	80	35	20.18	0.00	0.00

Table 4. Correlation between abiotic factors and pests of cabbage during *Rabi* 2016.

Sr. No.	**Meteorological Parameters**			
	Pest	**Max. Temp.**	**Relative Humidity**	**Pest Incidence**
	Correlation coefficient (‘r’) values			
1	Aphid	-0.63562	0.32489*	1.000*
2	Diamondback moth	0.057411*	0.259567*	1.000*
3	*S. litura*	-0.29686	0.745539*	1.000*

* Significant at 5 per cent level

4.2 Efficacy of Different Modules Against Pest Complex of Cabbage.

4.2.1 Efficacy of Different Modules Against Aphid (*B. Brassicae)* of Cabbage.

Data pertaining to the survival population of aphid on cabbage one day before and 30, 45, 60, and 75 days after transplanting are presented in Table 5 and graphically depicted in Fig. 4. All the modules were found to be significantly superior in reducing population of aphids when observations were recorded at 30 DAT. Among the modules, module M3 was found to be the most effective with 7.90 aphids/plant and significantly superior to all other modules. The module M7 (8.02 aphids/plant), M2 (9.32 aphids plant^{-1}), and M5 (10.45 aphids plant^{-1}) were found to be next in order of efficacy. Maximum survival population of aphids was found in the module M8 (14.95 aphids plant^{-1}) among the modules as compared to untreated control (19.12 aphids plant^{-1}).

At 45 DAT, the module M7 was found to be significantly superior than the rest of modules where 4.38 aphids plant^{-1} survival population was recorded. The treatments with module M3, M2, and M5 were found to be on par with 5.84, 6.24 and 6.75 aphids plant^{-1}, respectively and found to be next in order of efficacy.

The observations recorded on 60 DAT showed that all the modules were significantly superior over control in reducing aphid population. Module M7 was found the best module (1.23 aphids plant^{-1}), M3 (3.27 aphids plant^{-1}) and M2 (3.43 aphids plant^{-1}) was found the next in order of efficacy. However, module M6 was least effective recording 7.04 aphids plant^{-1} survival population.

At 75 DAT, module M7 was found as best module recording 0.52 aphids plant^{-1} survival population. The module M4 (2.02 aphids plant^{-1}), and M2 (2.12 aphids plant^{-1}) were found to be equally effective. Maximum survival population of aphids was found in the module M8 (3.28 aphids plant^{-1}) among the modules as compared to untreated control (26.32 aphids plant^{-1}).

From the overall performance of all the modules it was found that all the modules were significantly superior over control in reducing aphid population. The module M7 (3.54 aphids plant^{-1}) was found as the best treatment. The next promising modules was M3 (4.87 aphids/plant^{-1}) and M2 (5.28 aphids plant^{-1}) were found in next order of efficacy. The module M8 (7.87 aphids plant^{-1}), M6 (8.06 aphids plant^{-1}) and M4 (8.43 aphids plant^{-1}) were least effective.

The module M7 recorded highest per cent reduction of aphid over control i.e. 84.49%. Module M2 (78.86%) and M_2 (78.65%) recorded similar result in per cent reduction of aphid over control. Module M8 (65.50%) was relatively less effective in controlling the aphid.

These result are confirmative with the results of Bhardwaj (2006) evaluated various aphid management modules revealed that module (berseem+ imidacloprid+ *C. camea+* lamda cyhalothrin) was not only most effective against aphid complex but also facilitated high parsitization of aphids under natural conditions.

Table 5: Efficacy of different modules on aphid (*B. brassicae)* of cabbage.

Sr. No.	Module	Pre-count no. of aphids Plant^{-1}	Mean survival population of Aphids plant^{-1}				Mean	Percent reduction over untreated control
			30 DAT	45 DAT	60 DAT	75 DAT		
1	M1	12.60 (3.61)	12.20 (3.56)*	7.40 (2.81)	3.60 (2.02)	2.42 (1.71)	6.41 (2.63)	71.90
2	M2	13.04 (3.68)	9.32 (3.13)	6.24 (2.60)	3.43 (1.98)	2.12 (1.62)	5.28 (2.40)	78.86
3	M3	11.80 (3.50)	7.90 (2.90)	5.84 (2.52)	3.27 (1.94)	2.48 (1.73)	4.87 (2.32)	78.65
4	M4	14.05 (3.81)	13.95 (3.80)	12.60 (3.62)	5.14 (2.37)	2.02 (1.59)	8.43 (2.99)	63.05
5	M5	12.36 (3.59)	10.45 (3.31)	6.75 (2.69)	4.80 (2.30)	3.50 (2.00)	6.38 (2.62)	72.03
6	M6	13.73 (3.77)	13.07 (3.68)	9.20 (3.11)	7.04 (2.75)	2.93 (1.85)	8.06 (2.93)	64.67
7	M7	11.60 (3.48)	8.02 (2.92)	4.38 (2.21)	1.23 (1.31)	0.52 (1.01)	3.54 (2.01)	84.49
8	M8	15.04 (3.94)	14.95 (3.93)	8.20 (2.95)	5.04 (2.35)	3.28 (1.94)	7.87 (2.89)	65.50
9	Control	17.40 (4.23)	19.12 (4.42)	21.76 (4.72)	24.02 (4.95)	26.32 (5.18)	22.81 (4.83)	-
	SE	NS	0.13	0.10	0.08	0.06	-	-
	CD at 5 %	NS	0.41	0.32	0.25	0.20	-	-
	CV	-	6.90	6.20	6.08	5.65	-	-

DAT = Days after transplanting

***Figures in parentheses are transformed values $\sqrt{X + 0.5}$

4.2.2 Efficacy of Different Modules Against Diamondback Moth (*P. xylostella)* of Cabbage.

Data pertaining to the survival population of Diamondback moth on cabbage one day before and 45, 60, and 75 days after transplanting are presented in Table 6 and graphically depicted in Fig. 5. All the modules were found to be significantly superior in reducing population of DBM when observations were recorded at 45 DAT. Among the modules, module M7 was found to be the most effective with 1.46 larvae plant^{-1} and significantly superior to all other modules. The module M2 (1.72 larvae plant^{-1}), M3 (1.76 larvae plant^{-1}), and M5 (1.90 larvae plant^{-1}) were found to be equally effective and next in order of efficacy. Maximum survival population of DBM was found in the module M4 (2.08 larvae plant^{-1}) among the modules as compared to untreated control (3.68 larvae plant^{-1}).

At 60 DAT, the module M7 was found to be significantly superior than the rest of modules where 0.82 larvae plant^{-1} survival population was recorded. The module M2, M3, and M5 were found to be on par with 1.16, 1.42 and 1.56 larvae plant^{-1}, respectively and found to be next in order of efficacy.

At 75 DAT, module M7 was found as best module recording 0.38 larvae/plant survival population. The module M2 (0.62 larvae plant^{-1}) was found to be the next best module; and module M3 (0.94 larvae plant^{-1}), M6 (1.08 larvae plant^{-1}) were found to be equally effective next in order of efficacy. Maximum survival population of DBM was found in the module M8 (1.36 larvae plant^{-1}) among the modules as compared to untreated control (5.82 larvae plant^{-1}).

From the overall performance of all the modules it was found that all the modules were significantly superior over control in reducing DBM population. The module M7 (0.88 larvae plant^{-1}) was found as the best treatment. The next promising modules was M2 (1.16 larvae plant^{-1}) and M3 (1.37 larvae plant^{-1}) and M6 (1.55 larvae plant^{-1}) M5 (1.56 larvae plant^{-1}) were found in next order of efficacy. The module M1 (1.70 larvae plant^{-1}), M4 (1.84 larvae plant^{-1}) were least effective.

The module M7 recorded highest per cent reduction of Diamondback moth population over control i.e. 84.48%. Module M2 (75.58%) and M3 (71.09%) recorded next best moddule in per cent reduction of Diamondback moth population over control. Module M4 (61.27%) was relatively less effective in controlling the Diamondback moth population.

These results are confirmative with the results of Vinoth and Manisegaran (2014) they tested five IPM modules, the suggested module was found effective against DBM *P. xylostela* irrespective of the seasons. The suggested module M4 (seed treatment thiram and carbendazim, Inter crop: cabbage + onion, Pheromone trap, spray NSKE 5%, spray indoxacarb + emamectin benzoate + *Bt*., spinosad spray). Has recorded lowest mean population (0.90 and 0.75 nos. head^{-1}).

Murthy *et al*., (2006) evaluated four commercial neem formulations *viz*., Soluneeem (0.15%), Econeem plus (0.3%), Vijayneem (0.3%), Neemark (0.6%), two plant extracts *viz*., leaf extracts of *Vitex negundo* and rhizome extracts of *Acorns calamus* (both at 10%), two new insecticide molecules viz., indoxacarb (0.0075%) and fipronil (0.01%) and a standard check, neem seed kernel extracts (NSKE 4%) for their efficacy against diamondback moth (DBM), *Plutella xylostella* on cabbage. Among the treatments, indoxacarb, fipronil and NSKE were found to be effective in reducing the DBM population and recorded significantly higher marketable cabbage heads followed by Soluneeem, Econeem plus, Vijayneem and Neemark.

Table 6: Efficacy of different modules against diamondback moth (*P. xylostella)* of cabbage.

Sr. No.	Module	Pre-count no. of larvae plant^{-1}	Mean survival population larvae of Diamondback Moth plant^{-1}			Mean	Percent reduction over untreated control
			45 DAT	60 DAT	75 DAT		
1	M1	2.32 (1.68)	2.06 (1.60)*	1.76 (1.50)	1.28 (1.33)	1.70 (1.48)	64.22
2	M2	2.27 (1.66)	1.72 (1.49)	1.16 (1.29)	0.62 (1.06)	1.16 (1.29)	75.58
3	M3	2.80 (1.82)	1.76 (1.50)	1.42 (1.39)	0.94 (1.20)	1.37 (1.37)	71.09
4	M4	2.38 (1.70)	2.08 (1.61)	1.80 (1.52)	1.16 (1.29)	1.84 (1.53)	61.27
5	M5	2.28 (1.67)	1.90 (1.55)	1.56 (1.43)	1.24 (1.32)	1.56 (1.44)	67.16
6	M6	2.78 (1.81)	1.98 (1.57)	1.60 (1.45)	1.08 (1.26)	1.55 (1.43)	67.37
7	M7	2.66 (1.78)	1.46 (1.40)	0.82 (1.15)	0.38 (0.94)	0.88 (1.17)	81.48
8	M8	2.20 (1.64)	1.94 (1.56)	1.72 (1.49)	1.36 (1.36)	1.67 (1.47)	64.78
9	Control	3.07 (1.89)	3.68 (2.04)	4.76 (2.29)	5.82 (2.51)	4.75 (2.29)	-
	SE	NS	0.07	0.07	0.05	-	-
	CD at 5 %	NS	0.21	0.21	0.17	-	-
	CV	-	7.89	8.55	7.41	-	-

DAT = Days after transplanting

*****Figures in parentheses are transformed values $\sqrt{X + 0.5}$

4.2.3 Efficacy of Different Modules Against *S. litura* of Cabbage.

Data pertaining to the survival population of *S. litura* on cabbage one day before and 30, 45, 60, and 75 days after transplanting are presented in Table 7 and graphically depicted in Fig. 6. All the modules were found to be significantly superior in reducing population of *S. litura* when observations were recorded at 30 DAT. Among the modules, module M7 was found to be the most effective with 1.62 larvae plant^{-1} and significantly superior to all other modules. The module M3 (1.82 larvae plant^{-1}), M2 (1.94 larvae plant^{-1}), and M4 (1.98 larvae plant^{-1}) were found to be equally effective next in order of efficacy. Maximum survival population of *S. litura* was found in the module M8 (2.12 larvae plant^{-1}) among the module treatments as compared to untreated control (2.62 larvae plant^{-1}).

At 45 DAT, the module M7 was found to be significantly superior than the rest of modules where 0.72 larvae plant^{-1} survival population was recorded. The module M2, and M3 were found to be on par with 1.36, and 1.38 larvae plant^{-1}, respectively and found to be next in order of efficacy.

The observations recorded on 60 DAT showed that all the modules were significantly superior over control in reducing *S. litura* population. Module M7 was found the best module (0.18 larvae plant^{-1}), and module M2 (0.74 larvae plant^{-1}) and M3 (0.84 larvae/plant) were found to be equally effective and next in order of efficacy. However, module M5 and M8 were least effective recording 1.16 larvae plant^{-1} survival population.

At 75 DAT, module M7 (0.08 larvae/plant^{-1}) was at par with module M2, M4, M3, and M6 recording 0.12, 0.14 0.16 and 0.18 larvae/plant were found to be best module as compared with other modules. Maximum survival population of *S. litura* was found in the module M8 (0.62 larvae plant^{-1}) among the modules as compared to untreated control 4.12 larvae plant^{-1}).

From the overall performance of all the modules it was found that all the modules were significantly superior over control in reducing *S. litura* population. The module M7 (0.65 larvae plant^{-1}) was found as the best treatment. The next promising modules was M2 (1.04 larvae plant^{-1}) and M3 (1.05 larvae plant^{-1}) and M4 (1.14 larvae plant^{-1}) were found equally effective in next order of efficacy. The module M5 (1.32 larvae plant^{-1}), and M8 (1.41 larvae plant^{-1}) were least effective.

The module M7 recorded highest per cent reduction of *S. litura* population over control i.e. 80.77%. Module M2 (69.24%) and M3 (68.94%) recorded next best moddule in per cent reduction of *S. litura* population over control. Module M8 (58.29%) was relatively less effective in controlling the *S. litura* population.

Purwar and Yadav (2003) tested the efficacy of pesticides from different origin against tobacco caterpillar, *S. litura* (Fab.) on two cultivars of soybean crop, i.e. PK-1029 and PK-416. These included synthetic chemical insecticide, plant extract, animal origin, insect growth regulator and entomopathogenic fungi. The chitin inhibitor i.e. Dimilin (diflubenzuron), Entomopathogenic Fungi, *Beauveria bassiana* (Dispel) showed more effectiveness than botanicals.

Table 7: Efficacy of different modules against *S. litura of* cabbage.

Sr. No.	Module	Pre-count no. of larvae plant^{-1}	Mean survival population larvae of *S. litura* plant^{-1}				Mean	Percent reduction over untreated control
			30 DAT	45 DAT	60 DAT	75 DAT		
1	M1	2.13 (1.62)	2.04 (1.59)*	1.46 (1.40)	1.06 (1.25)	0.48 (0.99)	1.26 (1.33)	62.73
2	M2	2.07 (1.60)	1.94 (1.56)	1.36 (1.36)	0.74 (1.11)	0.12 (0.79)	1.04 (1.24)	69.24
3	M3	2.00 (1.58)	1.82 (1.52)	1.38 (1.37)	0.84 (1.16)	0.16 (0.81)	1.05 (1.24)	68.94
4	M4	2.16 (1.63)	1.98 (1.57)	1.46 (1.40)	0.96 (1.21)	0.14 (0.80)	1.14 (1.28)	66.43
5	M5	2.27 (1.66)	2.16 (1.63)	1.62 (1.46)	1.16 (1.29)	0.34 (0.92)	1.32 (1.35)	60.95
6	M6	2.18 (1.64)	2.06 (1.60)	1.52 (1.42)	0.88 (1.17)	0.18 (0.82)	1.16 (1.29)	65.69
7	M7	2.23 (1.65)	1.62 (1.46)	0.72 (1.10)	0.18 (0.82)	0.08 (0.76)	0.65 (1.07)	80.77
8	M8	2.20 (1.64)	2.12 (1.62)	1.74 (1.50)	1.16 (1.29)	0.62 (1.06)	1.41 (1.38)	58.29
9	Control	2.28 (1.67)	2.62 (1.77)	3.12 (1.90)	3.68 (2.04)	4.12 (2.15)	3.39 (1.97)	-
	SE	NS	0.05	0.05	0.04	0.04	-	-
	CD at 5 %	NS	0.15	0.15	0.14	0.12	-	-
	CV	-	5.75	6.08	6.91	7.02	-	

DAT = Days after transplanting

***Figures in parentheses are transformed values $\sqrt{X + 0.5}$

4.3 Effect of Different Modules on Natural Enemies of Cabbage.

4.3.1 Effect of Different Modules on Predatory Coccinellids Population in Cabbage.

The data regarding predatory coccinellids population after 20, 35, 50 and 65 days after transplanting are presented in Table 8 and graphically depicted in Fig. 7. The data revealed that the results before application of chemical insecticides having nonsignificant differences among all the treatments including control showing even distribution of coccinellids population and population ranged from 0.62 to 1.58 predatory coccinellid beetles plant^{-1}. The observations recorded 30, 45, 60 and 75 days after planting showed significant treatment differences for predatory coccinellids population.

After 30 DAT there was no decrease in population of predatory coccinellids in all treated plots. Among all treatments module M5 recorded highest number of coccinelids population 1.72 predatory coccinellid beetles plant^{-1}, followed by M6 (1.63), M8 (1.50) coccinellid beetles plant^{-1}, as against untreated control 1.75 coccinellids beetles plant^{-1}. Significant differences did not exist among all the treatments.

After 45 DAT there was slight increase in the population of coccinellids in all the treatments. This reveals that there was no effect of entomopathogenic fungi, NSE and IGR agents on coccinellids population. Among all the treatments module M6 showed highest number of coccinellids population 1.94, followed by M5 (1.88), and M8 (1.73) coccinellid beetles plant^{-1} as compare to untreated control 1.98 coccinellid beetles plant^{-1}. However, significant differences did not existed among the treatments.

After 60 DAT similar trend of increase in the population of coccinellids in all the treatments was observed. Data revealed that population of predatory coccinellids ranged between 1.08 to 2.20 coccinellids beetles plant^{-1}. Among all the treatments module M6 recorded highest average number of coccinellids population 2.12 coccinellid beetles plant^{-1}, followed by M5 (2.02), and M8 (1.95) as compared to untreated control 2.20 coccinellid beetles plant^{-1}.

After 75 DAT there was increase in the population of coccinellids in module M8 (2.22) and untreated control (2.38) and slightly increase in module M1 (1.24) and M2 (1.85). The reduction in population of coccinellids in other modules M7 (0.28), M6 (0.36), and M5 (0.84) as compared to untreated control 2.38 coccinellid beetles plant^{-1}.

From the overall performance of all the modules it was found that, the module M8 showed highest average number of coccinellids population 1.85, followed by module M2 (1.67) and M5 (1.61) coccinellid beetles plant^{-1}. As compared to untreated control 2.07 coccinellid beetles plant^{-1}.

The module M8 recorded lowest per cent mortality of coccinellids over control i.e. 10.62 Which is relatively safer to the coccinellids followed by M2 19.32%. Module M1 53.60 recorded high mortality of coccinellids as comparedto the untreated control.

Overall the data obtained after 75 DAT revealed that there was no adverse effect of entomopathogenic fungi, NSE, *B t.*, and IGR (Insect growth regulator) on coccinellids population and there was adverse effect of different molecules of chemical insecticides on coccinellids population.

Hence the present results are discussed with the following findings of previous workers. Thungrabeab and Tongma (2007) who reported that *B. bassiana* Bb. 5335 and *M. anisopliae* Ma.7965 have the potential use as biological control agents against insect pests because they were relatively safe on non-target insects, such as natural enemies and beneficial soil insects. Akmal *et al*. (2013) reported that the entomopathogenic fungus, *B. bassiana* showed little or no detrimental effects to coccinellids.

Table 8: Effect of different modules on Coccinellids population in cabbage.

Sr. No.	Modules	Pre-count no. of Coccinellid Beetles plant^{-1}	Mean survival population of Coccinellid Beetles plant^{-1}				Mean	Percent mortality
			30 DAT	45 DAT	60 DAT	75 DAT		
1	M1	0.62 (1.06)	0.68 (1.08)	0.87 (1.17)	1.08 (1.26)	1.24 (1.32)	0.96 (1.21)	53.62
2	M2	1.36 (1.36)	1.44 (1.39)	1.61 (1.45)	1.79 (1.51)	1.85 (1.53)	1.67 (1.47)	19.32
3	M3	0.98 (1.22)	1.06 (1.25)	1.16 (1.29)	1.36 (1.36)	1.30 (1.34)	1.22 (1.31)	41.06
4	M4	1.26 (1.33)	1.32 (1.35)	1.53 (1.43)	1.77 (1.51)	1.43 (1.39)	1.51 (1.42)	27.05
5	M5	1.68 (1.48)	1.72 (1.49)	1.88 (1.54)	2.02 (1.59)	0.84 (1.16)	1.61 (1.45)	22.22
6	M6	1.56 (1.44)	1.63 (1.46)	1.94 (1.56)	2.12 (1.62)	0.36 (0.93)	1.51 (1.42)	27.05
7	M7	1.28 (1.33)	1.35 (1.36)	1.56 (1.44)	1.84 (1.53)	0.28 (0.88)	1.25 (1.32)	39.61
8	M8	1.43 (1.39	1.50 (1.42)	1.73 (1.49)	1.95 (1.57)	2.22 (1.65)	1.85 (1.53)	10.62
9	Control	1.58 (1.44)	1.75 (1.50)	1.98 (1.57)	2.20 (1.64)	2.38 (1.70)	2.07 (1.60)	-
	SE	NS	0.04	0.04	0.04	0.03	-	-
	CD at 5 %	NS	0.13	0.14	0.13	0.11	-	-
	CV	-	5.65	5.62	5.16	5.25	-	-

DAT = Days after transplanting

***Figures in parentheses are transformed values$\sqrt{X + 0.5}$

4.4 Cost Benefit Ratio for Pests of Cabbage.

4.4.1 Cost Benefit Analysis of Modules for Pests of Cabbage:

The data in table 9 revealed that the maximum net returns was recorded with module M7 (Rs. 200441 ha^{-1}) followed by module M2 (Rs. 185635 ha^{-1}) and module M3 (Rs. 160089 ha^{-1}) as compared to check plot (Rs. 67300 ha^{-1}). The highest benefit cost ratio was observed in module M7 (5.64) and it was followed by module M2 (5.44). However, highest incremental cost benefit ratio was observed in module M5 (67.44) followed by module M2 (48.83). But, as per cabbage growers point of view, net returns per hectare was received with module M7 (Rs. 200441 ha^{-1}), which was followed by module M2 (Rs. 185635 ha^{-1}). Hence, it is concluded that the application of module M7 and M2 can be recommended to control pests of cabbage.

Table 9. Cost benefit ratio of module application for pests of cabbage.

Module No.	Cabbage yield (Ton Ha^{-1})	Additional yield over control (Ton Ha^{-1})	Additional income over control Rs ha^{-1}	Cost of cultivation except cost of insecticide Rs ha^{-1}	Cost of insecticide Rs ha^{-1}	Total cost of cultivation Rs ha^{-1}	Gross monitory return Rs ha^{-1}	Net return Rs ha^{-1}	B:C ratio	ICBR
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
M1	14.82	4.24	42400	39500	5480	44980	148200	103220	3.29	7.74
M2	22.74	11.06	110600	39500	2265	41765	227400	185635	5.44	48.83
M3	20.18	9.5	95000	39500	2211	41711	201800	160089	4.84	42.97
M4	16.37	5.69	56900	39500	8976	48476	163700	147345	3.38	6.34
M5	20.02	9.34	93400	39500	1385	40885	200200	159315	4.90	67.44
M6	18.26	7.58	75800	39500	3320	42820	182600	139780	4.26	22.83
M7	24.36	13.68	136800	39500	3659	43159	243600	200441	5.64	37.39
M8	14.38	3.7	37000	39500	3055	42555	143800	101245	3.37	12.11
M9	10.68	-	-	39500	-	39500	106800	67300	2.70	-

Price of cabbage: Rs. 10/kg

5. SUMMARY AND CONCLUSION

5.1 Summary

The present investigations were carried out to study the seasonal incidence of pests infesting cabbage, evaluate efficacy of different modules against pests infesting cabbage.

The experiment was laid out in a randomized block design with nine modules for cabbage pests replicated three times.

5.1.1 Seasonal Incidence of Pests on Cabbage.

5.1.1.1 Aphid.

The incidence of aphid was noticed from 44th MW up to the 2nd MW corresponding to October last week up to January 2nd week. The incidence was first observed during 44th MW (3.5 aphid plant^{-1}) and ranged from 3.5 to 22.13 aphid plant^{-1} with its peak population (22.13 aphid plant^{-1}) when the abiotic factors like maximum temperature was 30.06^{0}C and morning humidity was 81 per cent. The correlation studies for population of aphid and weather parameters revealed that aphid population was negatively nonsignificant with maximum temperature (-0.635), and positively significant with average relative humidity (0.324).

5.1.1.2 Diamondback moth

The incidence of DBM was noticed from 48th MW up to the 1st MW corresponding to November last week to January 1st week. The incidence was first observed during 48th MW (0.26 larvae plant^{-1}) and ranged from 0.26 to 6.40 larvae plant^{-1} with its peak population (6.40 larvae plant^{-1}) when the abiotic factors *viz.* the maximum temperature was 31.4^{0}C and morning humidity was 80 per cent. The correlation studies for population of DBM and weather parameters revealed that diamondback moth population was positively significant with maximum temperature (0.057), and average relative humidity (0.259).

5.1.1.3 Tobacco caterpiller.

The incidence of *S. litura* was noticed from 46th MW up to the 52nd MW corresponding to November 2nd week to December last week. The incidence was first observed during 46th MW (0.80 larvae plant^{-1}) and ranged from 0.80 to 1.40 larvae plant^{-1} with its peak population (1.40 larvae plant^{-1}) when the abiotic factors like maximum temperature was 30.7^{0}C and morning humidity was 84 per cent. The correlation studies for population of *S. litura* and weather parameters revealed that *S. litura* population was negatively nonsignificant with maximum temperature (-0.296) and positively significant with average relative humidity (0.745).

5.1.2 Efficacy of Different Modules Against Pests Infesting Cabbage.

5.1.2.1 Aphid.

In field testing of modules, the number of aphids reduced significantly in plots treated with module M7 after 30, 45, 60 and 75 days after transplanting and next best module was M2.

5.1.2.2 Diamondback moth.

The number of DBM reduced significantly in plots treated with module M7 after 45, 60 and 75 days after transplanting and next best module was M2.

5.1.2.3 Tobacco caterpiller.

The module M7 was found most superior in reducing larval population of *S. litura* after 30, 45, 60 and 75 days after transplanting and next best module was M2.

5.1.3 Effect of Different Modules on Natural Enemies of Cabbage.

5.1.3.1 Coccinellid beetle.

The module M8 showed highest average number of coccinellid population, followed by module M2 and M5 coccinellid beetles plant^{-1}. As compared to untreated control coccinellid beetles plant^{-1}.

5.2 Conclusion

The study revealed that the incidence of aphid was comparatively more than that of DBM, and *S. litura* on cabbage. To study the population dynamics of cabbage pests under field condition revealed that, maximum aphids 22.13 were recorded at 50th MW corresponding to December 2nd week. The maximum number of Diamondback moth population observed in 1st MW corresponding to January 1st week (6.40 larvae plant^{-1}) and the *S. litura* population recorded in various weeks was found in range of 0.60 to 1.40 larvae plant^{-1}.

The module M7 (3.54 aphids plant^{-1}) was found most superior in reducing population aphid at 30, 45, 60 and 75 days after transplanting. The next best module M3 (4.87 aphids plant^{-1}) and M2 (5.28 aphids plant^{-1}). The module M7 recorded highest per cent reduction of aphid over control i.e. 84.49%. Module M2 (78.86%) & M_2 (78.65%) recorded similar result in per cent reduction of aphid over control. Module M8 (65.50%) was relatively less effective in controlling the aphid.

The module M7 (0.88 larvae plant^{-1}) was found most superior in reducing population of DBM at 45, 60 and 75 days after transplanting. The next best module were M2 (1.16 larvae plant^{-1}) and M3 (1.37 larvae plant^{-1}). The module M7 recorded highest per cent reduction of Diamondback moth population over control i.e. 84.48%. Module M2 (75.58%) and M3 (71.09%) recorded next best moddule in per cent reduction of Diamondback moth population over control. Module M4 (61.27%) was relatively less effective in controlling the Diamondback moth population.

As regards with *S. litura*, the module M7 (0.65 larvae plant^{-1}) was most effective at 30, 45, 60 and 75 days after transplanting. The next best modules M2 (1.04 larvae plant^{-1}) and M3 (1.05 larvae plant^{-1}). The module M7 recorded highest per cent reduction of *S. litura* population over control i.e. 80.77%. Module M2 (69.24%) and M3 (68.94%) recorded next best module in per cent reduction of *S. litura* population over control. Module M8 (58.29%) was relatively less effective in controlling the *S. litura* population.

The module M8 showed highest average number of coccinellid population i.e. 1.85 beetles plant^{-1}, followed by module M2 (1.67 beetles plant^{-1}) and M5 (1.61 beetles plant^{-1}) as compared to untreated control 2.07 beetles plant^{-1}. The module M8 recorded lowest per cent mortality of coccinellids over control i.e. 10.62 which is relatively safer to the coccinellid beetles followed by module M2 19.32%. Module M1 53.60% recorded high mortality of coccinellid beetles as compared to the untreated control.

The module M7 showed maximum B:C ratio (5.64) followed by module M2 (5.44). While regarding ICBR ratio, module M5 showed maximum (67.44) followed by module M2 (48.83) for the pests of cabbage.

Future trust:

It needs to conduct the experiments for two or more years with the large plot size to confirm the present results; after which, the same way disseminated to farmers.

6. LITERATURE CITED

Aggarwal Meenakshi; Masarrat Haseeb and Uzma Manzoor. 2014. Biology and seasonal incidence of aphid, *Brevicoryne brassicae* on Cabbage. *Annals of Plant Protection Sciences*, 22 (2): 275-277.

Ahmad, M., Arif, M.I. and Ahmad, M. 2007. Occurrence of insecticide resistance in field population of *Spodoptera litura* (Lepidoptera: Noctuidae) in Pakistan. *Crop Protection* 26: 809-817.

Akmal, M., Freed, S., Malik, M.N. and Gul, H.T. 2013**.** Efficacy of *Beauveria bassiana* (Deuteromycotina: Hypomycetes) against different aphid species under laboratory conditions. *Pak. J. of Zool*. 45(1): 71-78.

Ameta, O. P., Bunker, G. K.(2007) Efficacy of flubendiamide 480 SC against diamondback moth, *Plutella xylostella* (L.) in cabbage and its effect on natural enemies under field conditions. *Pestology,* ; 30(6): 21-24.

Anonymous, (2017), Horticulture at a glance.

Armes, N.J., Wightman, J.A., Jadhav, D.R. and Rao, G.V.R. 1997. Status of insecticide resistance in *Spodoptera litura* (Fab.) in Andhra Pradesh, India. *Pesticide Science*. 50: 240-258.

Ayalew G., Baumgartner J.O., Callistus K.P.O and Lohr B. 2006. *P. xylostella* (*Lepidoptera: Plutellidae*) at two sites in central Ethiopia, with particular reference to parasitism. *Biocontrol Sci. Technol*. 16 (6): 607–618.

Badjena, T. and Mandal, S. M. A. 2005. Seasonal Incidence of Major Insect Pests and Predators in Cauliflower. Ann. Pl. Protec. Sci. 13 (2): 465-529.

Bala 2015. Evaluation of bioefficacy of some insecticides against thrips (*Thrips tabaci* L.) in Onion. M. Sc. Thesis.

Bana, J. K.; Jat, B. L. and Bajya, D. R. 2012. Seasonal incidence of major insect pests of cabbage and their natural enemies. *Indian Journal of Entomology*, 74 (3): 236 - 240.

Bhardwaj, V. 2006. Management of aphid complex on cabbage. Ph.D. Thesis, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.) India.

Bhaskar, H. and Viraktamath, C.A. 2002. Diversity and abundance of aphidophagous coccinellids in cabbage field. *Insect Environment*, 8 (1): 31.

Bhavani, B., Venugopal Rao, Ch.V. (2009). Evaluation of Different I.P.M. modules for the management of insect pests of cabbage. *Pestology* Vol. XXXIII No. 12.

Biradar, V.K. and Dhanorkar, B.K. 2001. Efficacy of certain insecticides against diamond back moth infesting cauliflower. *J. Maharashtra Agri. Univ*., 26 (1): 115-116.

Campos, W.G., Schoereder, J.H. and Desouza, O.F. 2006. Seasonality in neotropical populations of *Plutella xylostella* (Lepidoptera): resource availability and migration. *Popul. Ecol*. 48: 151–158.

Chandra, S. and Kushawa, K.S. 1987. Impact of environmental resistance on aphid complex of cruciferous crops under the agro-climatic conditions of Udaipur II biotic components. *Indian Journal of Entomology*, 49 (1): 86-113.

Chatterjee, H and Senapati, S.K., 2000. Studies on some biopesticides against *Plutella xylostella*. Linn. infesting cabbage in Terai regions of West Bengal. *Pestology*., 24 (7): 51-54.

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

Correa-Cuadros, J.P., Rodriguez-Bocanegra, M.X. and Saenz-Aponte, A. 2014.Susceptibility of *Plutella xylostella* (Lepidoptera: Plutellidae; Linnaeus 1758) to *B. bassiana* Bb9205, *M. anisopliae* Ma9236 and *H. bacteriophora* HNI0100. *Univ. Sci*. 2014, Vol. 19 (3): 277-285.

Dai Jianqing, Jianyu Deng and Jiawei Du 2008. Development of bisexual attractants for diamondback moth, *Plutella xylostela* (Lepidoptera: Plutellidae) based on sex pheromone and host volatiles. *Appl. Entomol. Zool*. 43 (4): 631-638.

Deivendran, A., Yadav, G.S. and Rohilla, H.R. and 2007. Efficacy of some insecticides against, *Plutella xylostella* (L.) on cauliflower. *Journal of Insect Science*, 20 (1): 102-105.

Dewanda, Puja and Khan Sabiha. 2016. Field study of population dynamics of major insect pests and their natural enemies on cauliflower of Ajmer district. *International Journal of Agriculture Sciences*, 8(53): 2642-2645.

Dotasara, S. K.; Agrawal, N.; Singh Narendra and Swami Dinesh. 2017. Efficacy of some newer insecticides against mustard aphid *Lipaphis erysimi* Kalt. In cauliflower. *Journal of Entomology and Zoology Studies*, 5(2): 654-656.

Feakin, S.D. 1973. Pest control in groundnut, *PANS Manual No*. 2, *Centre for Overseas Pest Research, London*: 197.

Fletcher, T.B. 1914. Some South Indian insects. *Subdt. Govt. Press, Madras*, 656pp.

Furlong, M.J. 2004. Infection by the immature stages of *Diadegma semiclausum*, an endolarval parasitoid of the diamondback moth by *Beauveria bassiana*. *J. of Invertebrate Pathol*. 85: 52–55.

Gadad, H., Hegde, M. and Balikai, R. A. 2013. Seasonal incidence of Spodoptera litura and leaf miner in rabi/summer groundnut. *J. Exp. Zool.* India. 16 (2): 619-622.

Gosalwad, S. S. and Tikotkar, A. B. 2016. Effect of insecticides on green lace wing and lady bird beetle in Tomato (*Lycopersicam esculentum* L.). *Bioinfolet* 13 (2 a): 239 – 242.

Goud, C.R.; Rao, S.R.K. and Chiranjeevi, C.H. 2006. Influence of weather parameters on the population buildup of diamondback moth, *Plutella xylostella* (L.) infesting cabbage. *Pest management in Horticulture Ecosystem*, 12 (1): 103-106.

Haruka oouchi, 2005. Insecticidal properties of a juvenoid, pyriproxyfen, on all life stages of the diamondback moth, *Plutella xylostella* (Lepidoptera: Yponomeutidae). *Appl. Entomol. Zool.* 40 (1): 145–149.

Javaid, I., Saifudine, N., Tombolane, L. and Rafael, E. 2000. Efficacy of aqueous neem extracts in the control of diamond back moth, *Plutella xylostella* (L.) on cabbage. *Insect Science and its Application, 20(2):167-170.*

Joshi, N.R. and Jhala, R.C. 2000. Field bioefficacy of synthetic insecticides and biopesticides against diamond back moth, *Plutella xylostella* (Linn.) infesting cress *(Lepidium sativum* Linneaus). Abstract: 5th *National Conference of Applied Zoologists Research Association*, December, 27-29, 2000, Chennai, 191.

Kadam, N.V.; Dalvi, C.S. and Dumbre, R.B. 1995. Efficacy of diflubenzuron a chitin synthesis inhibitor against diamond back moth. *J. Maharashrra Agric. Univ. 20(1): 17-20*.

Kamala, N.V.; Chandrashekara, K.; Srinivasreddy, K.M; and Sannaveerappanvar, V.T. 2003. Evaluation of biopesticides for management of diamond back moth on cabbage. *Proc. National Sym. on frontier areas of Ento. Res*. 5-7 Nov., 2003, New Delhi.

Kandoria, J.L.; Singh, G.; Labh, S.; Singh, G. and Singh, L. 2000. Efficacy of different formulations of *Bacillus thuringiensis* Berliner against diamondback moth, *Plutella xylostella* (L.) under field conditions. *Insect Environment*, 6 (2): 84-85.

Kirk, A. A., Mercadier, G., Bordat, D., Delvare, G., Pichon, A., Arvanitakis, L., Goudegnon, A. E., and Rincon, C.2004. Variability in *Plutella xylostella* and its natural enemies: implications for biological control. In: Enders by N. M., Ridland P. M., editors. The management of Diamondback moth and other crucifer pests. *Proceedings of the fourth international workshop*, 26-29 November 2001. Melbourne. Australia: Department of natural resources and environment. Pp 71- 77.

Kranthi, K. R., Jadhav, D. R., Kranthi, S., Wanjari, R. R., Ali, S.S. and Russell, D.A. 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection*. 21: 449-460.

Kranz, J., Schumutterer, H. and Koch, W. 1977. Disease pests and weeds in tropical crops. Berlin and Hamburg, Verlag Paul Parley: 55.

Krishna Kumar, H.K, Srinivasan, K. and Suman, C.L. 1983. Optimum control strategy of cabbage pests from a chemical control trial. *Singapore J. Pri. Industries.*

Krishnamoorthy, P.N. and Krishna Kumar, N.K. 2000. Efficacy of neem seed kernel powder extract on cabbage pests. *Pest Management in Horticulture Ecosystem, 6(1):27-31.*

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

Kumar, A.; Satpathy, S.; Shivalingaswamy, T.M. and Rai, M. 2007. Field efficacy of indoxacarb against diamondback moth, *Plutella xylostella* (L.) on cabbage. *Pestology,* 31 (4): 41-46.

Lal, O. P. 1998**.** Notes summer school on Advance Technologies in Important Vegetables Crops, including Cole Crops, May 4-24, IARI New Delhi. pp. 63-66.

Lal, O.P. and Meena, R.K. 2001. Effects of certain insecticides against diamondback moth (*Plutella xylostella* L.) on cabbage under field condition. *Pesticide Research Journal*. 13 (2): 242-246.

Liu, M.Y., Tzeng, Y.J. and Sun, C.N. 1981. Diamondback moth resistance to several synthetic pyrethroids. *Journal of Economic Entomology*. 74: 393-396.

Lin, M.Y., Tzeng, Y.J. and Sun, C.N. 1982. Insecticide resistance in the diamondback moth. *Journal of Economic Entomology*. 75: 153-155.

Lokare, R. U., Chandele, A. G. and Kharbade S. B. 1999. Relative toxicity of insect growth regulators against *Plutella xylostella* (L.) on cabbage. *Pestology*. 23 (7) : 52-54.

Magaro, J.J. and Edelson, J.V. 1992. Diamondback moth (Lepidoptera: Plutellidae) in south Texas: a technique for resistance monitoring in the field. *Journal of Economic Entomology*. 83: 1201-06.

Malik, A.P.; Borikar, P.S. and Waghmare, U.M. 2000. Population dynamics of *Brevicoryne brassicae* (L.) and *Plutella xylostella* (L.) on cauliflower (*Brassica oleracea* var. *botrytis*). *Pestology,* 27 (7): 48-50.

Mandal, S.M.A. and Patnaik, N.C. 2006. Predatory potential of aphidophagous predators associated with cabbage crop. *Journal of Plant Protection Environment,* 3 (1): 81-86.

Manjunatha, M., Hanchinal, S.G. and Kulkarni, S.V. 2000. Comparative bioefficacy of Nivaar against *Plutella xylostella* and *Myzus persicae* on cabbage. *Karnataka Journal of Agricultural Sciences*, 13(3): 741-743.

Manoharan, T., Pathma, J. and Preetha, G. 2010. Seasonal incidence of sugarbeet pests and natural enemies. *Indian Journal of Entomology*. 72(1): 36-41.

Meena, M.K. and Sharma, U.S. 2003. Seasonal incidence and assessment of some microbial insecticides against diamondback moth, *Plutella xylostella* (L.) in cabbage. *Journal of applied zoological Research*. 14 (1): 61-62.

Meena, S.C. and Singh, V. 2010. Bio-efficacy of insecticides against diamondback moth, *Plutella xylostella* (L.) on cabbage, *Brassica oleracea var. capitata* L. National Conference on Plant Protection in Agriculture, ARS, Durgapura, Jaipur, pp. 227-228.

Meena, S. C. and Singh, V. 2012. Seasonal incidence of *Plutella xylostella* L. on cabbage in arid region of Rajasthan. *Ann. of Plant Prot. Sci*. 20(2):326-328.

Mishra, Abhishek and Singh, S.V. 2015. Seasonal incidence of some insect pests associated with cabbage (*Brassica oleracea* var. *capitata*). *New Agriculturist*, 26(1): 79-83.

Monubrullah, Md., Bharti, P., Shamkar, U., Gupta, R., Srivastava, K. and Ahmad, H. 2007. Trap catches and seasonal incidence of *Spodoptera litura* on cauliflower and tomato. *Annals of Plant Protection Sciences.* 15(1): 73-76.

Murthy, M. S., Jagadish, P. S., Sannaveerappanavar, V. T., 2006. Efficacy of plant products and new insecticides against diamondback moth, *Plutella xylostella* (L.) (Yponomeutidae: Lepidoptera) on cabbage. *Journal of Plant Protection and Environment,* 2006. 3 (2):1-5.

Muthukumar, M., Sharma, R. K., Sinha, S. R. 2007. Field efficacy of biopesticides and new insecticides against major insect pests and their effect on natural enemies in cauliflower. *Pesticide Research Journal*, 19 (2):190-196.

Nayak, M.K.; Katiyar, O.P.; Yadav, H.S. and Srivastava, N. 2001. Seasonal abundance of aphid, *Lipaphis erysimi* (Kalt) on different host plant and extent of its parasitization under field conditions. *JNKVV Research Journal*, 34: (1-2): 74-76.

Panse, V.G. and Sukhatme, P.V. 1967. Statistical method for Agricultural Workers. ICAR, New Delhi, PP: 359.

Patel, J.J., Patel, B.H., Bhatt, P.D. and Kathiria, K.B. 2005. Indoxacarb 15 EC a newer insecticidal formulation for diamondback moth, *Plutella xylostella* (L.) management in cabbage. *National Conference on Applied Entomology*, 26-28, September, RCA, Udaipur: 120-121.

Patel, Lakshman Chandra; Konar, Amitava and Saha, Subendu Bikash. 2015. Seasonal incidence and insecticidal efficacy against diamondback moth and aphid of broccoli. *International Journal of Tropical Agriculture*, 33(4): 2459-2465.

Patidar, B.K. and Dadheech, L.N. 2000. Incidence and chemical control of *Lipaphis erysimi* (Kalt.) on cabbage. *Indian Journal of Applied Entomology*, 14: 5-8.

Patil, P. P., Gore, R. S. and Patil, N. G. 2016. Bioefficacy of new insecticide molecules against okra aphids (*Aphis gossypii* Glover). *IJTA*, Vol. 34, No. 7, 2016.

Patil, R.S., Goud, K.B. and Kulkarni, K.A. 2003. Management of diamondback moth on cabbage using plant extracts and new insecticides. *Karnataka- J. Agric. Sci*., 16 (2): 307-310.

Patra, S.; Dhote, V. W.; Alam, S. K. F.; Das, B. C.; Chatterjee, M. L. and Samanta, A. 2013. Population dynamics of major insect pests and their natural enemies on cabbage under new alluvial zone of West Bengal. *The Journal of Plant Protection Sciences*, 5(1): 42-49.

Pogue, M.G. 2003. World *Spodoptera* database (Lepidoptera: Noctuidae). US Department of Agriculture, Systematics and Entomology Laboratory, Beltsville, MD.

Pokharkar, D.S.; Hardeoad, A.B. and Puranik, T.R. 2002. Bioassay and persistence of *Bacillus thuringiensis* Ber. Against *Plutella xylostella* (L.) on cabbage, 10 (1): 1-4.

Pramanik, P. and Chatterjee, M.L. 2003. Efficacy of some new insecticides in the management of diamondback moth, *Plutella xylostella* (L.) in cabbage. *Indian Journal of Plant Protection*, 31 (2): 42-44.

Prasad, S.K. 1963. Quantitative estimation of damage to cruciferous crops caused by cabbage worm, cabbage lopper, diamondback moth and cabbage aphid. *Indian Journal of Entomology*, 25 (3): 242-259.

Pritin P Sontakke, G. T. Behere, D. M. Firake and D. P. Thubru, 2014. Evaluation of toxicity and cotoxicity of biopesticides against diamondback moth, *Plutella xylostella* (L.). *J Biopest* 7(1):90-97.

Purwar, J.P. Yadav, S.R. (2003). Field efficacy of pest controlling agents from different origins against tobacco caterpillar, *Spodoptera litura* on soybean. *Indian journal of Entomology*. 65(3): 382-385.

Radhika, P. 2013. Influence of weather on the seasonal incidence of insect pests on groundnut in the scarce rainfall zone of Andhra Pradesh. *Advance Research Journal of improvement.* 4(2): 123-126.

Raja, M.; William John and David, B. Vasantharaj. 2014. Population dynamics of key insect pests of cabbage in Tamil Nadu. *Indian Journal of Entomology*, 76(1): 01-07.

Ram, N.; Raju. S.V.S.; Singh, H.N. and Ram N. 2001. Bio-efficacy of some conventional and eco-friendly insecticides against diamondback moth, *Plutella xylostella* (L.) on cabbage. *Indian Journal of Entomology*, 63 (4): 429-434.

Ramkrishnan, N., Saxena, V.S. and Dhingra, S. 1984. Insecticide resistance in the population of *Spodoptera litura* (F.) in Andhra Pradesh. *Pesticides.* 18: 23-24.

Rame Gowda, G.K. 1999. Studies on resistance to insecticides in *Spodoptera litura* (F.) on groundnut. *M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad, Karnataka* (India).

Rao, J.R., Krishnayya, P.V and Rao, P.A. 2000. Efficacy of cryolite against major lepidopteron pest of cauliflower, *Pl. Prot. Bull*., 32 (3-4); 16-18.

Rao, S.R.K. and Lal, O.P. 2005. Seasonal incidence of mustard aphid, *Lipaphis erysimi* (Kalt) and diamondback moth, *Plutella xylostella* (L.) on cabbage. *Journal of Insect Science*, 18 (2): 106-110.

Reddy, A.R. and Mohan, *K.K.* 2001. Evaluation of azadirachtin (fortuneaza) and monocrotophos against diamond back moth *(Plutella xylostella* L.) III cauliflower. *Pestology*, 25(11):39-40.

Sabry Al-kazafy, H., Tarek A. Abd-El Rahman, Shaker, M. A.2015. Influence of some new insecticides on sweet potato whitefly, *Bemisia tabaci* and American serpentine leaf miner, *Liriomyza trifolii* and their residues in cucumber fruits. *International J. of Advanced Research*. Vol. 3, Issue 10, 1874 – 1881.

Sachan, J.N. and Srivastava, B.P. 1972. Studies of the seasonal incidence of insect pests of cabbage. *Indian Journal of Entomology*, 34 (2): 123-129.

Sai Reddy M.S., 2015. Seasonal incidence and chemical management of diamondback moth (*Plutella xylostela* L.) and tobacco caterpillar (*Spodoptera litura* F.) on cabbage. *M.Sc. Thesis, Submitted to Banaras Hindu University, Varanasi*.

Sakthi, E.; Seenivasan, N.; Devrajan, J. and Selvraj, N. 2003. Bioefficacy of new insecticides against cabbage diamondback moth, *Plutella xylostella* (L.). *Pestology*, 27 (4): 35-37.

Sangamithra, S., Vinothkumar, B., Karthik, P., Manoharan, T., Muthukrishnan, N., and Rathish, S. T. 2018. Evaluation of bioefficacy, phytotoxicity of fipronil 200 SC w/v against Pest complex and its safety to non target Invertebrates in Chilli. *Int. J. Curr. Microbiol. App. Sci.,* 7(1): 3354-3360.

Sannaveerappanavar, V.T.; Kamla, N.V.; Shankaramurthy, M. and Chandrashekhara, K. 2003. Field evaluation of insecticides against diamondback moth on cabbage. *National Symposium on frontier areas of Entomological Research* 5-7 November, 2003, New Delhi.

Satyanarayana, N.V.V., Ramatbandra Rao, G. and Arjuna Rao, P. 2010. Incidence and management of *Spodoptera litura* (Fab.) on post rainy season groundnut. *Annals of Plant Protection Science*. 18(1): 22-25.

Selvaraj, S., Adiroubanel, D., Ramesh, V. and Narayana, A.L. 2010. Impact of ecological factors on incidence and development of tobacco cut worm, *Spodoptera litura* (Fab) on cotton. *Journal of Biopesticides*. 3(1): 43-46.

Sewak, S.; Ahmad, S. and Mishra, M.S. 2008. Bioefficacy of indigenous 24 products and their combinations against diamondback moth, *Plutella xylostella* (L.), *Pestology*, 32 (6): 23-27.

Singh, S. V.; Yadav, N. K.; Shanker, K. and Malik, Y. P. 2010. Population dynamics of major insect pests of cabbage and cauliflower in gangetic plains. *Indian Journal of Applied Entomology*, 24(1): 82-83.

Shah Riaz; Shakeel Ahmed and Ashraf Poswal. 2013. Population dynamics of insect pests, parasitoids and predators in cabbage and cauliflower agro-ecosystems. J. ent. Res., 37 (2): 129-137.

Shalini; Maurya Veena and Sharma Kamal. 2016. Seasonal incidence of Brevicoryne brassicae and Plutella xylostella on Brassica oleracea in Rohtak District. Annals of Plant Protection Sciences, (2): 319 – 323.

Sharma, S.K. 2004. Eco-safe management of major insect pests of cabbage, Brassica oleracea var. capitata Linn. Ph.D. Thesis, Submitted to Rajasthan Agricultural University, Bikaner.

Shivankar, V. J. and Rao, C. N. 2003 Studies on selectivity of botanicals against *Serangium parcesetosum*. *Proceedings of the National Symposium on Frontier Areas Entomological Research. I.A.R.I. New Delhi*, *India*, November 5 - 7, pp. 360 – 361.

Shukla, A. and Kumar, A. 2003. Efficacy of some pesticides against diamondback moth infesting cabbage. *Proceedings of the National Symposium on Frontier Areas Entomological Research*., 5-7 Nov, 2003, New Delhi.

Shukla, A. and Kumar, A. 2004. Seasonal incidence of diamond back moth *(Plutella xylostella* L.) on cabbage. *Journal of Applied-Zoological-Researches*. 15(1): 48-50.

Shukla, A. and Kumar, A. 2004b. Seasonal incidence of diamondback moth, *Plutella xylostella* (L.) on cabbage. *Res. J. of Appl. Zool*. 15(1): 48-50.

Somchoudhary, A.K.; Saha, K. and Chatterjee, S. 1996. Bioefficacy of different treatment schedules of cascade (flufenoxuron) 10 WDC against diamondback moth on cabbage. *Pestology*, 20(9):5-7.

SP-IPM, 2006. Biological Alternatives to Harmful Chemical Pesticides. *IPM Research Brief No. 4. SP-IPM Secretariat, International Institute of Tropical Agriculture (IITA). Cotonou, Benin*, 24 pp.

Sreekant, M. and Babu, T.R. 2001. Evaluation of certain new insecticides against the aphid, *Lipaphis erysimi* (Kalt) on cabbage. *International Pest Control*, 43 (6): 242-244.

Srivastava, A.S.; Upadhyay, K.D.; Mishra, B.P. and Katiyar, R. 1978. Pray preference of *Coccinella septempunctata* L. (Coleoptera: Coccinellidae). *Indian Journal of Agricultural Science*, 48(2):84-86.

Sudhakaran, R. 2002. Efficacy of lufenuron (Match 5% EC) against *Spodoptera litura* (F.) under in vitro condition. *Insect Environment*. 8: 47-48.

Sumalatha, B. V., Kadam, D. R., Jayewar, N. E. and Thakare, Y. C. 2017. Bioefficacy of newer insecticides against onion thrips (*Thrips tabaci* L.) and their effect on ladybird beetle. *Agric. Update, ISSN*- 0976- 6847 vol. 12 (TECHSEAR-1) 2017: 182-188

Sun, C.N., Chi, H. and Feng, N.T. 1978. Diamondback moth resistance to diazinon and methomyl in Taiwan. *Journal of Economic Entomology*. 71: 551-554.

Tabashnik, B.E. and Cushing, N.L. 1987. Leaf residue vs topical bioassays for assessing insecticide in the diamondback moth, *Plutella xylostella* L. *FAO Pl. Prot. Bull*. 35: 11-14.

Tandon, P.L. and Bhalla, O.P. 1982. Evaluation of insecticide sprays against the cabbage aphid, *Brevicoryne brassicae* (Linn.) on cauliflower seed crop. *Indian Journal of Entomology*, 44 (1): 52-62.

Thungrabeab, M. and Tongma, S. (2007). Effect of entomopathogenic fungi, *B. bassiana* (BANSAM) and *M. anisopliae* (METSCH) on non target insects. *KMITL Sci. Tech. J.* Vol. 7 No. S1 Nov. 2007.

Thuy P.T., Thanh N.T. and Dinh N. 2001. Effect of *Beauveria bassiana* conidia suspension on insect pests. *Proceedings, International Workshop on Biology*, July 25, 2001, Hanoi, Vietnam: p. 436 - 441.

Tufail, A. and Ansari, M.S. 2010. Studies on seasonal abundance of Diamondback moth on cauliflower. *J. Plant protect. Res*., 50(3), 15-20.

Valda, C. A. S. Reginaldo, B., Edmilson, J. M., and Jorge B. T., 2003. Susceptibility of *plutella xylostella* (L.) (Lepidoptera: Plutellidae) to the Fungi *Beauveria bassiana* (Bals.) Vuill, and *Metarhizium anisopliae* (Metsch.) Sorok. Neotrop. *Entomol*. 38, 275-301.

Vanlaldiki H., Singh P. M. and Sarkar P. K. 2013. Efficacy of eco-friendly insecticides on the management of Diamondback moth (*Plutella xylostella* L.) on cabbage. *The bioscan* 8(4): 1225-1230.

Venkateswarlu, V., Sharma, R. K., Chander, S. and Singh, D.D. 2011. Population dynamics of major insect pests and their natural enemies in cabbage. *Ann. of Plant Prot. Sci*. 19(2): 272-277.

Vinoth R. and Manisegaran S., 2014. Effect of Integrated Pest Management Modules against Diamond Back Moth Plutella xylostella (L) and parasitoid Cotesia plutellae (Kurdjumov). Global Journal of Botanical Science, 2014, 2, 45-50.

Wagle, B.K.S.; Saravanan, L.; Sudha, J.P. and Gupta, P. 2005. Seasonal incidence of cabbage aphid, Brevicoryne brassicae (L.) and its natural enemies in relation to weather parameters on cabbage. National Conference on Applied Entomology, RCA, Udaipur, 26-28 September, 2005, pp. 22-23.

Walker, G.P., Wallace, A.R., Bush, R., Macdonald, F. H., and Suckling, D.M. 2003. Evaluation of pheromone trapping for prediction of diamondback moth infestations in vegetable brassicas. *New Zealand Plant Protection* 56: 180-184.

Wensu Han, Shufa Zhang, Fuying Shen, Meng Liu, Chengcai Ren and Xiwu Gao 2012. Residual toxicity and sublethal effects of chlorantraniliprole on *Plutella xylostella* (Lepidoptera: Plutellidae). *Pest manag sci*. 67:82-86.

Wo, H. S.; Liu H. and Zhao N. 2002. Control of Pieris rapae and *Plutella xylostella* with a preparation of a mustard strain of *Bacillus thuringiensis Bt* H3136. *Journal of Yunna Agricultural University*, 17 (3): 239-240.

Xiang-Ping Wang, Van-Trinh Le, Yu- Ling Fang and Zhong-Ning Zhang, 2004. Trap effect on the capture of *Plutella xylostella* (Lepidoptera: Plutellidae) with sex pheromone lures in cabbage fields in Vietnam. *Appl. Entomol. Zool*. 39 (2): 303-309.

VITAE

MR. MALI AUDUMBER SUMANT

MASTER OF SCIENCE (AGRICULTURE)

IN

AGRICULTURAL ENTOMOLOGY

2018

Title of thesis		:	Efficacy of different modules against pest complex of cabbage.
Major field		:	Agricultural Entomology.
Biographical information		:	
Personal	**Date of Birth**	:	22.06.1994
	Place of Birth	:	Veet
	Father's Name	:	Sumant
	Mother's Name	:	Surekha
Educational	**Bachelor Degree Obtained**	:	2016
	Class	:	First class
	Name of University	:	Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.
Address		:	At Post- Veet, Tal- Karmala, Dist- Solapur.
	Email- id	:	audumbermali2012@gmail.com
	Contact Number	:	9960906063

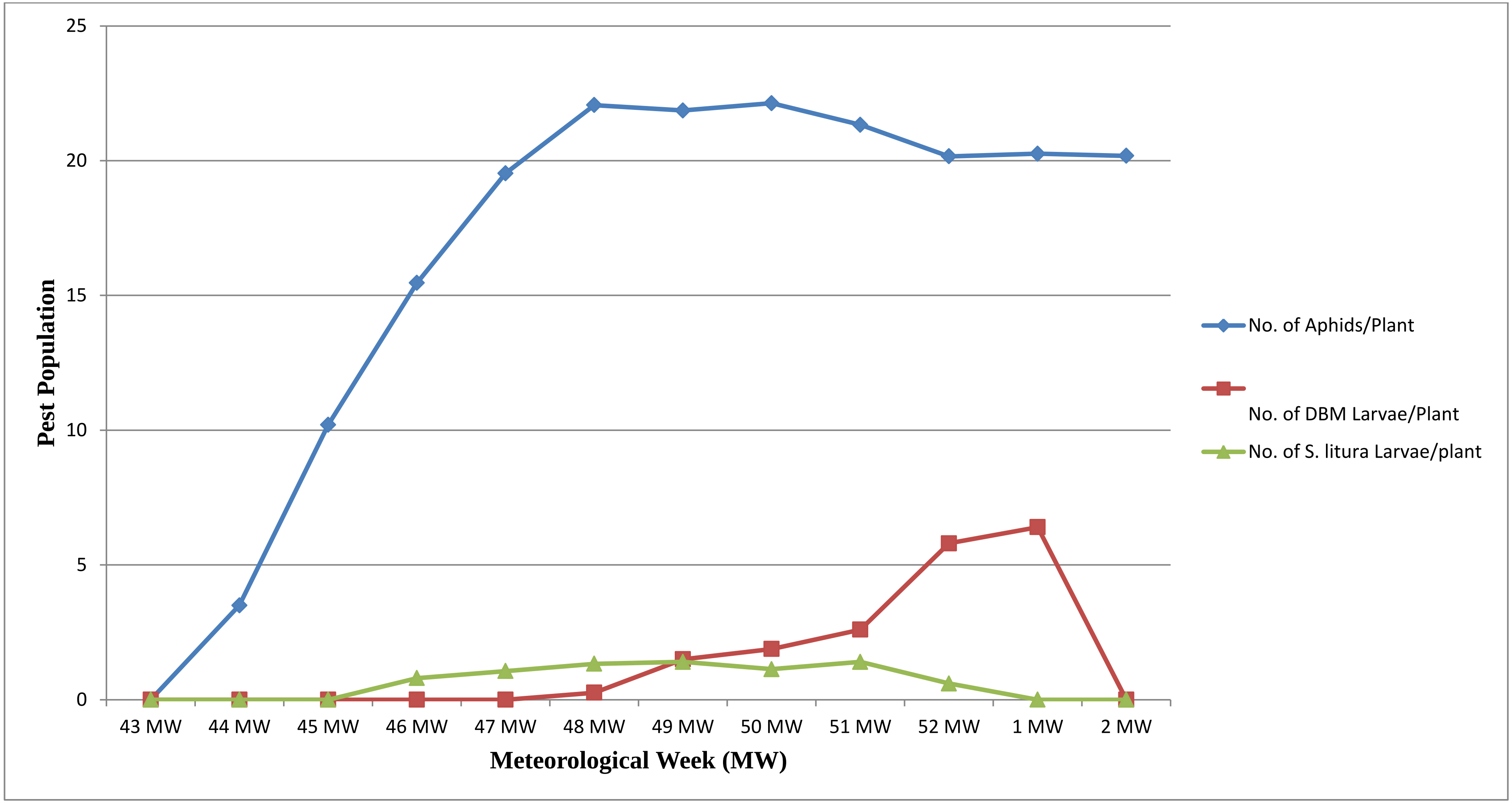

Fig. 2: Seasonal Incidence of Pests Infesting Cabbage During *Rabi*: 2016.

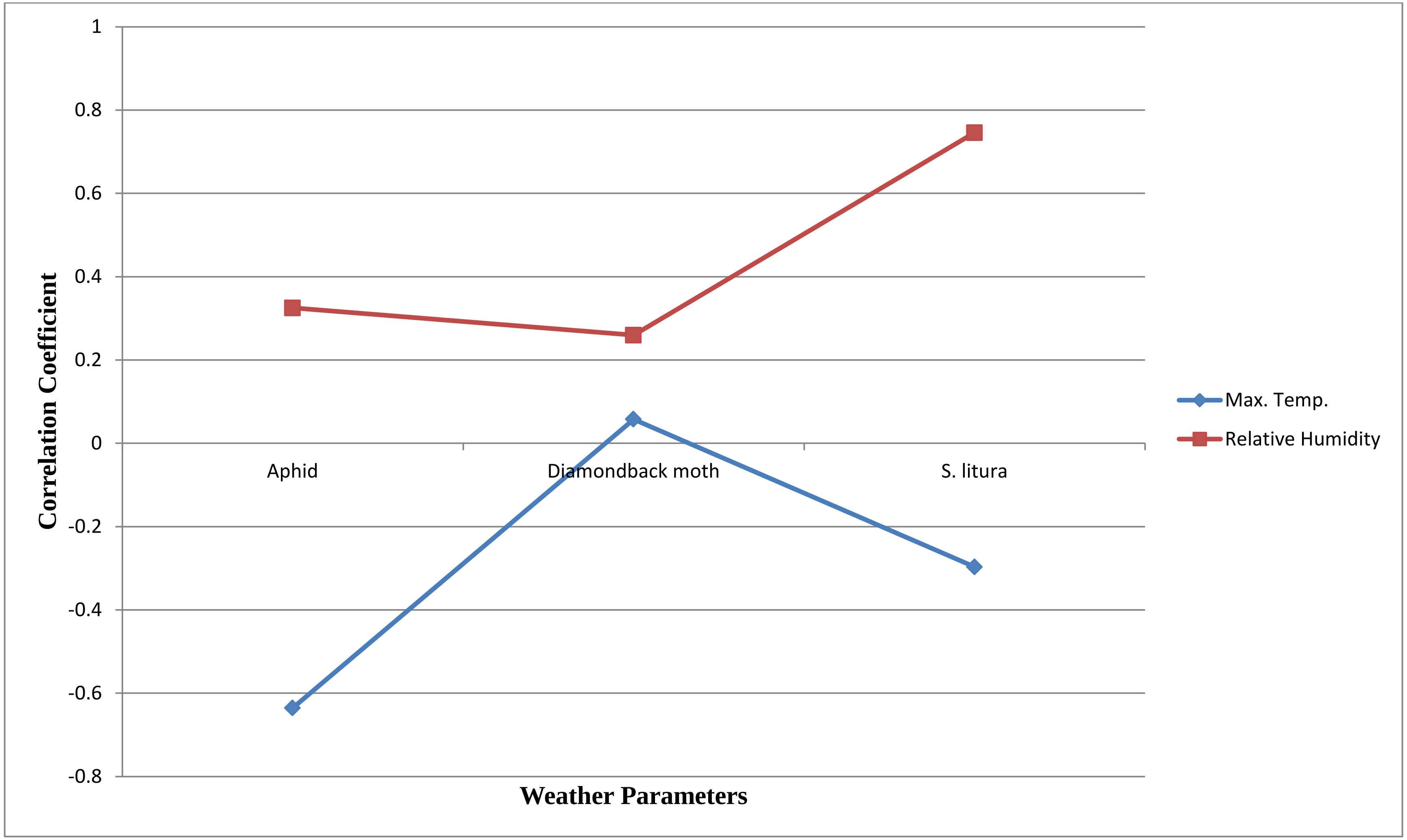

Fig. 3. Correlation between abiotic factors and pests of cabbage during *Rabi* 2016.

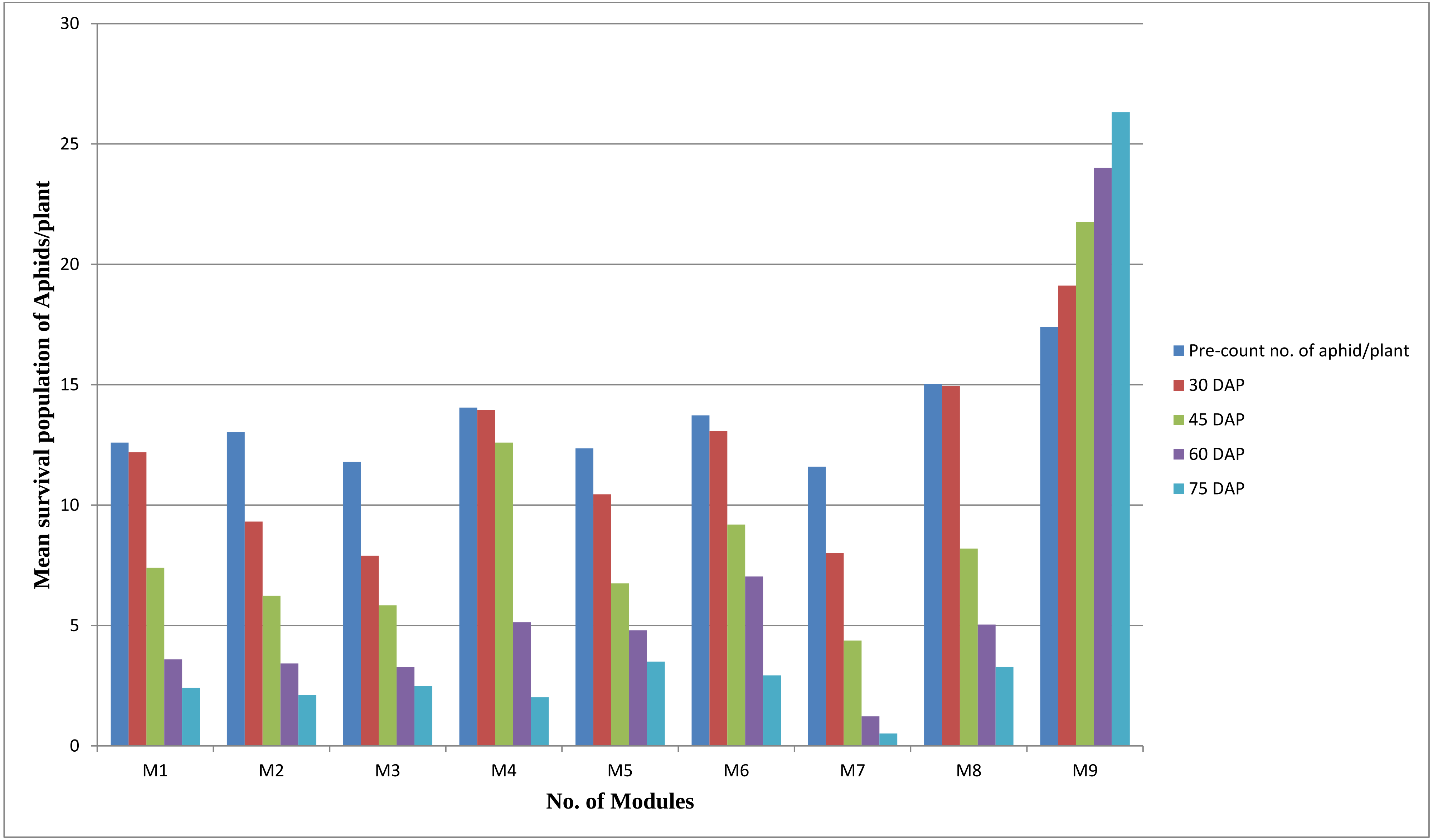

Fig. 4: Efficacy of different modules on aphid (*B. brassicae)* of cabbage.

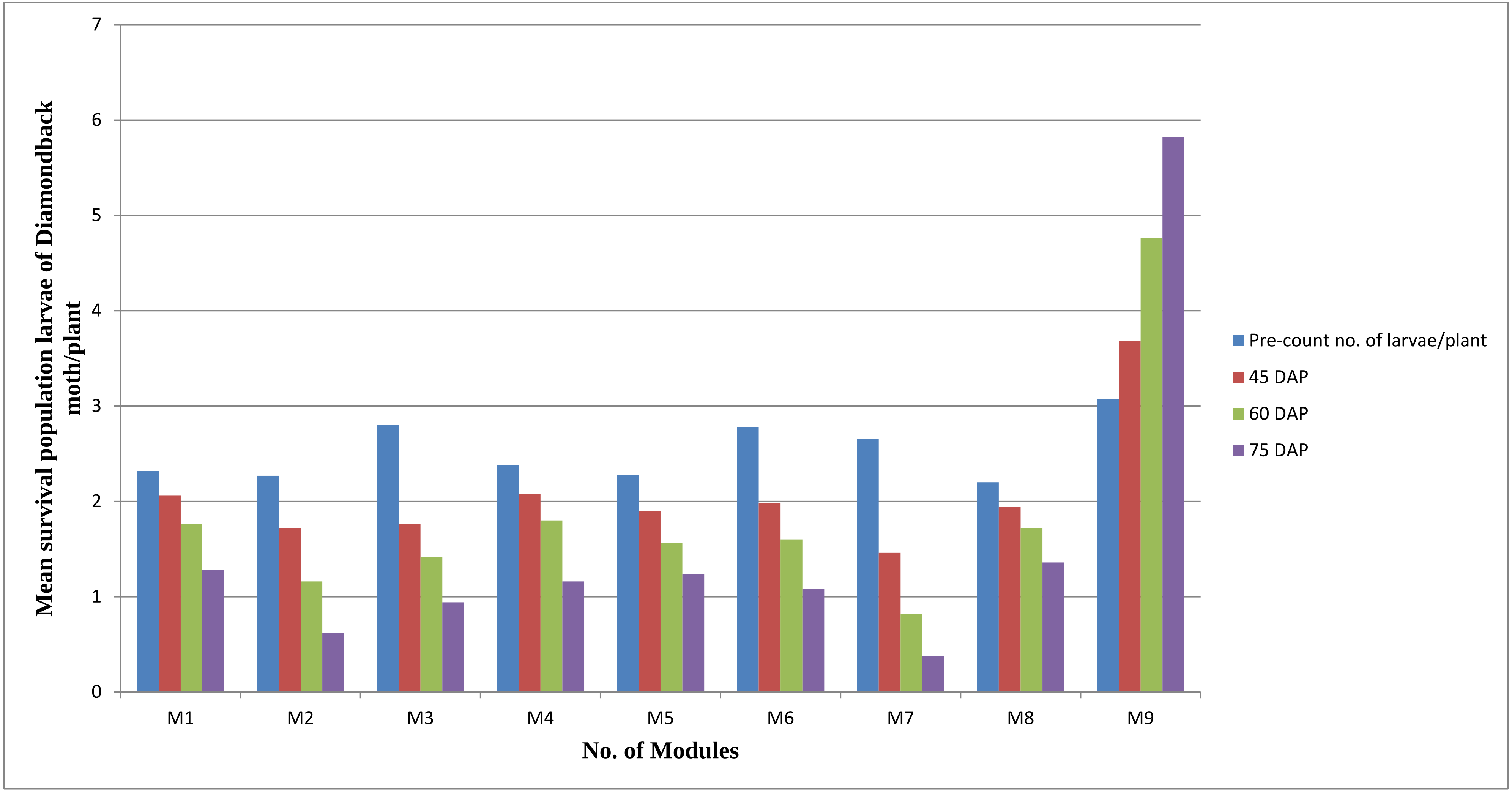

Fig. 5: Efficacy of different modules against diamondback moth (*P. xylostella)* of cabbage.

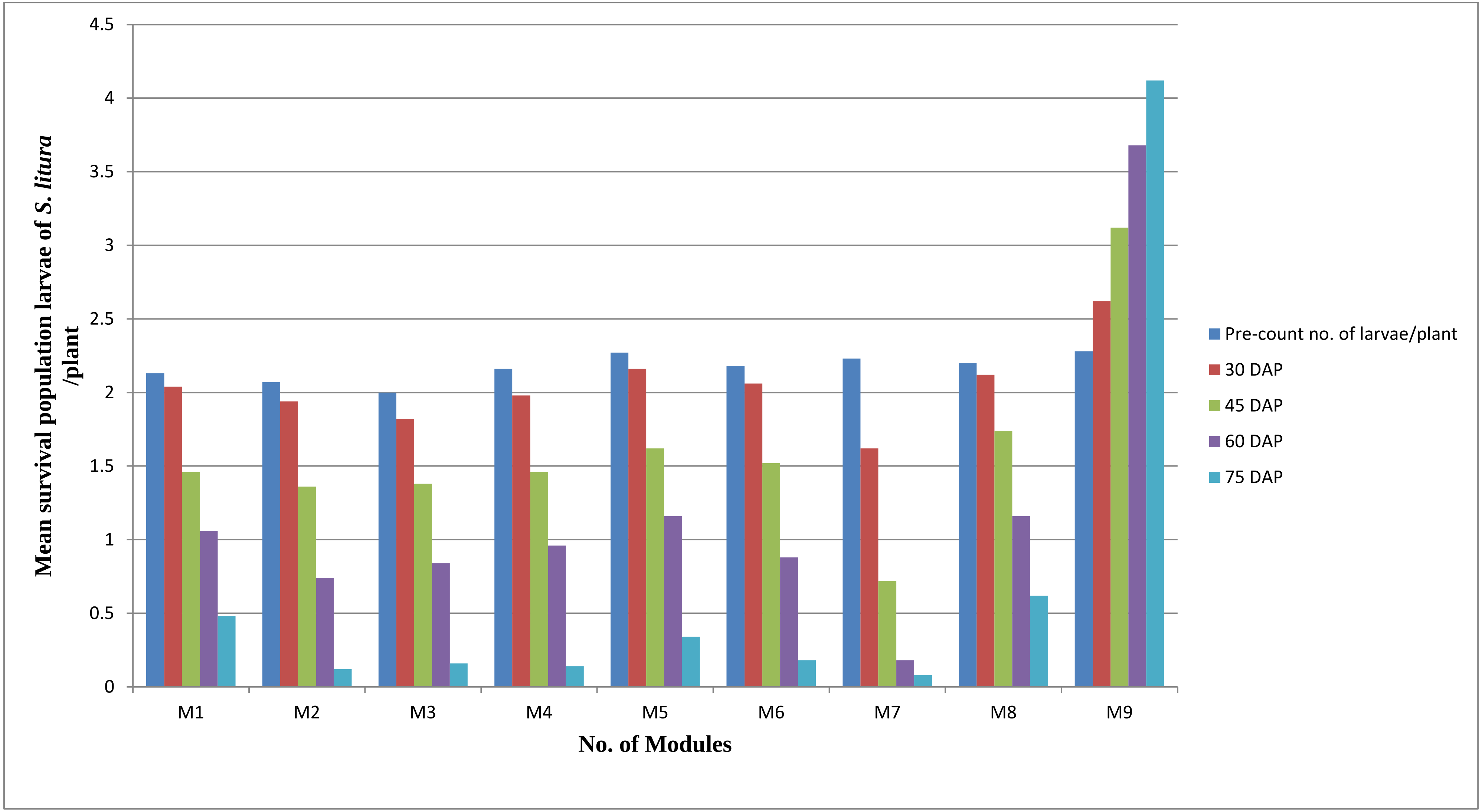

Fig. 6: Efficacy of different modules against *S. litura of* cabbage.

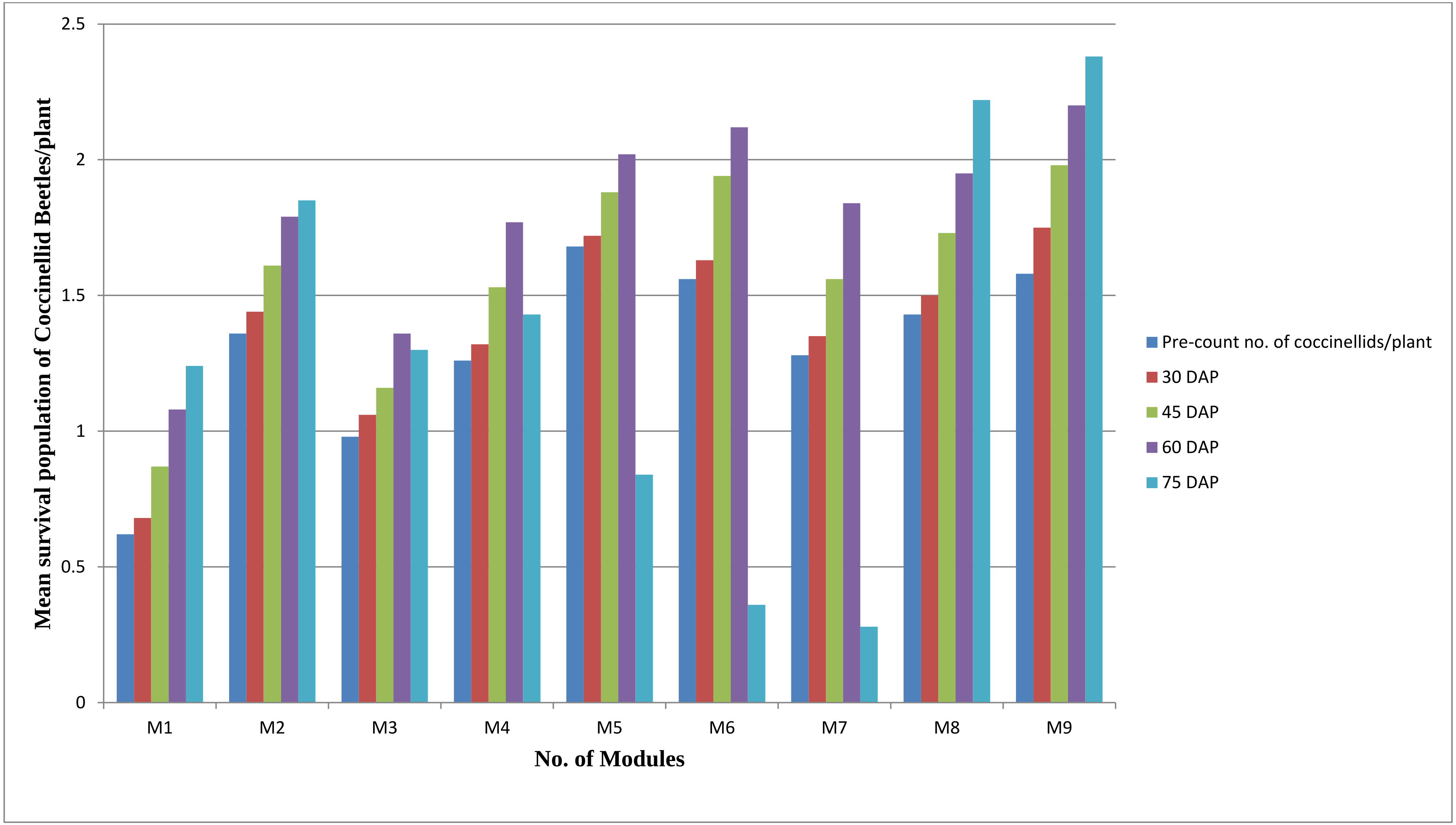

Fig. 7: Effect of different modules on Coccinellids population in cabbage.

Plate 1. Overall View of Experimental Plot.

Plate 2. Cabbage Aphid (*B. brassicae)* infesting cabbage.

Plate 3. Larvae of (*P. xylostella)* infesting cabbage

Plate 4. Larvae of *S. litua* infesting cabbage.

Plate 5. Coccinellid Beetle