

**STUDIES ON INSECT PEST DYNAMICS OF CABBAGE AND
MANAGEMENT STRATEGIES OF DIAMONDBACK MOTH, *Plutella
xylostella* (Linn.)**

गोभी की कीट-पीड़क गतिशीलता और डायमंडबैक मॉथ, प्लूटेला ज़ाइलोस्टेला (लिनियस) की प्रबंधन
रणनीतियों पर अध्ययन

THESIS

SUBMITTED TO THE

**SARDAR VALLABHBHAI PATEL UNIVERSITY OF AGRICULTURE AND
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BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

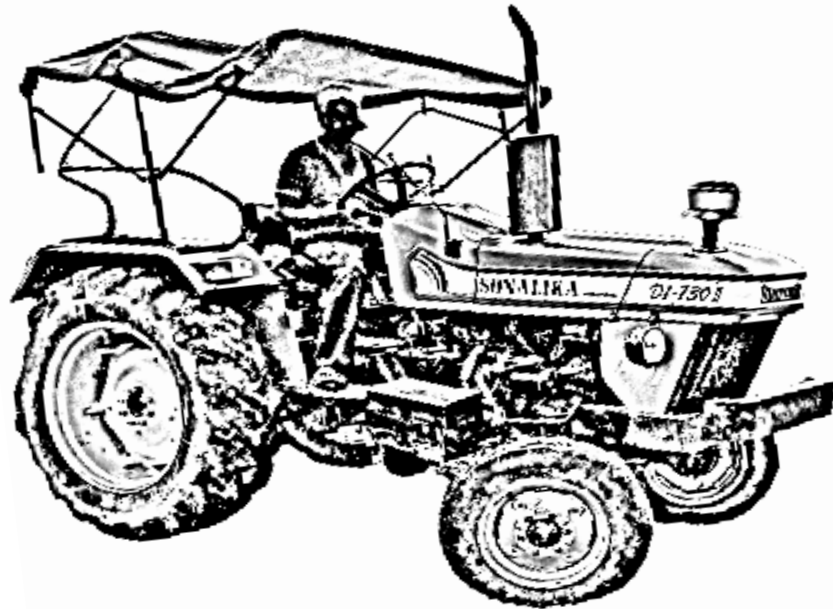
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

ENTOMOLOGY

SEPTEMBER, 2023



DEDICATED To

My

Beloved

Parents and Indian Farmers

Chandra Kant...✍

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CERTIFICATE

This is to certify that the thesis entitled ‘**Studies on insect pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**’ submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** with major in **Entomology** and minor in **Plant Pathology** of the College of Post-Graduate Studies, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut is a record of *bonafide* research carried out by **Mr. Chandra Kant, Id. No. PG/A-2216/20**, under my supervision and no part of the thesis has been submitted for the award of any other degree or diploma.

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

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We, the undersigned, members of the Advisory Committee of **Mr. Chandra Kant, Id. No. PG/A-2216/20**, a candidate for the degree of **Doctor of Philosophy** with major in **Entomology** and minor in **Plant Pathology** agree that the thesis entitled '**Studies on insect pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**' may be submitted by **Mr. Chandra Kant** in partial fulfillment of the requirements for the degree.

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LIST OF ABBREVIATIONS

%	-	Per cent
°C	-	Degree Celsius
@	-	At the rate of
<i>a. i.</i>	-	Active ingredient
ANOVA	-	Analysis of variance
Av	-	Average
C. D.	-	Critical Difference
cm	-	Centimeter
Con.	-	Concentration
d. f.	-	Degree of freedom
DAA	-	Days after application
DAT	-	Days after transplanting
DBA	-	Days before application
DBM	-	Diamondback moth
E. S. S.	-	Error sum of square
<i>e.g.</i>	-	For example
EC	-	Emulsifiable concentrate
<i>et al.</i>	-	And others
<i>etc.</i>	-	And the rest
F. cal.	-	Calculated value of 'F'
F. tab.	-	Table value of 'F'
FAO	-	Food and Agriculture Organization
Fig.	-	Figure
FYM	-	Farm yard manure
gm.	-	Gram
h.	-	Hour

ha	-	Hectare
<i>i.e.</i>	-	That is
J.	-	Journal
K	-	Potash
kg	-	Kilogram
L.	-	Litre
lbs.	-	Pounds
MS	-	Mean squares
N	-	Nitrogen
No.	-	Number
No.	-	Number
NS	-	Non significant
NS	-	Non-significant
P	-	Phosphorus
ppm	-	Parts per million
psi	-	Pounds per square inch
r	-	Replication
S	-	Significant
S.S.	-	Sum of squares
SC	-	Suspension concentrate
SL	-	Soluble liquid
Sp.	-	Species
Spp.	-	More than one species
SW	-	Standard Week
<i>viz.</i>	-	Videlicet (That is to say)
wt.	-	Weight

Cabbage, *Brassica oleracea* var. *capitata* (Linn.) is a member of the “Cruciferous” family along with other vegetables such as broccoli, cauliflower and Brussels sprouts. Its numerous varieties including green cabbage, red cabbage and savoy cabbage offer versatility in cooking, making it a staple in many cuisines. The genus cabbage is a cole crop vegetable, it is considered as one of the exotic vegetables. It is one of the most popular winter seasons leafy vegetables that is widely consumed across the globe as well as overall in India. The Head of cabbage may reach 0.5 to 1.5 kilograms. In India, cabbage is cultivated in a wide range of tropical and temperate regions. Many researchers have observed that *Brassica oleracea* (Linn.), with a chromosome number of $n=9$ and $2n=18$, exhibits distinct characters. It is believed to have originated from the coastal regions of Northern Europe or the Mediterranean region. **Snogerup (1980).**

Cabbage was brought to India by the “Portuguese” somewhere between the 14th and 17th centuries. China is the leading cabbage producer globally, followed by India as the second-largest producer. India contributes an area under cabbage cultivation is about 0.412 million hectares and production may reach about 9.56 million tonnes in the financial year 2021. In the financial year 2022, the volume of cabbage production in India was about 9.82 million tonnes and the area of cabbage cultivation was about 0.423 million ha. **Anonymous (2022).**

In India, the crop is cultivated in almost all the states. Annual production of Cabbage in West Bengal in 2021-22, ranked first, the state accounted for 24.38 per cent of total production. The cultivated area and average productivity of cabbage were 22.18 tonnes/ha. Cabbage seeds germinate properly at 12.7°C to 15.5°C temperatures. The

major cabbage-growing states in the country are West Bengal (24.38 per cent), Odisha (11.77 per cent), Gujrat (8.29 per cent), Madhya Pradesh (8.29 per cent), Assam (7.75 per cent), Bihar (7.52 per cent), Chhattisgarh (4.38 per cent) Uttar Pradesh (3.63 per cent), followed by Haryana, Karnataka and Maharashtra. In Uttar Pradesh, the area under cultivation of cabbage is about 9.06 thousand hectares with a production of about 302.97 thousand tonnes **Anonymous (2022)**.

The head is an excellent source of vitamins, minerals and dietary fibre. The crop demands a higher amount of plant nutrients, particularly nitrogen for head production. However, an excess supply of nitrogen through inorganic fertilizers increases the total dry weight but adversely affects the head quality by producing coarse and loose heads, reducing keeping quality and enhancing the nitrate, nitrogen content of the head **Ojetayo et al. (2011)**.

Cabbage is a low-calorie vegetable that is rich in nutritional value per 100 g of cabbage consists of carbohydrates 5.8 g, fat 0.1 g, protein 1.28 g, vitamins (thiamine or vitamin B₁ 0.061 mg, riboflavin or B₂ 0.040 mg, niacin or vitamin B₃ 0.234 mg, pantothenic acid or vitamin B₅ 0.212 mg, folate or vitamin B₉ 43 mg, vitamin C 36.6 mg and vitamin K 76 mg) and minerals Ca 40 mg, Fe 0.47 mg, Mg 12 mg, Mn 0.16 mg, P 26 mg, K 170 mg, Na 18 mg and Zn 0.18 mg, **Sharma et al. (2017)**. Besides its culinary uses, cabbage has traditionally been used for its medicinal properties. Se-enriched sauerkraut extracts exhibit high antioxidant and anti-inflammatory properties. **Penas et al. (2012)**. Cabbage has an anti-cancer property it protects against bowel cancer due to the presence of indole-3-carbinol. Cabbage juice was used as a remedy against poisonous mushrooms **Keck et al. (2004)**.

People of most ages prefer fast foods because they are quick to prepare, simple to access, moderately affordable and tasty. It is generally used in making fast food (Burger, Noodles, Pizza and Rolled) as well as cooked vegetables either alone or mixed with potato, peas or other vegetables as fried or in curry form **Bahadoran et al. (2012)**.

Pest complexes are a significant stumbling block in the cultivation of cabbage from seed to harvest. The cabbage aphid, *Brevicoryne brassicae* (Linn.), the head borer, *Hellula undalis* (Fabr.), the mustard sawfly, *Athalia lugens proxima* (Klug.), the leaf webber, *Crocidolomia binotalis* (Zeller.), the diamondback moth (DBM), *Plutella xylostella* (Linn.) cabbage semiloopers, *Trichoplusia ni* (Linn.) and *Pieris brassicae* (Linn.). The per cent yield loss in cabbage due to insect pests ranged from 19.24 to 30.30 per cent with an average of 25.80 per cent. Out of these, the diamondback moth *Plutella xylostella* (Linn.) is the most destructive and cosmopolitan pest **Mahla et al. (2005)**.

The plant damage is induced by larval feeding, leading to the complete defoliation of foliage except for the leaf veins. This damage typically affects seedlings and can disrupt head formation in cabbage, broccoli, cauliflower, and other related crops. *Plutella xylostella* was first reported in South Africa in the early 1900s this pest received serious attention.

The Diamondback Moth, *Plutella xylostella* (Linn.) is a major pest of cruciferous crops, including cabbage, *Brassica oleracea* (Linn.). Despite its small size, this moth can cause significant damage to cabbage crops, reducing yields and compromising the quality of the harvested produce. In India, the diamondback moth has national importance on the cabbage as it causes a 50-80 per cent annual loss in the marketable yield. In India, **Krishnamoorthy (2004)** also reported a 52 per cent yield loss on cabbage due to the attack of the diamondback moth **Devjani and Singh (1999)** loss of 16 million US \$ every year **Mohan and Gujar (2003)**.

In recent years, the use of chemical pesticides has been the primary method of controlling this pest. However, there is growing concern about the environmental impact of these chemicals and the development of resistance to them by the diamondback moth. Diamondback moth has developed resistance to almost all groups of chemical pesticides. This has necessitated the use of eco-friendly insecticides to sustain the management of

diamondback moth. This has led to a renewed interest in alternative methods of controlling this pest, including the use of biological control agents, such as natural predators and pathogens and the implementation of integrated pest management strategies. The efficacy of neem products and microbial insecticides like *Bacillus thuringiensis* has been reported by several workers **Nethravathi and Hugar (2010); Raut and Simon, 2010** and **Meena *et al.* (2011)**.

Since it has attained the status of a major pest, farmers are more concerned to control it. It has been estimated that globally the cost of control is about 1 billion US \$ **Grzywacz *et al.* (2010)**. However, in India, the cost of pest control particularly DBM *P. xylostella* (Linn.), cabbage worm *S. litura* (Fab.) and aphids *Brevicoryne brassicae* (Linn.) was estimated at around US \$ 168 million **Sandur (2004)**.

The widespread use of insecticides on cabbage and cauliflower has led to the elimination of natural enemies such as predators, parasitoids and pathogens of DBM, thus paving the way to attain the status of the most noxious pest of various cole crops in India **Singh *et al.* (2005)**.

Indiscriminate use of insecticides may cause pest resistance, an outbreak of the secondary insect pests, residue problems, ill effects on natural enemies, phytotoxicity, degradation of the environment and many more harmful impacts on flora and fauna. Thus, it is imperative to look for some other better alternatives to synthetic insecticides being used at present, which should be naturally and locally available, cost-effective, least hazardous, biodegradable and safe for beneficial organisms.

Inducing resistance through natural methods and the use of botanical insecticides has become more practical due to the seriousness of the widespread use of chemical insecticides in the management of vegetable insect pests and the consequent significant insecticide residues in consumable products. In this context, the use of bio-pesticides has become

popular over the past two decades as an alternative strategy. Bio-pesticides are thought to be much safer for the environment and other beneficial organisms in the long run as well as the rational course of action due to their high target selectivity, environmental compatibility, economic viability and novel mode of action. Entomopathogenic fungi, bacteria and viruses, like all microorganisms, have distinctive biological traits that affect their activity in the environment. **Parker *et al.* (2003).**

Biological control agents, including predators, parasitoids, bacteria, fungi, viruses and nematodes have demonstrated their effectiveness in reducing diamondback moth populations. Predatory insects like ladybugs and lacewings play a crucial role by consuming the moth's larvae and eggs while pathogens such as bacteria and fungi can infect and eliminate the larvae. By employing these biological control agents, the reliance on chemical pesticides can be minimized, leading to a decreased risk of pesticide resistance and a reduced environmental impact associated with these chemical compounds.

Integrated pest management (IPM) is a comprehensive and eco-friendly approach to pest control, aimed at reducing the reliance on chemicals and promoting the use of natural predators and alternative pest control methods. It encompasses various strategies such as cultural, physical and biological control methods that focus on sustainability. The successful application of IPM has been demonstrated in reducing diamondback moth populations and enhancing the overall health of cabbage crops. Presently on bio-pesticides, more emphasis is being given to developing suitable integrated insect-pest management strategies, based on ecological principles. Several workers have explored the utility of bio-pesticides as a potential source to manage the diamondback moth, *Plutella xylostella* (Linn.). **Deguine *et al.* (2021)**

Cabbage is rich in vitamins and minerals, making it beneficial for human health. The demand for cabbage is consistently high throughout the year, driven by its use in Chinese

dishes such as Noodles, Burgers and Momos. However, in the pursuit of higher production and reduced losses, farmers have resorted to using various types of synthetic pesticides. Unfortunately, these pesticides pose hazards to human health, non-targeted organisms and the environment. To address these issues, an experiment was conducted to compare the effects of newer insecticides and bio-pesticides on cabbage. **Alexandra et al. (2020)**

This study involved a comparative analysis of research done on cabbage insect-pest dynamics and management strategies for the diamondback moth *Plutella xylostella* (Linn.). The evaluation was focused on the efficacy of specific synthetic chemical insecticides and bio-pesticides against the diamondback moth on cabbage. Additionally, an economic analysis of insecticide and bio-pesticide application against the diamondback moth on cabbage was performed to assess their cost-effectiveness and impact on crop yield.

Therefore, the proposed study was done on the management of diamondback moth which is a serious insect pest under agro-climatic conditions with some safer insecticides in Western Uttar Pradesh. Keeping in view the above facts the proposed work has been undertaken for the study on the given aspect “**Studies on insect-pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**” has been conducted at Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during two consecutive *Rabi* season 2021 and 2022 with the following objectives:

1. To study the insect-pest complex of cabbage.
2. To study the seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) of cabbage.
3. To study the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.).
4. To study the effect of newer insecticides and biopesticides on natural enemies.

5. To calculate the incremental cost-benefit ratio of different treatments.

Numerous pieces of literature have been published over time on the current study of the Diamondback moth, covering various aspects of the research. However, there is a few numbers of literature specifically reviewing the aspect of “**Studies on insect-pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**”. Consequently, this chapter compiles and evaluates the available published works under different categories.

1. To study the insect-pest complex of cabbage

Cordero *et al.* (2006) observed some Lepidopteran pest species including *P. xylostella*, *Pieris rapae* (Linn.), *Trichoplusia ni* (Hübner), *Spodoptera frugiperda* (J. E. Smith), *Estigmene acrea* (Drury), *S. exigua* (Hübner), *Helicoverpa zea* (Boddie), *Evergestis rimosalis* (Guenée) and *Hellula rogatalis* (Hulst) in field condition.

Duchovskienė *et al.* (2010) observed the occurrence of cabbage aphid *Brevicoryne brassicae* (Linn.) and parasitoids from *Braconidae*, *Syrphidae* and *Cecidomyiidae* families were found to be associated with white cabbages.

Hemchandra and Singh (2007) studied the insect pest complex of cabbage Hemchandra recorded the 20 different natural enemies which included 5 birds, 3 syrphid fly, 3 spiders, 2 ants, 1 coccinellid and 5 species of parasitoids associated with *Plutella xylostella* (Linn.)

Venkateswarlu (2011) conducted a field experiment on cabbage, where mustard aphid, *Lipaphis erysimi*, diamondback moth (DBM), *Plutella xylostella*, Cabbage butterfly, *Pieris brassicae* were recorded. Mustard aphid was noticed from the last week of December while the diamondback moth was observed during the first week of February and the cabbage butterfly appeared during 2nd week of January during both rabi 2009-2010 and

2010-2011. The peak incidence of mustard aphid (169.9 aphids per plant), diamondback moth (7.9 larvae per plant) and cabbage butterfly (27.7 caterpillars per plant) were recorded during 2nd week of March, 1st week of March and 2nd week of March.

Embaby and Lotfy (2015) conducted a field study on cabbage and observed that cabbage crop was associated with Cabbage worm, *Pieris rapae* (Linn.), Pieridae, Lepidoptera, Cabbage aphid, *Brevicoryne brassicae* (Linn.), Aphididae, Homoptera, diamond back moth, *Plutella xylostella* (Linn.), plutellidae, Lepidoptera and Beet armyworm *Spodoptera exigua* (Linn.), Noctuidae, Lepidoptera. The most common brassica pests were *Pieris rapae* (17.9 per cent) followed by Cabbage aphid, *Brevicoryne brassicae* (Linn.), (7.59 per cent) and *Plutella xylostella*, diamondback moth (1.38 per cent) while the secondary pest was Beet army worm *Spodoptera exigua* (Linn.) (0.27 per cent).

Yadav et al. (2015) studied 23 different insect-pest species with seven different orders on cabbage field out of which maximum 31per cent insect pest species was from the order Lepidoptera and 5 per cent insect-pest species was from the order Diptera and Isoptera. The pest which showed highest population were diamondback moth, *Plutella xylostella* (Linn.) and cabbage head borer, *Hellula undalis*. Among natural enemies it includes predators like rove beetle, *Paederus spp.* and ladybird beetle, *Coccinella septumpunctata* (Linn.) parasitoids, *Diaeretiella rapae* and *Cotesia plutellae*.

Baidoo and Mochiah (2016) reported two species of natural enemies of *B. brassicae* on the cabbage plants. These were the ladybird beetle *Cheilomenes vicina* (Coleoptera: Coccinellidae) and the carpenter ant *Camponotus sp.* (Hymenoptera: Formicidae). Their numbers were significantly lower on the plots sprayed with insecticide in comparison of the plot sprayed with garlic and pepper.

Dey et al. (2017) that the cabbage crop is prone for infestation by a number of insect pests consisting sucking and defoliating insects starting from germination to the harvesting

stage of the crop. In India, the diamondback moth, *Plutella xylostella* (Linn.) and cabbage butterfly, *Pieris brassicae* Linn. are the major Lepidopterous pests of cabbage. Adjusting planting dates can sometimes help to avoid certain insect infestations and reduce the need for chemical control. Planting dates influence crop performance due to changed biotic and abiotic factors. The time of planting of cabbage, which is a season-bound crop, has a profound effect on the incidence of diamondback moth and cabbage butterfly.

Labou et al. (2017) concluded that the diamondback moth *Plutella xylostella* (Linn.) was by far the most important pest associated with the cabbage crop, with high levels of incidence (37.1 per cent infested plants), particularly in the later part of the dry season in the South of Niayes (50 per cent infested plants). The cabbage webworm *Hellula undalis* (Fabb.) was mainly observed in the early dry season in the south of Niayes, with an incidence of up to 12.5 per cent infested plants. More surprising was the detection of the tomato fruit worm *Helicoverpa armigera* (Hubner), with damage of up to 9.4 per cent of cabbage heads. The incidence of sucking pests such as whiteflies *Bemisia tabaci* (Gennadius), or aphids including *Lipaphis pseudobrassicae* (Davis, 1914), *Myzus persicae* (Sulzer) or *Brevicoryne brassicae* (Linn.) was generally low. The incidence of *P. xylostella* increased significantly with the number of insecticide applications, indicating that control deployed by growers was ineffective.

Chaubey and Murthy (2018) reported that the pest population peaked during the early summer, March-April months (342 and 243/60 plants) followed by post rainy season, August-October (184 and 208/60 plants) and was low during the early winter months December-January (65 and 68/60 plants) followed by July-August (98 and 96/60 plants). A maximum temperature of 30-35°C with a relative humidity of 61-75 per cent favored the buildup of the pest. The larval incidence had a significant positive correlation with maximum temperature ($r = 0.837$; $P = 0.01$) and with minimum temperature ($r = 0.594$; $P = 0.05$).

Rainfall and number of sunshine hours had a negative impact. The larval parasitoid *Cotesia vestalis* and the late larval-pupal parasitoid *Oomyzus Sokolowski* were predominant during both years of study. Parasitism by *C. vestalis* was maximum during the August- September month (64.89-82.2 per cent), and was low during December-January month (41.5-47.5 per cent). *O. Sokolowski* prevailed high during December- January months (33.33-37.5 per cent) and low during February - March (8.82-8.75 per cent) and July/August-September (6.25-10.0 per cent). Occurrence of the parasitoids was more at a minimum temperature of 16-19 °C and maximum temperature of 19-33 °C with relative humidity 62.5-73.5 per cent. Rainfall did not influence the activity of both parasitoids.

Aiswarya et al. (2018) studied the population dynamics of major lepidopterous insect pests on cabbage during *Rabi* 2016-17 at Parbhani (M.S.). The larval population of DBM, head borer, leaf webber, cabbage semilooper and tobacco leaf eating caterpillar ranged from 1.2 to 5.5, 0.45 to 1.8, 2.0 to 7.0, 0.77 to 1.2 and 1.98 to 3.2, respectively. The infestation of DBM, head borer, leaf webber and cabbage semilooper was initiated during 47th MW and of tobacco leaf eating caterpillar during 46th MW. The peak incidence of DBM, head borer, leaf webber, cabbage semilooper and tobacco leaf eating caterpillar was observed during 51th, 3rd, 48th, 49th and 49th MW, respectively during 2016-17.

Larinfeli et al. (2019) studied the biodiversity of major insect pests of cole crops in mid hills of Meghalaya. Limited information is available on insect pests in cole crops ecosystem in mid-hills of Meghalaya. A total of 12 insect pests belonging to four insect orders viz., Lepidoptera (6), Coleoptera (2), Diptera (2), Hemiptera (2) were documented during the year 2014-2015. The large white cabbage butterfly, *P. brassicae* green peach aphid, *Myzus persicae* and tobacco caterpillar *Spodoptera litura* were found to be the most serious pest of cole crops in this region. Besides, diamondback moth, *Plutella xylostella* was also found to be one of the major pests of late planted cole crops. Striped flea beetle

Phyllotreta striolata, leaf beetle, *Monolepta quadriguttata*, cabbage looper, *Thysanoplusia orichalcea*, cabbage stink bug, *Eurydema dominolus*, small white cabbage butterfly, *P. canidia*, fruit fly, *Bactrocera tau*, dipteran fly, *Allactoneura* sp and cabbage heart caterpillar, *Crocidolomia pavonana* appeared to be a minor pest.

Sahu et al. (2019) study the insect pest succession and field incidence on cabbage crop. He observed that the major insect pest species damaging the cabbage crop were from the order of painted bug, *Bagrada cruciferarum* (Hemiptera: Pentatomidae), tobacco caterpillar, *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae), Gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae), flea beetle, *Phyllotreta cruciferae* (Coleoptera: Chrysomelidae), aphid, *Lipaphis erysimi* (Kalt.) (Hemiptera: Aphididae), diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae), and cabbage head borer, *Hellula undalis* (Lepidoptera: Crambidae) and two natural enemies' spider (Unidentified) and ladybird beetle, *Coccinella septempunctata* were also found.

Imbert et al. (2020) observed that the cabbage crop was predominantly affected by whitefly eggs (67.9 per cent), whitefly adults (65.2 per cent) and lepidopteran eggs (61.2 per cent). Aphid abundances were low around 10–20 individuals per plant, with a large difference between plots for *M. parisiaca*.

Lal et al. (2020) observed that the cabbage crop was abundantly infested by aphids and DBM (Rabi, 2016-17). The incidence of painted bugs was observed during December whereas, the flea beetles and tobacco caterpillars were observed in the month of January. The major insect pests reached their peak mean populations from February to March. During Rabi, 2015-16, the mean atmospheric temperature had a significant positive correlation ($r = 0.63, 0.63, 0.85$) with painted bug, flea beetle and diamondback moth, respectively. The sunshine hours had a significant positive correlation ($r = 0.62, 0.78$) with painted bug during 2015-16 and 2016-17, respectively. Whereas, relative humidity had a significant negative

correlation ($r = -0.62$) with flea beetle during 2015-16.

Bhat (2020) studied the 40 natural bio-control agents (parasitoids, predators and pathogens) working against the major lepidopteron pests in vegetable crops. This study will be useful in future studies for the understanding of lepidopteron pests of this region. It will also be helpful for the studies which aim at planning and devising of Integrated Control of lepidopteron pests in this region.

Kumar et al. (2021) reported that in the Bihar region, Diamondback moth was found to be the most serious insect pest of cabbage. The infestation appeared during the first week of January (SMW1) at the vegetative stage and lasted up to the harvesting of the crop *i.e.*, 11th SMW. Among the natural enemies, two species of coccinellids (*Coccinella septempunctata*, *C. transversalis*), one larval parasitoid (*Cotesia plutellae*), one Syrphid fly (*Toxomerus geminatus*) and one unidentified spider was observed during crop period.

Sarma et al. (2021) study the diversity of insect pests and predators of cabbage ecosystem in different phonological stages of cabbage. Major insect pests recorded during both the crop season from 20 DAP, were cabbage aphid, *Brevicoryne brassicae* (Linn.), diamondback moth, *Plutella xylostella* (Linn.), cabbage butterfly, *Pieris canidia* (Linn.), cutworm, *Agrotis ipsilon* (Hfn.), cabbage looper *Trichoplusia ni* (Hub.) and flea beetle, *Monolepta signata* Oliv with minor pests *viz.*, sawfly, *Athalia lugens proxima*, cabbage head borer, *Hellulaundalis* (Linn.), handmaiden moth, *Syntomoides imaon* (Linn.), epilachna beetle, *Epilachna* spp. (Linn.) and green stink bug, *Nezara viridula* (Linn.) were also persisted in the crop right from the seedling stage to harvesting of the crop. The following predators *viz.*, *Coccinella transversalis* (Fab.), *Maenochilus sexmaculatus* *C. Septem punctata* (Linn.), *Micraspis discolor* (Fab.), *Harmonia dimidiata* (Fab.), *Episyrphus belteotus* (Linn.) and one number of predatory spiders, *Oxyopes* spp. were recorded from cabbage ecosystem.

Pathak et al. (2021) reported that the cabbage crop was infested by bihar hairy caterpillar, diamondback moth, cabbage aphid, cabbage maggot, cabbage butterfly, tobacco caterpillar, ladybird beetle, rice bug, cricket and spider. The population of diamondback moth was positively correlated with maximum, minimum, average temperature and maximum relative humidity and negatively correlated with minimum RH, wind speed and rainfall. The highest larval population was recorded during 1st week of January (1st Standard Meteorological Week, SMW).

Hasan et al. (2021) reported the rate of plant infestation, by flea beetles (100.0 per cent), propania caterpillar (33.3 per cent) and diamondback moth (33.3per cent) and categorized them as major pests whereas epilachna beetle, leaf miner, cutworm and cabbage worm were categorized as minor pests having per cent plant infestation of 16.7 per cent, 11.1 per cent, 1.9 per cent and 1.6 per cent, respectively. The average population density of different arthropod pests of cabbage per plot (3m × 2m) in 7 observations was 0.14, 1.85, 2.00, 0.00, 0.71, 6.71, 9.85 for cutworm, epilachna beetle, flea beetle, leaf miner, cabbage looper, propania caterpillar and diamondback moth (DBM), respectively. The abundance of insect pests was maximum during the 3rd week of February (5.3 ± 0.4 per 6m²), the richness was the maximum (1.3 ± 0.1) during the 3rd week of January, whereas the diversity was the maximum (1.0 ± 0.0) during the 1st week of December and the 3rd week of January.

Chauhan et al. (2022) performed an experiment on the diamondback moth, *Plutella xylostella* (Linn.) (Insecta: Lepidoptera: Plutellidae), their ecology and integrated management to achieve essential conclusion about the most appropriate techniques to reduce pest infestation for higher yield and productivity with as little damage to the environment as possible. Therefore, current knowledge about the diamondback moth, *Plutella xylostella* (Linn.) and their natural enemies on cabbage, *Brassica oleracea*, is a prerequisite for the introduction of effective and successful management tactics against them.

Sharma et al. (2022) reported that the population of diamondback moth (*Plutella xylostella*) initially appeared during the 49th SMW and the peak incidence was reported during the 3rd SMW (9.0 larva/plant) and cabbage head borer (*Hellula undalis*) caterpillar population initially appeared during 51th SMW and reach its peak incidence was reported during the 2nd SMW (5.0 larva/plant) respectively, while the cabbage leaf webber (*Crocidolomia binotalis*) appeared from 48th SMW to 8th SMW with peak incidence in 1th SMW (4.3 larva/plant). Cabbage aphids (*Brevicoryne brassica*) were observed from 49th SMW to 8th SMW with the peak incidence in 5th SMW (41.0 larva/plant) and ladybird beetle (*Coccinella septempunctata*) appeared from 49th SMW to 8th SMW with peak incidence 4th SMW (1.0 larva/plant) respectively.

Joshi et al. (2020) investigated seventeen species of insects that were damaging (pests) the cabbage crop in different villages of Udham Singh Nagar during Rabi 2020. Out of these, five species of defoliators, viz., *Spodoptera litura*, *Helicoverpa armigera*, *Plutella xylostella*, *Phyllotreta cruciferae* and *Attractomorpha similis* and one sucking pest, i.e., Aphid *Brevicoryne brassicae* were recorded to cause noticeable damage to the crop. Among the various insect pests of cabbage *S. litura*, *B. brassicae* and *H. armigera* were more in number and had relatively higher abundance as compared to other species and hence considered the major pest of economic importance. Considering the pest complex of cabbage in the present study the order Lepidoptera occupied the largest number of species followed by Hemiptera, Coleoptera and Orthoptera.

2. To study the seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) of cabbage

Bindu et al. (2000) carried out a periodical survey on the farm of AICRP on Medicinal and Aromatic Plants GAU, Anand Gujarat during the *Rabi* season 1998-99 to know the seasonal abundance of *Plutella xylostella* on *Lepidium sativum*. The oviposition and larval

population of *Plutella xylostella* were observed during the second week of February to the last week of March. The egg and larval populations were comparatively low till the third week of February which gradually increased till the first week of March and declined thereafter the significant positive association was found between minimum temperature and oviposition as well as larval population.

Guilloux et al. (2003) reported that the populations of *Plutella xylostella* followed a logistic growth curve leading to the destruction of the crops in the first cropping season. In the second cropping, rains prevented the development of *Plutella xylostella*. Seven species of parasitoids were observed, *Diadegma leontinae* (Brethes) and *Apanteles piceotrichosus* (Blanchard) being dominant. *Cotesia plutellae* (Kurdjumov) and *Actia* sp., previously more abundant, became very minor parasitoids. Significant differences were observed in specific parasitism rates between the plots. The combined parasitism rates were identical on both plots (around 23 per cent) and were insufficient to regulate the populations of *Plutella xylostella*. Six species of hyperparasites were reared from *Diadegma leontinae* and *Apanteles piceotrichosus*, showing a high diversity of natural enemies in the region of recent colonization by *Plutella xylostella*.

Hemchandra and Singh (2007) reported that the initial pest density of Diamondback moth on cabbage crop was very low *i.e.*, 0.10 larvae per plant, 0.05 larvae per plant and 0.20 larvae per plant during the first, second, and third year, respectively in Manipur. Their abundance gradually increased reaching the peak values of 16.15 larvae per plant, 28.05 larvae per plant and 20.45 larvae per plant with infestation of 90 per cent (2001-02), 70 per cent (2002-03) and 95 per cent (2003-04) during March.

Ahmad and Ansari (2010) reported that the seasonal abundance of diamondback moth, *Plutella xylostella* occurred just after the transplantation of cauliflower seedlings and the population density of *Plutella xylostella* ranged between 0.90 to 2.38 and 0.27 to 5.84

larvae and pupae per plant in 1st week of July 2004 and 2005, respectively, and the rate of parasitization was quite low with respect of maximum and minimum Temperature and maximum and minimum humidity re-corded *i.e.* 24.15° to 32.91°C and 68.60 to 91.30 per cent, respectively. Population build-up is usually observed in 2nd to 4th week of September. *Cotesia plutellae* was found to be a dominant larval parasitoid while *Oomyzus sokolowskii* parasitized relatively few pupae of *Plutella xylostella*. 34.77°C significantly ($p < 0.01$) enhanced the population of DBM also on 8th September, 8th October, 2004 and 26th January, 2005. Rainfall negatively affected the DBM population in 2004–2005 and 2005–2006.

Vanlaldiki *et al.* (2013) evaluated that in both years, the larvae of the diamondback moth first appeared at the end of January (0.20 and 0.15/plant), increased gradually and reached its peak by the end of March with a population (12.05 and 11.20/plant) during both the seasons respectively. The larval population declined (2.20 and 0.60/ plant) by the second week of April in both years. The correlation studies indicated a significant positive correlation between the larval population of diamondback moth and max. and min. temperature with an exception to the second-year max. temperature, which showed a non-significant interaction. During 2009-10, the relative humidity (R.H), total rainfall and bright sunshine hours (BSSH) had a negative correlation, whereas in the second year (2010-2011), R.H and rainfall had positive relation with the larval population of diamondback moth. There was a marked variation of diamondback moth incidence on different dates of planting. The result showed that early planted crop (15th Nov.) harboured the least number of the target pest (0.06/plant) with the highest yield (20.80t/ha) whereas late planting (14th Jan.) resulted in the highest population (3.37 /plant) with the lowest yield of 6.15 t/ha and devoid of any marketable heads.

Ahmad *et al.* (2015) recorded the highest mean population of larvae and pupae *i.e.* 4.75±2.14 per plant and 6.7±1.71 per plant respectively, in September whereas the lowest

(0.2 ± 0.41 and 0.4 ± 0.71) was recorded in July 2012 and 2013 respectively. A negatively non-significant correlation ($r = -0.31$ and -0.18) was recorded with maximum temperatures, whereas with minimum temperature, the association ($r = 0.02$ and 0.06) was positively non-significant.

Khan and Talukder (2017) observed a positive correlation ($r = 0.824$ and $r = 0.920$) between the population of *Spodoptera litura* and temperature (maximum and minimum). On the other hand, there was a negative correlation ($r = -0.439$) between population of *S. litura* and maximum relative humidity and a negative correlation ($r = -0.716$) between population of *S. litura* and minimum relative humidity. The population of *Pieris brassicae* was positively correlated ($r = 0.899$ and $r = 0.956$) with maximum and minimum temperatures. There was a negative correlation ($r = -0.443$) between population of *P. brassicae* and maximum relative humidity and a strong negative correlation ($r = -0.645$) between the population of *P. brassicae* and minimum relative humidity.

Sharma et al. (2017) reported that infestation of diamondback moth (*Plutella xylostella* L.) started in the third week of November and reached the peak (45.2 larvae /10 plants) in the first week of January and the experiment was conducted at Horticulture Farm of S.K.N. College of Agriculture, Jobner, Jaipur during *Rabi* season 2015-16. The maximum and minimum temperatures showed a significant negative correlation with the larval population of diamondback moth whereas, a non-significant correlation was observed with relative humidity and sunshine hours. The coccinellid beetle was recorded as an important predator of aphids, which was maximum (20.2 /10 plants) in the fourth week of January.

Sonika et al. (2017) observed the infestation of *Plutella xylostella* Linn., diamondback moth from the 5th standard week (0.88 larvae/ plant) and reached peak (18.68 larvae /plant) in the 14th standard week under the climatic condition of Jammu, India. The maximum and minimum temperatures showed a significant positive correlation with the larval population

of diamondback moth whereas, a non-significant correlation with relative humidity and rainfall. Regression studies revealed that the weather factors had a 77.60 per cent contribution toward the larval population. Abiotic factors like temperature, relative humidity, extent and distribution of rainfall, influenced the infestation and stabilization of *Plutella xylostella* Linn. in cabbage.

Venugopal et al. (2017) evaluated the seasonal incidence of diamondback moth, *Plutella xylostella* Linn. infesting cabbage (*Brassica oleracea* var. *capitata* Linn.) at Allahabad during 2015-2016. The *P. xylostella* L. damage was active throughout the year with a varying degree of infestation. It was recorded from a minimum of 0.32 per cent (2nd fortnight of February) to a maximum of 5.98 per cent (3rd fortnight of March). A study on the correlation studies indicated a significant positive correlation between the larval population of the diamondback moth and the relative humidity (R.H), total rainfall and sunshine hours (SSH) had a negative correlation with the larval population of the diamondback moth.

Aiswarya et al. (2018) conducted an experiment to study the population dynamics of major lepidopterous insect pests on cabbage during *rabi* 2016-17 at Parbhani (M.S.). The larval population of DBM, head borer, leaf webber, cabbage semi looper and tobacco leaf-eating caterpillar ranged from 1.2 to 5.5, 0.45 to 1.8, 2.0 to 7.0, 0.77 to 1.2 and 1.98 to 3.2, respectively. The infestation of DBM, head borer, leaf webber and cabbage semi looper was initiated during 47th MW and of tobacco leaf-eating caterpillar during 46th MW. The peak incidence of DBM, head borer, leaf webber, cabbage semi looper and tobacco leaf-eating caterpillar was observed during 51th, 3rd, 48th, 49th and 49th MW, respectively, during 2016-17.

Bhagat and Sharma (2018) evaluate the seasonal incidence of diamondback moth in cabbage crops and the impact of weather parameters on its population dynamics. Infestation

of diamondback moth started from the end of December in 2015-2016 (0.075/ 20 plants) and the first week of January in 2016-2017 (0.125/ 20 plants) and reached its peak in the month of March in both years (6.85/ 20 plants and 5.25/ 20 plants). The correlation study revealed that the maximum temperature had a non-significant negative correlation ($r = -0.005$) with the larval population but had a positive correlation ($r = 0.19$) in the year 2016-17. Minimum temperature had a positive correlation in both years ($r = 0.24$ and $r = 0.21$, respectively). Though, the relative humidity had negative and positive relation with the larval population of diamondback moth in both years ($r = -0.26$ and $r = 0.11$ respectively). Sunshine hours had negative but non-significant ($r=-0.31$) effect in 2015-16 while positive relation ($r=0.38$) was observed in 2016-2017. However, rainfall had positive nonsignificant relation ($r=-0.05$ and $r= -0.08$ respectively), in both years.

Chaube *et al.* (2018) studied the seasonal incidence of diamondback moth (*Plutella xylostella*), the pest population peaked during the early summer, March-April months (342 and 243/60 plants) followed by post rainy season, August-October (184 and 208/60 plants) and was low during the early winter months December-January (65 and 68/60 plants) followed by July-August (98 and 96/60 plants). A maximum temperature of 30-35°C with a relative humidity of 61-75 per cent favoured the buildup of the pest. The larval incidence had significant positive correlation with maximum temperature ($r = 0.837$; $P = 0.01$) and with minimum temperature ($r = 0.594$; $P = 0.05$). Rainfall and number of sunshine hours had a negative impact.

Maity *et al.* (2018) studies showed that bio-pesticides *Bacillus thuringiensis* var *kurstaki* and *Beauveria bassiana* gave 55.82 per cent and 32.24 per cent reduction of DBM larvae respectively. All the imposed test molecules were found to be nonharmful to prevailing natural enemies. The yield of cabbage was found to be highest in plots treated with rynaxypyr (550.50q/ha) followed by flubendiamide (535.65q/ha) and spinetorum

(530.55q/ha).

Anjali and Pandya (2019) studied the population dynamics of diamondback moth larvae on the cabbage variety, Golden Acre. He observed that the infestation of pests first started in the 50th SMW and peak larval population was observed in the 1st SMW. The larval population showed a highly significant negative correlation with maximum, minimum and average temperature. Wind speed had significant positive correlation with the larval population.

Pathak et al. (2019) studied that population of diamondback moth was positively correlated with maximum, minimum, average temperature and maximum relative humidity and negatively correlated with minimum RH, wind speed and rainfall. The highest larval population was recorded during 1st week of January (1st Standard Meteorological Week, SMW).

Sultana et al. (2019) reported that the lowest population of both DBM and prodania larvae per plant was found during November and January whereas, the highest population per plant was recorded during September and March 2014 and 2015, respectively. The same trend was observed in the case of the adult population in the sex pheromone trap. The adult prodania caterpillar population was the highest during October-November and March. During December-January population declined totally. The highest diamondback moth (*Plutella xylostella*) population was observed during November and March.

Shyam et al. (2020) studied the seasonal incidence of diamondback moth, *Plutella xylostella* Linn. infesting cabbage crop. He observed that the first appearance of the pest started during the second week of December and attended its peak (5.8 larvae/plant) in the last week of January (5th SMW). The correlation studies revealed that maximum ($r = -0.496$), minimum ($r = -0.484$), and average ($r = -0.534$) temperature had significant negative correlation, while the other weather parameters showed non-significant correlation with the

larval population of diamondback moth.

Bana et al. (2012) observed that cabbage crop was found to be infested diamondback moth, *Plutella xylostella* (Linn.). 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 populations of diamondback moth, whereas, relative humidity and sunshine hours showed non-significant correlation. 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.

Mane et al. (2021) reported that the first incidence of diamondback moth started in the second week of February. Infestation of the pest increased gradually and reached peak in the first week of March and thereafter declined subsequently in the coming Meteorological weeks. Minimum temperature, Morning relative humidity and rainfall showed a significantly positive correlation whereas Maximum temperature and Bright Sunshine hours showed non-significantly negative correlation with the population of Diamondback Moth.

Rajput et al. (2021) reported that the first incidence of diamondback moth, *P. xylostella* started in the first week of December. The maximum number of larvae was observed during the first week of February and thereafter, the population started declining. There was a significant negative association of *P. xylostella* population with maximum and minimum temperature. The influence of morning relative humidity and evening relative humidity was significantly positive on the larval population build-up. Though, the rainfall had a non-significant effect on larval population build-up.

Rasool et al. (2021) reported that the diamondback moth appeared first in the month of April and reached the peak (7.20 larvae/ plant and 6.53 larvae/ plant) in June during both years. Correlation studies revealed that the maximum temperature had a significant positive

correlation ($r= 0.5823$ and $r= 0.7173$) with the larval population. Minimum temperature showed non-significant ($r= 0.4956$) and significant ($r = 0.7931$) positive correlation in the respective years. However, the relative humidity morning ($r= -0.738$ and $r= -0.339$) and evening ($r= -0.57$ and $r=-0.288$) were negatively correlated. However, rainfall had negative but significant and non-significant relation ($r= 0.5001$ and $r=-0.259$) with the larval population during 2020 and 2021, respectively.

Faruq *et al.* (2022) reported that head infestation on cabbage commenced in the 1st week of November, when head development began, and increased gradually with crop age. During this time, the temperature gradually increased, while rainfall decreased.

Singh *et al.* (2023) observed that the maximum number of larvae of *P. xylostella* and *S. litura* was recorded in the Pataudi block as compared to those of Farukhnagar, Sohana and Gurugram. Seven neem-based bio-pesticides were evaluated along with check carbosulfan at hot spots. Data revealed that NSKE 5 per cent was quite effective followed by Nimbicidin and Neemgold. The cost-benefit ratio was maximum with NSKE (1:9.41, 1:9.53 for cabbage and cauliflower, respectively) followed by neem leaf extract (NLE) with (1:7.72 and 1:6.31). These results conclude that NSKE and NLE can be recommended against major pests of cabbage and cauliflower.

3. To study the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.) on cabbage

Patil *et al.* (1999) conducted an experiment to evaluate the efficacy of Spinosad 48 SC at four doses *viz.*, 25, 50, 75 and 100g a.i./ha for two seasons. Results indicated that Spinosad at 48 SC higher dosage recorded lower leaf hopper and Aphid population with average whitefly population reduction. Spinosad 48 SC @ 100 g a.i./ha recorded minimum per cent bollworm incident and was on par with its lower dosages 75 g a.i./ha treatments maximum good opened bolls and minimum bad open bolls peak plant with higher cotton yield was

recorded in Spinosad 48 SC @100 g a.i./ha.

Liang et al. (2002) observed that neem-based insecticides influenced *Plutella xylostella's* egg-laying preferences. Hatching rates differed among neem treatments, with agroneem, ecozin, and neemix resulting in 61.6 per cent 66.2 per cent and 75.2 per cent neonate development, respectively. Larvae on treated leaves exhibited antifeedant effects, ceasing feeding and dropping off, leading to minimal leaf damage. These larvae were smaller (0.012-0.016 mg/larva, 13.5-14.8 mm length, 2.0-2.5 mm diameter) compared to those fed water-treated leaves (0.058 mg/larva, 30.2 mm length, 4.8 mm diameter). Neem-treated larvae died within seven days, in contrast to 70-74% survival in the control. The study highlights neem insecticides' potential in managing *P. xylostella* populations.

Cordero et al. (2006) studied that the most efficacious insecticides over the five experiments included acephate, emamectin benzoate, esfenvalerate, methomyl, methoxyfenozide, novaluron, indoxacarb, and spinosad. Although acetamiprid, *Bacillus thuringiensis* subsp. *kurstaki* and azadirachtin have shown efficacy against lepidopteran pests in other studies, but they were inconsistent in their performance in these experiments. Insecticide options that provide reliable control of the suite of lepidopteran pests that attack collards in Virginia, and that are relatively less toxic to natural enemies and thus can fit well into integrated pest management programs include indoxacarb, Spinosad, novaluron, Emamectin Benzoate, and Methoxyfenozide.

Sitotaw et al. (2009) observed that the Dipel, Xen Tari, Neem 25 and Neem 50 were effective in controlling DBM at both locations. As a result, the yield of cabbage improved; for instance, at Wonji, the marketable yield ranged from 33.4 to 35.1 ton/ha, for Neem 25, Neem 50, Xen Tari and Dipel treatments; while the marketable yield ranged from 19.7 to 22.5 ton/ha for Karate and Nimbecidine. This finding indicates that the use of Bt. and neem seed extract should be considered in an integrated management strategy for the diamondback

moth.

Ranjbari et al. (2011) evaluate the toxicity of Spinosad to four instar larvae of the diamondback moth, *Plutella xylostella* (Linn.). In this study 1st, 2nd, 3rd and 4th instars larvae were exposed to different concentrations of Spinosad. The exposure times were 24, 48 and 72 h for oral trials. Experiments were performed in a complete randomized block design with four replications. After treatment, the samples were held under constant conditions in a laboratory rearing room ($25 \pm 2^{\circ}\text{C}$, 50 ± 5 per cent RH and 14: 10 h L: D photoperiod). The maximum mortality rate for 1st, 2nd, 3rd and 4th instars larvae in 600, 700, 800 and 900 ppm of Spinosad was achieved 100, 95, 98.3 and 93.3 per cent after 72h, respectively. Our results suggest Spinosad could be an important agent in control of larval instars of *Plutella xylostella*.

Venkateswarlu et al. (2011) tested neem baan, vermiwash, acetamiprid, and *Beauveria bassiana* on cabbage variety *i.e.*, Golden Acre and results showed that T₉ comprising acetamiprid-acetamiprid, fipronil and Spinosad showed significantly highest per cent reduction over control (PROC) of aphid, *Lipaphis erysimi* population (84.65 and 82.92), and (77.88 and 76.04) after 1st spray over two seasons at 3rd and 7th DAS respectively. Also acetamiprid in other treatment combinations, whether used as 1st or 2nd spray recorded significantly higher PROC of aphids than any other formulation. Chlorantraniliprole (18.5 per cent SC @ 10 g *a.i./ha*) showed highest PROC of diamondback moth, *Plutella xylostella* Linn. (83.65 and 82.08) and cabbage butterfly, *Pieris brassicae* L. (84.42 and 84.54) at 3 days after 3rd spray during 2009-10 and 2010-11, respectively in treatment T₄ having acetamiprid, chlorantraniliprole and Emamectin Benzoate with corresponding maximum marketable yield (30.6 and 32.17 ton/ ha). The high efficacy of chlorantraniliprole in T₄ with Emamectin Benzoate and acetamiprid as other insecticides could be an excellent choice in rotational strategy aimed at prolonging their efficacy by delaying the development of resistance due to diverse modes of action. *Beauveria bassiana* proved significantly superior

at 14 DAS as the highest PROC in T₅ (64.23 and 71.93) and T₇ (64.37 and 68.94) was recorded during 2009-10 and 2010-11, respectively after 1st spray

Legwaila et al. (2013) assessed Spinosad's efficacy against DBM, *Plutella xylostella* eggs and larvae using various concentrations (0.12 to 1.08 g/L) and bioassays at 30°C. Results at 72 and 96 hours indicated higher efficacy against eggs (LD90: 0.35-0.32 g/L) than larvae (LD90: 0.74-0.59 g/L). Probit analysis showed steeper mortality slopes for larvae (3.519 to 3.427) than eggs (1.725 to 1.086) with increased dosage, implying quicker larval mortality. The study demonstrates Spinosad's effective control of DBM eggs and larvae under Botswana conditions.

Vanlaldiki et al. (2013) observed that the *B.t.* (Dipel) recorded the lowest larval population (0.21/plant) and proved to be the most effective treatment, followed by *B.t.* (delfin) and nuvan with larval populations of 0.45 and 1.50/plant respectively, as against 8.88/plant in the untreated control. Vijayneem was found to be the most inferior insecticide by recording the highest population of 3.06/plant. The mean yield ranged from 17.92 to 22.73t/ha in insecticidal treatments with the maximum yield in dipel as against 14.75t/ha in the untreated control. Amongst all the tested compounds, agrineem and delfin proved to be the safest insecticide for the predatory beetle, *Coccinella septempunctata* with the highest population of 1.20/plant each against 1.28/plant in the untreated control. The lowest beetle population (0.87/plant) was recorded in untreated plots.

Singh et al. (2015) evaluates certain microbial pesticides against the diamondback moth, *Plutella xylostella*, (Linn.). He reported that all the insecticidal treatments resulted in significant suppression of the pest incidence. However, bioasp, *Bacillus thuringiensis* var. kurstaki @ 1000 g/ha was the most effective insecticide against *P. xylostella* with a record of minimum mean leaf damage of 13.32 per cent as against 69.18 per cent in untreated control, closely followed by Spinosad 2.5 SC applied @ 500 ml/ha (14.22 per cent LD)

which did not differ significantly from each other. Application of insecticides resulted in the reduction of the mean avoidable loss, which ranged between 4.32 and 22.21 per cent in different insecticidal treatments, the lowest being in bioasp *B. thuringiensis* var. *kurstaki* and highest in verticel *V. lecanii*.

Singh et al. (2015) evaluated the *Bacillus thuringiensis* var. *kurstaki* formulations viz. delfin, dipel, halt, biobit, biolep, bioasp, botanical insecticide neemgold, nematode *Steinernema feltiae* against lepidopterous pests of cabbage under field conditions. Delfin, was very effective in reducing the population of cabbage leaf webber, *Crociodolomia binotalis* (67.6 per cent) and diamondback moth, *Plutella xylostella* (57.1 per cent). Dipel was equally effective against these pests and recorded 67.4 and 56.2 per cent reduction, respectively.

Sarkar and Maity (2016) reported that diafenthiuron 50% WP at the rate of 600 ml/ha provided the most effective reduction of DBM population (88.68 per cent -90.82 per cent reduction of pest over control) with the substantial increase in yield (184.75 q/ha) subsequently the highest cost-benefit ratio of 1:5.89.

Stanikzi et al. (2016) evaluated the maximum reduction per cent of Spinosad 45% SC recorded the highest reduction of diamondback moth population *i.e.* 49.45 per cent which was significantly superior over control followed by Indoxacarb 14.5% SC (45.305), Cypermethrin 5% EC (44.215), Emamectin Benzoate 5% SG (42.78), Profenophos 50% EC (40.975), Neem Seed Kernal Extract (39.195), Neem oil (39.705) was least effective among all the treatments respectively. The highest yield was recorded in Spinosad 45% SC (187.60 q/ha), followed by Indoxocarb 14.5% SC (178.25 q/ha), Cypermethrin 5% EC (175.48 q/ha), Emamectin Benzoate 5% SG (173.75 q/ha), Profenophos 50% EC (165.24 q/ha), Neem oil (157.38 q/ha), NSKE 5per cent (152.61 q/ha), as compared to untreated check (80.24 q/ha).

Machekano et al. (2017) IPM adoption was mainly limited by a lack of locally-

developed packages, a lack of stakeholders' concept appreciation, limited alternatives to chemical control, knowledge paucity on biocontrol, climate mismatch between biocontrol agents' origin and release sites, and poor research expertise and funding. We discuss these challenges in light of climate change and variability impacts on small-scale farmers in SA and recommend climate-smart, holistic, and sustainable homegrown IPM options propelled through IPM-Farmer Field School approaches for widespread and sustainable adoption.

Dotasara et al. (2017) evaluated the insecticides against the DBM, Spinosad (45 SC @ 0.5ml/ litre) treated cauliflower plot showed the highest per cent reduction over control (89.97per cent) with a smaller number of larvae (0.58 larvae/ plant). 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 the untreated control. Flubendiamide 48 SC @ 0.3 ml/ litre and chlorantriliniprole 18.5 SC @ 0.3 g/liter were the next effective pesticides to reduce the pest incidence significantly. All the treatments were also observed to be significantly superior over the control.

Ramanujam et al. (2017) assessed the field efficacy of three isolates of entomopathogenic fungi (EPF) for the management of the cabbage aphid, *Brevicoryne brassicae*. All the tested isolates showed suppressive effect on aphid. Two-year pooled data revealed lower incidence of 13.9–17.1 aphids/plant in the EPF treated plots compared to the higher incidence of 107.5 aphids/plant in untreated control. Significantly higher yields were recorded in the plots treated with Bb-5a, Ma-4 and VI-8 isolates (28.0, 27.4 and 27.4 t/ha, respectively) compared to untreated control (22.3 t/ha). The populations of predatory coccinellid and spiders in EPF treated and untreated control plots were found statistically non-significant indicating the safety of entomopathogenic fungi to these predators.

Sawant and Patil (2018) reported that the chlorantraniliprole had the highest per cent larval reduction of *Plutella xylostella* (Linn.) over control was recorded treated plots (91.30

per cent with 1.02 larvae/plant) followed by Spinosad (87.55 per cent with 1.46 larvae/plant) and flubendiamide (86.61 per cent with 1.57 larvae/plant). The efficacy of insecticides is also reflected in the marketable yield of cabbage heads. The highest yield of 238.15 q/ha with a 129.23 per cent increase over control was registered in the treatment of chlorantraniliprole followed by Spinosad (233.83 q/ha with a 125.07 per cent increase over control).

Harika *et al.* (2019) reported that all the tested insecticides, Spinosad 45 % SC, Indoxacarb 14.5 % SC and Emamectin Benzoate 5% SG proved to be the most effective treatments in reducing the larval population of diamondback moth. During the study Flubendiamide 39.35 SC and Thiodicarb 70 SP were found moderately effective against Diamondback moth. The treatments Lufenuron 5 EC and Acephate 75 WP were found least effective.

Sambathkumar *et al.* (2020) observed that the larvae of *P. xylostella* and *C. binotalis* upon exposure to insecticides like Chlorantraniliprole 18.5% SC and Flubendiamide 39.5% stopped feeding and were found to be completely controlled. Later, Spinosad 2.5% SC @ 25 g a.i./ha, Emamectin Benzoate 5% SG @ 15 g a.i./ha and Fipronil 5% SC @ 750 g a.i./ha were joined in the lineage through reducing the population of these pests.

Shehzad *et al.* (2021) studied the potential of 2 entomopathogenic fungi (EPF), viz., *Beauveria bassiana* and *Metarhizium anisopliae* against 2nd and 3rd larval instars of *P. xylostella* by adopting leaf dip and direct spraying methods under laboratory conditions. A significant mortality rate was achieved by each fungus under adopted methodologies. However, *B. bassiana* was found to be more effective in both conditions than *M. anisopliae*. Highest mean corrected mortality (77.80 per cent) was recorded, when spores of *B. bassiana* were sprayed on the 2nd instar larvae (LC50= 1.78×10⁴ /ml) after the 6th day of treatment. Similarly, in the case of *M. anisopliae* LC50 for the 2nd instar at the same methodology was

2.78×10⁴ /ml with a mortality per centage of 70.0 per cent. Offspring sex ratio was non-significantly related to treatment concentration and methodology, except for the control.

Kumar et al. (2022) reported that the *P. xylostella* was active throughout the year with a varying degree of infestation. *Bacillus thuringiensis var. kurstaki* (Dipel 8 L) @ 0.2% as spray on standing crop with 41.85 per cent population reduction over control proved best among all treatments by reducing mean number of larvae 0.48/plant. The second most effective treatment applied to the cabbage on standing crop as spray form was *Beauveria bassiana* 1.15% WP @ 0.2% with 38.30 per cent population reduction over control with mean number of larvae 0.75/plant followed by Nimbecidine 0.15% EC (Azardirachtin 1500 ppm) @ 0.3% (37.29 per cent). It was statistically superior in comparison to control in which 4.98 mean larvae were recorded.

Sapkota et al. (2022) reported that the maximum reduction of *P. xylostella* larval population over untreated control was recorded in Emamectin Benzoate 5 SG (95 per cent) and Neemix (95 per cent) sprayed field. Bio-pesticides such as *M. anisopliae* and *B. bassiana* were effective only after the first spray with maximum efficacy of (76 per cent) and (65 per cent), respectively, and decreased efficacy in the second and third sprays. Both yields with the least number of damaged leaves and maximum net profit were recorded in Emamectin Benzoate sprayed plots with a higher benefit-cost ratio of (3.47), which was followed by *M. anisopliae* (2.96) and Neemix (2.92) treatments, respectively. Emamectin Benzoate 5 SG and Neemix are effective and safe insecticides in controlling diamondback moth in cabbage crops and are viable options for integrated management of *P. xylostella*.

Kommoji et al. (2022) evaluated Spinosad 45% SC, Indoxacarb 14.5% SC, Emamectin Benzoate 5% SG, Chlorantraniliprole 18.5% SC, Fipronil 5% SG, *Beauveria bassiana* (1x10⁸ CFU/gm), Neem oil 0.3% along with an untreated control. The data on Per cent reduction of the larval population were significantly superior over control but among

all treatments, chlorantraniliprole 18.5% SC is best effective for diamondback moth showing (80.35 per cent) per cent reduction of larval population followed by Spinosad 45% SC (77.06 per cent), Indoxacarb 14.5 SC (73.43 per cent), Emamectin Benzoate 5% SG (71.77per cent), Fipronil (68.26 per cent), *Beauveria bassiana* (67.06per cent) and Neem oil was least effective had showing (61.18 per cent) per cent reduction of larval population but superior over control

Beena et al. (2022) assessed the bio-efficacy of insecticides used against Diamondback moth (DBM), *Plutella xylostella*. The results revealed that the diamide insecticides like cyantraniliprole 10.26 OD @ 60 g a.i/ha, chlorantraniliprole 18.50 SC @ 10 g a.i/ha and flubendiamide 20 WG @ 18.24 g a.i/ha registered more than 95 per cent population reduction over untreated control followed by Emamectin Benzoate 5 SG @ 10 g a.i/ha and thiodicarb 75 WP @ 750 g a.i/ha.

Prakashrao and Kumar (2022) observed that larval population mean of diamondback moth, *Plutella xylostella* was reported lowest in the plot treated with Spinosad 45 SC i.e. (2.74) which was significantly superior over control followed by (T₁) Indoxacarb 14.5per cent (3.04) and (T₂) Emamectin Benzoate 5% SG (3.25), (T₅) *Bacillus thuringiensis* (3.41), (T₄) *Beauveria bassiana* (3.57), (T₇) Neem oil 1% (3.73) and (T₆) NSKE 5% (3.92) was least effective among all the treatments respectively. The highest yield was recorded in Spinosad 45 SC (217.81 q/ha), followed by Indoxacarb 14.5% SC (180.21 q/ha), Emamectin Benzoate 5% SG (165.30 q/ha), *Bacillus thuringiensis* (155.82 q/ha), *Beauveria bassiana* (148.51 q/ha), Neem oil 1% (142.00 q/ha) and NSKE 5% (125.35 q/ha) as compared to untreated check (67.55 q/ha).

Sharma et al. (2022) recorded that Spinosad was most effective and caused a reduction up to 94.33 per cent population followed by indoxacarb (91.00 per cent) and Flubendiamide (78.66 per cent). The insecticides, viz., fipronil, Emamection benzoate and

chlorantraniliprole were found moderately effective as they resulted in 70.66, 70.33 and 68.66 per cent reduction, respectively and chlorfenapyr, pyridalyl and acephate were proved least effective reduced up to 55.33, 56.66 and 56.00 per cent, respectively.

Nyaupane *et al.* (2022) reported that highest reduction of cabbage aphid was obtained in Dimethoate (30 EC) treated plot followed by Derisom treated plot. The highest yield of cabbage head was obtained in Dimethoate treated plots (66.47 mt/ha) which was significantly at par with the Derisom (58.79 mt/ ha) treated plots. The yield for other treated plots was 47.60 mt/ha for Margosom, 43.77 mt/ha for Verticillium, 41.63 mt/ ha for Cow urine, 36.77 mt/ ha for Spinosad and control (33.45 mt/ ha) in terms of cabbage head yield. At the same time, natural enemies' population was significantly lower to Dimethoate treated plots compared to bio-rational insecticides. It was also evident from the research that Margosom (Neem based botanical) was found beneficial not only to conserve natural enemies in the cabbage field but also to minimize cabbage aphid population.

4. To study the effect of newer insecticides and bio-pesticides on natural enemies.

Habeeb *et al.* (2000) evaluated that cartap, chlorfenapyr, Emamectin Benzoate and permethrin were highly toxic, causing 100 per cent mortality of adult females DBM as well as natural enemies in every treatment. The residual effects of these four insecticides on cabbage foliage showed that only Cartap was highly persistent. Cartapresidues caused 100 per cent mortality for over 30 days.

Paikra *et al.* (2007) reported that the Azadirachtin 0.15 per cent (neem) @ 2500 ml/ha was observed least effective against diamondback moth and all the insecticides did not affect the natural enemy's population.

Thungrabeab and Tongma (2007) studied the effect of entomopathogenic fungi, *Beauveria bassiana* (Balsamo) (isolate Bb.5335) and *Metarhizium anisopliae* (Metsch) (isolate Ma.7965) on non-target insects, such as natural enemies, *Coccinella septempunctata*

L. (Col., Coccinellidae), *Chrysoperla carnea* (Stephens) (Neur., Chrysopidae) and *Dicyphus tamaninii* Wagner (Him., Miridae), as well as beneficial soil insect, *Heteromurus nitidus* Templeton (Collembola: Entomobryidae), were studied. The experiments were conducted on conidial suspensions at a concentration of 1×10^8 conidia/ml. The 1st larval instars of *C. septempunctata*, *C. carnea* and adults of *D. tamaninii* and *H. nitidus* were tested. Mortality was recorded daily till the next generation. The results showed that *B. bassiana* was found to be non-pathogenic to natural enemies and a beneficial soil insect. While *M. anisopliae* had pathogenicity to natural enemies, *C. carnea* and *D. tamaninii*, in which *D. tamaninii* was more susceptible than *C. carnea* with corrected mortalities of 10 and 4 per cent, respectively.

Venkateswarlu et al. (2011) Neem baan, Spinosad, Emamectin Benzoate and chlorantraniliprole were proved to be safe from natural enemies in cabbage but less effective against DBM, *Plutella xylostella* (Linn.)

Riccardo et al. (2015) reported that the negative effects of using insecticides against diamondback moth were found for the density of parasitoids and generalist predatory wasps, and tended to affect spiders negatively. The observed increased leaf damage in insecticide-treated plants may be a combined consequence of insecticide resistance in the pest, and of lower predation and parasitization rates from naturally occurring predators that are suppressed by the insecticide applications.

Jat et al. (2017) conducted a field experiment during the *Rabi* season of 2012-13 and 2013-14. The study revealed that the major natural enemies recorded were coccinellids, *Coccinella septempunctata* (Fab.), *Cheilomenes sexmaculatus* (Fab.) (Coleoptera: Coccinellidae); common green lacewing, *Chrysoperla sp.* (Neuroptera: Chrysopidae); aphid parasitoid, *Diaeretiella sp.* (Hymenoptera: Braconnidae); diamondback moth and tobacco caterpillar on parasitoid of *Cotesia sp.* (Hymenoptera: Braconidae). However, their population was found to fluctuate during the crop season. Among foliage feeding pests the

tobacco caterpillar incidence was higher followed by diamondback moth. While, natural enemies the maximum mean population was found for *Coccinella septempunctata* during both the years.

Borkakati et al. (2019) were found to be the best in reducing the larval population of *Plutella xylostella* (1.89 / plant), *Pieris canidia* (2.82/plant), *Agrotis ipsilon* (1.26 /plant) and *Brevicoryne brassicae* (2.03 aphid/leaves). The highest numbers of Coccinellid predators (1.81/ leaves) with highest yield of (17872 kg/ha) and highest cost benefit ratio (1: 4.60) also recorded from the same module. Thus, cabbage intercropped with cowpea and mustard as a border crop could be adopted to get rid of key pests of cabbage.

Begum et al. (2021) revealed that the highest number of ladybird beetle (8.00) was found from T₄ (Spodolure + Spinosad) treatment whereas the lowest number of ladybird beetle (6.50) was found from control treatment T₆. Under the treated plot, the lowest number of ladybird beetle (6.75) was found from T₂ (SNPV; *Spodoptera litura* nuclear polyhedrosis virus @ 2.47/ha at 7days intervals) which was statistically identical with T₁ (Spinosad @ 25 ml/ha at 7 days intervals).

Shonga and Getu (2021) reported that the botanical mix, imidacloprid and neem seed extract were highly effective in aphid control as well as less hazardous to ladybird beetle *Coccinella septempunctata* (Linn.).

5. To calculate the incremental cost-benefit ratio of different treatments.

Tripathi et al. (1999) reported that the operational and commercial costs were Rs 2,215 and Rs 7,094/ha for the cultivation of cabbage in high-hills of Uttar Pradesh. Labour cost accounted for nearly 74 per cent of the total cost, whereas materials cost was about 16 per cent in cabbage production. The yield and gross income were highest on the largest size group of farms due to the high use of manure and fertilizers.

Macharia et. al. (2005) studied the potential economic impact of the introduction of

Diadegma semiclausum, an exotic parasitoid of *Plutella xylostella* on cabbage production in Kenya. The study first established yield losses caused by diamondback moth through measurements from farmer- managed fields and through farmer's interviews. Crop losses were calculated at 31 per cent from farmer managed fields, and at 36 per cent from farmer interviews. With a crop loss of 31 per cent, yield loss was estimated at 6.8 tons/ha or US\$ 452.9/ha, and at US\$ 7.9 million per year for the whole country. The project costs amount to a net present value of US\$ 1.2 million. Based on an annual cabbage production of 256, 524 tons, a cabbage price of US\$ 66.3/ton, a 30 per cent abatement of yield losses, and a 7.9 per cent reduction in cost of production. Consumers were estimated to get 58 per cent of the benefit and 13 producers 42 per cent. The benefit-cost ratio was estimated at 24:1, with an internal rate of return of 86 per cent, indicating a high return to the investment.

Murthy *et al.* (2006) reported that the cost: benefit ratio was highest for NSKE (1:9.58) treated plots followed by indoxacarb (1:8.25), fipronil (1:7.66), Econeem Tus (1:4.99) and Vijayneem (1:4.41).

Vidogbena *et al.* (2015) reported that the insecticide costs significantly declined by 68 per cent -95 per cent when shifting from unnetted protection to netted protection and total operational and labor costs declined by 3 per cent to 40 per cent. Insect net use generated threefold higher margins and an average 1:2.66 cost:benefit ratio compared to 1:1.58 for current practices.

Devi *et al.* (2017) studied the comparative efficacy of some bio-agent and reported the highest per cent reduction of diamondback moth larvae against control was observed in *Bacillus thuringiensis* (61.22 per cent). The mean crop yield ranged between 211 q/ha to 371 q/ha in the insecticidal treatment, the highest being *Bacillus thuringiensis* (371 q/ha) followed by Neem oil (331 q/ha). The cost-benefit ratio varied from 1:3.1 to 1:6.9 in different insecticidal treatments being the highest in NSKE (1:6.9) followed by Neem oil (1:6.8).

Patra et al. (2017) reported that Chlorfenapyr@200 g *a.i./ha* was effective in reducing the mean larval population of diamondback moth (1.21 larvae/plant) with 85.81 per cent reduction over untreated control. The next best treatment was pyridyl@ 150 g *a.i. ha* with 82.71 per cent reduction followed by indoxacarb @ 150 g *a.i./ha* (78.44 per cent reduction). Recommended doses of pyridyl (75 g *a.i./ha*), indoxacarb (75 g *a.i./ha*) and chlorfenapyr (100 g *a.i./ha*) were also found to be effective treatments in reducing the larval population of the diamondback moth. The highest cost-benefit ratio (1:10.94) was recorded in pyridalyl at the recommended dose (75g *a.i./ha*) followed by chlorpyriphos @250 g.

Basnet et al. (2018) observed the highest biological yield was found in Spinosad @ 0.725ml/lit and the lowest was found in Spinosad @ 0.25ml/lit treated plot. The highest economic yield was found from *Beauveria* @ 3ml/lit (49.05 mt/ha) and lowest was from Spinosad @ 0.25ml/lit (37.97 mt/ha) treated plot. The highest Benefit: Cost ratio was found in Beauveria @ 3ml/lit (2.51) treated plots and the lowest in Spinosad @ 0.25 ml/lit (1.96) treated plots. Further field and laboratory studies will be imperative for improving efficacy of eco-friendly pesticides.

Patil et al. (2018) reported the incremental cost: benefit ratio (ICBR) analysis of pesticidal treatments in cowpea showed that imidacloprid treated plot recorded highest average green fodder yield (10.47 t/ha) followed by dimethoate (9.73 t/ha), thiamethoxam (9.55 t/ha) and acetamiprid (9.55 t/ha). The other treatments recorded average green fodder yield of 8.81 t/ha (diafenthiuron), 8.26t/ha (spiromesifen), 8.17 t/ha (chlorfenapyr) and 7.52 t/ha (untreated control). The highest cost benefit ratio was recorded by acetamiprid (1:1.59) followed by dimethoate (1:1.48) and imidacloprid (1:1.41). Thiamethoxam showed the next best ratio (1:1.33). Whereas, diafenthiuron, chlorfenapyr and spiromesifen had ICBR ratios of 1:1.17, 1:1.15 and 1:1.14, respectively.

Sawant and Patil (2018) analysed the efficacy of insecticides reflected on the

marketable yield of cabbage heads. The highest yield of 238.15 q/ha with 129.23 per cent increase over control was registered in the treatment of chlorantraniliprole followed by Spinosad (233.83 q/ha with 125.07 per cent increase over control) and flubendiamide (224.98 q/ha with 116.56 per cent increase over control). The highest ICBR (1:16.40) was registered from chlorantraniliprole treated plots followed by flubendiamide (1:14.98) and Spinosad (1:12.22).

Harika *et al.* (2019) reported the highest marketable yield of cauliflower heads was recorded in Spinosad 45 SC (228.80 q/ha). It was followed by Indoxacarb 14.5 SC (219.10 q/ha) and Emamectin Benzoate 5 per cent SG, which yielded (193.90 q/ha) Flubendiamide 39.35 SC, Thiodicarb 70 SP, Lufenuron 5 EC and Acephate 75 WP yielded the lowest marketable yields of 165.90, 145.50, 120.80 and 108.00 q/ha respectively. The highest Cost Benefit (C: B) ratio of 69.85 was obtained with the treatment Indoxacarb 14.5 SC followed by Emamectin Benzoate 5 per cent SG (60.18), Spinosad 45 SC (30.13) and Flubendiamide 39.35 SC (24.56).

Beena *et al.* (2022) calculate the treatments, the highest yield (314.9q/ha) and Cost-benefit ratio (1:7.59) was recorded in Chlorantraniliprole 18.5 per cent SC followed by Spinosad 45% SC with a yield of (273.73q/ha) and Cost benefit ratio (1:6.77) as compared to control.

Yousafi *et al.* (2020) calculate the benefit-cost ratio for each treatment combination. The lowest aphid infestation was found for 4DAFA. The highest benefit-cost ratio (2.57) was recorded for Imidacloprid applied at 4DAFA with 120 kg/ha nitrogen fertilizer. But for the management of cabbage aphids in an environment-friendly manner we recommend Emamectin enzoate at 8DAFA with nitrogen level of 60 kg/hac giving slightly lower BCR (2.37).

Shonga amd Getiu (2021) reported that the highest cost-benefit ratio was recorded in

the plot treated with profenofos (1:1.14) followed by lufenuron (1:0.2), Spinosad and nimbecidine (1:0.18). He concluded that the imidacloprid and plant-based insecticides can reduce aphid populations equally to conventional insecticides and could be used as an alternative component for the integrated pest management (IPM) of cabbage aphid, *Brevicoryne brassicae* (Linn.)

Tayde and Khan (2022) reported that the mean reduction in the larval population per plant was significantly superior over the control (6.51) in all the treatments. Chlorantraniliprole 18.5 per cent SC recorded the lowest mean larval population of *P. xylostella* (1.52), followed by Spinosad 45 per cent SC (1.75), Indoxacarb 14.5 SC (2.00), Emamectin Benzoate 5 per cent SG 2.28, *B. thuringiensis* (2.68), *B. bassiana* (2.87), *M. anisopilae* (3.02). The highest yield (280 q/ha) as well as B: C ratio (1:6.37) was obtained from the treatment Chlorantraniliprole 18.5 per cent SC followed by Indoxacarb 14.5 SC (1:6.33), Emamectin Benzoate 5 per cent SG (1:6.25), *B. thuringiensis* (1:5.97), Spinosad 45 per cent SC (1:5.75), *B. bassiana* (1:5.72), *M. anisopilae* (1:5.50) as compared to control (1:3.34).

The present investigation entitled “**Studies on insect pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**” was carried out during *Rabi*, 2021-22 and 2022-23. The details of the materials used and methodologies adopted for studying the insect-pest dynamics of cabbage, population dynamics of diamondback moth, *Plutella xylostella*, (Linn.) on cabbage in relation to abiotic factors. Evaluation of certain newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella*, (Linn.) on cabbage, estimation of the effect of newer insecticides and biopesticides on natural enemies and economic analysis of incremental cost-benefit ratio on cabbage is being systematically described in this chapter under appropriate subheads.

3.1 Experimental Site

The field experiments were conducted during *Rabi*, 2021-22 and 2022-23 at Crop Research Center (CRC), Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh. The soil of experimental plots was sandy loam with an average fertility level, good drainage and adequate irrigation facility.

3.2 Geographical Situation

The district Meerut is situated at a 28°57' to 29°02' North latitude and 77°40' to 77°45' East longitude North latitude of 237 meters above mean sea level. The district Meerut falls under the north-western plains sub-region of the upper Gangetic plain zone. The district is spread over a geographical area of 2522 km². The general climate of the Meerut district is semi-arid and sub-tropical characterized by very hot summers and cold winters. The maximum temperature shoots up to 45°C during summer whereas the minimum temperature is 4-5°C and below during the winter season. The average annual rainfall is about 886mm, of which about 75-80 per cent is received through the southwest monsoon during the month

of July to September. Few rain showers occasionally occur in the winter and summer seasons. The meteorological information of Modipuram, Meerut was obtained from the meteorological laboratory of the IIFSR-Indian Institute of Farming System Research Modipuram (Meerut). The average weather parameter during the crop period of the present experiment in the *Rabi* season was recorded from transplanting to the harvesting of the crop. Meteorological observations on temperature, relative humidity (RH), rainfall, sunshine hour and wind velocity were recorded at a weekly interval from the meteorological observatory of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh. Weather parameter represented in (**Table no.-3.1, 3.2**) and (**Figure-1, 2**).

3.3 Agronomic practices followed

3.3.1 Nursery raising

The cabbage seeds are generally sown in the seedbed and 4–6-week-old seedlings were transplanted to the field. The cabbage variety “Golden Acre” nursery was raised in a bed of 5x3 m² during the first week of October 2021 and 2022, respectively. The seed was treated with Thiram@ 2.5 g/kg seed for protection against fungal disease before sowing. The nursery bed was avoided from direct sunlight and moisture was maintained accordingly.

3.3.2 Preparation of field

The field was prepared to fine-tilth for transplanting of the seedlings. First weeds were removed manually to avoid their further growth in the field and then a deep plowing was done by turning soil plow during the first week of October in both the year during 2021 and 2022, later two deep plowing was done by cultivator and required manures and fertilizer were incorporated into the soil for providing good soil condition for plant growth in the field followed by planking. The seedlings of the cabbage variety ‘*Golden Acre*’ were procured from Agrawal Beej Bhandar, Mandi, Meerut, UP.

3.3.3 Manures and Fertilizers

The field was provided with the recommended dose of farmyard manures (FYM) at the rate 20-25 tonnes/ha and fertilizers N: P: K at the rate of 100: 80: 50 kg/ha in the form of Urea, Single super phosphate (SSP) and Murate of Potash (MOP) in order to increase quality and quantity of head. Half amount of nitrogen and a full dose of phosphorus and potash were applied as a basal dose at the time of last plowing during field preparation. The remaining half dosage of nitrogen is applied as a top dressing in two installments at 30th and 45th days after transplanting (DAP) to support crop growth and yield.

3.3.4 Transplantation of seedlings

The transplanting of the cabbage crop was done on 8th November 2021 and 7th November 2022, for experiments in both years. For the experiment, 30-35 days-old seedlings of the cabbage variety '*Golden Acre*' were transplanted manually by keeping one plant per hill in the main field. Both the experiments were laid out in Randomized complete block design (RCBD) having eight treatments including one control and replicated thrice. The cabbage seedlings were transplanted in 3 × 4 m plot size with 60 × 50 cm. row-to-row and plant-to-plant spacing and all the recommended agronomical practices were followed to raise the crop. The single seedling was transplanted at a single spot and a light irrigation was provided after planting of the seedlings. Only the healthy plants were allowed to grow and weaker and dead plants were replaced by the gap-filling process after one week of transplanting.

3.3.5 Irrigation

Plants were irrigated through a channel of 1m. in size in between each replication. First irrigation is given just after transplanting of the seedlings and subsequent irritations are given at 7-10 days of intervals and depending on the weather condition. The crop was irrigated based on moisture availability in the soil as and when required. Head formation

stages are the most critical stages for watering which determines the yield of cabbage.

3.3.6 Weeding

Weeds are a big nuisance as they take up the nutrients in the soil and can also harbor insects and diseases that cause harm to cabbage. These weeds start growing after four to five weeks after transplanting the cabbage saplings. The field was kept free from noxious weeds by hand weeding after irrigation until the crop covers the soil canopy. The soil was fairly pulverized by *Khurpi* and *hoes* as to increase and conserve the soil aeration and moisture in the field.

3.4. Experimental details

3.4.1 Test Insect

Diamondback moth, *Plutella xylostella* (Linn.) (1758)

3.4.2 Systematic Position of diamondback moth

Kingdom : Animalia
Phylum : Arthropoda
Class : Insecta
Order : Lepidoptera
Family : Plutellidae
Genus : *Plutella*
Species : *xylostella*

3.4.3 Identification

The Diamondback moths are small, 12 mm long, with an 18-20 mm wingspan., gray-brown colored insects with folded wings flaring outward and upward toward their tips. Males have a row of three diamond-shaped yellow spots visible where the wings meet when the insect is at rest. Eggs are laid singly on canola or cabbage foliage. Larva is a small, Spindle-shaped, pale-green colored full grown, the larvae measure about 8 mm in length. The tail

end has a forked appearance. Diamondback moth larvae are distinguished by their violent wriggling, often dropping from foliage while suspended by a silken thread. Larvae feed on foliage but in dry years they may move to the head of cabbage and reproductive parts of the plant and feed on buds, blooms and pods. Larva numbers are especially vulnerable to rainfall and humid conditions. Dry weather will cause leaf drop and cause larvae to move to the reproductive portions of the plant. Feeding causes small, round holes and tends to be spread across the foliage rather than concentrated in the head. There are typically two generations per year, their importance as a pest is dependent on moth migration population, timing and conditions. The caterpillar's name comes from the diamond-shaped back markings on the adult moth.

3.4.4 Layout of Experiment

The experiment was laid out in randomization block design (RBD) with three replications each containing eight treatments including control. The plot size for each treatment was kept at 3x4 m², with spacing between row to row and plant to plant is 60x50 cm.

3.4.5 Experimental Layout

Crop	-	Cabbage
Variety	-	Golden Acre
Design	-	Randomized Block Design (RBD)
Treatments	-	8
Replications	-	3
Plot size	-	3.0 x 4.0 m
Variety	-	Golden Acre
Spacing	-	60x50 cm

3.5 Spray details

3.5.1. Preparation of spray solution

Following insecticides and bio-pesticides were sprayed in different formulations for managing diamondback moth (DBM). The final insecticidal spray solutions were prepared by the following formula:

$$\text{Amount of insecticidal formulation} = \frac{\text{concentration required(\%)} \times \text{Volume required(Litre)}}{\text{Concentration of toxicant in insecticidal formulation}} \times 100$$

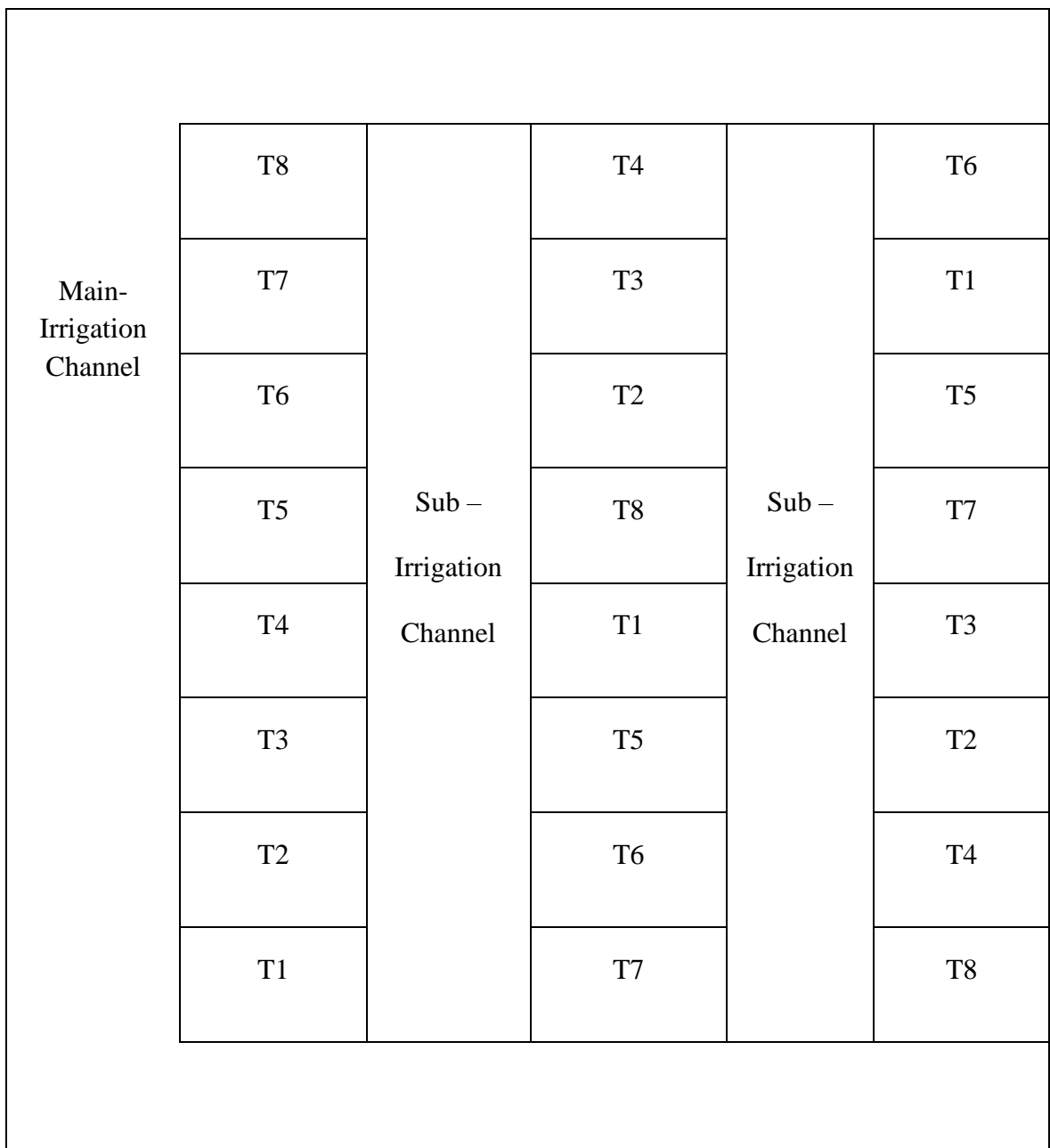


Figure- 3. Layout plan of the experimental field

3.5.2 Treatments

Table- 3.3. Details of newer insecticides and bio-pesticide use in research.

S. No.	Common Name	Trade Name	Manufactured by	Dose (g/ml per ha)
T ₁	Spinosad 2.50% SC	Premise	Bayer	600 ml/ha
T ₂	Emamectin benzoate 5 % SG	Confidor	Dhanuka	200 g/ha
T ₃	Diafenthiuron 50% WP	Pegasus	Syngenta	600 g/ha
T ₄	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	Dipole	Amit Biotech	1000 g/ha
T ₅	<i>Metarhizium anisopliae</i>	-	SVPUAT Meerut	1500 g/ha
T ₆	<i>Beauveria bassiana</i>	-	SVPUAT Meerut	2000 g/ha
T ₇	Nimbecidine 0.03%	Stanes	T. Stanes & Company Ltd.	2500 ml/ha
T ₈	Untreated (Control)	-	-	-

3.6. Methods of observation

3.6.1 To study the insect-pests complex on cabbage.

The field experiments were conducted at CRC of SVPUA & T, Meerut. The cabbage variety Golden Acre was selected for observation. This is the most popular HYV cabbage variety suitable for all agro-climatic zones. The observations of major insect pests on cabbage crop were recorded on five plants selected randomly once in a standard week. Observations on different insects were recorded as pests and some natural enemies. The observation was started after transplanting and continues till maturity or harvesting of the crop. The population of cabbage insect pests was recorded by counting the number of

larvae/plants. The population of insects was recorded by counting the number of nymphs and adults per leaf (top, middle and bottom) plant. The data recorded on major insect pests and meteorological parameters were used for statistical analysis. The results of seasonal incidence between populations of insect pests were calculated.

3.7 To study the population dynamics of the diamondback moth, *Plutella xylostella* L. on cabbage in relation to abiotic and biotic factors.

3.7.1 Layout of experimental field

The experiments were laid out for the study on the population dynamics of the diamondback moth, *Plutella xylostella* (Linn.) on cabbage in relation to abiotic factors was carried out during 2021-22 and 2022-23 at Crop Research Center (CRC) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. The cabbage variety Golden Acre was planted in eight plots with a plot size 4.0 x 3.0 m and spacing 60 x 50 cm on the 8th of November 2021 and 7th of November 2022 for both years.

3.7.2 Observations recorded

To estimate the larval population of the diamondback moth, *Plutella xylostella* (Linn.) on cabbage by direct visual counting method was recommended by (Meena *et al.*, 2012). The observations were recorded at weekly intervals throughout the crop growth on five randomly selected plants from each plot. The weather data viz., maximum and minimum temperature (°C) relative humidity (per cent), rainfall (mm), sunshine hours (hrs./day) and wind velocity (km/hrs.) was collected from the meteorological observatory of the IIFSR for correlating with the population fluctuation phenomena of diamondback moth.

3.7.3 Correlation studies

The correlation between the larval population of diamondback moth in relation to abiotic and biotic factors *i.e.*, average maximum and minimum temperature (°C), relative humidity (%) rainfall (mm), sunshine (hrs./day), wind velocity (km/hrs.) and the adult

population of *Coccinella septempunctata* Linn. was worked out by using following formula-

$$r_{xy} = \frac{\sum xy - (\sum x)(\sum y)}{\left[\sum x^2 - \frac{(\sum x)^2}{n} \right] \left[\sum y^2 - \frac{(\sum y)^2}{n} \right]}$$

Where,

r_{xy} = Simple correlation coefficient

x = Variable *i.e.*, abiotic component.

(Average temperature and relative humidity)

y = Variable *i.e.*, mean number of insect pests

n = Number of observations

3.7.4 Critical difference

The critical difference was calculated for experiments to find out the better treatment. The statistical analysis was made to determine the standard error and critical difference at 5% level of significance and calculated by following the formula.

$$CD = SE (d) \times t (5\%)$$

Where,

CD = Critical difference

t = Table value at 5% probability level.

3.8 To study the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.).

The field experiments were conducted at the crop research center (CRC) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, during *Rabi*, 2021-22 and 2022-23. The cabbage variety Golden Acre was selected for observation. The experiment was laid out in randomization block design (RBD) with three replications each containing eight treatments including control. The plot size for each treatment was kept at 4

x 3 m², with spacing between row to row and plant to plant is 60x50 cm.

3.8.1 Spraying

The first spraying was done in the first year on 03/12/2021 and 18/12/2021 and the second spray on 05/12/2022 and 20/12/2023 in the evening hours at the time of infestation which coincides with the head formation stage. Spraying was done with the help of a knapsack sprayer. The second spray was done at 15-day intervals after the first spray. All plots were sprayed with allotted newer pesticides and the bio-pesticide control plot was sprayed with water only.

3.8.2 Observation

After transplanting of crop and when 2 larval populations of DBM per five plants (ETL) were seen in the experiment, two sprayings were made and data was recorded after the 3rd, 7th, and 14th days of each spraying and presented in tables. The observations were recorded on the population of diamondback moth larvae of five randomly selected plants in each plot one day before every spray which served as a pre-treatment observation and the subsequent counts were taken on the 3rd, 7th, and 14th days after each spray (post-treatment) and the observation on the larval population of diamondback moth was recorded during morning hours. However, the performance of each treatment against this pest was assessed by recording the number of diamondback moth larvae in each plot on five randomly selected plants after treatment on the 3rd, 7th and 14th day after each spray. The data of insect population were subjected for calculation of the mean as suggested by **(Devi and Tayde 2017)**.

3.8.3 Statistical Analysis:

The experiments for the evaluation of botanicals were laid out in Randomized complete block design (RCBD) with three replications and eight treatments for finding out the infestation per centage of *Plutella xylostella* (Linn.). All the observations were analyzed

statistically to compare the treatment effect on the larval population. The larval population data were transformed using square root transformation as $\sqrt{x + 0.5}$ value (where observed insect population per plot).

$$SE (d) = \sqrt{\frac{2 EMS}{r}}$$

Where,

SE (d) = Standard error of difference

EMS = Error mean sum of square

r = Replication

3.8.3. Critical difference

The critical difference was calculated for experiments to find out the better treatment. The statistical analysis was made to determine the standard error and critical difference at 5% level of significance and calculated by following formula suggested by. **Bana (2012)**

$$CD = SE (d) \times t (5\%)$$

Where,

CD = Critical difference

t = Table value at 5% probability level.

3.9 To study the effect of newer insecticides and biopesticides on natural enemies.

The experiment was laid out in randomization block design (RBD) with three replications each containing eight treatments including control. The plot size for each treatment was kept at 4 x 3 m², with spacing between row to row and plant to plant is 60x50 cm. After the application of all treatments, the natural enemies population were counted on five randomly selected plants in each plot one day before every spray which served as a pre-treatment observation and the subsequent count were taken on the 3rd, 7th, and 14th days after each spray (post-treatment) and the observation on the adult population of natural enemies

was recorded during morning hours.

3.10 To calculate the incremental cost-benefit ratio of different treatments.

The incremental cost-benefit ratio (ICBR) was worked out as a ratio of net profit to the cost of plant protection of treatment which exhibits the economic viability of the treatments. This was calculated separately for each treatment as per following formulae suggested by **Ojha (2017) and Nemade *et al.* (2017)**.

$$\text{ICBR} = \frac{\text{Net profit (Rs/ha)}}{\text{Total cost of plant protection or treatment (Rs/ha)}}$$

The results of observation in the present study entitled “**Studies on insect-pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**” was carried out during *Rabi* 2021-22 and 2022-23 at Crop Research Center (CRC), Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh. The studies were discussed in the light of earlier findings and presented under the following objectives that are the insect pest complex on cabbage, seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) on cabbage, the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.), the effect of newer insecticides and biopesticides on natural enemies and the incremental cost-benefit ratio analysis on cabbage. The findings of the experiment in the present study were discussed under different headings and interpreted with the help of available research findings and presented under the following appropriate headings.

4.1 To study the Insect pest complex of cabbage

4.1.1. Insect pest complex of cabbage during *Rabi*, 2021-22

Incidence of insect-pest population and associated natural enemies were observed on cabbage var. “Golden Acre” during *Rabi*, 2021-22. Cabbage pests were identified during field monitoring belonged to the orders Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Hymenoptera and Arachnida. The six orders of insect pests that were identified including natural enemies, represented in **(Table no.-4.1)**. Lepidoptera were recorded highest incidence among all these orders followed by Hemiptera and Coleoptera, Orthoptera, Hymenoptera and Arachnida were recorded similar incidence. Out of these, some were recorded in a significant number and some orders were recorded a very low number categorized as major and minor pests and some others as beneficial insects. Some orders

showed moderate infestation during the experimental period.

The diamondback moth, *Plutella xylostella* (Linn.), cabbage butterfly, *Pieris brassicae*, cabbage head borer, *Hellula undalis*, cabbage aphid, *Brevicoryne brassicae* were recorded highest infestation. The leaf webber, *Crocidolomia pavonana*, and cabbage looper, *Trichoplusia ni* (Hubner) were recorded medium incidence and the tobacco caterpillar, *Spodoptera litura*, painted bug, *Bagrada cruciferarum* spp, surface grasshopper *Chrotogonus trachypterus* (Blanchard), and Mustard sawfly, *Athalia proxima* (Klung) were observed lowest incidence. Among these two natural enemies, *i.e.*, Coccinellids, *Coccinella septempunctata* and one unidentified spider were observed during crop period.

4.1.1. Insect pest complex of cabbage during Rabi, 2022-23

Incidence of insect-pest population and associated natural enemies were observed on cabbage var. “Golden Acre” during *Rabi*, 2022-23. Cabbage pests were identified during field monitoring belonged to the orders Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Hymenoptera and Arachnida. The six orders of insect pests that were identified including natural enemies, are represented in **(Table no.-4.2)**. Lepidoptera were recorded highest incidence among all these orders followed by Hemiptera and Coleoptera, Orthoptera, Hymenoptera and Arachnida recorded similar incidence. Out of these, same were recorded in a significant number and some orders were recorded in a very low number categorized as major and minor pests and some others as beneficial insects. Some orders showed moderate infestation during the experimental period.

The diamondback moth, *Plutella xylostella* (Linn.), cabbage butterfly, *Pieris brassicae*, cabbage head borer, *Hellula undalis*, cabbage aphid, *Brevicoryne brassicae* were recorded highest incidence. The leaf webber, *Crocidolomia pavonana*, and cabbage looper, *Trichoplusia ni* (Hubner) were recorded medium infestation and the surface grasshopper, *Chrotogonus trachypterus* (Blanchard) and fleabeetle, *Phyllotreta cruciferae* were observed

lowest incidence. Among these three natural enemies, *i.e.*, Coccinellids, *Coccinella septempunctata*, one larval parasitoid, *Cotesia plutellae* and one unidentified spider were observed during crop period.

4.1.1. Pooled insect pest complex of cabbage during Rabi, 2021-22 and 2022-23

Pooled incidence of insect-pest population and associated natural enemies were observed on cabbage var. “Golden Acre” during *Rabi*, 2021-22 and 2022-23. Cabbage pests were identified during field monitoring belonged to the orders Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Hymenoptera and Arachnida. The six orders of insect pests that were identified including natural enemies, represented in **(Table no.-4.3)** and **(Figure-4)**. Lepidoptera were recorded highest per centage of insects among these orders, approximately 43 per cent while Orthoptera and Arachnida were recorded lowest population percentage of insect pests about 7 per cent each order. The orders Coleoptera, Hemiptera and Hymenoptera were responsible for about 14 per cent in each insect pests as well as natural enemies respectively. Out of these, some were discovered in a significant number and some orders had a very low number categorized as major and minor pests and some others as beneficial insects. Some orders showed moderate infestation during the experimental period.

The six orders were recorded *i.e.*, Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Hymenoptera and Arachnida. Out of these there was fourteen insect pests and natural enemies were reported *viz.*, diamondback moth, *Plutella xylostella* (Linn.), cabbage butterfly, *Pieris brassicae*, cabbage head borer, *Hellula undalis*, cabbage aphid, *Brevicoryne brassicae* has high infestation. The leaf webber, *Crocidolomia pavonana*, and cabbage looper, *Trichoplusia ni* (Hubner) has medium infestation and the tobacco caterpillar, *Spodoptera litura*, painted bug, *Bagrada cruciferarum* spp, surface grasshopper *Chrotogonus trachypterus* (Blanchard), fleabeetle, *Phyllotreta cruciferae* and Mustard sawfly, *Athalia proxima* (Klung) were observed lowest incidence. Among the three natural

enemies *i.e.*, Coccinellids, *Coccinella septempunctata*, one larval parasitoid, *Cotesia plutellae* and one unidentified spider was observed during crop period.

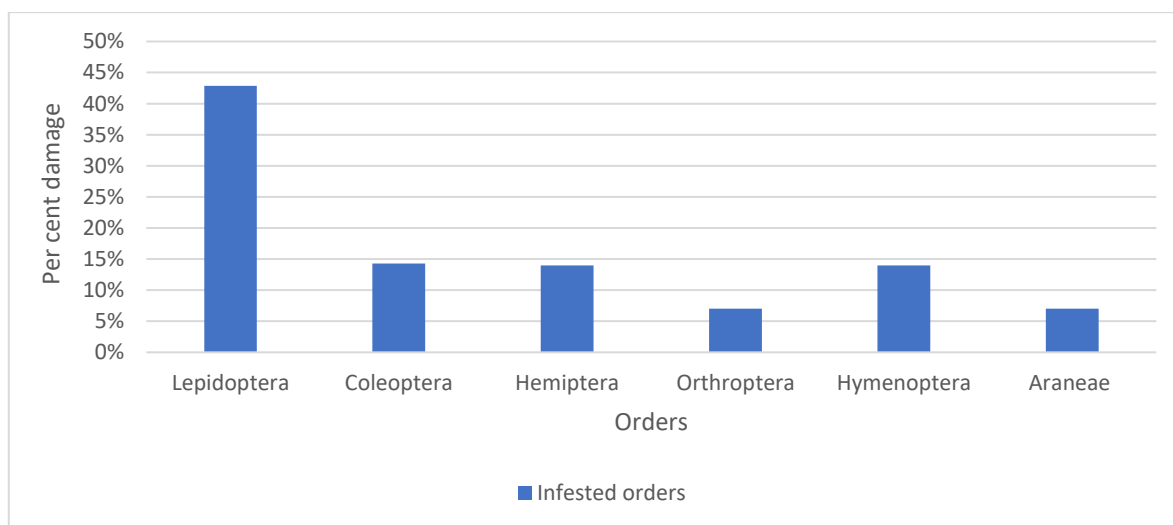


Figure-4. Graph shows the per cent infestation of different orders of insect pest complex on cabbage *Brassica oleracea* var. *capitata* (Linn.).

4.2. To study the seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) on cabbage.

The incidence of *Plutella xylostella* (Linn.) on cabbage was recorded at the regular weekly interval from the five randomly selected plants of the experimental field and correlated with the corresponding meteorological data to understand the relationship between them during the season. The population intensity of *Plutella xylostella* (Linn.) was also observed throughout the cropping season in both years from 2021 to 2022.

4.2.1 Rabi, Year 2021-22

The seasonal incidence of *Plutella xylostella* (Linn.) was observed throughout the cropping season. The data were presented in (Table no.-4.4) and depicted in (Figure-5). The first incidence of *Plutella xylostella* (Linn.) was observed on 21st, November 2021 in the 4th week of November (46th standard week) with a mean number of larvae 0.67 larvae per five plants. The maximum, minimum and average temperatures that prevailed during the initial infestation were 29.01 °C, 13.86°C and 21.43°C respectively. Maximum, minimum and

average relative humidity were 76.43, 49.71 and 63.07 per cent respectively. The rainfall was 0.00 mm. and the wind speed prevailing during this week was 6.71 km/h. The sunshine was 6.50 hrs./day during this period. The head damage reached its peak on 16th, January 2022, during the 3rd week of January (2nd standard week) with a mean larval population of 9.67 diamondback moths per five plants recorded. The maximum, minimum and average temperatures that prevailed during its peak infestation were 17.70°C, 5.30°C and 11.50°C respectively and the maximum, minimum and average relative humidity were 91.90, 80.60 and 86.25 per cent respectively. The rainfall was 67.50 mm., wind speed 6.20 km/h. and sunshine hours were 1.20 hrs/ day during that period.

The correlation with weather parameter shows the strong significant negative correlation between the larval population of *Plutella xylostella* (Linn.) with maximum temperature ($r = -0.778$), minimum temperature ($r = -0.720$), and average temperature ($r = -0.767$) but the morning relative humidity ($= 0.703$) shows the strong significant positive correlation. While sunshine ($= -0.586$) shows significant negative correlation and wind velocity ($= -0.706$) shows the negatively non-significant correlation whereas evening relative humidity ($r = 0.294$) average relative humidity ($r = 0.435$) and rainfall (0.4125) shows the non-significant positive correlation between the larval population of *Plutella xylostella* (Linn.).

4.2.2 Rabi, Year 2022-23

The seasonal incidence of *Plutella xylostella* (Linn.) was observed throughout the cropping season. The data were presented in (Table no.-4.5) and depicted in (Figure-6). The first incidence of *Plutella xylostella* (Linn.) was observed on November 27, 2022 in the 4th week of November (47th standard week) with a mean number of larvae 0.67 larvae per five plants. The maximum, minimum and average temperatures that prevailed during the initial infestation were 27.40°C, 12.10°C and 19.75°C respectively. Maximum, minimum and

average relative humidity were 77.00, 64.70 and 70.85 per cent respectively. The rainfall was 0.00 mm., wind speed prevailing during this week was 4.90 km/h. and sunshine hours were 3.80 hrs/day during that period. The head damage reached to its peak by January 22, 2023 during the 4th week of January (3rd standard week) with a mean larval population of 9.33 *Plutella xylostella* (Linn.) per five plants. The maximum, minimum and average temperatures prevailed during its peak infestation were 17.40°C, 5.10°C and 11.025°C respectively and the maximum, minimum and average relative humidity ranged from 92.00, 71.90 and 81.95 per cent respectively. The rainfall was 0.00 mm., wind speed 8.00 km/h. and sunshine hours were 02.40 hrs./day during that period.

The correlation with weather parameter shows the strong significant negative correlation between the larval population of *Plutella xylostella* (Linn.) with maximum temperature ($r = -0.961$), minimum temperature ($r = -0.962$), and average temperature ($r = -0.977$) but the morning relative humidity ($r = 0.845$), evening relative humidity ($r = 0.657$) and average relative humidity ($r = 0.798$) shows the strong significant positive correlation. While sunshine ($r = -0.769$) shows strong significant negative correlation. Whereas wind velocity ($r = 0.247$) and rainfall ($r = 0.051$) show the positively non-significant correlation between the larval population of *Plutella xylostella* (Linn.).

4.2.3 Pool data Rabi, Year 2021-22 to 2022-23

The seasonal incidence of *Plutella xylostella* (Linn.) was observed throughout the cropping season. The data were presented in (**Table no.-4.6**) and depicted in (**Figure-7**). The first incidence of *Plutella xylostella* (Linn.) was observed in the 45th standard week with a mean number of larvae 0.34 larvae per five plants. The maximum, minimum and average temperatures that prevailed during the initial infestation were 28.61°C, 14.18°C and 21.39°C respectively. The Maximum, minimum and average relative humidity were 78.07, 57.50 and 56.91 per cent respectively. The rainfall was 0.10 mm., wind speed prevailing during this

week 7.60 km/h. and sunshine hours was 4.00 hrs/ day during that period. The head damage reached to its peak during the 2nd standard week with a mean larval population of 9.34 *Plutella xylostella* (Linn.) per five plants. The maximum, minimum and average temperature prevailed during its peak infestation were 16.65°C, 5.40°C and 11.30°C respectively and the maximum, minimum and average relative humidity ranged from 93.30, 80.15 and 86.73 per cent respectively. The rainfall 33.75 mm., wind speed 7.60 km/h. and sunshine hours were 00.60 hrs./day during that period.

The correlation with weather parameter shows the strong significant negative correlation between the larval population of *Plutella xylostella* (Linn.) with maximum temperature ($r = -0.933$), minimum temperature ($r = -0.893$), and average temperature ($r = -0.926$) but the morning relative humidity ($r = 0.899$), evening relative humidity ($r = 0.730$) and average relative humidity ($r = 0.843$) shows the strong significant positive correlation. While the sunshine ($r = -0.787$) shows strong significant negative correlation. Whereas wind velocity ($r = 0.124$) and rainfall ($r = 0.440$) show the positively non-significant correlation between the larval population of *Plutella xylostella* (Linn.).

4.3. To study the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.).

4.3.1. Bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.) during, Rabi, 2021-22.

The effects of different treatments were evaluated against Diamondback moth infestations in cabbage during the *Rabi* seasons of 2021 and 2022. Data was obtained during both cropping seasons and pooled to observe the overall effects. The recorded observations are given below-

4.3.1.1. One day before first application

The statistically analysed data presented in (Table no.-4.7) and (Figure-8) observed

that the average larval population of *Plutella xylostella* (Linn.) at one day before application in all the treatments ranged from 7.00 to 8.00 per five plants on cabbage during *Rabi*, 2021-22. No significant difference was found among all the different treatments.

4.3.1.2. After first application

Data recorded on third day after first application, the minimum diamondback moth larvae (3.00 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (3.66 larvae per five plants) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (4.00, 5.33, 5.66, 6.33 and 6.66 larvae per five plants) respectively. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments had similar efficacy to each other. Whereas maximum diamondback moth larvae (8.00 per five plants) were recorded in untreated control.

Similar trend was recorded on seventh day after first application, the minimum diamondback moth larvae (2.33 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (3.00 larvae per five plants) Followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 3.33, 4.67, 5.00, 5.67 and 6.00 larvae per five plants respectively. All the chemical pesticides were significantly superior over biopesticides and the chemical treatments were statistically at par in their efficacy, similarly biological treatments had similar efficacy to each other. Whereas maximum diamondback moth larvae (8.33 per five plants) were recorded in untreated control.

Data recorded fourteen days after first application, the minimum diamondback moth larvae (2.67 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (3.33 larvae per five plants) Followed by

Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 3.67, 5.00, 5.33, 6.00 and 6.67 larvae per five plants respectively. All the chemical pesticides were significantly superior over biopesticides and the chemical treatments were statistically at par in their efficacy, similarly biological treatments had similar efficacy to each other. Whereas maximum diamondback moth larvae (8.67 per five plants) were recorded in control plot.

4.3.1.3. After second application

The observations were recorded on third day after second application, the minimum diamondback moth larvae (2.00 larvae per five plants) were recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.67 larvae per five plants) Followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 3.00, 4.67, 5.00, 5.67 and 6.33 larvae per five plants respectively. Whereas maximum diamondback moth larvae (9.00 per five plants) were recorded in the untreated control. All the chemical pesticides were significantly superior over biopesticides and the chemical treatments were statistically at par in their efficacy, similarly biological treatments were similar efficacy to each other.

Data were recorded on seventh day after second application, the minimum diamondback moth larvae (1.33 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.00 larvae per five plant) Followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 2.67, 3.67, 4.33, 5.00 and 5.67 larvae per five plants respectively. Whereas maximum diamondback moth larvae (9.33 per five plants) were recorded in untreated control. All the treatments were recorded statistically at par in their efficacy which was significantly superior over untreated control.

Similar trend was recorded on fourteen days after second application, the minimum

diamondback moth larvae (1.67 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.33 larvae per five plant) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 3.00, 4.00, 4.67, 5.33 and 6.00 larvae per five plants respectively. Whereas maximum diamondback moth larvae (9.00 per five plants) were recorded in untreated control. All the treatments were recorded statistically at par in their efficacy which was significantly superior over control.

4.3.2. Bio-efficacy of newer insecticides and bio-pesticides against diamondback moth *Plutella xylostella* (Linn.) during, Rabi, 2022-23.

4.3.2.1. One day before first application

The statistically analysed data presented in (Table no.-4.8 and Figure-9) observed that the average larval population of *Plutella xylostella* one day before application in all the treatments ranged from 7.33 to 8.67 per five plants on cabbage during Rabi, 2022-23. No significant difference was recorded among all the different treatments.

4.3.2.2. After first application

Data recorded on third day after first application, the minimum diamondback moth larvae (3.67 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (4.00 larvae per five plant) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (4.33, 5.67, 6.00, 6.67 and 7.00 larvae per five plants) respectively. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments were similar efficacy to each other. Whereas maximum diamondback moth larvae

(8.00 per five plants) were recorded in untreated control plot.

The similar observation was recorded on seventh day after first application, the minimum diamondback moth larvae (2.00 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.33 larvae per five plants) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (2.67, 4.00, 5.00, 5.33 and 6.00 larvae per five plant) respectively. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments were similar efficacy to each other. Whereas maximum diamondback moth larvae (9.00 per five plants) were recorded in untreated control plots.

The similar observation was recorded on fourteen days after the first application, the minimum diamondback moth larvae (2.33 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.67 larvae per five plant) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (3.00, 4.33, 5.33, 5.67 and 6.33 larvae per five plant) respectively. Whereas maximum diamondback moth larvae (9.00 per five plants) were recorded in untreated control plots. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments were similar efficacy to each other.

4.3.2.3. After second application

The observations were recorded on third day after second application, the minimum diamondback moth larvae (1.33 larvae per five plants) were recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.00 larvae per five plants). Both Spinosad and Emamectin benzoate were at par with their efficacy and

Diafenthiuron 50% WP, significantly different with (2.67 larval per five plants) Followed by *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 3.67, 4.67, 5.00 and 5.67 larvae per five plants respectively. Whereas maximum diamondback moth larvae (9.33 per five plants) were recorded in untreated control.

Similar trend was recorded on seventh day after second application, the minimum diamondback moth larvae (1.00 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (1.33 larvae per five plants). Both Spinosad and Emamectin benzoate are at par with their efficacy and Diafenthiuron 50% WP, significantly different with (2.00 larval per five plant). All the biological pesticides are statistically at par with their efficacy Followed by *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with, 3.00, 4.00, 4.33 and 5.00 larvae per five plants respectively. Whereas maximum diamondback moth larvae (8.33 per five plants) were recorded in untreated control.

Data were recorded on fourteen days after second application, the minimum diamondback moth larvae (1.00 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (1.67 larvae per five plants) Followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 2.33, 3.33, 4.33, 4.67 and 5.67 larvae per five plants respectively. In which all the treatments are statistically at par, there was no significant difference. Whereas maximum diamondback moth larvae (8.00 per five plants) were recorded in untreated control.

4.3.3. Pool Bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.) during Rabi, 2021-22 and 2022-23.

4.3.3.1. One day before first application

The statistically analysed data presented in (Table no.-4.9) and (Figure-10)

observed that the average larval population of *Plutella xylostella* at one day before application in all the treatments ranged from 7.00 to 8.00 per five plants on cabbage during both the years 2021-22 to 2022-23. No significant difference was recorded among all the different treatments.

4.3.3.2 After first application

Data recorded on third day after first application, the minimum diamondback moth larvae (3.33 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (3.83 larvae per five plants) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (4.17, 5.50, 5.83, 6.50 and 6.83 larvae per five plants) respectively. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments had similar efficacy to each other. Whereas maximum diamondback moth larvae (8.33 per five plants) were recorded in untreated control plot.

The similar observation was recorded on seventh day after first application, the minimum diamondback moth larvae (2.17 larvae per five plants) was recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.67 larvae per five plant) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (3.00, 4.33, 5.00, 5.50 and 6.00 larvae per five plant) respectively. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments had similar efficacy to each other. Whereas maximum diamondback moth larvae (8.67 per five plants) were recorded in untreated control plot.

The similar observation was recorded on fourteenth day after first application, the minimum diamondback moth larvae (2.50 larvae per five plants) was recorded in the

Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (3.00 larvae per five plants) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with (3.33, 4.67, 5.33, 5.83 and 6.50 larvae per five plants) respectively. Whereas maximum diamondback moth larvae (8.83 per five plants) were recorded in untreated control plot. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments were similar efficacy to each other.

4.3.3.3 After second application

The observations were recorded on third day after second application, the minimum diamondback moth larvae (1.67 larvae per five plants) were recorded in the Spinosad 2.50% SC. The second effective treatment was Emamectin benzoate 5% SG with (2.33 larvae per five plants) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% (2.83, 4.17, 4.83, 5.33 and 6.00 larvae per five plants) respectively. Whereas maximum diamondback moth larvae (9.17 per five plants) were recorded in untreated control plot. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at par in their efficacy, similarly biological treatments had similar efficacy to each other.

The observations were recorded on seventh day after second application, the minimum diamondback moth larvae (1.17 larvae per five plants) were recorded in the Spinosad 2.50% SC. The second effective treatment was Emamectin benzoate 5% SG with (2.67 larvae per five plant) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% (2.33, 3.33, 4.17, 4.67 and 5.33 larvae per five plant) respectively. Whereas maximum diamondback moth larvae (8.83 per five plants) were recorded in untreated control plot. The chemical pesticides and biopesticides were significantly different and the chemical treatments were statistically at

par in their efficacy, similarly biopesticides were similar efficacy to each other.

Data were recorded on fourteen days after second application, the minimum diamondback moth larvae (1.33 larvae per five plants) were recorded in the Spinosad 2.50% SC. The next best treatment was Emamectin benzoate 5% SG with (2.00 larvae per five plants) followed by Diafenthiuron 50% WP, *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae* and Nimbecidine 0.03% with 2.67, 3.67, 4.50, 5.00 and 5.83 larvae per five plants respectively. Whereas maximum diamondback moth larvae (8.00 per five plants) were recorded in untreated control plot. In which all the treatments are statistically at par, there was no significant difference.

4.4.To study the effect of newer insecticides and biopesticides on natural enemies.

4.4.1. Effect of newer insecticides and biopesticides on adults of *Coccinella septempunctata* in cabbage during Rabi, 2021-22.

4.4.1.1. One day before first application

The statistically analysed data presented in (Table no.-4.10 and Figure-11) observed that the average adult population of *Coccinella septempunctata* at one day before application in all the treatments ranged from 4.33 to 5.67 per five plants on cabbage during Rabi, 2021-2022. No significant difference was found among all the different treatments.

4.4.1.2. After first application

After three days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (4.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (4.00 adult per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.67, 3.33, 3.00, 2.67 and 2.33 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of *Coccinella septempunctata*. Whereas

maximum adult population of *Coccinella septempunctata* was recorded from untreated control (5.33 adult population per five plants).

After seven days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (4.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.67 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.33, 3.00, 2.67, 2.33 and 1.67 adult per five plants respectively. All the chemical insecticides prove less safe to the adult population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control *i.e.* (5.67 adults per five plants).

After fourteen days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (4.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (4.00 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.67, 3.33, 3.00, 2.67 and 2.00 adult per five plants respectively. All the treatments chemical insecticides prove less safe for adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* were recorded from untreated control plot *i.e.*, 5.67 adults per five plants.

4.4.1.3. After second application

After three days of second application among all the biopesticides Nimbecidine 0.03% proved to be the safest for adults of *Coccinella septempunctata* with highest population (4.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.33 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*,

Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.00, 2.67, 2.00, 1.67 and 1.00 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control *i.e.* (5.33 adult population per five plants).

After seventh days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with the highest population (3.67 adults per five plants). The next best treatment was *Metarhizium anisopliae* with (3.00 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.33, 2.00, 1.33, 1.00 and 0.33 adult per five plants respectively. All the chemical insecticides prove less safe for adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (5.00 adults per five plants).

After fourteen days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with the highest population (4.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.33 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.67, 2.33, 1.67, 1.33 and 0.67 adult per five plant respectively. All the chemical insecticides prove less safe to adult population of *Coccinella septempunctata*. Whereas the maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (4.67 adults per five plants).

4.4.2. Effect of newer insecticides and biopesticides on adults of *Coccinella septempunctata* in cabbage during Rabi, 2022-23.

4.4.2.1. One day before first application

The statistically analysed data presented in (Table no.-4.11 and Figure-12) observed that the average adult population of *Coccinella septempunctata* at one day before application in all the treatments ranged from 3.33 to 4.67 per five plants on cabbage during Rabi, 2021-2022. No significant difference was found among all the different treatments.

4.4.2.2. After first application

After three days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (4.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.67 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.33, 3.00, 2.67, 2.33 and 2.00 adult per five plants respectively. All the chemical insecticides prove less safe to the adult population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (4.33 adults population per five plants).

After seven days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (3.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.00 adults per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.67, 2.33, 1.67, 1.33 and 1.00 adults per five plants respectively. All the chemical insecticides prove less safe to the adult population of *Coccinella septempunctata*. Whereas maximum adults population of *Coccinella septempunctata* was recorded from untreated control with 4.67 adults per five plants.

After fourteen days of first application among all the biopesticides Nimbecidine

0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (3.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.33 adult per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.00, 2.67, 2.00, 1.67 and 1.33 adult per five plant respectively. All the chemical insecticides prove less safe to the adult population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* were recorded from untreated control plot with (5.00 adults per five plants).

4.4.2.3. After second application

After three days of second application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (3.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.67 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, 1.00, 0.67 and 00.00 adult per five plants respectively. All the chemical insecticides prove less safe to the adult population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (5.00 adult population per five plants).

After seven days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with the highest population (2.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.00 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.67, 1.33, 0.33, 0.00 and 0.00 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of *Coccinella septempunctata*. Whereas maximum adult

population of *Coccinella septempunctata* was recorded from untreated control with (4.67 adults per five plant).

After fourteen days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with the highest population (2.67 adult per five plant) the next best treatment was *Metarhizium anisopliae* with (2.33 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, .67, .33 and 0.00 adult per five plant respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (3.33 adults per five plants).

4.4.3. Pool data of newer insecticides and biopesticides on adults of *C. septempunctata* in cabbage during *Rabi*, 2021-22 and 2022-23

4.4.3.1. One day before first application

The statistically analyzed data presented in (Table no.-4.12.) and (Figure-13) observed that the average adult population of *Coccinella septempunctata* at one day before application in all the treatments ranged from 4.17 to 5.17 per five plants on cabbage during *Rabi*, 2021-2022 and 2022-23. There was no significant difference was found among all the different treatments.

4.4.3.2. After first application

After three days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (4.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.83 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC

with 3.50, 3.17, 2.83, 2.50 and 2.17 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* were recorded from untreated control with (4.83 adult population per five plants).

After seventh days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (3.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.33 adult per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.00, 2.66, 2.17, 1.83 and 1.33 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (5.17 adults per five plants).

After fourteen days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with highest population (4.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (3.67 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 3.33, 3.00, 2.50, 1.17 and 1.67 adult per five plant respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* were recorded from untreated plot with (5.33 adults per five plants).

4.4.3.3. After second application

After three days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with

highest population (3.50 adult per five plant) the next best treatment was *Metarhizium anisopliae* with (3.00 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.50, 2.17, 1.50, 1.17 and 0.50 adult per five plant respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* were recorded from untreated control with (5.17 adult population per five plant).

After seventh days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with the highest population (3.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.50 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, 0.83, 0.50 and 0.17 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control *i.e.* (4.83 adults per five plants).

After fourteen days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of *Coccinella septempunctata* with the highest population (3.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.83 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.33, 2.00, 1.17, 0.83 and 0.33 adult per five plant respectively. All the chemical insecticides prove less safe to adults population of *Coccinella septempunctata*. Whereas maximum adult population of *Coccinella septempunctata* was recorded from untreated control with (4.00 adults per five plants).

4.4.4. Effect of newer insecticides and biopesticides on adults of Spider in cabbage during *Rabi*, 2021-22.

4.4.4.1 One day before first application

The statistical analysis data presented in (Table no.-4.13 and Figure-14.) observed that the average adult population of Spider one day before application in all the treatments ranged from 2.33 to 3.67 per five plants on cabbage during *Rabi*, 2021-2022. no significant difference was found among all the different treatments.

4.4.4.2. After first application

After three days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (3.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.67 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.33, 2.00, 1.67, 1.33 and 1.00 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.00 adult population per five plants).

After seven days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.33 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, 1.33, 1.00 and 0.67 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.00 adult population per five plants).

After fourteen days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (3.33 adult per five plant) the next best treatment was *Metarhizium anisopliae* with (3.00 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.67, 2.33, 2.00, 1.67 and 1.33 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.67 adult population per five plants).

4.4.4.3. After second application

After three days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (3.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.67 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.33, 2.00, 1.67, 1.33 and 1.00 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.67 adults population per five plants).

After seventh days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.33 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, 1.33, 1.00 and 0.67 adults per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.33 adult population per five plants).

After fourteen days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (3.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.67 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.33, 2.00, 1.00, 0.67 and 0.33 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.67 adults population per five plants).

4.4.5. Effect of newer insecticides and biopesticides on adults of Spider in cabbage during Rabi, 2022-23.

4.4.5.1 One day before first application

The statistically analysed data presented in (Table no- 4.14. and Figure-15) observed that the average adult population of Spider at one day before application in all the treatments ranged from 2.33 to 3.33 per five plants on cabbage during Rabi, 2022-23. no significant difference was found among all the different treatments.

4.4.5.2. After first application

After three days of first application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.33 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, 1.33, 1.00 and 0.67 adults per five plants respectively. All the chemical insecticides proved to be less safe for the adult population of Spider. Whereas the maximum adult population of Spider was recorded from untreated control with (3.00 adults population per five plants).

After seven days of first application among all the biopesticides Nimbecidine 0.03%

proved to be the safest insecticide for adults of Spider with the highest population (2.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.00 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.67, 1.33, 1.00, 0.67 and 0.33 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.00 adult population per five plants).

After fourteen days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.33 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.67, 1.33, 1.00 and .67 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.33 adults population per five plants).

4.4.5.3. After second application

After three days of second application among all the biopesticides Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with the highest population (2.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.00 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.67, 1.33, 1.00, 0.33 and 0.00 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.67 adult population per five plant).

After seven days of second application among all the biopesticides Nimbecidine

0.03% proved to be the safest insecticide for adults of Spider with highest population (2.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (1.67 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.33, 0.67, 0.33, 0.00 and 0.00 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.33 adults population per five plants).

After fourteen days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.00 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.67, 1.00, 0.67, 0.00 and 0.00 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.00 adult population per five plants).

4.4.6. Pool Effect of newer insecticides and biopesticides on adults of Spider in cabbage during Rabi, 2021-22 and 2022-23

4.4.6.1. One day before first application

The statistically analysed data presented in (Table no.-4.15. and Figure-16) observed that the average adult population of Spider at one day before application in all the treatments ranged from 2.50 to 3.33 per five plants on cabbage during Rabi, 2021-2022 and 2022-23. no significant difference was found among all the different treatments.

4.4.6.2. After first application

After three days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2. 83

adults per five plant) the next best treatment was *Metarhizium anisopliae* with (2.50 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.17, 1.83, 1.50 1.17 and 0.83 adult per five plants respectively. All the chemical insecticides proved to be the less safe for the adult population of Spider. Whereas the maximum adult population of Spider was recorded from untreated control with (3.50 adult population per five plant).

After seven days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with the highest population (2.50 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.17 adult per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.83, 1.50, 1.17, 0.83 and 0.50 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.50 adult population per five plants).

After fourteen days of first application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (3.00 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.67 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.33, 2.00, 1.67, 1.33, and 1.00 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.00 adult population per five plants).

4.4.6.3. After second application

After three days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with the highest population

(2.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.33 adult per five plant) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.50, 1.17, 0.83 and 0.50 adult per five plants respectively. All the chemical insecticides prove less safe to adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (4.17 adult population per five plants).

After seven days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.33 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.00 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 1.67, 1.17, 0.83, 0.50 and 0.33 adult per five plants respectively. All the chemical insecticides prove less safe to the adult population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.83 adult population per five plants).

After fourteen days of second application among all the biopesticides the Nimbecidine 0.03% proved to be the safest insecticide for adults of Spider with highest population (2.67 adults per five plants) the next best treatment was *Metarhizium anisopliae* with (2.33 adults per five plants) followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin benzoate 5% SG and Spinosad 2.50% SC with 2.00, 1.50, 0.83, 0.33 and 0.17 adult per five plants respectively. All the chemical insecticides prove less safe to adults population of Spider. Whereas maximum adult population of Spider was recorded from untreated control with (3.83 adult population per five plants).

4.5. To calculate the incremental cost-benefit ratio of different treatments.

4.5.1. To calculate the incremental cost-benefit ratio of different treatments (Year 2021-22)

The data is depicted in **Table No. 4.16.** reported that the highest incremental cost-benefit ratio (ICBR) was recorded in Emamectin benzoate 5% SG *i.e.*, 1:11.87 which was comparatively superior over all treatments as sprayed on standing crop. The mean yield of cabbage was recorded from this treatment *i.e.*, 170.00 q/ha and the net profit obtained from the increased yield was 23400 Rs/ha. The next best treatment was Spinosad 2.50%SC with incremental cost-benefit ratio (ICBR) *i.e.*, 1:7.92 that produced mean yield of cabbage *i.e.*, 181.67 q/ha followed by Diafenthiuron 50% WP, *Beauveria bassiana*, *Metarhizium anisopliae*, *Bacillus thuringiensis* var. *kurstaki*, Nimbecidine 0.03% with ICB ratio 6.94, 7.36, 5.19, 3.31 and 2.09 respectively, mean yield with 169, 157.00, 155 and 167 q/ha respectively. All treatments were superior over control (Untreated). The lowest cabbage yield 144.00 q/ha was observed in the untreated control.

4.5.2. To calculate the incremental cost-benefit ratio of different treatments (Year 2022-23)

The data depicted in **Table no.- 4.17** reported that the highest incremental cost-benefit ratio (ICBR) was recorded in Emamectin benzoate 5% SG *i.e.*, 1:9.27 which was comparatively superior over all treatments as sprayed on standing crop. The mean yield of cabbage was recorded from this treatment *i.e.*, 183.33 q/ha and the net profit obtained from the increased yield was 16848.67 Rs/ha. The next best treatment was Spinosad 2.50%SC with incremental cost-benefit ratio (ICBR) *i.e.*, 1:4.92 that produced mean yield of cabbage *i.e.*, 191.00 q/ha followed by Diafenthiuron 50% WP, *Beauveria bassiana*, *Metarhizium anisopliae*, *Bacillus thuringiensis* var. *kurstaki*, Nimbecidine 0.03% with ICB ratio 4.65, 5.07, 3.36, 4.00, 1.80 and 1.46 respectively, mean yield with 178, 163.00, 162 and 160 q/ha respectively. All treatments were superior over control (Untreated). The lowest cabbage yield 146.00 q/ha was observed in the untreated control.

4.5.3. To calculate the pooled incremental cost-benefit ratio of different treatments

(Year 2021-22 and 2022-23)

The data depicted in **Table no.-4.18** reported that the highest incremental cost-benefit ratio (ICBR) was recorded in Emamectin benzoate 5% SG *i.e.*, 1:10.57 which was comparatively superior over all treatments as sprayed on standing crop. The mean yield of cabbage was recorded from this treatment *i.e.*, 186.33 q/ha and the net profit obtained from the increased yield was 21033.33 Rs/ha. The next best treatment was Spinosad 2.50%SC with incremental cost-benefit ratio (ICBR) *i.e.*, 1:6.42 that produced mean yield of cabbage *i.e.*, 186.33 q/ha followed by Diafenthiuron 50% WP, *Beauveria bassiana*, *Metarhizium anisopliae*, *Bacillus thuringiensis* var. *kurstaki*, Nimbecidine 0.03% with ICB ratio 5.79, 6.21, 4.59, 2.56 and 1.77 respectively, mean yield with 173.50, 160.00, 158.00 and 156.17 q/ha. respectively. All treatments were superior over Untreated control. The lowest cabbage yield 145.00 q/ha was observed in the control (untreated).

Table no.- 3.1. Meteorological observations during *Rabi*, 2021-22

Standard Meteorological Week (SMW)	Date of Observation	Meteorological parameters								
		Temperature (°C)			Relative Humidity (%)			Rain Fall (mm)	Sun Shine hrs./day	Wind Velocity (km/hr.)
		Max.	Min.	Average (X ₁)	Morning	Evening	Average (X ₂)			
45 th	14/11/2021	28.73	12.86	20.79	76.86	48.00	62.43	00.00	06.21	07.07
46 th	21/11/2021	29.01	13.86	21.43	76.43	49.71	63.07	00.00	06.50	06.71
47 th	28/11/2021	28.11	11.00	19.55	80.57	46.86	63.71	00.00	06.31	03.54
48 th	05/12/2021	26.76	9.71	18.23	81.57	46.29	63.93	00.00	05.96	04.27
49 th	12/12/2021	23.07	11.64	17.35	84.29	48.14	66.21	00.90	04.21	05.33
50 th	19/12/2021	22.40	09.36	15.88	83.43	39.43	61.43	00.00	05.80	06.10
51 st	26/12/2021	20.74	07.17	13.95	82.43	38.43	60.43	00.00	06.20	05.06
52 nd	02/01/2022	20.00	06.49	13.24	88.63	49.50	69.06	02.50	04.69	05.33
1 st	09/01/2022	20.60	07.50	14.05	84.60	61.10	72.85	09.90	04.10	04.70
2 nd	16/01/2022	17.70	05.30	11.50	91.90	80.60	86.25	67.50	01.20	06.20
3 rd	23/01/2022	16.20	04.70	10.45	92.60	71.10	81.85	03.70	01.60	06.80
4 th	30/01/2022	16.60	05.30	10.95	91.60	67.90	79.75	33.90	03.20	04.60
5 th	06/02/2022	20.10	06.00	13.05	88.60	67.00	77.80	18.40	02.60	05.40
6 th	13/02/2022	20.50	07.30	13.90	85.90	64.10	75.00	04.50	05.30	05.40

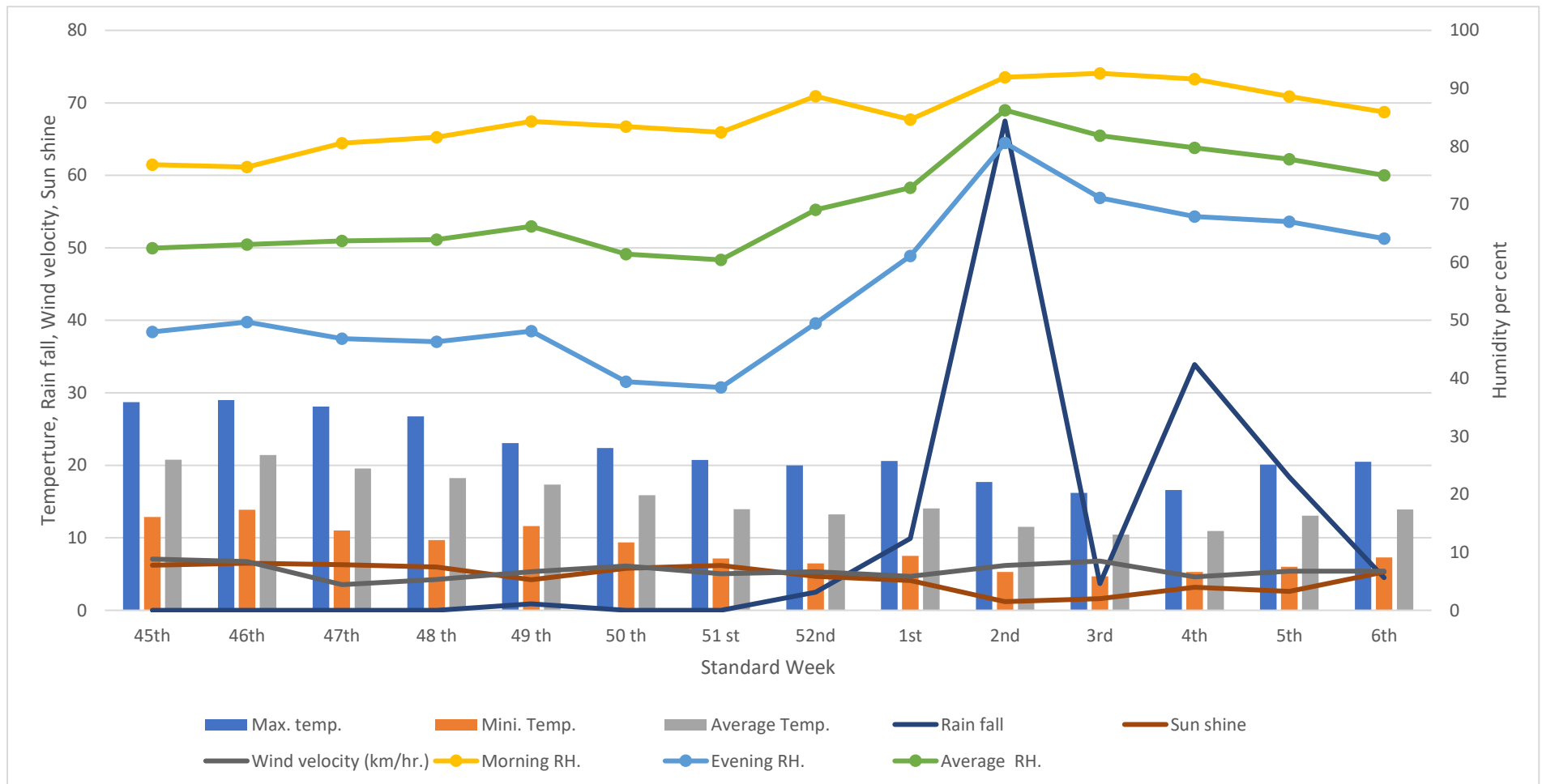


Figure-1. Meteorological observations during Rabi, 2021-22

Table no.-3.2. Meteorological observations during *Rabi*, 2022-23

Standard Meteorological Week (SMW)	Date of Observation	Meteorological parameters								
		Temperature (°C)			Relative Humidity (%)			Rain Fall (mm)	Sun Shine hrs./day	Wind Velocity (km/hrs.)
		Max.	Min.	Average (X ₁)	Morning	Evening	Average (X ₂)			
45 th	13/11/2022	29.60	13.00	21.30	81.40	61.00	71.20	00.00	03.20	07.70
46 th	20/11/2022	28.20	14.50	21.35	79.70	64.10	71.90	00.20	04.00	07.60
47 th	27/11/2022	27.40	12.10	19.75	77.00	64.70	70.85	00.00	03.80	04.90
48 th	04/12/2022	27.80	10.20	19.00	72.60	58.00	65.30	00.00	04.40	06.60
49 th	11/12/2022	24.90	08.80	16.85	79.70	64.00	71.85	00.00	02.60	07.50
50 th	18/12/2022	23.40	08.60	16.00	88.50	69.20	78.85	00.00	03.50	06.70
51 st	25/12/2022	21.80	07.00	14.40	95.10	75.00	85.05	00.00	01.10	09.00
52 nd	01/01/2023	18.90	06.10	12.50	95.70	77.70	86.70	00.00	00.45	08.20
1 st	08/01/2023	15.40	04.60	10.00	97.90	82.90	90.40	00.00	00.10	08.10
2 nd	15/01/2023	15.60	05.50	10.55	94.70	79.70	87.20	00.00	00.60	07.60
3 rd	22/01/2023	17.40	05.10	11.25	92.00	71.90	81.95	00.00	02.40	08.00
4 th	29/01/2023	20.60	06.60	13.60	88.10	60.00	74.05	00.20	02.40	08.30
5 th	05/02/2023	21.10	06.00	13.55	90.90	59.30	75.10	11.00	02.90	13.00
6 th	12/02/2023	25.10	09.50	17.30	83.40	51.10	67.25	00.00	04.80	10.10

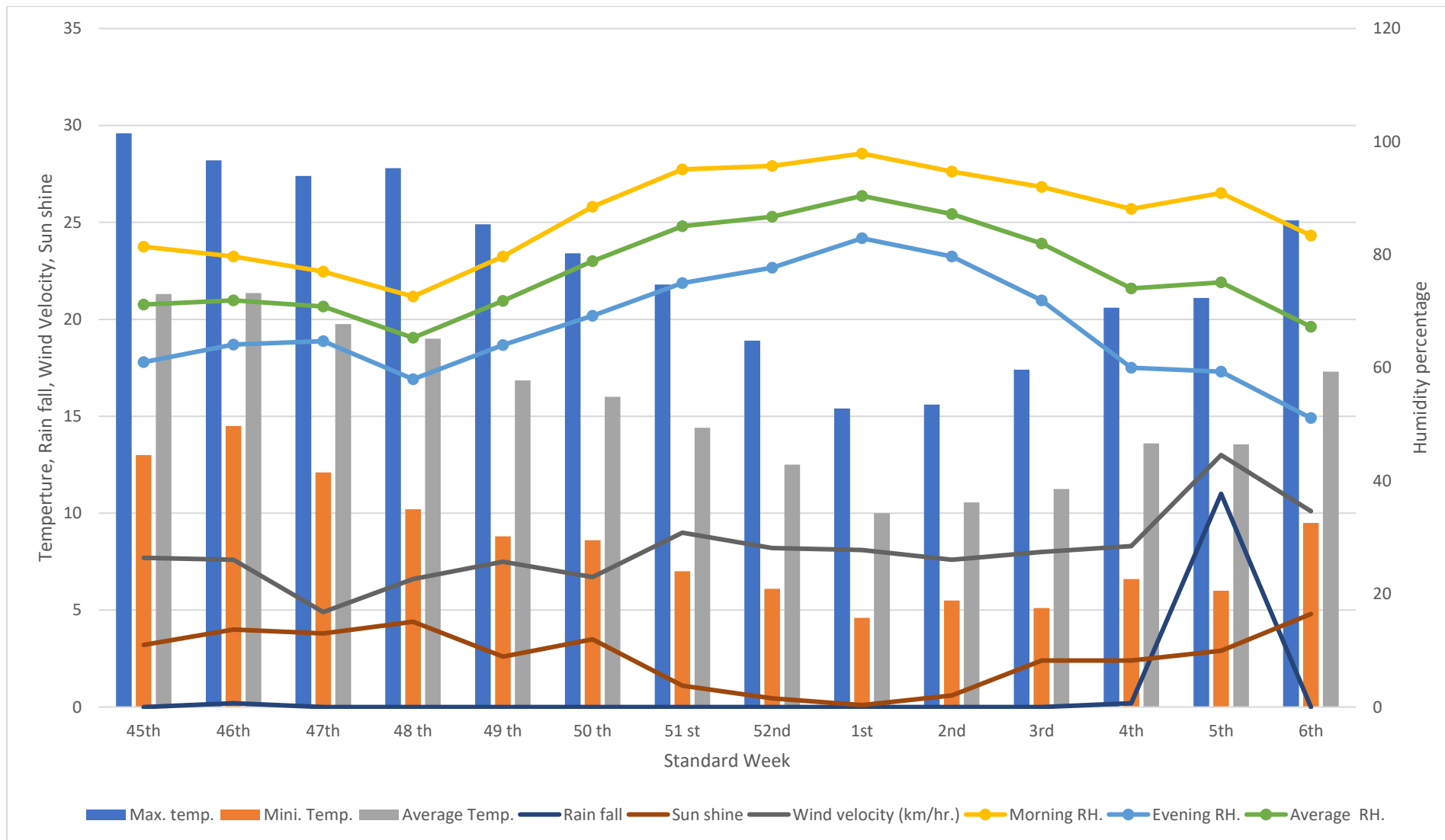


Figure- 2. Meteorological observations during *Rabi*, 2022-23

Table no.- 4.1. Insect pest complex on cabbage, *Brassica oleracea* var. *capitata* (Linn.) during Rabi, 2021-22

S. No.	Common name	Scientific Name	Order: Family	Level of incidence	Period of activity
1.	Diamondback moth	<i>Plutella xylostella</i> (Linn.)	Lepidoptera: Plutellidae	High	November - February
2.	Cabbage butterfly	<i>Pieris bressicae</i> (Linn.)	Lepidoptera: Pieridae	High	December - February
3.	Leaf Webber	<i>Crocidolomia pavonana</i> (Fab.)	Lepidoptera: Pyralidae	Medium	January - February
4.	Cabbage head borer	<i>Hellula undalis</i>	Lepidoptera:Crambidae	High	December - February
5.	Cabbage looper	<i>Trichoplusia ni</i> (Hubner)	Lepidoptera: Noctuidae	Medium	December - February
6.	Tobacco caterpillar	<i>Spodoptera litura</i>	Lepidoptera: Noctuidae	Low	December - February
7.	Cabbage aphid	<i>Brevicoryne brassicae</i> (Linn.)	Hemiptera: Aphididae	High	November - February
8.	Painted bug	<i>Bagarada cruciferarum</i> (Krik)	Hemiptera: Pentatomidae	Low	December - February
9.	Surface grasshopper	<i>Chrotogonus trachypterus</i> (Blanchard)	Orthoptera: Acrididae	Low	November - February
10.	Ladybird beetle	<i>Coccinella septumpunctata</i> (Linn)	Coleoptera: Coccinellidae	Medium	November - February
11.	Mustard sawfly	<i>Athalia proxima</i> (Klung)	Hymenoptera: Tenthredinidae	Low	December - February
12.	Spider	(Unidentified)	Arachnida: Araneae	Low	November- February

Table no.- 4.2. Insect pest complex on cabbage, *Brassica oleracea* var. *capitata* (Linn.) during Rabi, 2022-23

S. No.	Common name	Scientific Name	Order: Family	Level of incidence	Period of activity
1.	Diamondback moth	<i>Plutella xylostella</i> (Linn.)	Lepidoptera: Plutellidae	High	November - February
2.	Cabbage butterfly	<i>Pieris brassicae</i> (Linn.)	Lepidoptera: Pieridae	High	December - February
3.	Leaf Webber	<i>Crocidolomia pavonana</i> (F.)	Lepidoptera: Pyralidae	Medium	January - February
4.	Cabbage head borer	<i>Hellula undalis</i>	Lepidoptera:Crambidae	High	December - February
5.	Cabbage looper	<i>Trichoplusia ni</i> (Hubner)	Lepidoptera: Noctuidae	Medium	December - February
6.	Cabbage aphid	<i>Brevicoryne brassicae</i> (Linn.)	Hemiptera: Aphididae	High	November - February
7.	Surface grasshopper	<i>Chrotogonus trachypterus</i> (Blanchard)	Orthoptera: Acrididae	Low	November - February
8.	Flea beetle	<i>Monolepta signata</i> (Oliv).	Coleoptera: Chrysomelidae	Low	December - February
9.	Ladybird beetle	<i>Coccinella septumpunctata</i> L.	Coleoptera: Coccinellidae	Medium	December - February
10.	Larval Endoparasitoid	<i>Cotesia plutellae</i>	Hymenoptera: Braconidae	Low	January- February
11.	Spider	(Unidentified)	Arachnida: Araneae	Low	Late January- February

Table no.- 4.3. Pooled Insect pest complex on cabbage, *Brassica oleracea* var. *capitata* (Linn.) during *Rabi*, 2021-22 and 2022-23

S. No.	Common name	Scientific Name	Order: Family	Level of incidence	Period of activity
1.	Diamondback moth	<i>Plutella xylostella</i> (Linn.)	Lepidoptera: Plutellidae	High	November - February
2.	Cabbage butterfly	<i>Pieris bressicae</i> (Linn.)	Lepidoptera: Pieridae	High	December - February
3.	Leaf Webber	<i>Crocidolomia pavonana</i> (F.)	Lepidoptera: Pyralidae	Medium	January - February
4.	Cabbage head borer	<i>Hellula undalis</i>	Lepidoptera:Crambidae	High	December - February
5.	Cabbage looper	<i>Trichoplusia ni</i> (Hubner)	Lepidoptera: Noctuidae	Medium	December - February
6.	Tobacco caterpillar	<i>Spodoptera litura</i>	Lepidoptera: Noctuidae	Low	December - February
7.	Cabbage aphid	<i>Brevicoryne brassicae</i> (Linn.)	Hemiptera: Aphididae	High	November - February
8.	Painted bug	<i>Bagarada cruciferarum</i> (Krik)	Hemiptera: Pentatomidae	Low	December - February
9.	Surface grasshopper	<i>Chrotogonus trachypterus</i> (Blanchard)	Orthoptera: Acrididae	Low	November - February
10.	Flea beetle	<i>Monolepta signata</i> (Oliv).	Coleoptera: Chrysomellidae	Low	December - February
11.	Ladybird beetle	<i>Coccinella septumpunctata</i> L.	Coleoptera: Coccinellidae	Medium	December - February
12.	Mustard sawfly	<i>Athalia proxima</i> (Klung)	Hymenoptera: Tenthredinidae	Low	December - February
13.	Larval Endoparasitoid	<i>Cotesia plutellae</i>	Hymenoptera: Braconidae	Low	January- February
14.	Spider	(Unidentified)	Arachnida: Araneae	Low	Late January- February

Table no. 4.4. Larval population of DBM, *Plutella xylostella* (Linn.) on cabbage during *Rabi*, 2021-22.

Standard Meteorological Week (SMW)	Date of Observation	Average Population Larvae/ 5Plants	Meteorological Parameters								
			Temperature (°C)			Relative humidity (%)			Rainfall (mm)	Sun shine hrs./day	Wind Velocity (km/hr.)
			Max.	Min.	Average (X ₁)	Morning	Evening	Average (X ₂)			
45 th	14/11/2021	0.00	28.73	12.86	20.79	76.86	48.00	62.43	00.00	06.21	07.07
46 th	21/11/2021	0.67	29.01	13.86	21.43	76.43	49.71	63.07	00.00	06.50	06.71
47 th	28/11/2021	2.33	28.11	11.00	19.55	80.57	46.86	63.71	00.00	06.31	03.54
48 th	05/12/2021	4.00	26.76	9.71	18.23	81.57	46.29	63.93	00.00	05.96	04.27
49 th	12/12/2021	5.67	23.07	11.64	17.35	84.29	48.14	66.21	00.90	04.21	05.33
50 th	19/12/2021	7.33	22.40	09.36	15.88	83.43	39.43	61.43	00.00	05.80	06.10
51 st	26/12/2021	8.00	20.74	07.17	13.95	82.43	38.43	60.43	00.00	06.20	05.06
52 nd	02/01/2022	8.33	20.00	06.49	13.24	88.63	49.50	69.06	02.50	04.69	05.33
1 st	09/01/2022	9.00	20.60	07.50	14.05	84.60	61.10	72.85	09.90	04.10	04.70
2 nd	16/01/2022	9.67	17.70	05.30	11.50	91.90	80.60	86.25	67.50	01.20	06.20
3 rd	23/01/2022	8.67	16.20	04.70	10.45	92.60	71.10	81.85	03.70	01.60	06.80
4 th	30/01/2022	6.67	16.60	05.30	10.95	91.60	67.90	79.75	33.90	03.20	04.60
5 th	06/02/2022	3.67	20.10	06.00	13.05	88.60	67.00	77.80	18.40	02.60	05.40
6 th	13/02/2022	2.33	20.50	07.30	13.90	85.90	64.10	75.00	04.50	05.30	05.40

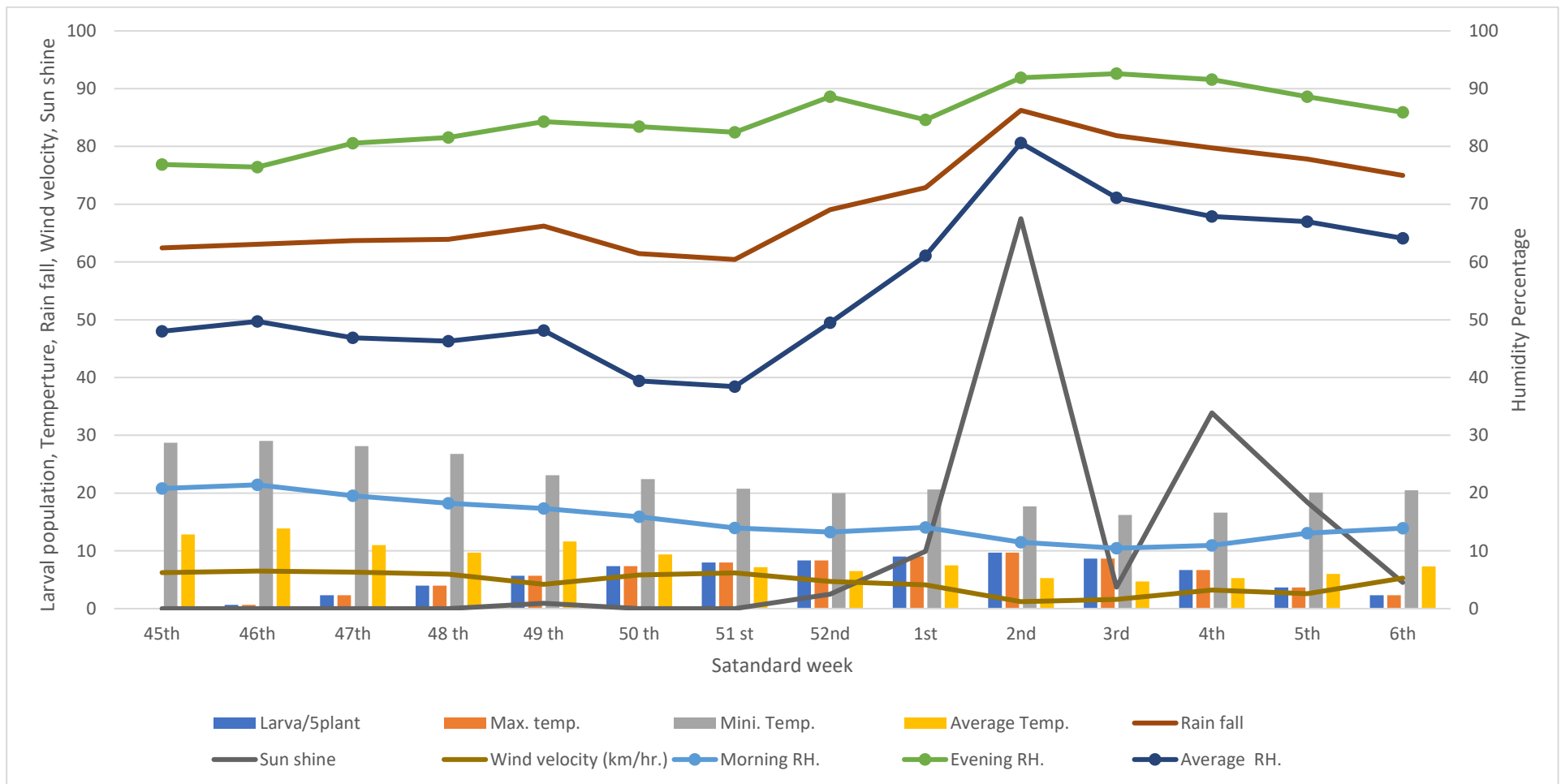


Figure- 5. Larval population of DBM *Plutella xylostella* (Linn.) on cabbage during Rabi, 2021-22

Table no.- 4.5. Larval population of DBM, *Plutella xylostella* (Linn.) on cabbage during Rabi, 2022-23

Standard Meteorological Week (SMW)	Date of Observation	Average Population Larvae/5 Plants	Meteorological Parameters								
			Temperature (°C)			Relative Humidity (%)			Rainfall (mm)	Sun Shine hrs./day	Wind Velocity (km/hr.)
			Max	Min	Average (X ₁)	Morning	Evening	Average (X ₂)			
45 th	13/11/2022	0.00	29.6	13.0	21.30	81.40	61.00	71.20	00.00	03.20	07.70
46 th	20/11/2022	0.00	28.2	14.5	21.35	79.70	64.10	71.90	00.20	04.00	07.60
47 th	27/11/2022	0.67	27.4	12.1	19.75	77.00	64.70	70.85	00.00	03.80	04.90
48 th	04/12/2022	2.33	27.8	10.2	19.00	72.60	58.00	65.30	00.00	04.40	06.60
49 th	11/12/2022	4.33	24.9	08.8	16.85	79.70	64.00	71.85	00.00	02.60	07.50
50 th	18/12/2022	5.67	23.4	08.6	16.00	88.50	69.20	78.85	00.00	03.50	06.70
51 st	25/12/2022	6.33	21.8	07.0	14.40	95.10	75.00	85.05	00.00	01.10	09.00
52 nd	01/01/2023	8.00	18.9	06.1	12.50	95.70	77.70	86.70	00.00	00.45	08.20
1 st	08/01/2023	8.67	15.4	04.6	10.00	97.90	82.90	90.40	00.00	00.10	08.10
2 nd	15/01/2023	9.00	15.6	05.5	10.55	94.70	79.70	87.20	00.00	00.60	07.60
3 rd	22/01/2023	9.33	17.4	05.1	11.25	92.00	71.90	81.95	00.00	02.40	08.00
4 th	29/01/2023	7.67	20.6	06.6	13.60	88.10	60.00	74.05	00.20	02.40	08.30
5 th	05/02/2023	5.67	21.1	06.0	13.55	90.90	59.30	75.10	11.00	02.90	13.00
6 th	12/02/2023	2.67	25.1	09.5	17.30	83.40	51.10	67.25	00.00	04.80	10.10

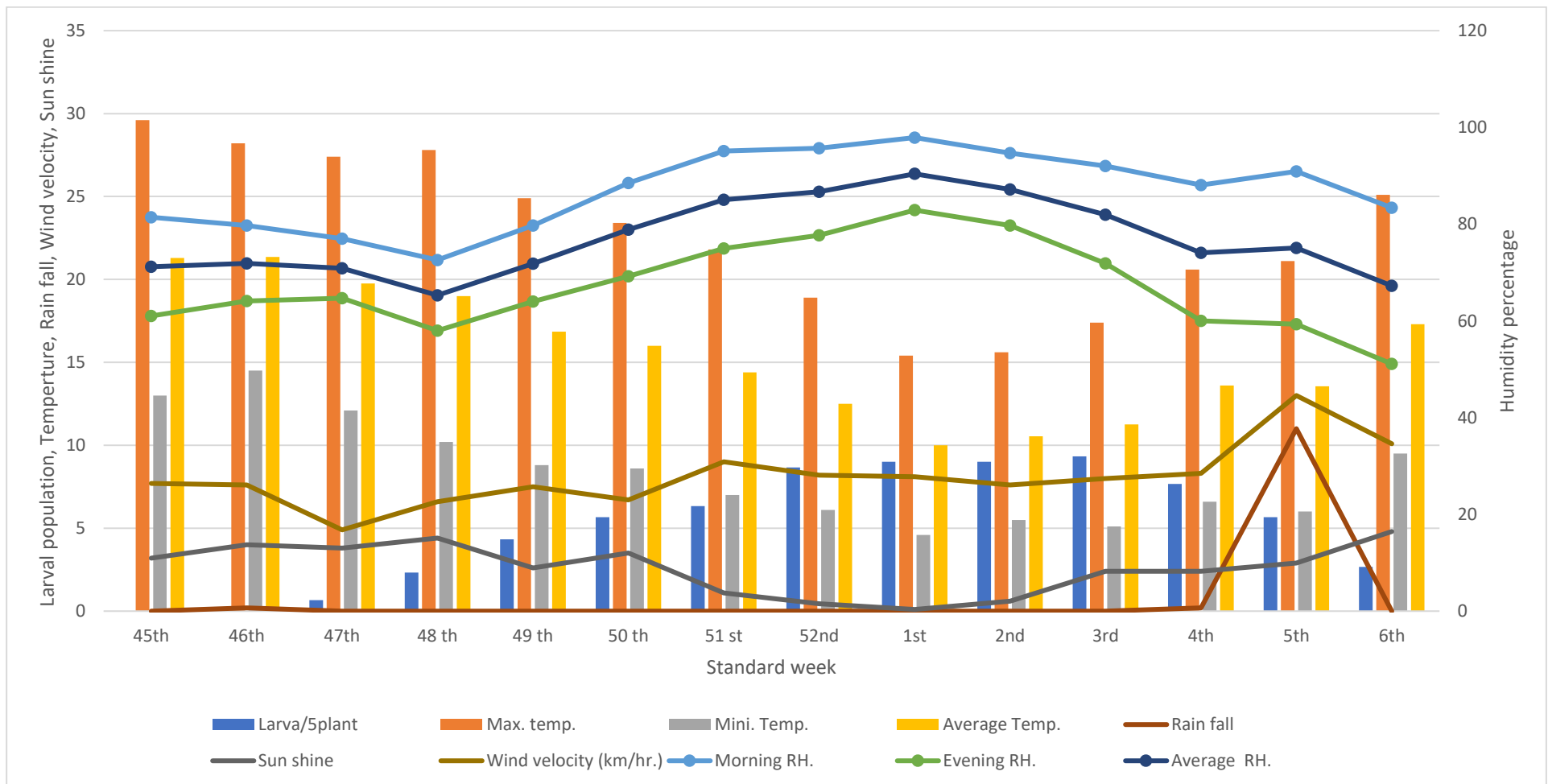


Figure- 6. Larval population of DBM, *Plutella xylostella* (Linn.) on cabbage during Rabi, 2022-23

Table no. 4.6. Pooled data Larval population of DBM, *Plutella xylostella* (Linn.) on cabbage during *Rabi*, 2021-22 to 2022-23

Standard Meteorological Week (SMW)	Average Population Larvae/ 5Plants	Meteorological parameters								
		Temperature (°C)			Relative humidity (%)			Rainfall (mm)	Sun Shine hrs./day	Wind Velocity (km/hr.)
		Max.	Min.	Average (X ₁)	Morning	Evening	Average (X ₂)			
45 th	0.00	29.17	12.93	21.05	79.13	54.50	66.82	0.00	03.20	07.70
46 th	0.34	28.61	14.18	21.39	78.07	56.91	67.49	0.10	04.00	07.60
47 th	1.50	27.76	11.55	19.65	78.79	55.78	67.28	0.00	03.80	04.90
48 th	3.17	27.28	9.96	18.62	77.09	52.15	64.62	0.00	04.40	06.60
49 th	5.00	23.99	10.22	17.10	82.00	56.07	69.03	0.45	02.60	07.50
50 th	6.50	22.90	8.98	15.94	85.97	54.32	70.14	0.00	03.50	06.70
51 st	7.17	21.27	7.09	14.18	88.77	56.72	72.74	0.00	01.10	09.00
52 nd	8.17	19.45	6.30	12.87	92.17	63.60	77.88	1.25	00.45	08.20
1 st	8.84	18.00	6.05	12.03	91.25	72.00	81.63	4.95	00.10	08.10
2 nd	9.34	16.65	5.40	11.03	93.30	80.15	86.73	33.75	00.60	07.60
3 rd	9.00	16.80	4.90	10.85	92.30	71.50	81.90	1.85	02.40	08.00
4 th	7.17	18.60	5.95	12.28	89.85	63.95	76.90	17.05	02.40	08.30
5 th	4.67	20.60	6.00	13.30	89.75	63.15	76.45	14.70	02.90	13.00
6 th	2.50	22.80	8.40	15.60	84.65	57.60	71.13	2.25	04.80	10.10

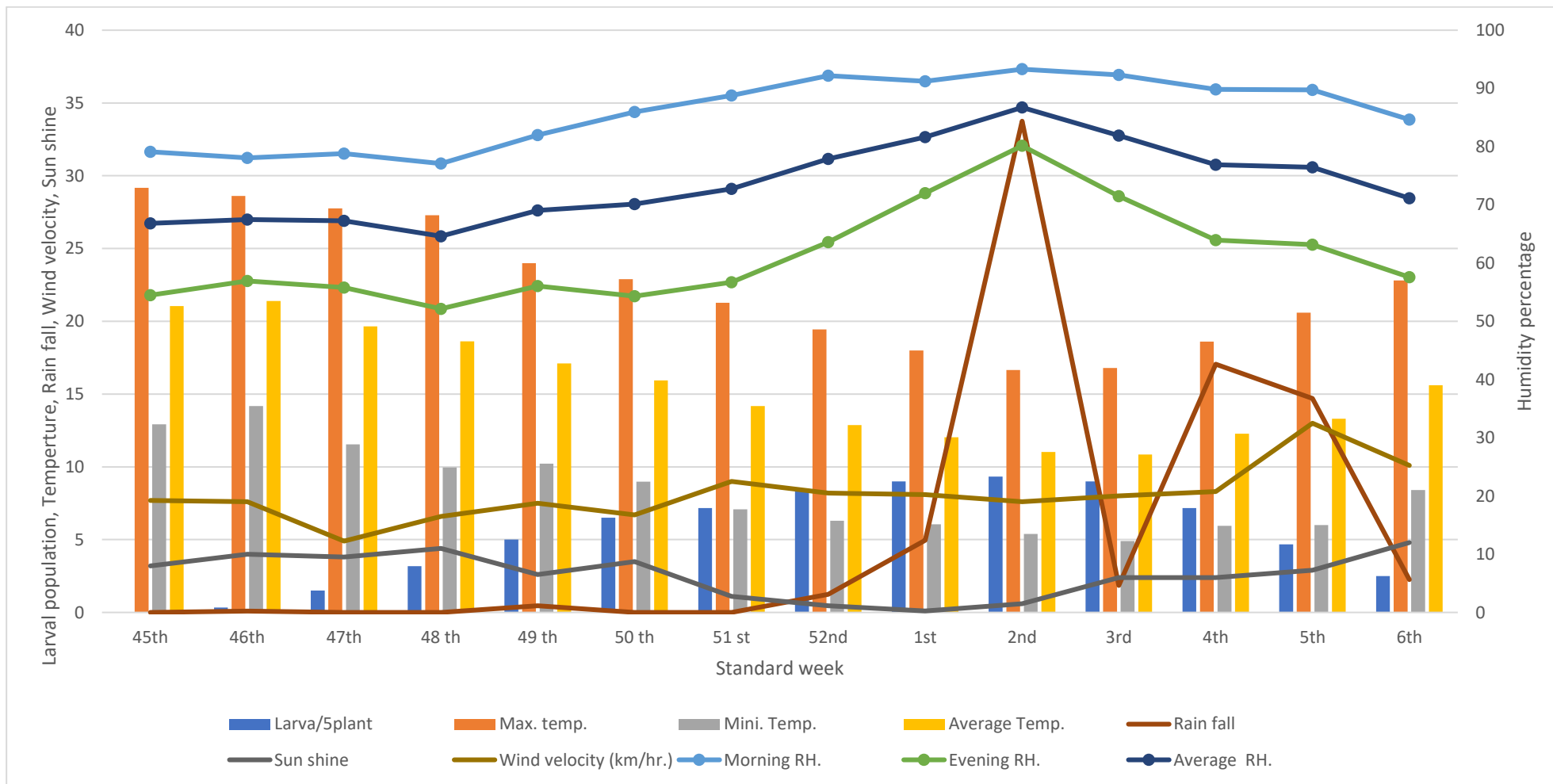


Figure- 7. Pooled Larval population of DBM *Plutella xylostella* (Linn.) on cabbage during *Rabi*, 2021-22 to 2022-23

Table no. 4.7. Efficacy of newer insecticides and bio-pesticides against *Plutella xylostella* (Linn.) in cabbage during Rabi, 2021-22.

S. No.	Treatments	Dose (g/ml per ha)	No. of Diamondback moth per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	7.00 (2.83)	3.00 (1.99)	2.33 (1.82)	2.67 (1.91)	2.00 (1.73)	1.33 (1.52)	1.67 (1.63)
T2	Emamectin Benzoate 5% SG	200 g/ha	7.33 (2.89)	3.66 (2.16)	3.00 (2.00)	3.33 (2.08)	2.67 (1.91)	2.00 (1.73)	2.33 (1.82)
T3	Diafenthiuron 50% WP	600 g/ha	7.67 (2.94)	4.00 (2.23)	3.33 (2.08)	3.67 (2.16)	3.00 (2.00)	2.67 (1.82)	3.00 (2.00)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	7.33 (2.89)	5.33 (2.51)	4.67 (2.38)	5.00 (2.44)	4.67 (2.38)	3.67 (2.16)	4.00 (2.24)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	7.67 (2.94)	5.66 (2.57)	5.00 (2.44)	5.33 (2.52)	5.00 (2.45)	4.33 (2.31)	4.67 (2.51)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	7.33 (2.89)	6.33 (2.71)	5.67 (2.58)	6.00 (2.71)	5.67 (2.58)	5.00 (2.44)	5.33 (2.51)
T7	Nimbecidine 0.03%	2500 ml/ha	8.00 (3.00)	6.66 (2.77)	6.00 (2.26)	6.67 (2.77)	6.33 (2.71)	5.67 (2.58)	6.00 (2.65)
T8	Untreated (Control)	-	7.67 (2.94)	8.00 (3.00)	8.33 (3.05)	8.67 (3.11)	9.00 (3.16)	9.33 (3.21)	9.00 (3.16)
CD at 5%			N/S	1.06	1.18	1.33	0.96	1.10	1.05
SE (m) (±)			0.30	0.35	0.39	0.43	0.31	0.36	0.34

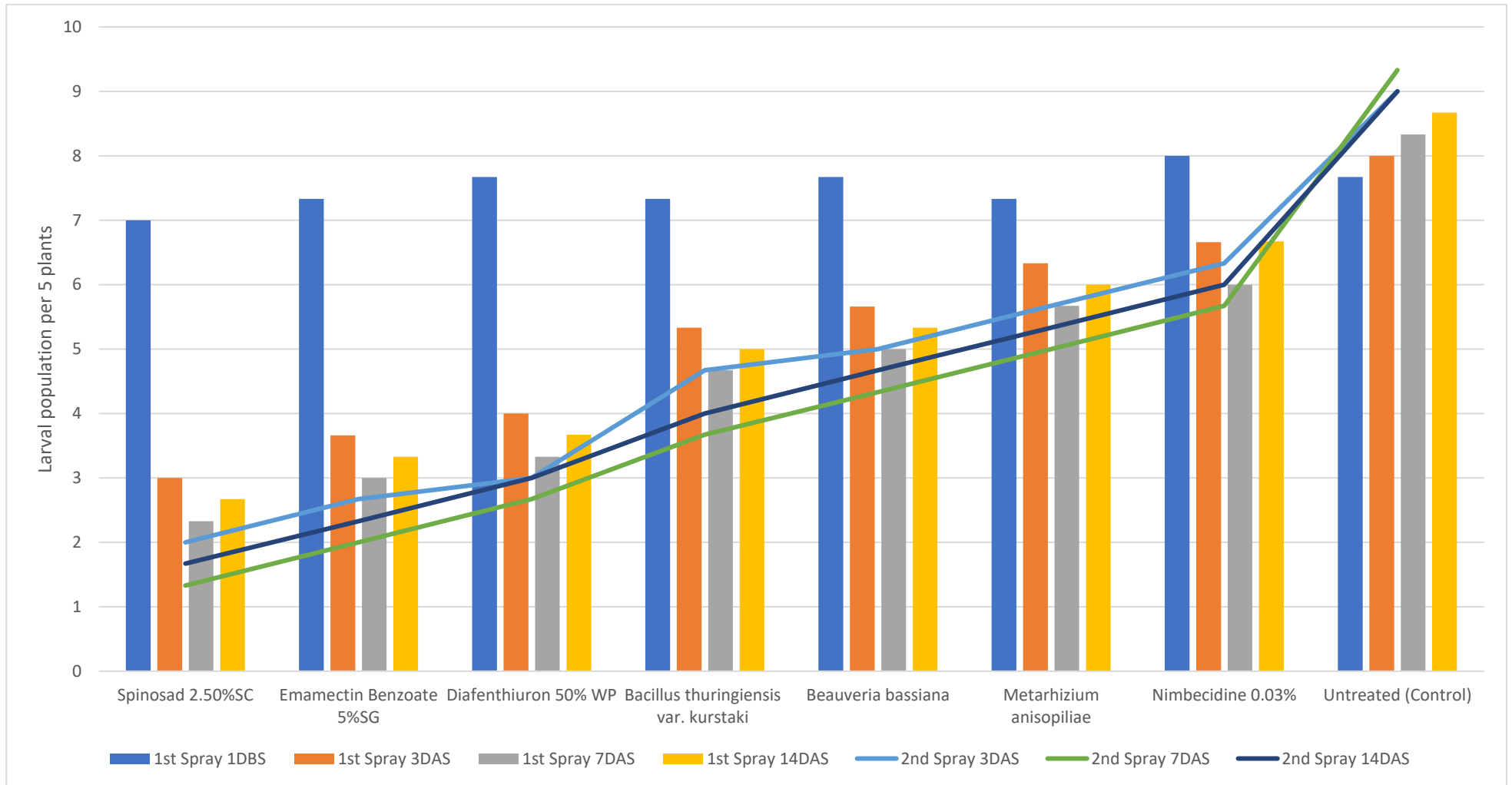


Figure- 8. Efficacy of newer insecticides and bio-pesticides against *Plutella xylostella* (Linn.) in cabbage during Rabi, 2021-22.

Table no.- 4.8. Efficacy of newer insecticides and bio-pesticides against *Plutella xylostella* (Linn.) in cabbage during Rabi, 2022-23

S. No.	Treatments	Dose (g/ml per ha)	No. of Diamondback moth per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50%SC	600 ml/ha	8.00 (3.00)	3.67 (2.16)	2.00 (1.73)	2.33 (1.82)	1.33 (1.52)	1.00 (1.41)	1.00 (1.38)
T2	Emamectin Benzoate 5%SG	200 g/ha	8.67 (3.11)	4.00 (2.23)	2.33 (1.82)	2.67 (1.91)	2.00 (1.73)	1.33 (1.52)	1.67 (1.63)
T3	Diafenthiuron 50% WP	600 g/ha	7.67 (2.94)	4.33 (2.31)	2.67 (1.91)	3.00 (2.00)	2.67 (1.91)	2.00 (1.73)	2.33 (1.82)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	8.33 (3.05)	5.67 (2.58)	4.00 (2.24)	4.33 (2.31)	3.67 (2.16)	3.00 (1.99)	3.33 (2.08)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	7.33 (2.89)	6.00 (2.64)	5.00 (2.44)	5.33 (2.52)	4.67 (2.38)	4.00 (2.24)	4.33 (2.38)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	8.33 (3.05)	6.67 (2.77)	5.33 (2.52)	5.67 (2.58)	5.00 (2.44)	4.33 (2.31)	4.67 (2.38)
T7	Nimbecidine 0.03%	2500 ml/ha	8.00 (3.00)	7.00 (2.83)	6.00 (2.64)	6.33 (2.71)	5.67 (2.58)	5.00 (2.45)	5.67 (2.58)
T8	Untreated (Control)	-	8.33 (3.05)	8.67 (3.11)	9.00 (3.16)	9.00 (3.16)	9.33 (3.21)	8.33 (3.05)	8.00 (3.00)
CD at 5%			N/S	1.07	1.15	1.15	0.81	0.92	1.10
SE (m) (±)			0.43	0.35	0.37	0.38	0.26	0.30	0.36

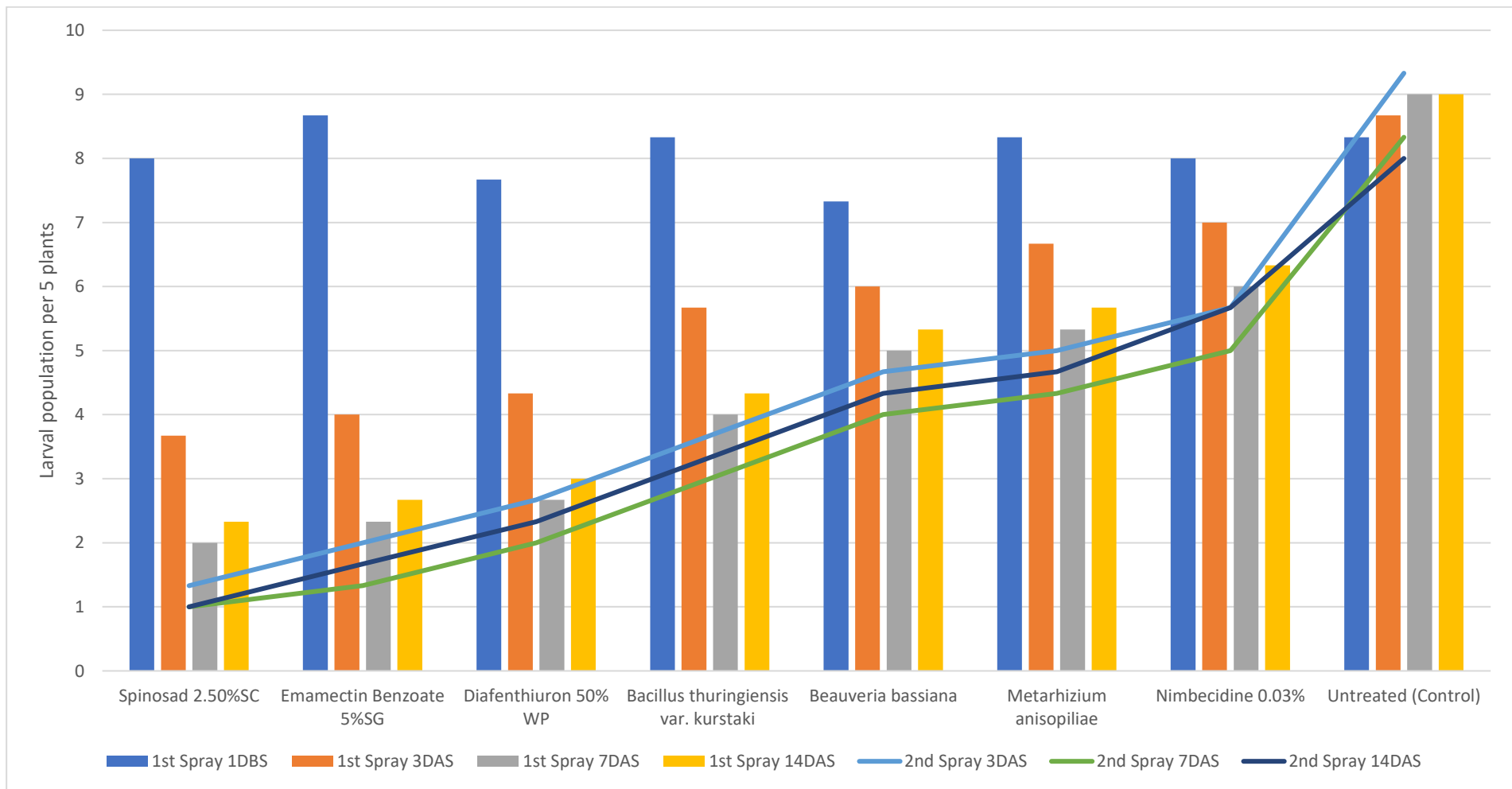


Figure- 9. Efficacy of newer insecticides and bio-pesticides against *Plutella xylostella* (Linn.) in cabbage during Rabi, 2022-23.

Table no.- 4.9. Pooled Efficacy of newer insecticides and bio-pesticides against *Plutella xylostella* (Linn.) in cabbage during Rabi, 2021-

22 and 2022-23

S. No.	Treatments	Dose (g/ml per ha)	No. of Diamondback moth per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	7.50 (2.91)	3.33 (2.07)	2.17 (1.78)	2.50 (1.87)	1.67 (1.63)	1.17 (1.47)	1.33 (1.50)
T2	Emamectin Benzoate 5% SG	200 g/ha	8.00 (3.00)	3.83 (2.19)	2.67 (1.91)	3.00 (2.00)	2.33 (1.82)	1.67 (1.63)	2.00 (1.72)
T3	Diafenthiuron 50% WP	600 g/ha	7.67 (2.94)	4.17 (2.27)	3.00 (2.00)	3.00 (1.99)	2.83 (1.96)	2.33 (1.78)	2.67 (1.91)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	7.83 (2.97)	5.50 (2.54)	4.33 (2.31)	4.67 (2.38)	4.17 (2.27)	3.33 (2.07)	3.67 (2.16)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	7.50 (2.91)	5.83 (2.61)	5.00 (2.44)	5.33 (2.52)	4.83 (2.41)	4.17 (2.27)	4.50 (2.38)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	7.83 (2.97)	6.50 (2.74)	5.50 (2.55)	5.83 (2.61)	5.33 (2.51)	4.67 (2.38)	5.00 (2.44)
T7	Nimbecidine 0.03%	2500 ml/ha	8.00 (3.00)	6.83 (2.80)	6.00 (2.64)	6.50 (2.74)	6.00 (2.64)	5.33 (2.51)	5.83 (2.61)
T8	Untreated (Control)	-	8.00 (3.00)	8.33 (3.05)	8.67 (3.11)	8.83 (3.13)	9.17 (3.19)	8.83 (3.13)	8.50 (3.08)
CD at 5%			N/S	1.24	1.17	1.24	1.03	1.01	1.07
SE (m) (±)			0.37	0.41	0.38	0.40	0.34	0.33	0.35

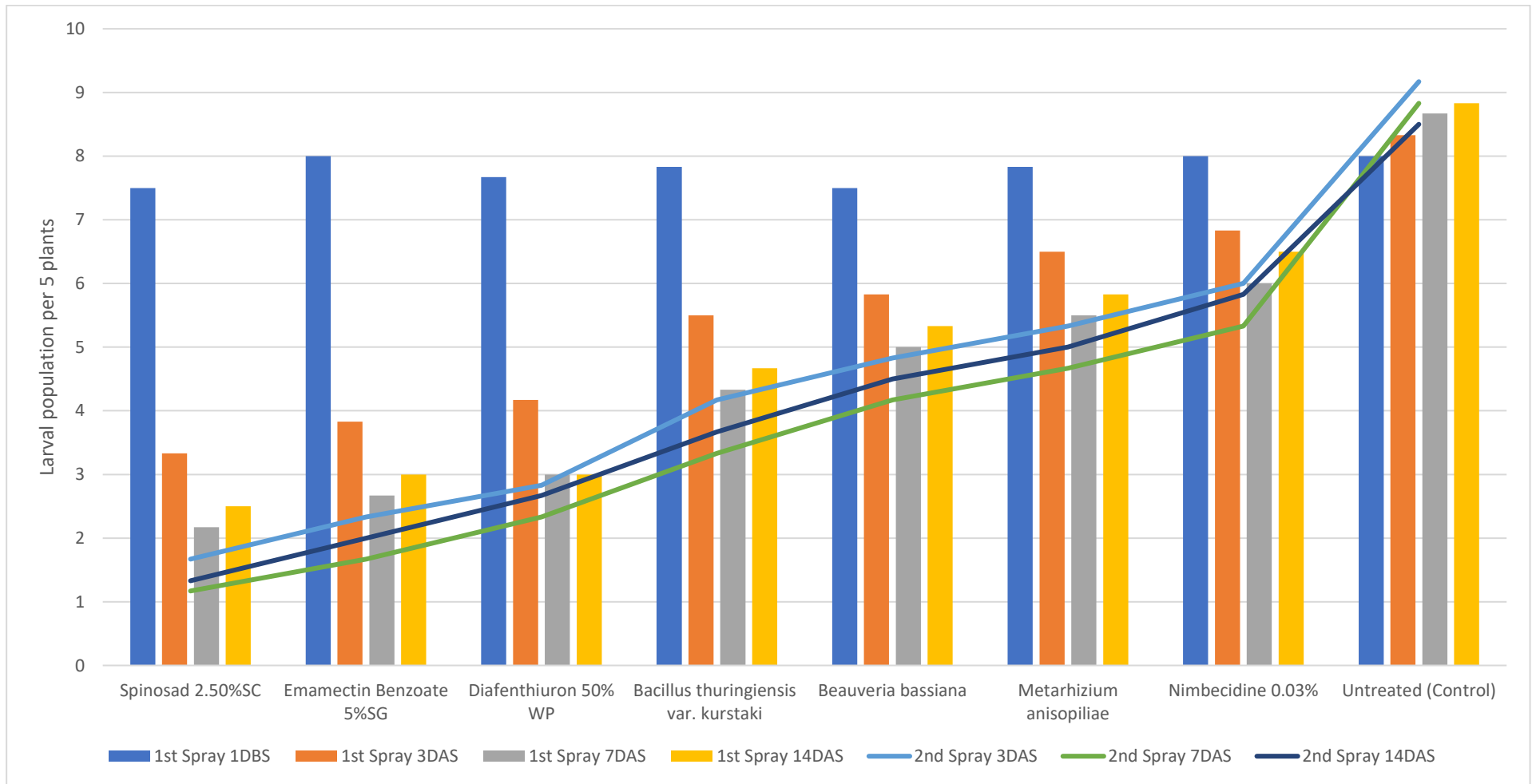


Figure- 10. Pooled Efficacy of newer insecticides and bio-pesticides against *Plutella xylostella* (Linn.) in cabbage during Rabi, 2021-22 and 2022-23.

Table no.- 4.10. Efficacy of newer insecticides and bio-pesticides against *Coccinella septumpunctata* in cabbage during Rabi, 2021-22

S. No.	Treatments	Dose (g/ml per ha)	No. of <i>Coccinella septumpunctata</i> per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	4.33 (2.31)	2.33 (1.82)	1.67 (1.63)	2.00 (1.72)	1.00 (1.41)	0.33 (1.14)	0.67 (1.28)
T2	Emamectin Benzoate 5% SG	200 g/ha	4.67 (2.38)	2.67 (1.91)	2.33 (1.82)	2.67 (1.91)	1.67 (1.63)	1.00 (1.41)	1.33 (1.52)
T3	Diafenthiuron 50% WP	600 g/ha	5.00 (2.45)	3.00 (2.00)	2.67 (1.91)	3.00 (2.00)	2.00 (2.73)	1.33 (1.52)	1.67 (1.63)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	5.33 (2.52)	3.33 (2.08)	3.00 (2.00)	3.33 (2.08)	2.67 (1.91)	2.00 (1.73)	2.33 (1.82)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	5.67 (2.58)	3.67 (2.16)	3.33 (2.08)	3.67 (2.16)	3.00 (2.00)	2.33 (1.82)	2.67 (1.91)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	5.33 (2.52)	4.00 (2.23)	3.67 (2.16)	4.00 (2.23)	3.33 (2.08)	3.00 (2.00)	3.33 (2.08)
T7	Nimbecidine 0.03%	2500 ml/ha	5.67 (2.58)	4.67 (2.37)	4.00 (2.24)	4.33 (2.31)	4.00 (2.23)	3.67 (2.16)	4.00 (2.24)
T8	Untreated (Control)	-	5.00 (2.45)	5.33 (2.52)	5.67 (2.58)	5.67 (2.58)	5.33 (2.52)	5.00 (2.45)	4.67 (2.38)
SE (m) (±)			N/S	1.27	0.94	1.23	0.74	0.60	0.68
CD at 5%			0.31	0.42	0.31	0.40	0.24	0.19	0.22

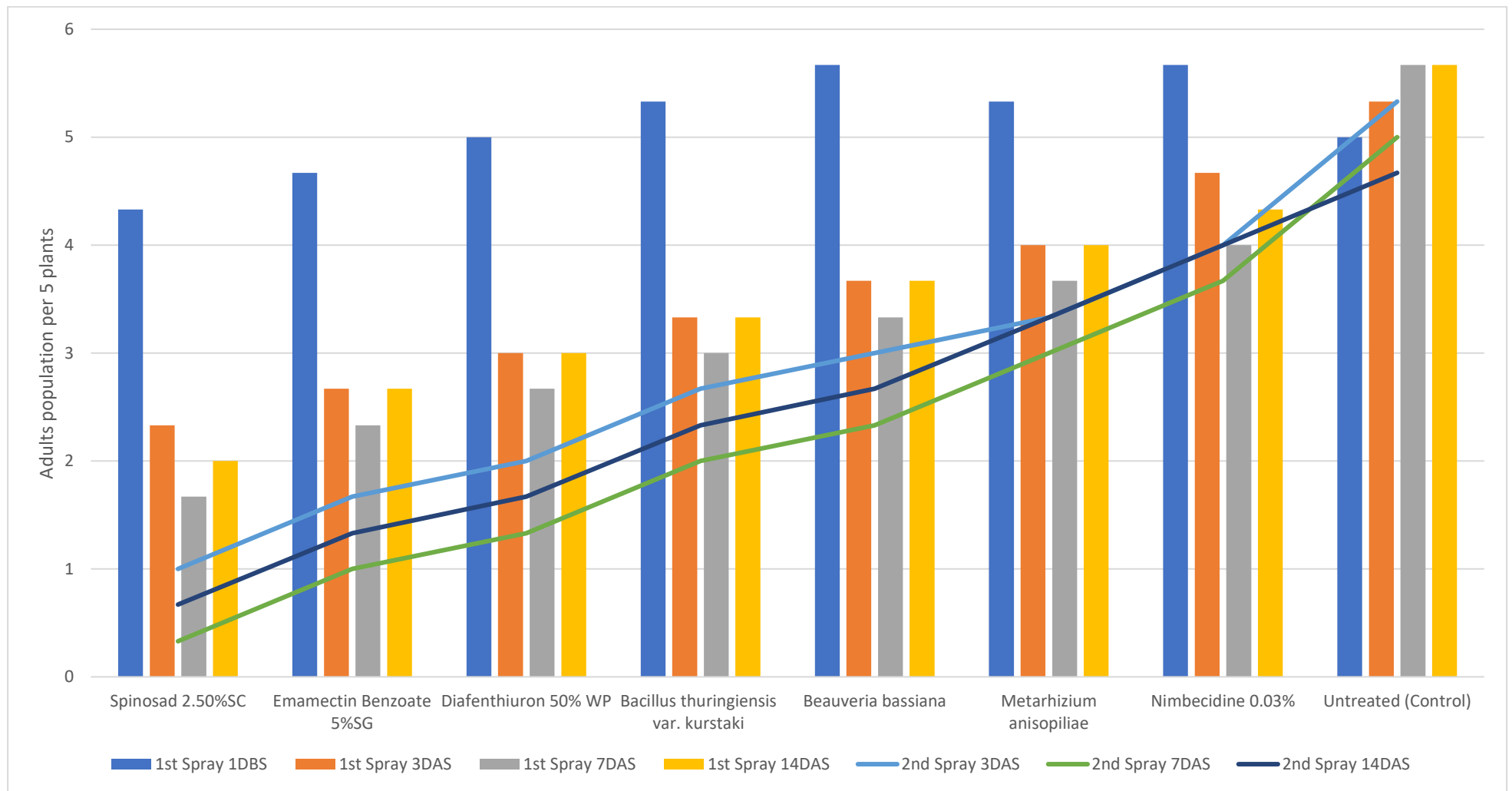


Figure- 11. Efficacy of newer insecticides and bio-pesticides against *Coccinella septumpunctata* in cabbage during Rabi, 2021-22

Table no.- 4.11. Efficacy of newer insecticides and bio-pesticides against *Coccinella septumpunctata* in cabbage during Rabi, 2022-23

S.No.	Treatments	Dose (g/ml per ha)	No. of <i>Coccinella septumpunctata</i> per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	4.67 (2.38)	2.00 (1.72)	1.00 (1.41)	1.33 (1.52)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T2	Emamectin Benzoate 5% SG	200 g/ha	3.67 (2.16)	2.33 (1.82)	1.33 (1.52)	1.67 (1.63)	0.67 (1.28)	0.00 (1.00)	0.33 (1.14)
T3	Diafenthiuron 50% WP	600 g/ha	4.00 2.24	2.67 (1.91)	1.67 (1.63)	2.00 (1.73)	1.00 (1.41)	0.33 (1.14)	0.33 (1.28)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	4.33 (2.31)	3.00 2.00	2.33 (1.82)	2.67 (1.91)	1.67 (1.63)	1.33 (1.52)	1.67 (1.63)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	3.67 (2.16)	3.33 (2.08)	2.67 (1.91)	3.00 (2.00)	2.00 (1.73)	1.67 (1.63)	2.00 (1.73)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	3.33 (2.08)	3.67 (2.16)	3.00 (2.00)	3.33 (2.08)	2.67 (1.91)	2.00 (1.73)	2.33 (1.82)
T7	Nimbecidine 0.03%	2500 ml/ha	4.67 (2.38)	4.00 (2.24)	3.33 (2.08)	3.67 (2.16)	3.00 (2.00)	2.33 (1.82)	2.67 (1.91)
T8	Untreated (Control)	-	4.00 (2.23)	4.33 (2.31)	4.67 (2.38)	5.00 (2.45)	5.00 (2.45)	4.67 (2.38)	3.33 (2.08)
CD at 5%			N/S	1.08	0.92	0.85	0.53	0.85	0.92
SE (m) (±)			0.36	0.35	0.30	0.28	0.17	0.28	0.30

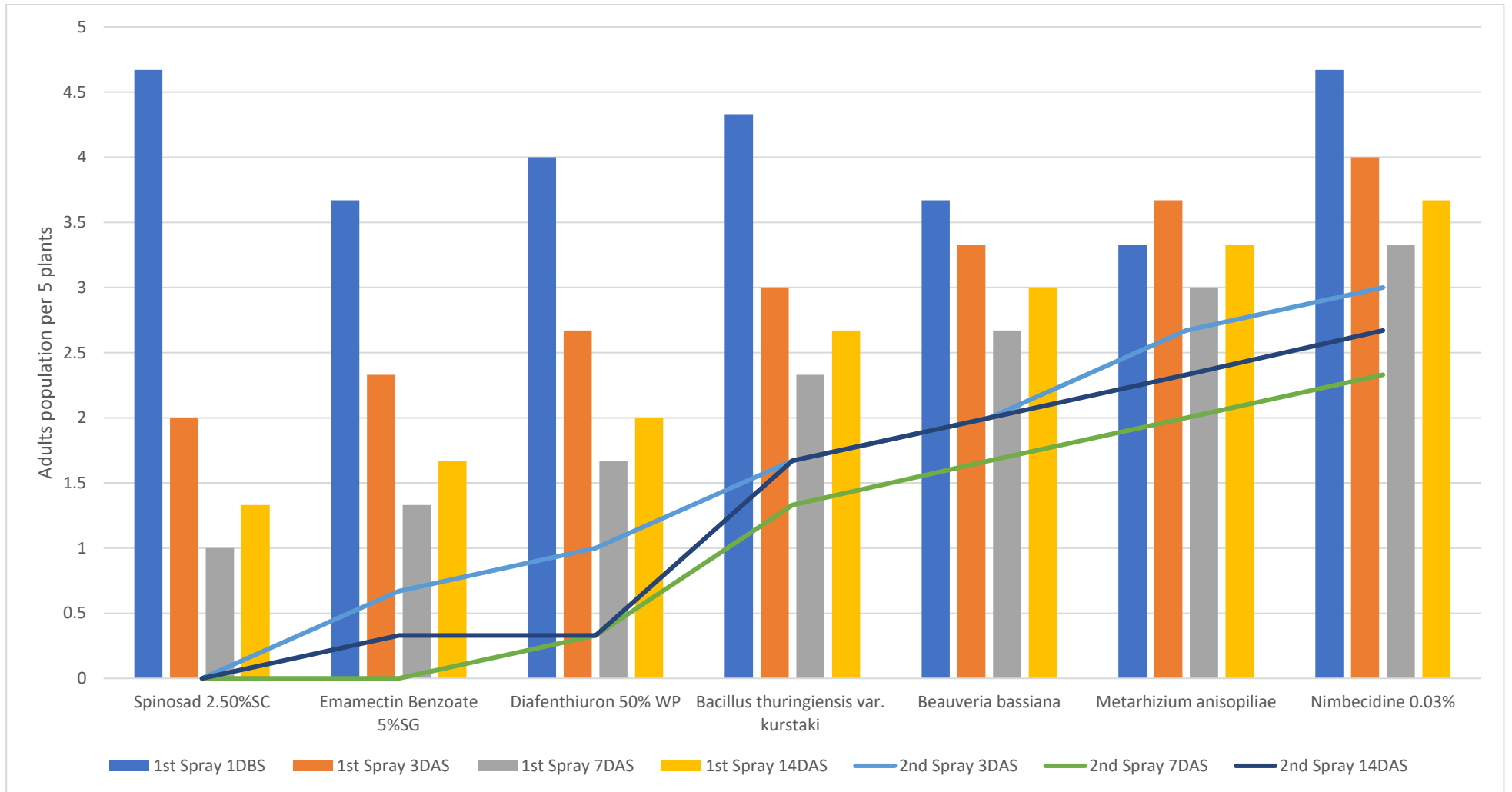


Figure- 12. Efficacy of newer insecticides and bio-pesticides against *Coccinella septempunctata* in cabbage during Rabi, 2022-23

Table no.- 4.12. Pooled Efficacy of newer insecticides and bio-pesticides against *Coccinella septempunctata* in cabbage during Rabi,

2021-22 and 2022-23

S. No.	Treatments	Dose (g/ml per ha)	No. of <i>Coccinella septumpunctata</i> per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	4.50 (2.38)	2.17 (1.77)	1.33 (1.52)	1.67 (1.62)	0.50 (1.21)	0.17 (1.07)	0.33 (1.14)
T2	Emamectin Benzoate 5% SG	200 g/ha	4.17 (2.16)	2.50 (1.87)	1.83 (1.67)	2.17 (1.77)	1.17 (1.45)	0.50 (1.21)	0.83 (1.33)
T3	Diafenthiuron 50% WP	600 g/ha	4.50 (2.24)	2.83 (1.96)	2.17 (1.77)	2.50 (1.87)	1.50 (1.57)	0.83 (1.33)	1.17 (1.45)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	4.83 (2.31)	3.17 (2.04)	2.67 (1.91)	3.00 (2.00)	2.17 (1.77)	1.67 (1.63)	2.00 (1.72)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	4.67 (2.16)	3.50 (2.12)	3.00 (2.00)	3.33 (2.08)	2.50 (1.87)	2.00 (1.72)	2.33 (1.82)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	4.33 (2.08)	3.83 (2.19)	3.33 (2.08)	3.67 (2.15)	3.00 (2.00)	2.50 (1.87)	2.83 (1.95)
T7	Nimbecidine 0.03%	2500 ml/ha	5.17 (2.38)	4.33 (2.30)	3.67 (2.16)	4.00 (2.23)	3.50 (2.11)	3.00 (1.99)	3.33 (2.07)
T8	Untreated (Control)	-	4.50 (2.23)	4.83 (2.41)	5.17 (2.48)	5.33 (2.51)	5.17 (2.48)	4.83 (2.41)	4.00 (2.23)
CD at 5%			N/S	1.18	0.93	1.04	0.63	0.72	0.80
SE (m) (±)			0.33	0.38	0.30	0.34	0.21	0.24	0.26

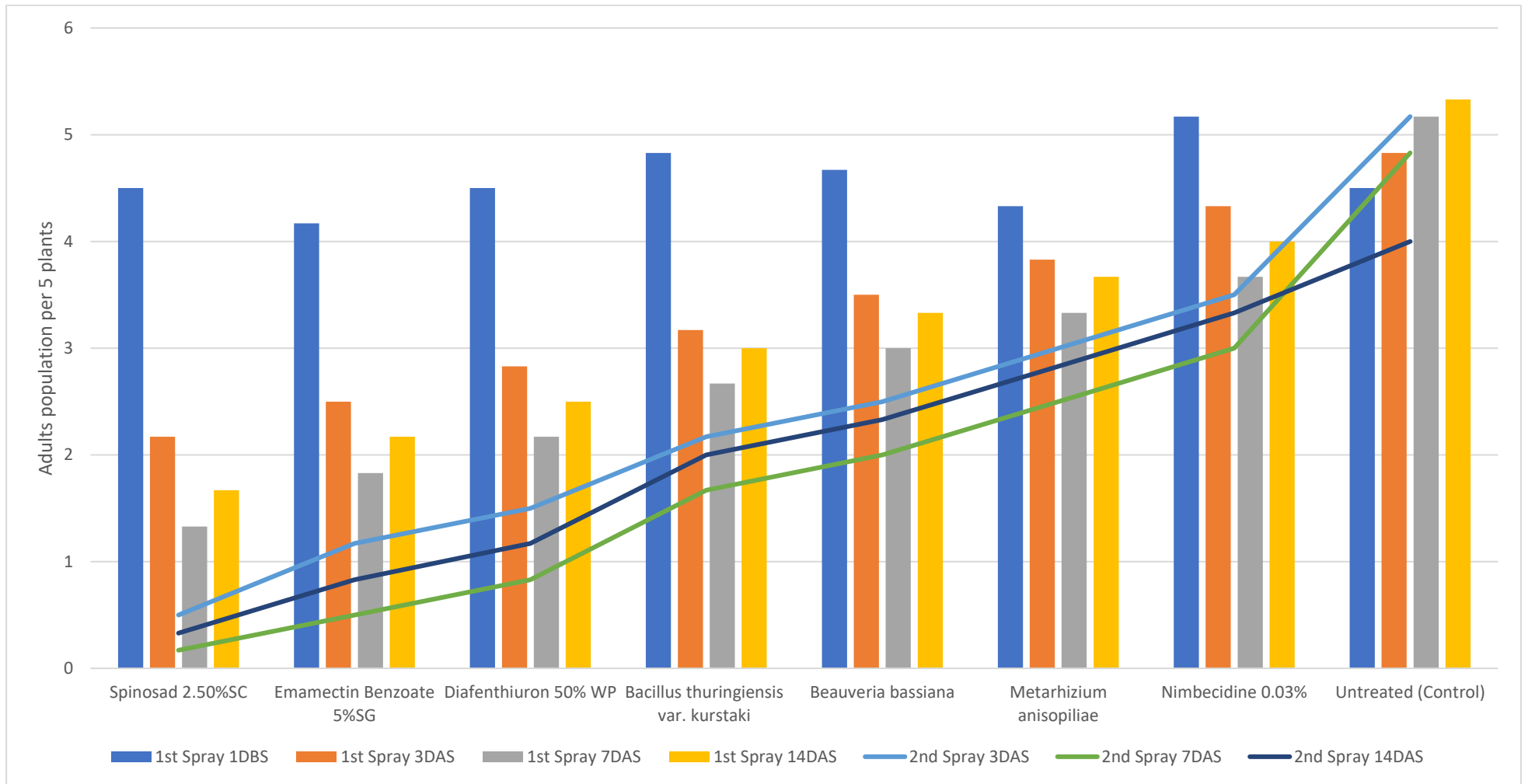


Figure- 13. Pooled Efficacy of newer insecticides and bio-pesticides against *Coccinella septumpunctata* in cabbage during *Rabi*, 2021-22 and 2022-23.

Table no. 4.13. Efficacy of newer insecticides and bio-pesticides against Spider in cabbage during *Rabi*, 2021-22.

S. No.	Treatments	Dose (g/ml per ha)	No. of Spider per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	2.67 (1.91)	1.00 (1.41)	0.67 (1.28)	1.33 (1.52)	1.00 (1.41)	0.67 (1.28)	0.33 (1.14)
T2	Emamectin Benzoate 5% SG	200 g/ha	2.33 (1.82)	1.33 1.52	1.00 (1.41)	1.67 (1.63)	1.33 (1.52)	1.00 (1.41)	0.67 (1.28)
T3	Diafenthiuron 50% WP	600 g/ha	3.00 (1.99)	1.67 (1.63)	1.33 (1.52)	2.00 (1.73)	1.67 (1.63)	1.33 (1.52)	1.00 (1.41)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	2.33 (1.82)	2.00 (1.73)	1.67 (1.63)	2.33 (1.82)	2.00 (1.73)	1.67 (1.63)	2.00 (1.73)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	2.67 (1.91)	2.33 1.82	2.00 (1.73)	2.67 (1.91)	2.33 (1.82)	2.00 (1.73)	2.33 (1.82)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	3.33 2.08	2.67 (1.91)	2.33 (1.82)	3.00 (2.00)	2.67 (1.91)	2.33 (1.82)	2.67 (1.91)
T7	Nimbecidine 0.03%	2500 ml/ha	3.67 (2.16)	3.00 (2.00)	2.67 (1.91)	3.33 (2.08)	3.00 (2.00)	2.67 (1.91)	3.00 (2.00)
T8	Untreated (Control)	-	3.67 (2.16)	4.00 (2.24)	4.00 (2.24)	4.67 (2.38)	4.67 (2.38)	4.33 (2.31)	4.67 (2.38)
CD at 5%			N/S	0.772	0.82	0.85	0.85	0.92	0.85
SE(m) (±)			0.396	0.252	0.27	0.28	0.28	0.30	0.28

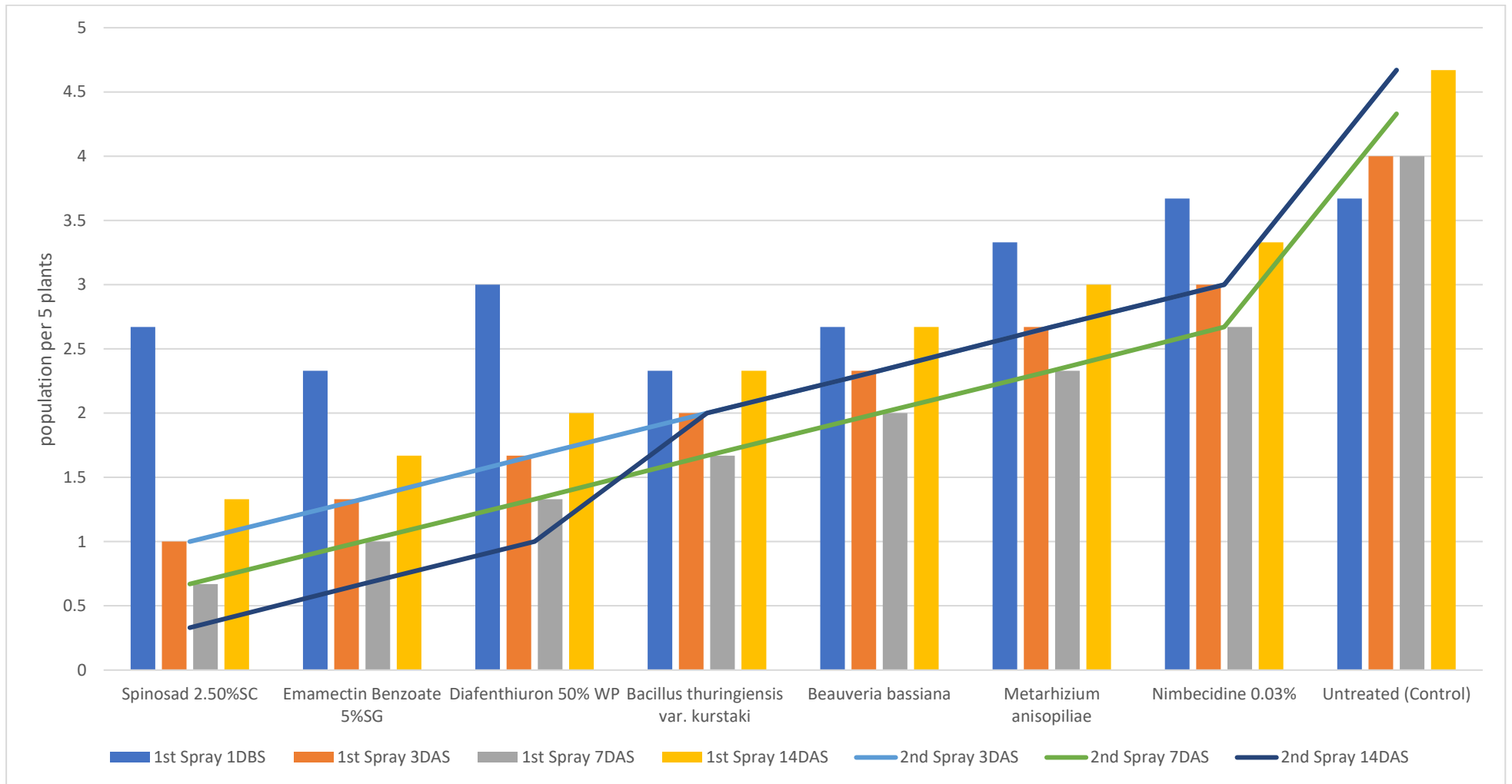


Figure- 14. Efficacy of newer insecticides and bio-pesticides against Spider in cabbage during Rabi, 2021-22.

Table no.- 4. 14. Efficacy of newer insecticides and bio-pesticides against Spider in cabbage during Rabi, 2022-23.

S. No.	Treatments	Dose (g/ml per ha)	No. of Spider per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	2.33 (1.82)	0.67 (1.28)	0.33 (1.14)	0.67 (1.28)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T2	Emamectin Benzoate 5% SG	200 g/ha	2.67 (1.91)	1.00 (1.41)	0.67 (1.28)	1.00 (1.41)	0.33 (1.14)	0.00 (1.00)	0.00 (1.00)
T3	Diafenthiuron 50% WP	600 g/ha	2.67 (1.91)	1.33 (1.52)	1.00 (1.41)	1.33 (1.52)	0.67 (1.28)	0.33 (1.14)	0.67 (1.28)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	3.33 (2.08)	1.67 (1.63)	1.33 (1.52)	1.67 (1.63)	1.00 (1.41)	0.67 (1.28)	1.00 (1.41)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	2.33 (1.82)	2.00 (1.73)	1.67 (1.63)	2.00 (1.73)	1.67 (1.63)	1.33 (1.52)	1.67 (1.63)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	3.00 (2.00)	2.33 (1.82)	2.00 (1.73)	2.33 (1.82)	2.00 (1.73)	1.67 (1.63)	2.00 (1.73)
T7	Nimbecidine 0.03%	2500 ml/ha	3.00 (2.00)	2.67 (1.91)	2.33 (1.82)	2.67 (1.91)	2.33 (1.82)	2.00 (1.73)	2.33 (1.82)
T8	Untreated (Control)	-	2.67 (1.91)	3.00 (2.00)	3.00 (2.00)	3.33 (2.08)	3.67 (2.16)	3.33 (2.08)	3.00 (2.00)
CD at 5%			N/S	0.85	0.78	0.95	0.82	0.85	0.56
SE (m) (±)			0.23	0.28	0.26	0.31	0.27	0.28	0.18

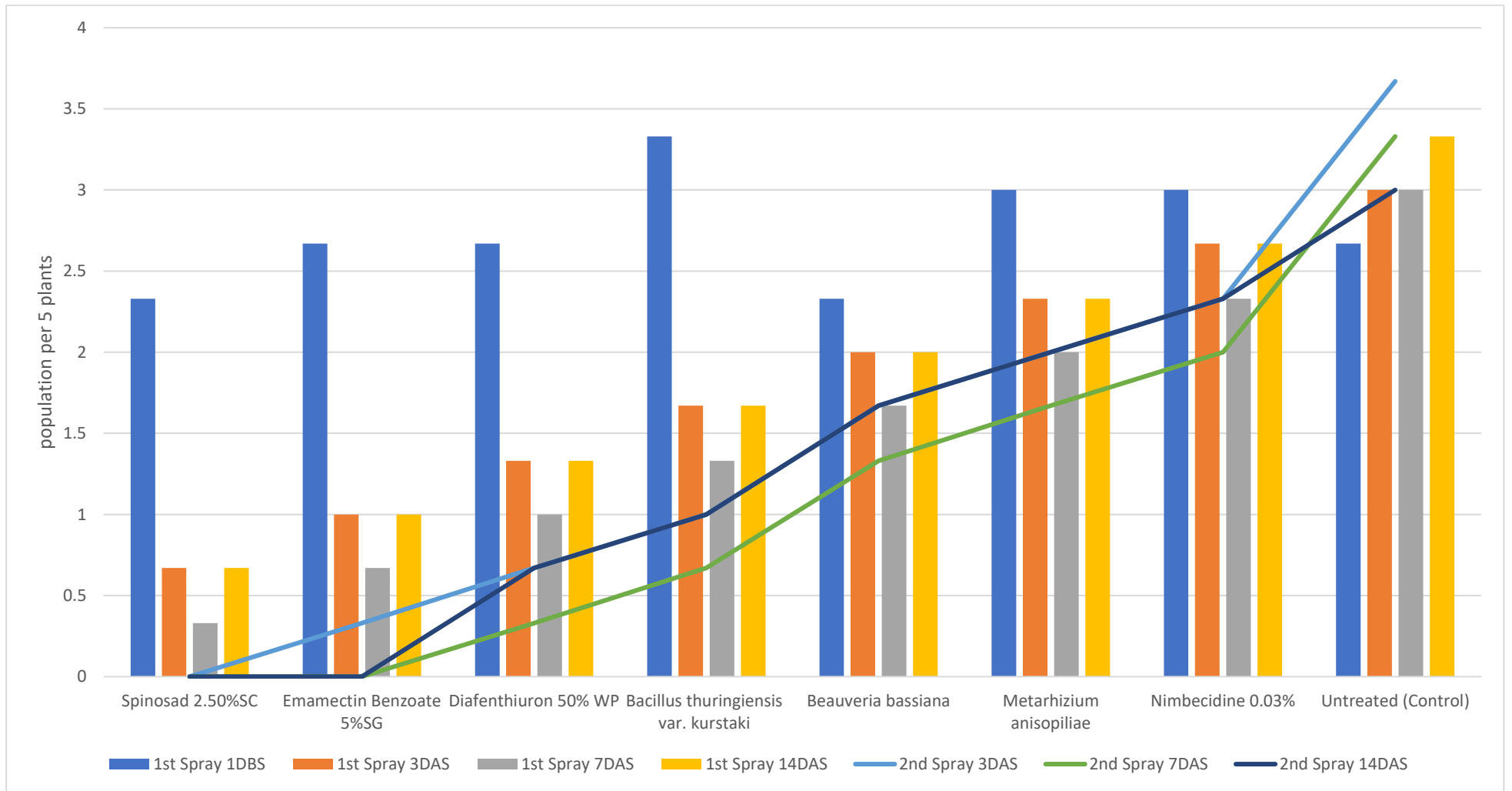


Figure- 15. Efficacy of newer insecticides and bio-pesticides against Spider in cabbage during *Rabi*, 2022-23.

Table no.- 4.15. Pooled Efficacy of newer insecticides and bio-pesticides against Spider in cabbage during Rabi, 2021-22 and 2022-23

S. No.	Treatments	Dose (g/ml per ha)	No. of Spider per five plants						
			1 st Spray				2 nd Spray		
			1DBS	3DAS	7DAS	14DAS	3DAS	7DAS	14DAS
T1	Spinosad 2.50% SC	600 ml/ha	2.50 (1.87)	0.83 (1.35)	0.50 (1.21)	1.00 (0.69)	0.50 (1.21)	0.33 (1.14)	0.17 (1.07)
T2	Emamectin Benzoate 5% SG	200 g/ha	2.50 (1.87)	1.17 (1.47)	0.83 (1.35)	1.33 (0.76)	0.83 (1.33)	0.50 (1.21)	0.33 (1.14)
T3	Diafenthiuron 50% WP	600 g/ha	2.83 (1.95)	1.50 (1.57)	1.17 (1.47)	1.67 (0.76)	1.17 (1.45)	0.83 (1.33)	0.83 (1.35)
T4	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1000 g/ha	2.83 (1.95)	1.83 (1.68)	1.50 (1.57)	2.00 (0.86)	1.50 (1.57)	1.17 (1.45)	1.50 (1.57)
T5	<i>Beauveria bassiana</i>	1500 ml/ha	2.50 (1.87)	2.17 (1.78)	1.83 (1.68)	2.33 (0.91)	2.00 (1.72)	1.67 (1.63)	2.00 (1.72)
T6	<i>Metarhizium anisopliae</i>	2000 g/ha	3.17 (2.04)	2.50 (1.87)	2.17 (1.78)	2.67 (0.91)	2.33 (1.82)	2.00 (1.72)	2.33 (1.82)
T7	Nimbecidine 0.03%	2500 ml/ha	3.33 (2.08)	2.83 (1.96)	2.50 (1.87)	3.00 (1.00)	2.67 (1.91)	2.33 (1.82)	2.67 (1.91)
T8	Untreated (Control)	-	3.17 (2.03)	3.50 (2.12)	3.50 (2.12)	4.00 (1.08)	4.17 (2.27)	3.83 (2.19)	3.83 (2.19)
CD at 5%			N/S	0.81	0.80	0.90	0.84	0.88	0.71
SE (m) (±)			0.31	0.27	0.26	0.29	0.27	0.29	0.23

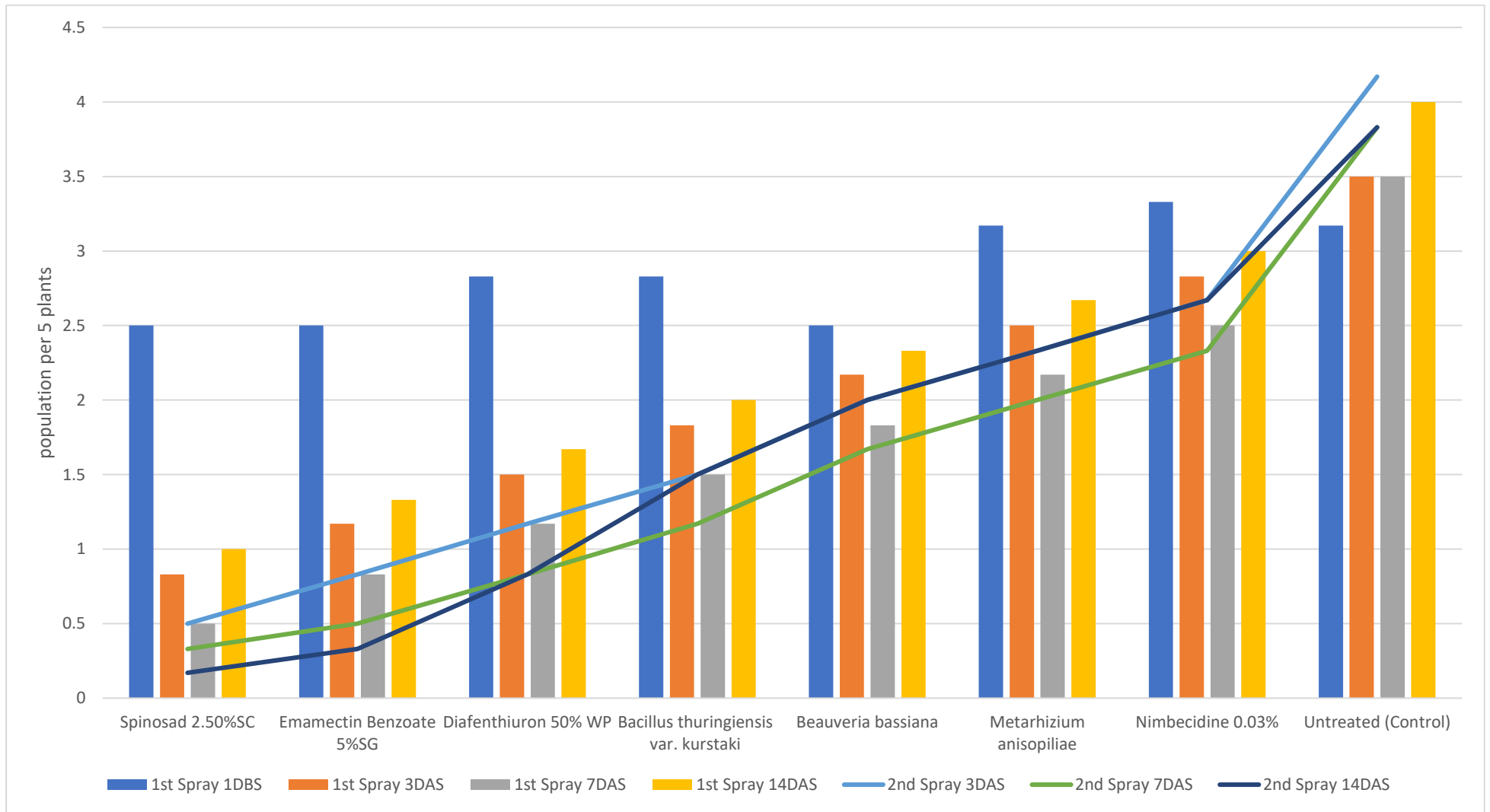


Figure- 16. Pooled Efficacy of newer insecticides and bio-pesticides against Spider in cabbage during *Rabi*, 2021-22 and 2022-23

Table no.- 4.16. Incremental Cost-Benefit Ratio analysis on cabbage during year 2021-22

Treatments	Yield of treatment (q/ha)	Increase yield over control (q/ha)	Cost of incremental yield (Rs./ha)	Cost of treatment (Rs./ha)	Net profit (Rs./ha)	Incremental cost benefit ratio
Spinosad 2.50% SC	181.67	37.67	33900	3800	30100	1: 7.92
Emamectin Benzoate 5% SG	170.00	26.33	23400	1818	21582	1: 11.87
Diafenthiuron 50% WP	169.00	25.00	22500	2834	19666	1: 6.94
<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	167.00	23.00	20700	4800	15900	1: 3.31
<i>Beauveria bassiana</i>	157.00	13.00	11700	1400	10300	1: 7.36
<i>Metarhizium anisopliae</i>	155.00	11.00	9900	1600	8300	1: 5.19
Nimbecidine 0.03%	154.00	10.00	9000	2915	6085	1: 2.09
Untreated (Control)	144.00	-	-	-	-	-

Table no.-4.17. Incremental Cost-Benefit Ratio analysis on cabbage during year 2022-23

Treatments	Yield of treatment (q/ha)	Increase yield over control (q/ha)	Cost of incremental yield (Rs./ha)	Cost of treatment (Rs./ha)	Net profit (Rs./ha)	Incremental cost benefit ratio
Spinosad 2.50% SC	191.00	45.00	22500.00	3800	18700.00	1: 4.92
Emamectin Benzoate 5% SG	183.33	37.33	18666.67	1818	16848.67	1: 9.27
Diafenthiuron 50% WP	178.00	32.00	16000.00	2834	13166.00	1: 4.65
<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	173.00	27.00	13500.00	4800	8700.00	1: 1.81
<i>Beauveria bassiana</i>	163.00	17.00	8500.00	1400	7100.00	1: 5.07
<i>Metarhizium anisopliae</i>	162.00	16.00	8000.00	1600	6400.00	1: 4.00
Nimbecidine 0.03%	160.33	14.33	7166.67	2915	4251.67	1: 1.46
Untreated (Control)	146.00	-	-	-	-	-

Table no.- 4.18. Pooled Incremental Cost-Benefit Ratio analysis on cabbage during year 2021-22 and 2022-23

Treatments	Yield of treatment (q/ha)	Increase yield yield over control (q/ha)	Cost of incremental yield (Rs./ha)	Cost of treatment (Rs./ha)	Net profit (Rs./ha)	Incremental cost benefit ratio
Spinosad 2.50% SC	186.33	41.33	28700.00	3800	24400.00	1: 6.42
Emamectin Benzoate 5% SG	176.67	31.67	21033.33	1818	19215.33	1: 10.57
Diafenthiuron 50% WP	173.50	28.50	19250.00	2834	16416.00	1: 5.79
<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	170.00	25.00	17100.00	4800	12300.00	1: 2.56
<i>Beauveria bassiana</i>	160.00	15.00	10100.00	1400	8700.00	1: 6.21
<i>Metarhizium anisopliae</i>	158.50	13.50	8950.00	1600	7350.00	1: 4.59
Nimbecidine 0.03%	156.17	12.17	8083.33	2915	5168.33	1: 1.77
Untreated (Control)	145.00	-	-	-	-	-

Table-I. Correlation of DBM per five plants with weather parameter during *Rabi*, 2021-22.

Weather parameter	Max. Tem.	Min. Tem.	Ave. Tem.	Mor. RH.	Eve. RH.	Ave. RH.	Rainfall	Sunshine	Wind Velocity
DBM/5plant	-0.778**	-0.720**	-0.767**	0.703**	0.294 ^{NS}	0.435 ^{NS}	0.412 ^{NS}	-0.586*	-0.076 ^{NS}

Table-II. Correlation of DBM per five plants with weather parameters during *Rabi*, 2022-23.

Weather parameter	Max. Tem.	Min. Tem.	Ave. Tem.	Mrn. RH.	Eve. RH.	Ave. RH.	Rainfall	Sunshine	Wind Velocity
DBM/5plants	-0.961**	-0.962**	-0.977**	0.845**	0.657*	0.798**	0.051 ^{NS}	-0.769**	0.247 ^{NS}

Table-III. Pooled correlation of DBM per five plants with weather parameters during *Rabi*, 2021-22 and 2022-23.

Weather parameter	Max. Tem.	Min. Tem.	Ave. Tem.	Mrn. RH.	Eve. RH.	Ave. RH.	Rainfall	Sunshine	Wind Velocity
DBM/5plants	-0.933**	-0.893**	-0.926**	0.899**	0.730**	0.843**	0.440 ^{NS}	-0.787**	0.124 ^{NS}



A



B



C



D

Plate 1. A. Transplanting of nursery. **B.** Showing the research field. **C.** Plant infected with Tobacco caterpillar. **D.** Field inspection



A



B



C



D

Plate- 2. A. Egg B. Larvae C. Pupae D. Adult stage of DBM, *Plutella xylostella* (Linn.)



A



B



C



D

Plate- 3. A. Incidence of Aphid B. Infestation of head borer C & D Damage symptom of diamondback moth.



A



B



C



D

Plate- 4. Natural enemies A & B Unidentified spiders C. *Coccinella septempunctata*. D. Taking observations from the field.



A



B



C

Plate- 5. A. Damage symptoms of Diamondback moth **B.** Spraying of different treatments of insecticide and bio-pesticides **C.** Field inspection

The results of the present investigation entitled “Studies on insect-pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)” described in the preceding chapters have been discussed in the following lines.

5.1. To study the Insect pest complex of cabbage

The results of the present investigation are similar to the results of **Yadav et al. (2015)** reported the seven order and 23 insect pest including natural enemies. These findings corroborate the results of **Rao and Lal (2004)** who documented 19 insect pests and 4 natural enemies during the *Rabi* season. Among these the two primary pests were identified that is mustard aphid, *Lipaphis erysimi* (Kalt) and the diamondback moth (DBM), *Plutella xylostella* (Linn.). **Thakur et al. (2008)** reported the Similar patterns in various crops at different locations of the India. **Bhat, D. M. (2020)** who presented a comprehensive overview of lepidopteron pests and their natural bio-control agents affecting vegetable crops in the Jammu and Kashmir (J&K) region. They found that a total of 28 lepidopteron pest species are responsible for causing damage to vegetable crops in Jammu and Kashmir. Moreover, the research establishes the presence of 40 natural bio-control agents, including parasitoids, predators and pathogens, which effectively regulate the population of major lepidopteron pests in vegetable fields.

5.2. To study the seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) on cabbage.

The results of the present investigation are similar to the results of **Shyam et al. (2020)** reported the correlation studies revealed that maximum ($r = -0.496$), minimum ($r = -0.484$), and average ($r = -0.534$) temperature had significant negative correlation, while the other weather parameters showed non-significant correlation with larval population of

diamond back moth. Whereas **Bana (2012)** observed that the infestation of diamondback moth started in the third week of November and reached peak in the first week of January. **Kawsar et al. (2021)** show the similar results the correlation with maximum temperature the correlation studies revealed that maximum ($r = -0.496$), minimum ($r = -0.484$), and average ($r = -0.534$) temperature had significant negative correlation, while the other weather parameters showed non-significant correlation with larval population of diamond back moth.

5.3. To study the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.).

These findings are supported by **Sharma et al. (2022)** who reported that the Spinosad was most effective and reduced up to 94.33 per cent of diamondback moth population followed by Indoxacarb (91.00 per cent) and Flubendiamide (78.66 per cent). The insecticides, viz., Fipronil, Emamection Benzoate and Chlorantraniliprole were found to be moderately effective as they resulted in 70.66, 70.33 and 68.66 per cent reduction, respectively and Chlorfenapyr, Pyridalyl and Acephate were proved least effective reduced up to 55.33, 56.66 and 56.00 per cent, respectively. The present finding also get supported from the observations of **Kumar et al. (2022)** the *Bacillus thuringiensis* var. *kurstaki* (Dipel 8 L) @ 0.2 per cent as spray on standing crop with 41.85 per cent population reduction over control proved best among all treatments by reducing mean number of larvae 0.48/plant. The second most effective treatment applied to the cabbage on standing crop as spray form was *Beauveria bassiana* 1.15% WP @ 0.2 per cent with 38.30 per cent population reduction over control with mean number of larvae 0.75/plant, followed by Nimbecidine 0.15 per cent EC (Azadirachtin 1500 ppm) @ 0.3 per cent (37.29 per cent) it was statistically superior in comparison to control in which 4.98 mean larvae were recorded. **Chauhan (2022)** Spinosad was found to be the most effective causing in reducing 94.33 per cent of the population and subsequently Indoxacarb (91.00 per cent) and Flubendiamide (78.66 per cent). The

insecticides, *i.e.*, Fipronil, Emamectin Benzoate and Chlorantraniliprole was found to be moderately effective which led to a reduction of 70.66, 70.33 and 68.66 per cent in that order and Chlorfenapyr, Pyridalyl and Acephate proved least effective reduced to 55.33, 56.66 and 56.00 per cent, respectively. Rynaxypyr was most effective in reducing larval population (96.41 per cent) closely followed Flubendiamide (94.86 per cent) and Spinetorum (92.62%). The combination of novaluron and Indoxacarb also gave good results reduction of the larval population (92.04 per cent). Bio-pesticides *Bacillus thuringiensis var kurstaki* and *Beauveria bassiana* gave 55.82 per cent and 32.24 per cent reduction in DBM larvae respectively. **Sawant (2018)** Chlorantraniliprole @ 10 g a.i. ha⁻¹ excelled over all other treatments by recording significantly least number of larvae (1.97, 0.17, 0.10 and 1.53) with 92.50 per cent reduction over control at 1, 3, 7 and 14 days after sprays, respectively. This was followed by Spinosad @ 17.5 g a.i. per ha (2.90, 0.58, 0.27 and 1.83 larvae per plant) with 89.17 per cent larval reduction and Flubendiamide 18.24 g a.i. per ha (3.00, 0.63, 0.40 and 1.90 larvae per plant) to 88.41 per cent larval reduction but they were at par with each other. Indoxacarb @ 40 g a.i. per ha, Emamectin Benzoate @ 10 g a.i. ha⁻¹ and Diafenthiuron @ 300 g a.i. per ha were next in the order of effectiveness with 85.17, 82.17 and 76.67 per cent larval reduction over control, respectively. Untreated plots recorded maximum larval population of *P. xylostella i.e.*, 9.47 to 13.23 larvae per plant. These findings are supported by **Sarkar (2016)** who reported that the Diafenthiuron 50 % WP at the rate of 600 ml/ha provided most effective reduction of DBM population (88.68%-90.82% reduction of pest over control) with substantial increase in yield (184.75 q/ha) subsequently the highest cost-benefit ratio of 1:5.89.

4.6. To study the effect of newer insecticides and biopesticides on natural enemies.

The results of present investigation corroborate with the results of **Mollah *et al.*, (2012)** who reported that the neem seed kernel extract (NSKE) treatment provide greatest

average all the pesticides. The Neemoil (fresh) @ 2.5 ml /L water, Curtap 50 SP @ 2.0 g/L and Emamectin Benzoate 5 SG @ 1.0 g/L ensure highest number of lady bird beetle in the treated plot resulting 22.45, 17.97 and 15.63 adult lady bird beetles per plot area respectively. Neemoil (fresh) @ 2.5 ml / L water, Neemoil (stored) @ 2.5 ml / L water and Emamectin Benzoate 5 SG @ 1.0 g / L water found least toxic to lady bird beetles confirming 9.37, 17.45 and 19.04 % mortality respectively. **Gautam et al., (2021)** who reported the similar finding that was the whole module reduces the natural enemy's population as compared to control. Among the entire module, module-1 was found most safe with maximum mean number of Spider (1.83 adult/ five plant) followed by module-3, module-5, module-2 and module-6 with 2.50, 2.17, 1.67, and 1.00 per five plants, respectively. When the data of both the year were pooled it revealed that and all the module were effective and significantly superior over untreated control. The most unsafe module for spider was module-4 (which had Spinosad), which recorded with minimum average adult's population of 0.00 per five plants during *Rabi*, 2018-19 and 2019-20. **Nyaupane et al., (2022)** reported similar the yield for other treated plots was 47.60 mt/ha for Margosom, 43.77 mt/ha for Verticillium, 41.63 mt/ ha for Cow urine, 36.77 mt/ ha for Spinosad and control (33.45 mt/ ha) in terms of cabbage head yield.

4.7. To calculate the incremental cost-benefit ratio of different treatments.

The results of present research investigation similar to the results of **Khan and Tayde (2022)** who reported the mean reduction in the larval population per plant revealed that all the treatments were significantly superior over the control (6.51). Chlorantraniliprole 18.5% SC recorded lowest mean larval population of *P. xylostella* (1.52), followed by Spinosad 45% SC (1.75), Indoxacarb 14.SC (2.00), Emamectin Benzoate 5% SG (2.28), *B. thuringiensis* (2.68), *B. bassiana* (2.87), *M. anisopilae* (3.02). Highest yield (280 q/ha) as well as B:C ratio (1:6.37) was obtained from the treatment Chlorantraniliprole 18.5% SC

followed by Indoxacarb 14.5 SC (1:6.33), Emamectin Benzoate 5%SG (1:6.25), *B. thuringiensis* (1:5.97), Spinosad 45% SC (1:5.75), *B. bassiana* (1:5.72), *M. anisopliae* (1:5.50) as compared to control (1:3.34). Spinosad 2.5 SC was observed similar result to the findings of **Gill et al., (2008)**. determine the efficacy of new insecticides, the three new insecticides resulted in significantly maximum reduction in *P. xylostella* larval population ranging from 84.54 to 93.58% on cauliflower and 89.24 to 91.49% on cabbage crop compared to 43.14-58.60% reduction in standard controls on cauliflower and 68.61-77.45% reduction on cabbage crop, respectively. The marketable yield was significantly more in Spinosad 2.5 SC treatment (193.03 q/ha of cauliflower and 320.26 q/ha of cabbage crop). **Debbarma et al., (2017)** has reported similar result the yield harvested in the bio-rational treatment were Spinosad 2.5 SC 24.77 t/ha, myco-jaal 10 SC 23.70 t / ha, malathion 50 EC 22.97 t/ha, racer (*Beauveria bassiana*) 22.85 t /ha, ahook (Azadirachtin 1500 ppm) 22.73 t/ha, lipel *Bacillus thuringiensis* var. kurstaki) 22.60 /ha, shakti (Azadirachtin 300 ppm) 20.13 t/ha, margosom (300 ppm) 20.10 t/ha, multineem (Azadirachtin 1500 ppm) 20.03 t/ha, Cow–urine + Melia azedarach 19.97 t/ha, pestoneem (Azadirachtin 1500 ppm) 19.90 t/ha, pacer (*Metarhizium anisopliae*) 19.27 t/ha and untreated control 15.40 t/ha respectively. The cost of inputs including labour charge involved in a treatment and cost of extra yield obtained from such treatment are reflected in cost benefit ratio. The cost of control involved per hectare in various insecticidal treatments ranged between Rs. 858.40 (myco-jaal 10 SC & malathion 50 EC) and Rs. 1489.40 (brigade, verticel, bioasp & bioasp) which resulted in additional monetary benefit of Rs. 17860.60 (verticel) to Rs 45621.60 (Spinosad) with the cost benefit ratio ranging from 1:43.09 to 1:11.99, the maximum being in myco-jaal 10 SC and minimum being in verticel treatments, which was mainly due to higher grain yield because of moderate effective control of *P. xylostella* and *P. brassicae*.

The present investigation entitled ‘**Studies on insect pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**’ was carried out during *Rabi*, 2021 and 2022 at Crop Research Center, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, U.P. India. The cabbage variety ‘**Golden Acre**’ was selected for the above studies. Under field conditions to study the insect-pests complex on cabbage, to study the seasonal incidence of diamondback moth, *Plutella xylostella* (Linn.) on cabbage, to study the bio-efficacy of newer insecticides and bio-pesticides against diamondback moth, *Plutella xylostella* (Linn.), to study the effect of newer insecticides and biopesticides on natural enemies and incremental Cost-Benefit Ratio analysis on cabbage. The results obtained in the study were summarized and are concluded below-

The study examined cabbage's insect pest complex, identifying six dominant orders: Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Hymenoptera, and Arachnida. Lepidoptera caused the most damage, followed by Hemiptera, Orthoptera, Coleoptera, Hymenoptera, and Arachnida. Notable pests included diamondback moth, cabbage butterfly and cabbage aphid. Beneficial insects like Coccinellids and *Cotesia plutellae* were also observed. These findings offer insights for effective pest management strategies in cabbage cultivation, considering the population dynamics of pests and natural enemies in both years.

The data revealed that the diamondback moth larval population reached its maximum level of 9.67 larvae/five plants during second week of January (4th standard week) when the temperature and relative humidity ranged from 17.70°C to 5.30°C and 91.90 to 80.60 per cent. The correlation with weather parameter shows the strong significant negative correlation between the larval population of *Plutella xylostella* (Linn.) with maximum

temperature ($r = -0.933$), minimum temperature ($r = -0.893$), and average temperature ($r = -0.926$) but the morning relative humidity ($r = 0.899$), evening relative humidity ($r = 0.730$) and average relative humidity ($r = 0.843$) shows the strong significant positive correlation. While the sunshine ($r = -0.787$) shows strong significant negative correlation. Whereas wind velocity ($r = 0.124$) and rainfall ($r = 0.440$) show the positively non-significant correlation between the larval population of *Plutella xylostella* (Linn.).

Pooled data of both the year (2021 and 2022), After treatments, Spinosad 2.50% SC consistently showed the lowest larval count on days 3, 7, and 14, with 3.33, 2.17, 2.25 larvae per five plants followed by Emamectin benzoate 5% SG, Diafenthiuron 50% WP, *Bacillus thuringiensis* var. *kurstaki*, *Beauveria bassiana* and *Metarhizium anisopiliae*, and Nimbecidine 0.03% respectively. The Nimbecidine 0.03% recorded the lowest efficacy. Chemical and biological treatments varied significantly, while chemicals had similar efficacy, and biologicals were equally effective. Control plots had the highest larvae count.

Before the first application, *Coccinella septempunctata* adult population ranged from 4.17 to 5.17 per five plants, with no significant differences among treatments. After application, Nimbecidine 0.03% consistently proved safest for adults, while chemical treatments were less safe. Untreated control had highest populations following a similar pattern after the second application, Nimbecidine remained the safest for adults, with chemical treatments posing greater risks. Control plots had the highest populations. In conclusion, Nimbecidine demonstrated consistent safety for *Coccinella septempunctata* adults, contrasting with chemicals' effects.

Before the first application, Spider adult population ranged from 2.50 to 3.33 per five plants, with no significant differences among treatments. After the first application, Nimbecidine 0.03% consistently proved safest for Spider adults, while chemical treatments were less safe. Untreated control had the highest populations following a similar pattern after

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The data regarding net profit in pooled data of both the year *Kharif* 2021 and 2022 revealed the highest net profit (Rs. 24400.00/ha) was obtained with the treatment Spinosad 2.5% SC followed by Emamectin benzoate 5% SG, Diafenthiuron 50% WP, *Beauveria bassiana*, *Metarhizium anisopliae*, *Bacillus thuringiensis* var. *kurstaki*, and Nimbecidine 0.03%, with the net profit 21033.33, 19250.00, 17100.00, 10100.00, 8950.00, and 8083.33 respectively. The lowest net profit (Rs. 8083.33) was calculated from the Nimbecidine 0.03%.

The maximum incremental cost benefit ratio (1:10.57) was recorded from Emamectin benzoate 5% SG followed by Spinosad 2.50% SC, *Beauveria bassiana*, Diafenthiuron 50% WP, *Metarhizium anisopliae* and *Bacillus thuringiensis* var. *kurstaki*, with the ICBR of 1: 6.42, 1: 6.21, 1: 5.79, 1: 4.59 and 1: 2.56 respectively. The minimum ICBR of 1: 1.77 was obtained from the Nimbecidine 0.03%.

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Abstract

Name: Chandra Kant
Major: Entomology
Degree: Doctor of Philosophy
Thesis title: Studies on insect-pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)

Id. No : PG/A-2216/20
Minor : Plant Pathology
Department : Entomology

The present investigation entitled ‘**Studies on insect-pest dynamics of cabbage and management strategies of diamondback moth, *Plutella xylostella* (Linn.)**’ was carried out on cabbage variety ‘Golden Acre’ during *Rabi*, 2021-22 and 2022-23. At Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture, Meerut (UP). The data were recorded on five randomly selected plants once in a standard week. The insect pest including natural enemies on cabbage, six orders (Lepidoptera, Hemiptera, Orthoptera, Coleoptera, Hymenoptera and Arachnida) were identified during field monitoring. Diamondback moth population reached up to maximum level of 9.67 and 9.33 larvae/five plant during 3rd week of January during *Rabi* 2021 and 4th week of January in *Rabi* 2022. The *P. xylostella* was active throughout the year with a varying degree of infestation. When the data of both the years were pooled all the treatments were found effective and significantly superior over untreated control.

Spinosad 2.50% SC @600 ml/ha was the most effective insecticide against *P. xylostella* with (1.33 larvae per five plant) followed by Emamectin Benzoate 5% SG @200 g/ha, Diafenthiuron 50% WP 600 g/ha, *Bacillus thuringiensis* @1000 g/ha, *Beauveria bassiana* @1500 ml/ha, *Metarhizium anisopiliae* @2000 g/ha and Nimbecidine 0.03%@2500 ml/ha with 2.00, 2.67, 3.67, 4.50, 5.00 and 5.83 *P. xylostella* larvae per five plants respectively. Maximum diamondback moth larvae (8.00/five plant) were recorded in untreated control. All the treatments reduce the natural enemy’s population as compared to control. Among all the treatments, Nimbecidine 0.03%@2500 was found most safe with maximum pool mean number of *C. septempunctata* (3.33) and Spider (2.67) adult/five plant followed by *Metarhizium anisopiliae* followed by *Beauveria bassiana*, *Bacillus thuringiensis*, Diafenthiuron 50% WP, Emamectin Benzoate 5% SG and Spinosad 2.50% SC with (2.83, 2.33, 2.00, 1.17, 0.83 and 0.33 adult *C. septempunctata* per five plant and 2.33, 2.00, 1.50, 0.83, 0.33 and 0.17) adult spider per five plants respectively. All the chemical insecticides prove less safe to the natural enemies. Whereas maximum adult population of *C. septempunctata* and Spider was recorded from untreated control with (4.00 and 3.83 adult per five plant). When the data of both the year were pooled and found all the treatments were found again effective and significantly superior over untreated control. The highest incremental cost benefit ratio (ICBR) was recorded in Emamectin Benzoate 5% SG *i.e.*, 1:10.57 which was comparatively superior over all treatments as sprayed on standing crop. The mean yield of cabbage was recorded from this treatment *i.e.*, 176.67 q/ha and net profit obtained from the increased yield was 21033.33 Rs/ha., followed by Spinosad 2.50%SC 1:6.42 that produced mean yield of cabbage *i.e.*, 186.33 q/ha, Diafenthiuron 50% WP, *Beauveria bassiana*, *Metarhizium anisopiliae*, *Bacillus thuringiensis* var. kurstaki, Nimbecidine 0.03% ICB ratio with 5.79, 6.21, 4.59, 2.56 and 1.77 respectively, mean yield with 173.50, 160.00, 158.50 and 156 q/ha. respectively. All treatments were superior over untreated control. The lowest cabbage yield 145.00 q/ha was observed in the untreated control.

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शोध शीर्षक: गोभी की कीट-पीड़क गतिशीलता और डायमंडबैक मॉथ, *प्लूटेला जाइलोस्टेला* (लिनियस) की प्रबंधन रणनीतियों पर अध्ययन

सारांश

'गोभी की कीट- पीड़क गतिशीलता और डायमंडबैक मॉथ, *प्लूटेला जाइलोस्टेला* (लिनियस) की प्रबंधन रणनीतियों पर अध्ययन' शीर्षक वाली वर्तमान अध्ययन रबी, 2021-22 और 2022-23 के दौरान फसल अनुसंधान केंद्र, सरदार वल्लभभाई पटेल कृषि एवं प्रौद्योगिक विश्वविद्यालय, मेरठ (उत्तर प्रदेश) में गोभी की किस्म 'गोल्डन एकड' पर की गई थी। मानक सप्ताह में एक बार पांच यादृच्छिक रूप से चयनित पौधों पर डेटा दर्ज किया गया था। दोनों फसल वर्षों में गोभी पर कीट तथा प्राकृतिक शत्रुओं सहित, छह ऑर्डर (लेपिडोप्टेरा, हेमिप्टेरा, ऑर्थोप्टेरा, कोलिओप्टेरा, हाइमनोप्टेरा और अरेकिनडा) की पहचान क्षेत्र की निगरानी के दौरान की गई थी। रबी 2021 के दौरान जनवरी के तीसरे सप्ताह तथा रबी 2022 में जनवरी के चौथे सप्ताह के दौरान डायमंडबैक मॉथ कीट की आबादी 9.67 और 9.33 लार्वा/पांच पौधे के अधिकतम स्तर तक पहुंच गई। *पी. जाइलोस्टेला* पूरे वर्ष अलग-अलग स्तर के संक्रमण के साथ सक्रिय था। जब दोनों वर्षों के डेटा को एकत्रित किया गया तो सभी उपचार प्रभावी पाए गए और अनुपचारित नियंत्रण से काफी बेहतर थे। स्पाइनोसेड 2.50% एससी @ 600 मिली/हेक्टेयर *पी. जाइलोस्टेला* के खिलाफ सबसे प्रभावी कीटनाशक था (प्रति पांच पौधे पर 1.33 लार्वा) इसके बाद इमामेक्टिन बेंजोएट 5% एसजी @200 ग्राम/हेक्टेयर, डायफेंथियुरोन 50% डब्ल्यूपी 600 ग्राम/हेक्टेयर एवं बैसिलस थुरिंजिएन्सिस @ 1000 ग्राम/हेक्टेयर था। *ब्यूवेरिया बैसियाना* @ 1500 मिली/हेक्टेयर, *मेटारिज़ियम एनिसोपिलिया* @ 2000 ग्राम/हेक्टेयर और निम्बेसिडाइन 0.03% @2500 मिली/हेक्टेयर प्रति पांच पौधों पर क्रमशः 2.00, 2.67, 3.67, 4.50, 5.00 और 5.83 *पी. जाइलोस्टेला* लार्वा अनुपचारित नियंत्रण में अधिकतम डायमंडबैक मॉथ लार्वा (8.00/पांच पौधा) दर्ज किया गया। सभी उपचार नियंत्रण की तुलना में प्राकृतिक शत्रु की जनसंख्या को कम करते हैं। सभी उपचारों में, निम्बेसिडीन 0.03% @ 2500 को अधिकतम पूल माध्य संख्या के साथ *कॉक्सिनेला सेप्टेमपंकटाटा* (3.33) और मकड़ी (2.67) वयस्क/पांच पौधे के साथ सबसे सुरक्षित पाया गया, इसके बाद *मेटारिज़ियम एनिसोपिलिया*, इसके बाद *ब्यूवेरिया बैसियाना*, बैसिलस थुरिंजिएन्सिस और डायफेंथियुरोन 50% थे। डब्ल्यूपी, इमामेक्टिन बेंजोएट 5% एसजी और स्पिनोसेड 2.50% एससी (2.83, 2.33, 2.00, 1.17, 0.83 और 0.33 वयस्क सी. सेप्टेमपंकटाटा प्रति पांच पौधे और 2.33, 2.00, 1.50, 0.83, 0.33 और 0.17) वयस्क मकड़ी प्रति पांच पौधे के साथ क्रमशः सभी रासायनिक कीटनाशक प्राकृतिक शत्रुओं के प्रति कम सुरक्षित सिद्ध होते हैं। जबकि सी. सेप्टेमपंकटाटा और मकड़ी की अधिकतम वयस्क आबादी अनुपचारित नियंत्रण से (प्रति पांच पौधे 4.00 और 3.83 वयस्क) दर्ज की गई थी। जब दोनों वर्षों के डेटा को एकत्रित किया तो पाया गया कि सभी उपचार प्रभावी और अनुपचारित नियंत्रण से काफी बेहतर पाए गए। उच्चतम वृद्धिशील लागत लाभ अनुपात (आईसीबीआर) इमामेक्टिन बेंजोएट 5% एसजी में 1:10.57 दर्ज किया गया था जो खड़ी फसल पर छिड़काव के रूप में सभी उपचारों से तुलनात्मक रूप से बेहतर था। इस उपचार से पत्तागोभी की औसत उपज 176.67 क्विंटल/हेक्टेयर दर्ज की गई और बढ़ी हुई उपज से प्राप्त शुद्ध लाभ 21033.33 रु./हेक्टेयर था, इसके बाद स्पाइनोसेड 2.50%एससी 1:6.42 था। जिसने गोभी की औसत उपज 186.33 क्विंटल/हेक्टेयर, दर्ज की गई, डायफेंथियुरोन 50% डब्ल्यूपी, *ब्यूवेरिया बैसियाना*, *मेटारिज़ियम एनिसोपिलिया*, बैसिलस थुरिंजिएन्सिस और निम्बेसिडाइन 0.03% का आईसीबी अनुपात क्रमशः 5.79, 6.21, 4.59, 2.56 और 1.77 के साथ, औसत उपज क्रमशः, 173.50, 160.00, 158.50 और 156 क्विंटल/हेक्टेयर रही, तथा सभी उपचार अनुपचारित नियंत्रण से बेहतर थे। अनुपचारित नियंत्रण में पत्तागोभी की सबसे कम उपज 145.00 क्विंटल/हेक्टेयर देखी गई।

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(परामर्शदाता)

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Vitae

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2020: Passed M.Sc. Agricultural Zoology and Entomology at University of Allahabad, Prayagraj

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