EFFECT OF BIOPESTICIDES ON MAJOR INSECT PESTS OF CABBAGE AND THEIR NATURAL ENEMIES

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EFFECT OF BIOPESTICIDES ON MAJOR INSECT PESTS OF CABBAGE AND THEIR NATURAL ENEMIES

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CERTIFICATE

This is to certify that the thesis entitled **“EFFECT OF BIOPESTICIDES ON MAJOR INSECT PESTS OF CABBAGE AND THEIR NATURAL ENEMIES”** submitted to the Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **Dr. Md. Abdul Latif**, Registration No. **17-08308** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

December, 2018
Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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EFFECT OF BIOPESTICIDES ON MAJOR INSECT PESTS OF CABBAGE AND THEIR NATURAL ENEMIES

ABSTRACT

The study was conducted in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October 2018 to March, 2019 to know the effect of biopesticides on major insect pests of cabbage and their natural enemies. Six treatments were used under the experiment. They were T_1= Spinosad, T_2= SNPV (*Spodoptera litura* nuclear polyhedrosis virus), T_3= Spodolure trap, T_4= Spodolure trap + Spinosad spray, T_5= Spodolure trap + SNPV spray and T_6= untreated control. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Results revealed that the lowest number of infested leaves by flea beetle (0.33/ 5 plants), tobacco cutworm (0.33/ 5 plants), semi-looper (0.33/ 5 plants), diamondback moth (1.33/ 5 plants) and aphid (7.50/ 5 plants) were found in T_4 treatment (Spodolure trap + Spinosad). In case of incidence of natural enemies, the highest number of lady bird beetle (8.00/plot) and spider (8.60/plot) was also found from T_4 (Spodolure trap + Spinosad) treatment compared to untreated control. The highest percentage of healthy plants (91.67%), highest weight of healthy cabbge head plant^{-1} (1.20 kg), marketable cabbage head plot^{-1} (19.48 kg) and marketable yield of healthy cabbage head (45.08 t ha^{-1}) was found in T_4 (Spodolure trap + Spinosad) treatment. Spodolure trap in combination with Spinosad spray may be considered as effective practice for the management of cabbage insect pests and conservation of natural enemies.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCPA	=	Bangladesh Crop Protection Association
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
Mg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) locally known as 'Bhadha Kopi' or 'Pata Kopi' is a popular and the most common winter vegetable grown from seed in Bangladesh. It is one of the five leading vegetables in the country which belong to the Cruciferae family. Cabbage is a leafy vegetable rich in vitamin C, vitamin E and tryptophan; an important amino acid for our body (Rashid 1993). During 2010-2011, two hundred seven thousand metric tons (BBS 2011) of cabbage was produced, which ranked fifth among the vegetables produced in Bangladesh. The yield produced by cabbage in Bangladesh is 75-100 ton/ha depending on selection of variety and season (Rashid *et al*. 2006). These yields are low comparing with other developing countries. Various reasons are responsible for low yield of cabbage. Insect pest infestation and other reasons like low nutrient, proper irrigation etc. are mainly responsible for low yield of cabbage.

Cabbage is prone to insect pest ravages from the time of sowing till the harvest. The crop is attacked by a number of insect pests, *viz*. tobacco caterpillar, *Spodoptera litura* (Fab.); diamond back moth, *Plutella xylostella* (L.); cabbage leaf webber, *Crocidolomia bionotalis* (Zell.); aphids, *Bravicornye brassicae* (L.) and *Lipaphis erysimi* (Kalt.); painted bug, *Bagrada cruciferarum* (Kirk.) and flea beetle, *Phyllotreta cruciferae* (Goeze.) etc. (Mohan *et al*. 1981). Among various insect pests attacking cabbage, some of them are very serious like diamond back moth, *P. xylostella* (L.) causes significant losses. Krishnaiah, (1980) and Krishna-Kumar *et al*. (1984) reported (44.6 and 53)% loss in yield due to the attack of *P. xylostella* on cabbage. Prasad (1963) reported 42 to 97 per cent yield losses in cabbage due to cumulative infestation by the pest complex, whereas, Krishnamoorthy (2004) reported 52% losses in yield due to the attack of only diamondback moth.

In vegetable production, the use of insecticides has become very common and no market vegetable is supposed to be free from pesticide residue. The indiscriminate use of insecticides over past four decades has created not only the serious problems of contaminating the different components of the environment excessively and pervasively but also resulted in long term persistence, pest outbreak, development of resistance, ill-effect on non target organism, resurgence and replacement of pests, and health hazards to man and animals due to presence of toxic residues in vegetables.

In Bangladesh, the frequency and amount of pesticide applications per unit area is highest in the high valued crops. Among the various vegetable, fruits and spices crops, profitable crops like brinjal, country bean, cabbage, cauliflower, cucurbits, summer tomatoes, okra, string beans, mango, litchi, chili etc. receive excessive amounts of pesticides as they suffer serious pest damage (Alam *et al*. 2004). According to BCPA (2006), pesticide use for growing vegetables was six times higher than the rice (1.12 kg/ha for vegetables, while it was only 0.20 kg/ha in rice).

It has been observed that it is difficult to control a pest only by the application of a single tactics. In order to achieve sustainable result, it is necessary to develop complete and coherent packages of technologies that meet farmers' needs and completely replace the need for application of toxic chemical pesticides. It has been observed that effective management of *Spodoptera litura* can be ensured with the mass trapping of *Spodoptera litura* by pheromone traps along with 2-3 application of SNPV (Alam *et al*. 2012). In Bangladesh, scientists of different public research institutes and universities, *viz*. Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural University etc. have already developed bio-pesticide based pest management packages against several destructive insect pests and diseases of different crops.

Conventional insecticides continue to be one of the most powerful weapons available for the control of pests, but their wide scale and indiscriminate application creates problems like, development of resistance and resurgence of pests; besides, leaving excessive residue on edible portions (Lal and Meena 2001, Patel *et al*. 2005). Moreover, indiscriminate use of synthetic pesticides is harmful for health. So, eco-friendly management using bio pesticide can be an alternative to control insect pest of cabbage as well as to keep sound environment. Consequently, the use of eco-friendly materials such as botanicals, biopesticides and some newer molecules, emerged as a superior alternative to the synthetic insecticides. Moreover, these were also reported to be compatible with other pest control measures to solve the pest problems.

Keeping this view in mind, the investigation was undertaken to test the efficacy of bio-pesticide for succession of insect pests and natural enemies in cabbage ecosystem and management of major insect pest with the following objectives:

1. To know the effect of bio-pesticides on incidence of major insect pests of cabbage and their natural enemies and
2. To evaluate the efficacy of bio-pesticide on yield contributing characters and yield of cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests, Aphid, Diamondback moth, Semi-looper, Flea beetle, Tobacco cutworm etc. insects are the major pests of Cabbage. Bio-pesticides can be used as an important tool to control these insect pests biologically and eco-friendly. But considerable literature dealing with reducing infestation of these insect pests of cabbage, performances and effectiveness of bio-pesticide control treatments are very limited. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following headings:

2.1 Seasonal incidence

2.1.1 Aphid

Agarwal and Dadheech (1990) reported that the aphid, *Lipaphis erysimi* (Kalt.) appeared in November on cauliflower, cabbage and mustard crops and reached its peak during last week of January to first week of February. A significant negative correlation was observed in pest population and temperature while there was a positive correlation with relative humidity.

Devjani and Singh (1998) reported four species of aphids *viz., Myzus persicae, Lipaphis erysimi*, *Brevicoryne brassicae* and *Aphis gossypii* infesting cauliflower in three crop varieties (early, mid and late). The population of the first two aphids was found dominating in all the crop varieties and their period of occurrence also more or less similar.

Ghosh *et al.* (2000) assessed the incidence of insect pest on cauliflowers cultivars in *Terai* regions. Maximum population of aphids *Lipaphis erysimi*

(33.36 aphids per leaf) and flea beetles, *Phyllotreta cruciferae* (0.78 beetle/plant) were found during the last week of December and 3rd week of December, respectively.

Malik *et al.* (2000) reported that the population of cauliflower aphid, *Brevicoryne brassicae* L. fluctuated from 51st meteorological week to 4th meteorological week. Correlation between aphid population and maximum-minimum temperature were negative and with morning relative humidity it was positive.

Chaudhuri *et al.* (2001) studied the fluctuation of aphid, *L. erysimi* population on cabbage and their reaction with prevailing weather conditions of *terai* region of West Bengal during winter and spring season. They observed that the population of aphid reached maximum during 3rd week of March on spring crop. The population of aphids was recorded in both the season but it was higher on spring crop. During winter seasons the aphid population was negatively correlated with temperature, sunshine and total rainfall and positively with average relative humidity and during spring season it was positively correlated with relative humidity and total rainfall.

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

Zaz (2001) studied the incidence of cabbage aphid, *B. brassicae* on cauliflower and cabbage crops and recorded maximum aphid population (17.4 aphids

/plant) on cauliflower followed by cabbage with 52.8 aphids per plant. The aphid population exhibited non-significant positive and nonsignificant negative correlation with temperature in cauliflower and cabbage, respectively, whereas, it showed a significant negative correlation with relative humidity and rainfall.

Sood (2004) studied on the seasonal population fluctuation of the aphids on cabbage and their predators in treated (Monocrotophos 0.04%, four sprays and endosulfan 0.05%, two sprays) and untreated plots during 1994-95 and 1995-96 at Pantnagar, North India and reported three aphid species, namely *M. persicae*, *L. erysimi* and *B. brassicae* attacking this crop. However, *M. persicae* was the most abundant aphid species. The peak population of aphid was recorded in 3rd week of February and last week of January in untreated plots, while in the treated plots its peak occurred in 2nd week of February and 2nd week of January during 1995 and 1996, respectively. The peak predators (syrphids and coccinellids) population in treated plots was recorded significantly lower than that of in the untreated plots.

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

Wagle *et al.* (2005) studied the seasonal incidence of aphid, B. *brassicae* and its natural enemies in relation to weather parameters on cabbage and reported that the incidence of aphid commenced from 22 days after sowing, *i.e.* second fortnight of January (3rd standard week) and reached its peak during first fortnight of March (10th standard week), thereafter a declining trend was observed. The aphid population exhibited non-significant positive correlation with maximum and minimum temperatures and sunshine hours whereas, negative correlation with wind velocity. Aphidophagous predators like *Coccinella septempunctata, Coccinella transversalis* and *Syrphus corollae* (Fab.) appeared more or less with aphid population (4th standard week). The coccinellids and syrphids reamins active upto February (9th standard week) and March (13th standard week), respectively. As the pest population decreased, the population of natural enemies also declined.

Bhavani and Punnaiah (2006) studied the seasonal incidence of aphid, *L. erysimi* in relation to weather parameters. They observed highest population of aphid on cabbage during second week of February, while the minimum population during last week of March. The minimum temperature exerted significant negative effect while, the morning and evening relative humidities showed significant positive relationship with aphid population.

2.1.2 Diamondback moth

Sachan and Gangwar (1990) studied the seasonal incidence of major insect pests of cabbage, cauliflower and knol-khol in and around Shillong. They observed that diamond back moth was the minor pest and usually causing minor damage to these crops. The incidence pattern has been correlated with the prevailing temperature and rainfall at upper Shillong.

Kim and Lee (1991) observed that *P. xylostella* (L.) can over-winter as eggs, larvae, pupae and adults in Southern region of Korea. The occurrence of adult moths reached their peaks in May, mid June to mid July and late September to early November and fell in late July to mid September. Under field cage conditions, 10-11 generations were recorded in a year.

Bhatia and Verma (1994) studied the incidence and sequence of appearance of major insect pests damaging cabbage under mid hill regions of Himachal Pradesh. Among the various key pests of this crop diamond back moth, *P. xylostella* was second in the sequence. The peak population of this pest was observed between last week of March to third week of April in which crop was winter cabbage.

Bhatia and Verma (1995) studied the incidence of major insect pests of summer cabbage under mid Hill region of Himachal Pradesh. Among the various insect pests of summer cabbage the incidence of *P. xylostella* started in the month of June and reached to its peak in the end of July or first week of August.

Chauhan *et al.* (1997) observed the bioecology of diamond back moth, *Plutella xylostella* (L.) in the mid Hills of Himachal Pradesh. The pest appeared in the first fortnight of March on cabbage and cauliflower. The peak larval population was observed in the first week of April during 1991 and in the third week of April during 1992.

Maltais *et al.* (1998) studied the seasonal variations of three lepidopterous pests, the diamond back moth, *P. xylostella;* the imported cabbage worm, *Pieris rapae* and the cabbage *looper, Trichoplusiani* over two years in broccoli *(Brassica oleracea* var. *italica)* plantings in SouthEastern New Burnswick. Four population peaks were recorded for the diamond back moth in 1990 and 1991 with 81 and 97 per cent of the total larval population, respectively, of the population being recorded after 23rd July.

Bindu *et al.* (2000) carried out a periodical survey on the farm of AICRP on Medicinal and Aromatic Plants, GAU, Anand during *Rabi* season 1998-99 to know the seasonal abundance of *Plutella xylostella* on cress, *Lepidium sativum*. The oviposition and larval population of *P. xylostella* was observed during the 2nd week of February to the last week of March. The egg and larval population was comparatively low till 3rd 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.

Chaudhuri *et al.* (2001) observed that population of diamondback moth, *P. xylostella* reached to maximum in the last week in March on the spring season on cabbage crop. The larval population of diamondback moth showed positive correlation with average temperature, relative humidity and total rainfall and negative correlation with sunshine hours per day.

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

Sharma (2004) studied the seasonal incidence of major insect pests of cabbage during 2001 and 2002 at Ajmer, Rajasthan and reported four regular pests, *viz.,* diamondback moth, *P. xylostella;* flea beetle, *Phyllotreta cruciferae* (Goeze); painted bug, *B. cruciferarum* and aphid, *L. erysimi* infesting on cabbage crop. Diamondback moth had been recorded as a major pest that appeared in mid September and touched its peak in the third and fourth week of October. Its population had non-significant correlation with temperature, rainfall and relative humidity. However, morning relative humidity had significant negative correlation. The aphid appeared late and reached its peak in second week of December and showed negative correlation with temperature and positive with relative humidity.

Shukla and Kumar (2004) reported that *P. xylostella* started attacking the cabbage crop initially in the first week of December and last week of November during 2000-01 and 2001-02, respectively. The population of *P. xylostella* touched its peak in the fourth week of January in both the years. The pest population was negatively correlated with mean temperature and mean relative humidity during 2000-01, while during 2001-02, a negative correlation with mean temperature and positive correlation with mean relative humidity was recorded.

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

2.1.3 Flea beetle

Swami (1995) observed that the flea beetle, *P. cruciferae* was first appeared in the first week of December. Thereafter, its population subsequently followed the trend of continuous increase till last week of December and then gradually declined up to third week of January. The population again increased in last week of January and disappeared towards harvesting.

Zhang *et al.* (2000) investigated the population dynamics of stripped flea-beetle *Phyllotreta striolata* on crucifer vegetable. The beetle produced seven generations annually, with infestation peaks from early April to late May, and in mid September. During the peak in mid September its number was 2.4 - 2.5 times that of the peak in spring. Population numbers were closely correlated to precipitation and mean 10 day temperature.

Chaudhari *et al.* (2001) reported that population of flea beetle, *P. brassicae* reached maximum during last week of March on spring cabbage crop. In comparison to winter crop, higher population was recorded on spring crop and showed positive correlation with average relative humidity and rainfall.

Prasad (2001) evaluated the incidence of flea beetle, *P. downsi* in radish c.v. pusa chetak. Results showed that the pest caused considerable damage to radish leaves, an average of six beetles were found per plant with a minimum of two and a maximum of 20 per plant.

Vig (2002) studied the biology of *Phyllotreta cruciferae* in field on cabbage. Adult over winter under plant debris and appear in large number by the end of April and beginning of May. Eggs are laid from May to spring until mid July. Larvae can be found from June to mid October. The young adults of the new generation appear in August and retire to the overwintering sites by the end of October.

2.1.4 Natural enemies

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

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

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

Cividanes (2002) reported that the period of highest increase and decline of the population of *B. brassicae,* ground spiders constituted the most significant mortality factor related with the variation of the population density of the aphid.

Newton *et al.* 2009 reported that the experimental reduction of natural enemy pressure had no effect on aphid colony size or production of winged dispersers. The results provide evidence for glucosinolate-mediated, bottom-up regulation of mealy cabbage aphid colonies in natural populations, but they found no indication of top-down regulation. They emphasizes that more studies of these processes should focus on tritrophic interactions in the wild.

Ayalew and Ogol (2006) reported that eight parasitoid species were recorded of which three species were important both in distribution and level of parasitism. These include *Oomyzus sokolowskii* (Hym., Eulophidae), *Diadegma spp.* (Hym., Ichneumonidae) and *Apanteles* sp. (Hym., Braconidae). Overall parasitism ranged from 3.6% to 79.5% with big differences between areas. *Apanteles* sp. and *Diadegma* spp. were largely confined to the south-western part of Ethiopia where insecticide use is minimal.

Gathu *et al.* (2009) reported that overall, four larval, one larval-pupal and one pupal parasitoid of DBM were recorded on wild crucifers: *Diadegma semiclausum, D. mollipla, Apanteles sp., Cotesia plutellae, Oomyzus sokoloskii* and *Brachymeria* species, respectively. *Diadegma semiclausum* was the most dominant species on all crucifers. They conclude that wild crucifers act as alternative hosts for DBM and provide refugia for DBM parasitoids, which risk local extinction through pesticide application or competition from introduced exotic parasitoid species.

2.2 Bio-pesticides in controlling insect pests

2.2.1 Definition of biopesticides

According to the United States Environmental Protection Agency (EPA), biopesticides are pesticides derived from natural materials, such as animals, plants, bacteria, and certain minerals (www.epa.gov). The EPA places biopesticides into three major classes: microbial pesticides, plant incorporated protectants (PIPs) and biochemical pesticides. Microbial pesticides consist of a microorganism as the active ingredient; all the entomopathogenic bacteria, fungi, and viruses are under this group. PIPs refer to transgenic plant materials; they are not reviewed in this paper. Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. These include sex pheromones and scented plant extracts that attract pests (Srinivas, 2012).

In Bangladesh, bio-pesticides mean a form of pesticide based on micro-organisms or natural products. That can be microbial, which consist of bacteria, entomopathogenic fungi or viruses or entomopathogenic nematodes, natural products like Azadirachtrin, Biochemical pesticides, *viz*. insect pheromone, parapheromone and other chemicals. Fermentation products such as Spinosad (a macro-cyclic lactone) or Abamectin (a natural fermentation product of soil bacterium *Streptomyces avermitilis*) are also considered as bio-pesticides. Natural plant-derived products, which includes alkaloids, terpenoids, phenolics and other secondary chemicals and products based on extract of plants like garlic, allamanda have now been registered as bio-pesticides. In Bangladesh biopesticides are mainly used in pest management of agricultural crops (Plant Protection Wing, 2011).

2.2.2 Effect of different bio-pesticides in controlling insect pests

John *et al.* (2000) tested the bio-efficacy of spinosad 2.5 SC against cabbage pests and found effective in controlling diamondback moth, *P. xylostella;* cabbage stem borer, *H. undalis* and leaf webber, *C. binotalis* when applied @ 15, 20 and 25 g a.i. ha^{-1} and persisted for seven days. However, it did not prove effective against aphid, *L. erysimi.*

Gupta (2000) recommended the doses of spinosad 2.5 SC ranging from 10-25 g a.i. ha^{-1} for protection of cabbage against lepidopterous pests such as diamondback moth, semilooper and tobacco caterpillar, which also resulted in significantly higher yield of cabbage.

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

Peter *et al.* (2000) tested the efficacy of spinosad against cabbage pests with cypermethrin, quinalphos and Biobit *(B. thuringiensis).* Spinosad was found superior in controlling diamondback moth, *P. xylostella;* cabbage stem borer, *H. undalis* and cabbage leaf webber, *C. binotalis* when applied @ 15, 20 and 25 g a.i. ha^{-1}.

Meena *et al.* (2002) conducted field experiment to test the toxic effect of insecticides on lady bird beetle predating on fenugreek aphid. Karanj seed extract (1.0%). Neem guard (0.5%), malathion (0.05%) and endosulfan (0.07%) were found to be relatively safe to lady bird beetle, whereas, phosphamidon (0.03%) was found to be highly toxic.

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

Tambe and Mote (2003) tested the effectiveness of new molecule, spinosad 2.5 SC at 10, 12.5, 15, 17.5, 20 and 25 g a.i. ha^{-1} against diamondback moth, *P. xylostella* on cabbage and compared with microbial insecticide Dipel 8 L *(B. thuringiensis)* at 1000 ml ha^{-1} and conventional insecticides, quinalphos 25 EC at 250 g a.i. ha^{-1} and chlopyriphos 20 EC at 400 g a.i. ha^{-1}. They found that spinosad 2.5 SC at 20 g a.i. ha^{-1} was significantly superior to the remaining treatments in reducing the infestation of diamondback moth larvae at 2 and 6 days after application and increased the yield of marketable cabbage heads.

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

Vastrad *et al*. (2003) studied on the management of insecticides resistant population of diamondback moth and found that thiodicarb, lufenuron, spinosad and *B. thuringiensis* (Biobit) emerged as the most promising insecticides for managing field population of diamondback moth to conventional insecticides resulted from 57.13 to 99.99 per cent reduction in larval population and gave higher cabbage yield. Standard check, malathion recorded lowest reduction (30.63 to 64.18%) in larval population of diamondback moth as well as lowest yield (498.40 and 542.70 q ha^{-1}) during both trials due to diverse mode of action. These chemicals could be excellent choice in a rotational strategy aimed at prolonging their efficacy by delaying the onset of resistance development.

Deivendran *et al*. (2007) evaluated the efficacy of new insecticides against *P. xylostella* on cauliflower, revealed that indoxacarb at 90 g a.i. ha^{-1} gave the highest mean larval mortality (67.0%) followed by spinosad at 75 g a.i. ha^{-1} (62.0%), fipronil at 75 g a.i. ha^{-1} (65.0%), thiodicarb at 750 g a.i. ha^{-1} (57.0%), dichlorvos at 115 g a.i. ha^{-1} (44.0%), endosulfan at 350 g a.i. ha^{-1}, Nimbecidine at 75 g a.i. ha^{-1} (37.0%) and *Bt* at 1000 g ha^{-1} (14.0%) one day after the spray and all were significantly better than control. The overall order of efficacy recorded was : Indoxacarb > spinosad > fipronil > thiodicarb > *Bt* > dichlorvos > endosulfan > nimbecidine.

Gill *et al*. (2008) tested the efficacy of new insecticides spinosad 2.5 SC @ 600 ml ha^{-1}, Proclaim 0.5 SG (emamectin benzoate @ 170 g ha^{-1} and KN 128 15

SC (indoxacarb) @ 333 ml ha^{-1} for the control of *P. xylostella* on cauliflower and cabbage. The insecticides were compared with standard checks ***i.e.*** Thiodan 35 EC (endosulfan) @ 1000 ml ha^{-1} and Padan 50 SP (cartap hydrochloride) @ 500 g ha^{-1} over the untreated control. Three new insecticides resulted in significantly maximum reduction of *P. xylostella* larval population ranging from 84.54-93.58 per cent on cauliflower and 89.14-91.49 per cent on cabbage crop as against 43.1458.60 per cent in standard checks on cauliflower and 68.61-77.45 per cent on cabbage crop. The marketable yield was significantly more in spinosad 2.5 SC treatment (193.03 q ha^{-1} of cauliflower and 320.26 q ha^{-1} of cabbage crop).

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

CHAPTER III

MATERIALS AND METHODS

The present experiment was conducted to evaluate the effectiveness of some bio-pesticides on major insect pests and their predators and also yield of cabbage. The components of materials and methods; experimental period, location, soil and climatic condition of the experimental area, treatment and design of the experiment, data collection and data analysis procedure of this experiment has been presented under the following sub-headings-

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during October 2018 to March 2019.

3.1.2 Experimental location

The present research work was conducted in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Climatic condition

The climatic condition of experimental site is subtropical and characterized by three distinct seasons, the Rabi from November to February and the Kharif-I, pre-monsoon period or hot season from March to April and the Kharif-II monsoon period from May to October. The monthly average temperature, relative humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II.

3.1.4 Soil characteristics

The general soil type of the experimental field was Shallow Red Brown Terrace soil and it is belongs to the Tejgaon series under the Agro-ecological Zone, Madhupur Tract (AEZ-28). A composite sample of the experimental field was made by collecting soil from several spots of the field at a depth of 0-15 cm before starting of the experiment. The collected soil was air-dried, grind and analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka for some important physical and chemical properties. The soil was having a texture of silty clay with pH and organic matter 5.8 and 1.16%, respectively. The results showed that the soil composed of 27% sand, 43% silt and 30% clay. Details morphological, physical and chemical properties presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

The seeds of BARI cabbage-2 (Agradut) were used as the test crop under the study.

3.2.2 Treatment of the experiment

The experiment comprised with six treatments including an untreated control of the following bio-pesticides –

T_1 = Spinosad (Tracer 45SC) @ 0.4 mL/L of water

T_2 = SNPV (*Spodoptera litura* nuclear polyhedrosis virus) @ 0.2g/L of water

T_3 = Spodolure trap @ 1/plot

T_4 = Spodolure trap + Spinosad (Tracer 45SC) @ 0.4 mL/L of water

T_5 = Spodolure trap + SNPV (*Spodoptera litura* nuclear polyhedrosis virus) @ 0.2g/L of water

T_6 = Untreated control

3.3 Collection and preparation of treatment components

3.3.1 Collection of plant materials

Seed of BARI cabbage-2 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.3.2 Application of treatments

Spinosad: Spinosad is an interesting tool for insect pest control. It was applied with the help of knapsack sprayer at 10 days interval.

SNPV (*Spodoptera litura* nuclear polyhedrosis virus): Application of SNPV was made with a Knapsack sprayer equipped with a single cone nozzle. The spray was applied evenly along each row of plants. Virus treatments were applied using a clean sprayer to avoid cross contamination. SNPV was applied @ 100g a.i. for one hectare using 15 liter of water and sprayed with the help of knapsack sprayer. This was applied at 7 days interval.

Spodolure: Spodolure was collected from Ispahani Agro Limited used as Lures containing sex pheromones are placed into insect trap and erected in the field at a recommended spacing. The lure will release the sex pheromone at a constant rate over a period of 2-4 weeks. Male moths are attracted and while attempting for mating, fall into a container having pesticide. Thus the female moths in the field are deprived of successful mates and fail to reproduce or lay viable eggs. Cut the polythene sheets into required size (2ft. length × 4 inch wide) and make polythene arm. Close the bottom end of the arm with rubber band to prevent the escaping of trapped insects and to flush out them. Wrap and fit the other end of polythene arm with wider end of the funnel with the help of rubber band/wire. Keep the lid of funnel one inch above mouth of the funnel. Make a small hole to place septa/ lure. Fix the trap containing lure in the field with the help of bamboo sticks keeping the lure nearly one foot above the crop canopy.

The spraying was always done in the afternoon to avoid bright sunlight to safe the foraging beneficial insects. The spray materials were applied uniformly to obtain complete coverage of whole plants of the assigned plots in 7 days interval. Caution was taken to avoid any drift of the spray mixture to the adjacent plots at the time of the spray application. At each spray application the spray mixture was freshly prepared.

3.4 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications, where the experimental area was divided into four equal blocks representing the replications to minimize the soil heterogenetic effects. Each block was divided into 6 equal unit plots demarked with raised bunds for allocating different treatments. Thus the total numbers of plots were 18. The unit plot size was 2.5 m × 2.0 m. The distance maintained between two blocks and two plots were 1.0 m and 1.0 m, respectively. The layout of the experiment is shown in Figure 1.

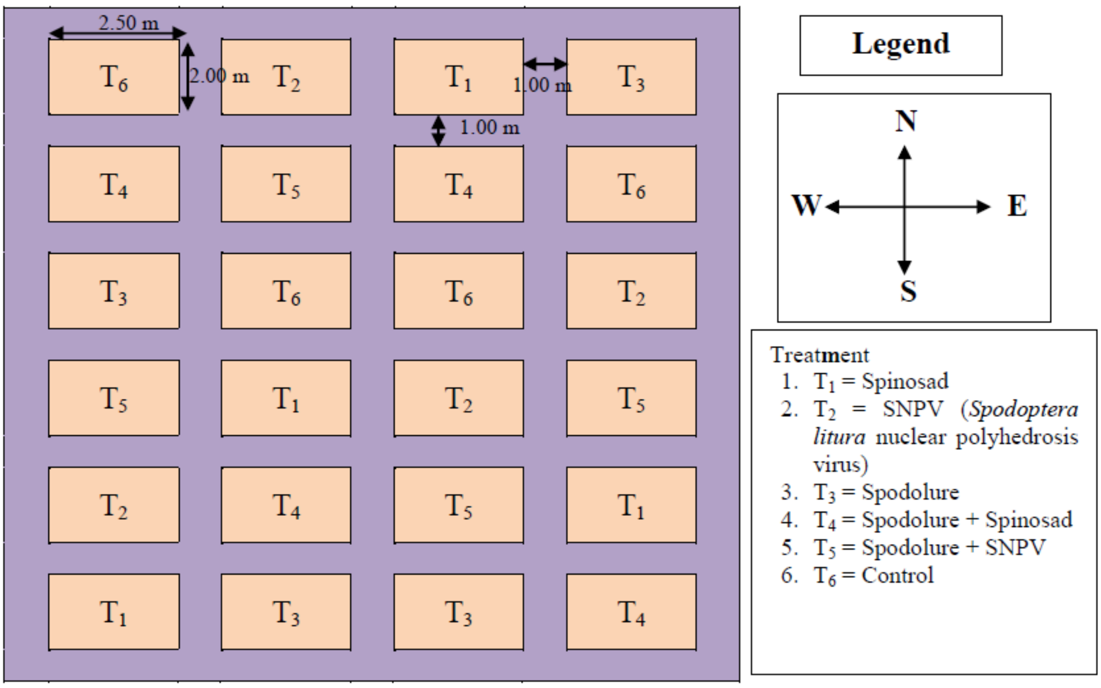

Figure 1. Layout of the experimental plot

3.5 Growing of crops

3.5.1 Raising of seedlings

Seeds were directly sown in the 15 October, 2018 in seed bed (18 cm × 12 cm) containing a mixture of equal proportion of well decomposed cowdung and irrigation of the seed bed regularly to bring moist condition for proper seed germination. After germination the seedlings were sprayed with water by a hand sprayer for easy uprooting and it was done once a day for one week.

3.5.2 Land preparation

The main plot which select for conducting the experiment was opened in the last week of October, 2018 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed accordingly. The experimental main plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated 3:3:4 were mixed with the soil of each unit plot.

3.5.3 Fertilizers and manure application

Standard dosages of cowdung and fertilizers were applied as recommended by BARI, 2018. Cowdung, urea, TSP and MoP were applied @ 10000, 350, 250 and 250 kg ha^{-1}. Full doses of cowdung and TSP were applied during final land preparation. The total amounts of urea and MoP were applied in two installments. The first half was 15 and second half at 35 days after seedling were transplanted and light irrigation was applied followed by fertilizer application.

3.5.4 Transplanting of seedling

Seedlings were placed in a shady place and were transplanted on 1 November, 2018 in the pits of each plot of the experimental field after 15 days of germination. At the time of transplanting, polyethylene bag was cut and removed carefully in order to keep the soil intact with the root of the seedling. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.6 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. The following intercultural operations were done.

3.6.1 Irrigation and drainage

Irrigation was provided to maintain moist condition in the early stages to establishment of the seedlings and then irrigated whenever necessary throughout the entire growing period. No water stress was encountered in reproductive phase.

3.6.2 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 30 DAT and 60 DAT by mechanical means.

3.7 Monitoring and data collection

The following data on different parameters were be collected as well as recorded twice in a week starting from 10 days after transplanting the seedlings from seedbed to the main field.

3.7.1 Number of healthy and infested plants

Number of healthy and infested plants were counted by visual observation during its vegetative to harvesting stage and infested plants were marked.

3.7.2 Number of healthy and infested leaves

Number of healthy and infested leaves were counted by visual observation during its vegetative to harvesting stage and infested plants were marked.

3.7.3 Harvesting

The head cabbage was first harvested on 10 February 2019 at 85 DAT. Harvesting was completed within 85-90 Days. When the plants formed compact heads, the harvested crop was done plot wise after testing the compactness of the cabbage head by hand. The compact head showed comparatively a hard feeling. Each head was cut by a sharp knife at the base of the plant.

3.7.4 Number of insect pest plant^{-1}

The data regarding insect population were recorded using sweep net, pitfall trap and direct field observation as needed. The species of different of insect pests were found in the cabbage field. The numbers of insect pest were recorded in five plants plot^{-1} and it was done by twice a week.

3.7.5 Number of healthy and infested heads

Number of healthy heads (HH) and infested heads (IH) were counted during its vegetative to harvesting stage and infested heads were marked by tagging.

3.7.6 Weight of healthy and infested heads

The weight of healthy and infested heads at harvesting stages were taken separately plot^{-1} for each treatment.

3.7.7 Yield plot^{-1}

After each harvest, the weight of total number of heads plot^{1} was recorded in each treatment.

3.7.8 Yield ha^{-1}

The yield of cabbage hectare[1] for each treatment was calculated in tons from cumulative head production in a plot.

3.7.9 Determination of plant infestation in number

From all the plants, 5 plants were randomly selected from middle rows of each plot and examined. The healthy plants were counted and the percent infested plant was calculated using the following formula:

$$\text{Plant infestation (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants}} \times 100$$

3.8 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments. The mean values of all the characters were calculated and analysis of variance was performed by using MSTAT-C software. The significance of the difference among the treatments means was estimated by the by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka during October 2018 to March 2019 to find out the succession of insect pests and natural enemies in cabbage field and the management of major insect pests by bio-pesticides. The results of the present study have been interpreted and discussed under the following sub-headings:

4.1 Occurrence of different insect pest during the cropping season

Significant variations of the occurrence of flea beetle, aphid, semi-looper, diamondback moth and tobacco caterpillar/cabbage caterpillar were observed in the field, which are interpreted and discussed on the following sub-headings:

4.1.1 Occurrence of cabbage flea beetle

Significant variation was observed on cabbage flea beetle/5 plants in number among the treatments (Figure 2). Results revealed that the lowest number of cabbage flea beetle/5 plants (0.33) was found from T_4 (Spodolure + Spinosad) treatment whereas the highest number of cabbage flea beetle/5 plants (5.28) was found from control treatment T_6. Under treated plot, the highest number of cabbage flea beetle/5 plants (3.00) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) which was statistically identical with T_1 (Spinosad).

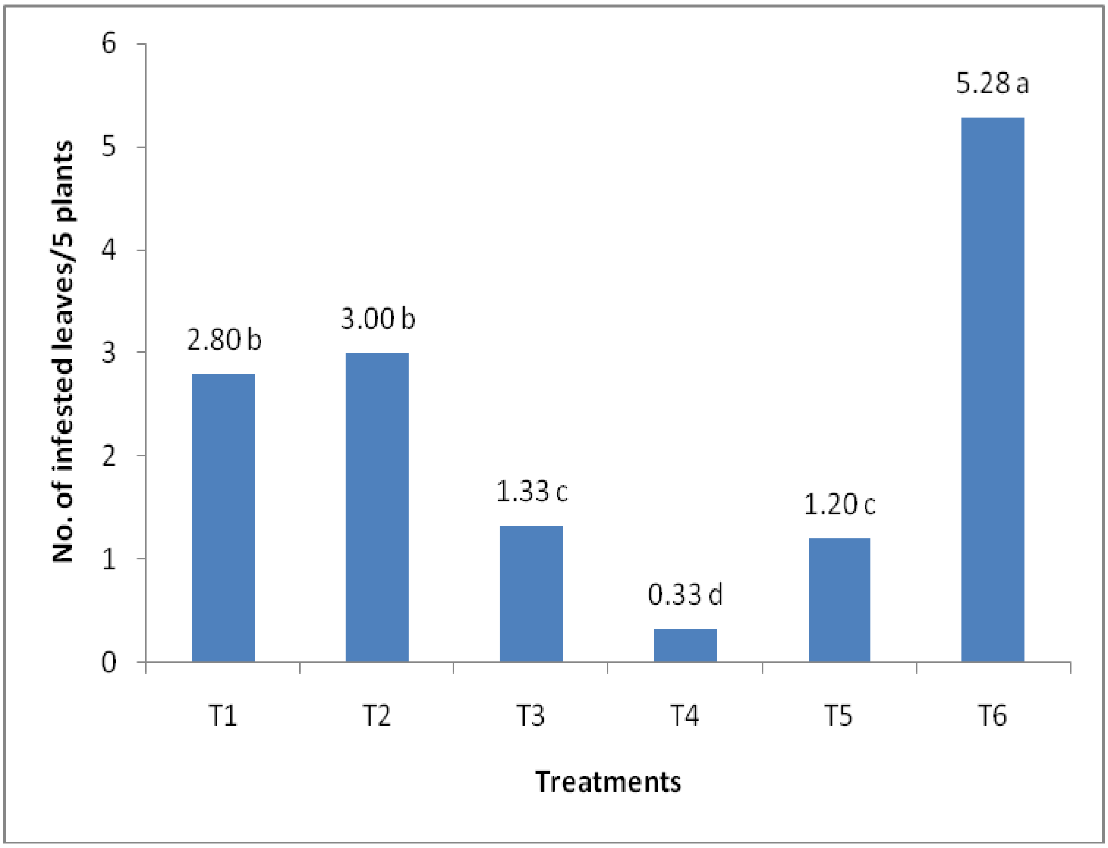

Figure 2. Effect of bio-pesticides on the leaf infestation level of cabbage by flea beetle during October 2018 to March 2019 at SAU research field, SAU, Dhaka.

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Untreated control.]

4.1.2 Occurrence of aphid

Significant variation was observed on number of aphids/5 plants among the treatments (Figure 3). Results revealed that the lowest number of aphid/5 plants (7.50) was found from T_4 (Spodolure + Spinosad) treatment whereas the highest number of aphid/5 plants (26.44) was found from control treatment T_6. Under treated plot, the highest number of aphid/5 plants (23.60) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) which was statistically identical with T_1 (Spinosad).

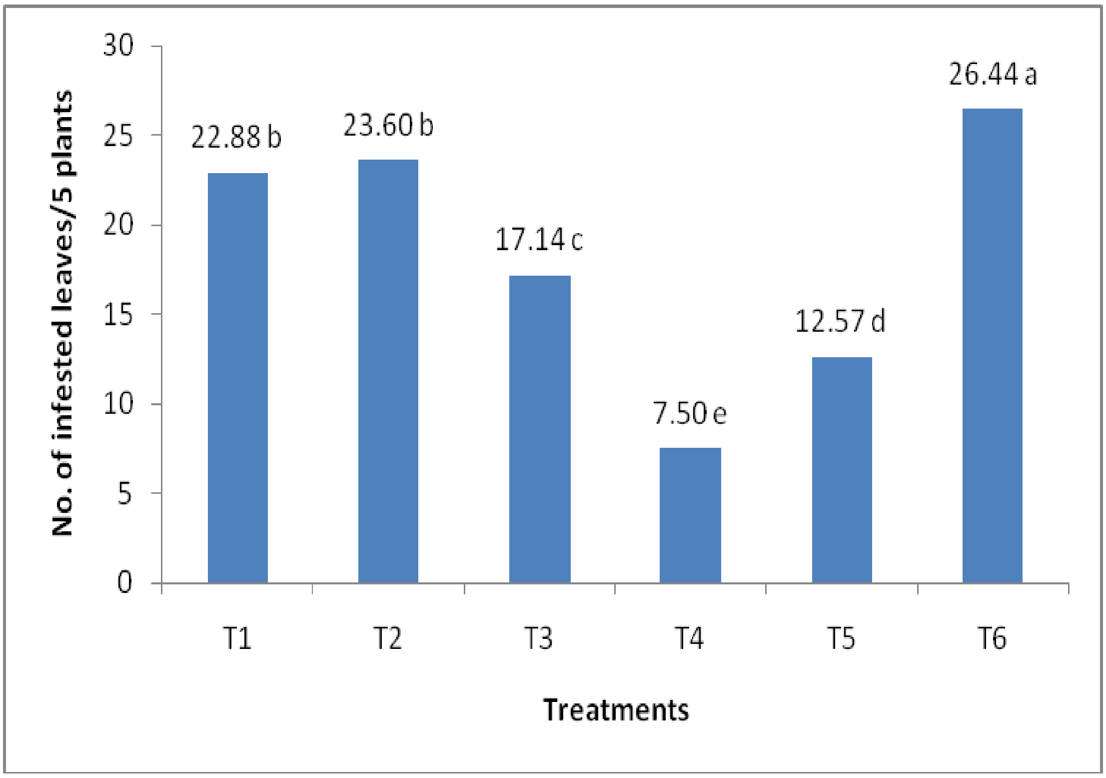

Figure 3. Effect of bio-pesticides on the leaf infestation level of cabbage by aphid during October 2018 to March 2019 at SAU research field, SAU, Dhaka

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Untreated control]

4.1.3 Occurrence of semi-looper

Significant variation was observed on semi-looper/5 plants in number among the treatments (Figure 4). Results revealed that the lowest number of semi-looper/5 plants (0.33) was found from T_4 (Spodolure + Spinosad) treatment whereas the highest number of semi-looper/5 plants (4.36) was found from control treatment T_6. Under treated plot, the highest number of semi-looper/5 plants (2.50) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) which was statistically identical with T_1 (Spinosad) and T_3 (Spodolure).

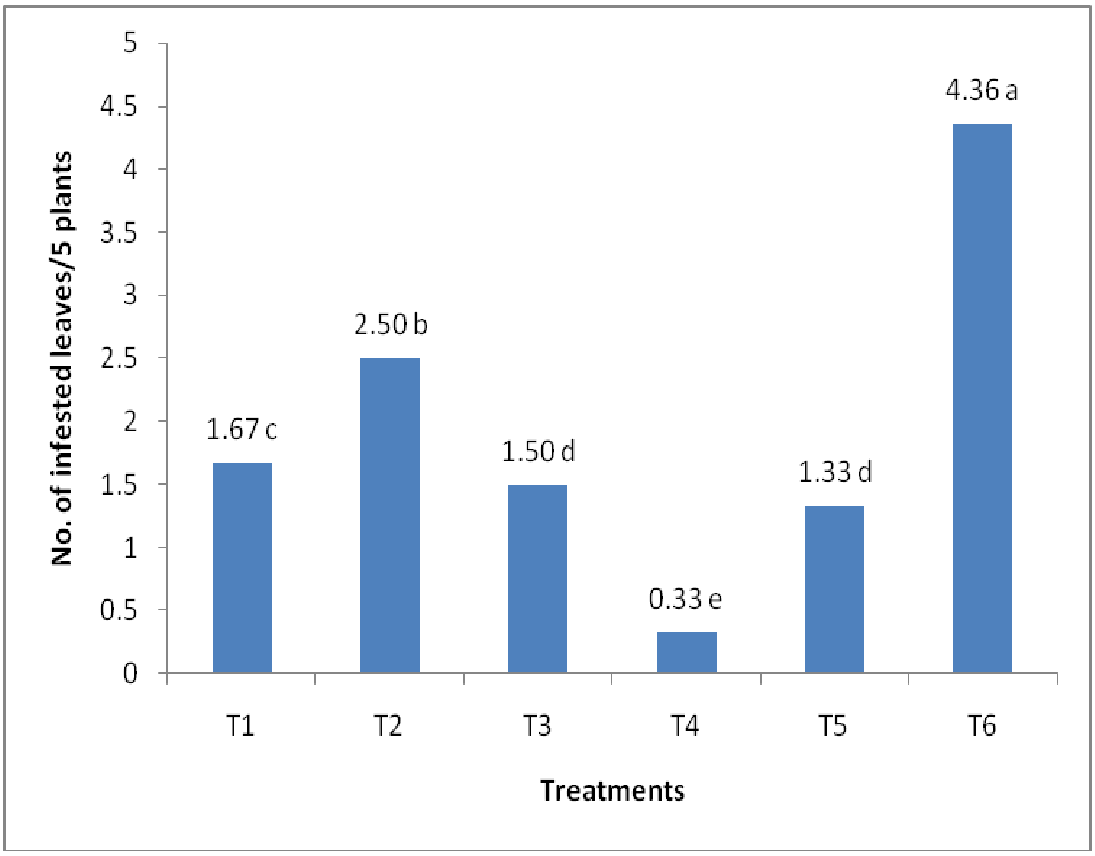

Figure 4. Effect of bio-pesticides on the leaf infestation level of cabbage by semi-looper during October 2018 to March 2019 at SAU research field, SAU, Dhaka

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Untreated control]

4.1.4 Occurrence of diamondback moth

Significant variation was observed on diamondback moth/5 plants in number among the treatments (Figure 5). Results revealed that the lowest number of diamondback moth/5 plants (1.33) was found from T_4 (Spodolure + Spinosad) treatment whereas the highest number of diamondback moth/5 plants (6.33) was found from control treatment T_6. Under treated plot, the highest number of diamondback moth/5 plants (4.00) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus).

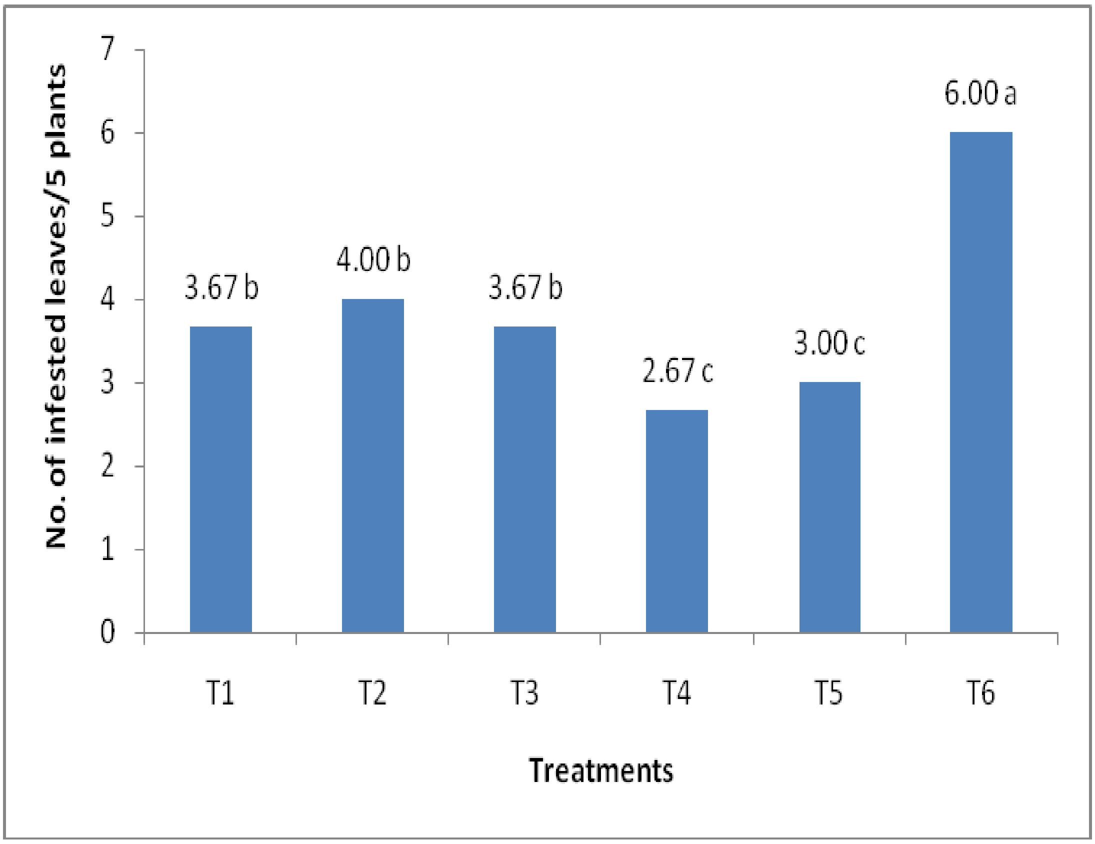

Figure 5. Effect of bio-pesticides on the leaf infestation level of cabbage by diamond backed moth during October 2018 to March 2019 at SAU research field, SAU, Dhaka

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Untreated control]

4.1.5 Occurrence of tobacco caterpillar

Significant variation was observed on number of larva of tobacco caterpillar/5 plants among the treatments (Figure 6). Results revealed that the lowest number of tobacco caterpillar (0.33) was found from T_4 (Spodolure + Spinosad) treatment whereas the highest number of tobacco caterpillar (5.28) was found from control treatment T_6. Under treated plot, the highest number of tobacco caterpillar (3.00) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) which was statistically identical with T_1 (Spinosad).

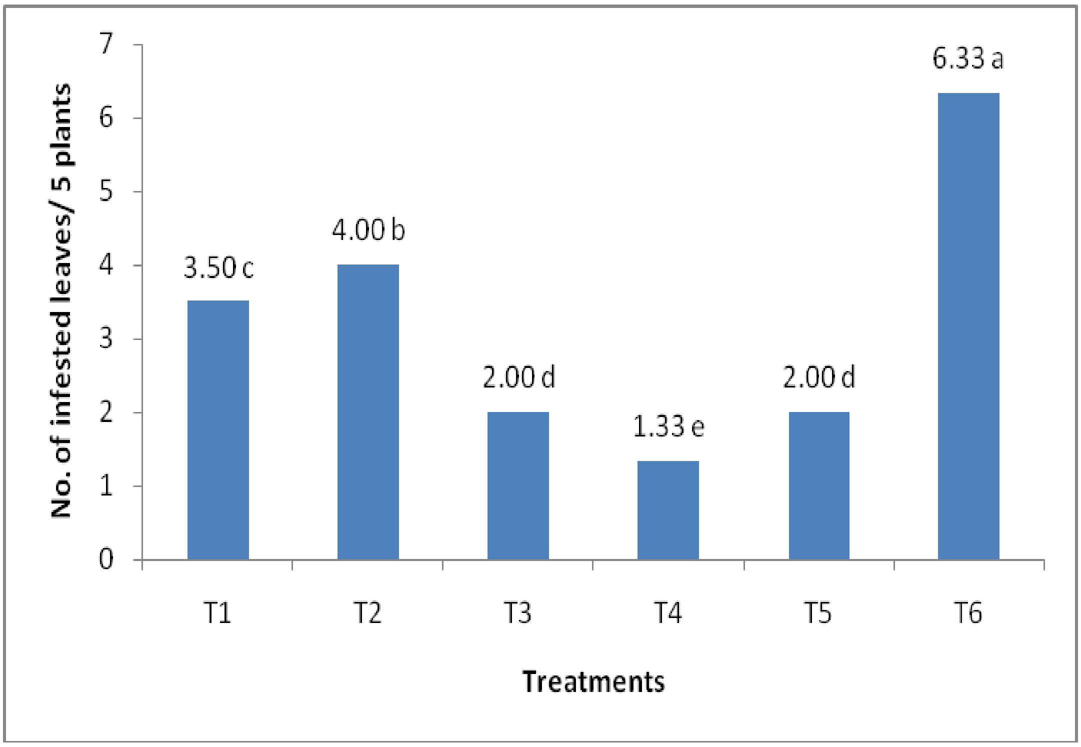

Figure 6. Effect of bio-pesticides on the leaf infestation level of cabbage by tobacco cater pillar during October 2018 to March 2019 at SAU research field, SAU, Dhaka

T_1 = Spinosad, T_2 = SNPV (*Spodoptera litura* nuclear polyhedrosis virus), T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control

4.2 Incidence of lady bird beetle and spider

4.2.1 Incidence of lady bird beetle

Significant variation was observed on lady bird beetle/5 plants in number among the treatments (Figure 7). Results revealed that the highest number of lady bird beetle/5 plants (8.00) was found from T_4 (Spodolure + Spinosad) treatment whereas the lowest number of lady bird beetle/5 plants (6.50) was found from control treatment T_6. Under treated plot, the lowest number of lady bird beetle/5 plants (6.75) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) which was statistically identical with T_1 (Spinosad).

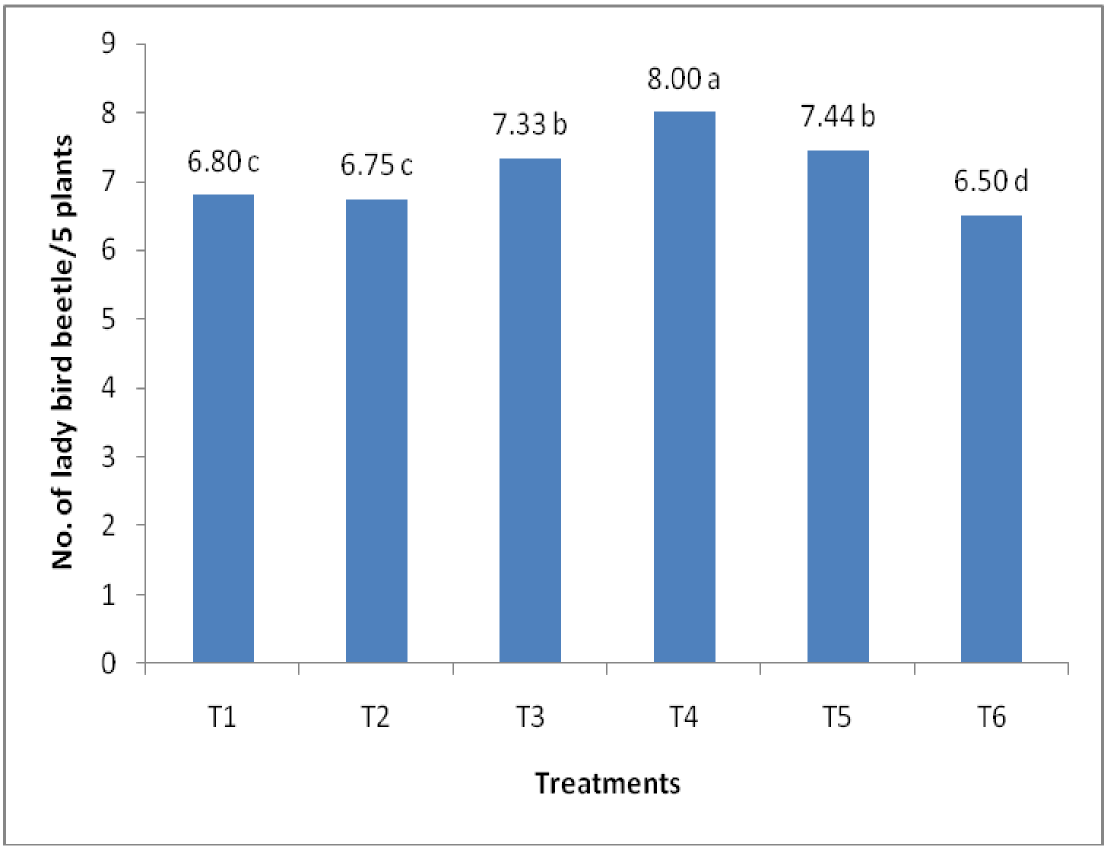

Figure 7. Effect of bio-pesticides on the abundance of lady bird beetle per 5 plants in cabbage field during October 2018 to March 2019 at SAU research field, SAU, Dhaka

T_1 = Spinosad, T_2 = SNPV (*Spodoptera litura* nuclear polyhedrosis virus), T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control

4.2.2 Incidence of spider

Significant variation was observed on number of spider/5 plants among the treatments (Figure 8). Results revealed that the highest number of spider/5 plants (8.60) was found from T_4 (Spodolure + Spinosad) treatment whereas the lowest number of spider/5 plants (6.80) was found from control treatment T_6. Under treated plot, the lowest number of spider/5 plants (7.48) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) which was statistically identical with T_1 (Spinosad).

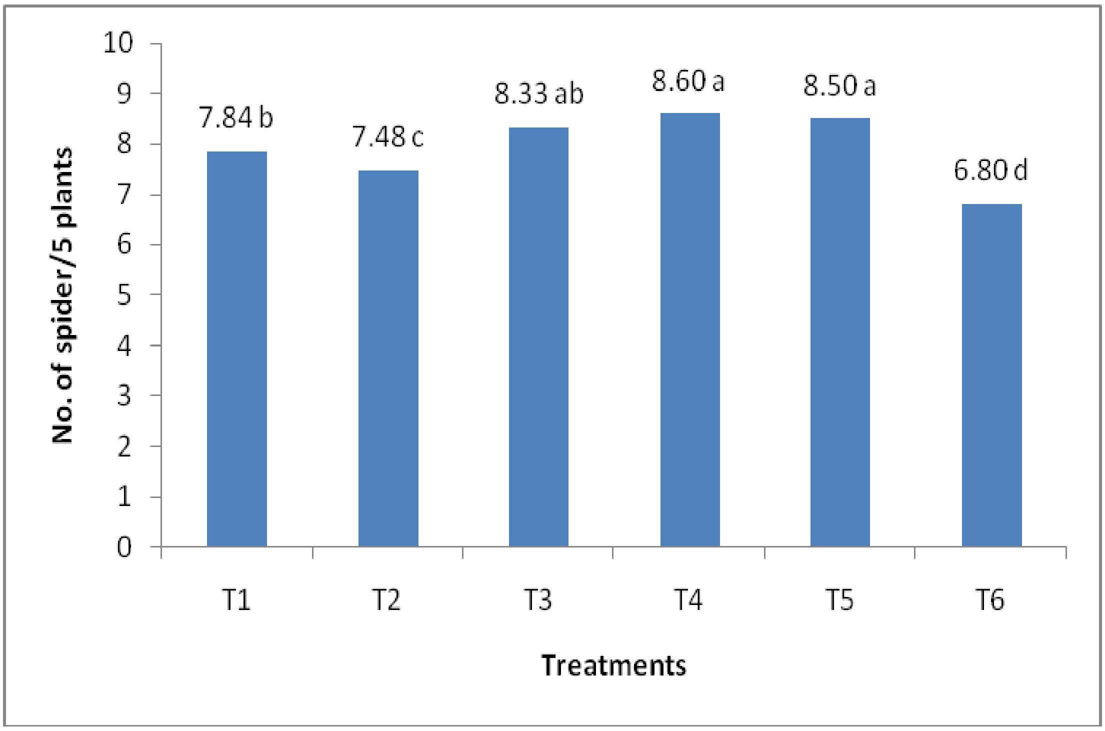

Figure 8. Effect of bio-pesticides on the abundance of spider per 5 plants in cabbage field during October 2018 to March 2019 at SAU research field, SAU, Dhaka

T_1 = Spinosad, T_2 = SNPV (*Spodoptera litura* nuclear polyhedrosis virus), T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control

4.3 Effect of biopesticides on yield parameters and yield of cabbage

4.3.1 Effect on healthy and infested plants plot^{-1}

Different treatments on percent number of healthy plants showed significant variation at different days of crop duration (Table 1). Results indicated that the highest percent number of healthy plants (100, 97.22, 94.44, 93.06 and 91.67% at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_4 (Spodolure + Spinosad) treatment the lowest percent number of healthy plants (90.28, 79.17, 69.44, 59.72 and 52.78% at 30, 50, 70, 90 DAT and at harvest, respectively) was found in control treatment T_6. But under treated plants the lowest percent number of healthy plants (91.67, 84.72, 77.7, 73.61 and 70.83%

at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment which was statistically identical with T_1 (Spinosad) at the time of harvest.

Table 1. Percent healthy cabbage plants at different days after transplanting affected by bio-pesticides during October 2018 to March 2019 at SAU research field, SAU, Dhaka

Treatments	Percent healthy plants				
	30 DAT	**50 DAT**	**70 DAT**	**90 DAT**	**At harvest**
T_1	93.06 bc	86.11 c	79.17 c	76.39 cd	73.61 d
T_2	91.67 c	84.72 c	77.78 c	73.61 d	70.83 d
T_3	94.44 bc	87.50 bc	81.94 c	79.17 c	77.78 c
T_4	100.00 a	97.22 a	94.44 a	93.06 a	91.67 a
T_5	97.22 ab	90.28 b	87.50 b	86.11 b	81.94 b
T_6	90.28 c	79.17 d	69.44 d	59.72 e	52.78 e
LSD	**0.76**	**0.73**	**0.79**	**0.63**	**0.72**
CV (%)	**4.97**	**7.07**	**6.52**	**9.57**	**8.98**

In a column, means followed by same latter(s) are not differ significantly at 5% level by DMRT. DAT= Days After Transplanting.

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control]

Different treatments on percent number of infested plants showed significant variation at different days of crop duration (Table 2). Results indicated that the lowest percent number of infested plants (0, 2.78, 5.56, 6.94 and 8.33% at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_4 (Spodolure + Spinosad) treatment the highest percent number of infested plants (9.72, 20.83, 30.56, 40.28 and 47.22% at 30, 50, 70, 90 DAT and at harvest, respectively) was found in control treatment T_6. Under treated plants the highest percent number of infested plants (8.33, 15.28, 22.22, 26.39 and 29.17% at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment which was statistically identical with T_1 (Spinosad) at the time of harvest.

Table 2. Percent infested cabbage plants at different days after transplanting affected by bio-pesticides during October 2018 to March 2019 at SAU research field, SAU, Dhaka

Treatments	**Percent infested plants**				
	30 DAT	**50 DAT**	**70 DAT**	**90 DAT**	**At harvest**
T_1	6.94 bc	13.89 b	20.83 b	23.61 bc	26.39 b
T_2	8.33 ab	15.28 b	22.22 b	26.39 b	29.17 b
T_3	5.56 c	12.50 bc	18.06 b	20.83 c	22.22 c
T_4	0.00 e	2.78 d	5.56 d	6.94 e	8.33 e
T_5	2.78 d	9.72 c	12.50 c	13.89d	18.06 d
T_6	9.72 a	20.83 a	30.56 a	40.28 a	47.22 a
LSD	**0.36**	**0.73**	**0.79**	**0.63**	**0.72**
CV(%)	**8.55**	**6.47**	**9.93**	**10.57**	**7.37**

In a column, means followed by same latter(s) are not differ significantly at 5% level by DMRT. DAT= Days After Transplanting.

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control]

4.3.2 Management of major insect regarding healthy leaves plant^{-1}

At 30 DAT, no significant variation was found on number of healthy leaves plant^{-1} (Table 3). But at 50, 70, 90 DAT and at harvest, significant variation was found due to different management practices against insect pest of cabbage (Table 4). Results revealed that the highest number of healthy leaves plant^{-1} (14.36, 18.99, 20.70, 19.88 and 17.35 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_4 (Spodolure + Spinosad) treatment. The lowest number of healthy leaves plant^{-1} (13.48, 14.90, 15.40, 14.63 and 12.68 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in control treatment T_6. But under treated plants the lowest number of healthy leaves plant^{-1} (13.85, 16.05, 16.85, 16.13 and 14.23 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

Table 3. Management of major insect pest by bio-pesticides on number of healthy leaves plant^{-1} of cabbage during October 2018 to March 2019 at SAU research field, SAU, Dhaka

Treatments	**Number of healthy leaves plant^{-1}**				
	30 DAT	**50 DAT**	**70 DAT**	**90 DAT**	**At harvest**
T_1	13.73	16.48 d	17.58 d	17.04 d	14.98 c
T_2	13.85	16.05 d	16.85 e	16.13 e	14.23 d
T_3	13.55	17.17 c	18.35 c	17.92 c	15.43 c
T_4	14.36	18.99 a	20.70 a	19.88 a	17.35 a
T_5	14.25	18.10 b	19.33 b	18.90 b	16.27 b
T_6	13.48	14.90 e	15.40 f	14.63 f	12.68 e
LSD	**1.72^{NS}**	**0.63**	**0.53**	**0.57**	**0.58**
CV(%)	**3.98**	**8.45**	**6.93**	**7.18**	**9.54**

In a column, means followed by same latter(s) are not differ significantly at 5% level by DMRT. DAT= Days after transplanting.

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control]

4.3.3 Management of major insect regarding infested leaves plant^{-1}

At 30, 50, 70, 90 DAT and at harvest, significant variation was found number of infested leaves plant^{-1} due to different management practices against insect pest of cabbage (Table 4). Results showed that the lowest number of infested leaves plant^{-1} (0.88, 1.05, 1.70, 2.18 and 2.63 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_4 (Spodolure + Spinosad) treatment. the highest number of infested leaves plant^{-1} (3.43, 4.10, 4.63, 5.38 and 6.38 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in control treatment T_6. But under treated plants the highest number of infested leaves plant^{-1} (2.80, 3.25, 3.50, 4.25 and 4.75 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

Table 4. Management of major insect pest by bio-pesticides on number of infested leaves plant^{-1} of cabbage during October 2018 to March 2019 at SAU research field, SAU, Dhaka

Treatments	**Number of infested leaves plant^{-1}**				
	30 DAT	**50 DAT**	**70 DAT**	**90 DAT**	**At harvest**
T_1	2.40 bc	2.75 bc	3.05 bc	3.50 c	3.88 c
T_2	2.80 ab	3.25 b	3.50 b	4.25 b	4.75 b
T_3	1.80 cd	2.43 cd	2.87 cd	3.25 cd	3.63 cd
T_4	0.88 e	1.05 e	1.70 e	2.18 e	2.63 e
T_5	1.55 de	2.03 d	2.38 d	2.75 d	3.25 d
T_6	3.43 a	4.10 a	4.63 a	5.38 a	6.38 a
LSD	**0.75**	**0.62**	**0.61**	**0.56**	**0.46**
CV(%)	**4.41**	**7.84**	**8.25**	**10.48**	**7.53**

In a column, means followed by same latter(s) are not differ significantly at 5% level by DMRT. DAT= Days After Transplanting.

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control]

4.4 Management of major insect regarding yield performance

4.4.1 Weight of healthy cabbage head plant^{-1}

Different treatments on weight of healthy cabbage head plant^{-1} showed significant variation (Table 5). Results indicated that the highest healthy cabbage head plant^{-1} (1.20 kg) was found in T_4 (Spodolure + Spinosad) treatment. the lowest healthy cabbage head plant^{-1} (0.88 kg) was found in control treatment $T_{6.}$ But under treated plants the lowest healthy cabbage head plant^{-1} (0.97 kg) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment which was statistically similar with T_1 (Spinosad).

In terms of % increase of healthy head weight plant^{-1} over control, the highest % increase (36.36%) was found in T_4 (Spodolure + Spinosad) whereas the lowest % increase (10.23%) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

4.4.2 Weight of infested cabbage head plant^{-1}

Different treatments on weight of infested cabbage head plant^{-1} showed significant influence (Table 5). Results indicated that the lowest infested cabbage head plant^{-1} (0.52 kg) was found in T_4 (Spodolure + Spinosad) treatment which was significantly different from other treatment. The highest infested cabbage head plant^{-1} (0.92 kg) was found in control treatment T_6 whereas under treated plants the highest infested cabbage head plant^{-1} (0.66 kg) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

In terms of % decrease of infested head weight plant^{-1} over control, the highest % decrease (43.48%) was found in T_4 (Spodolure + Spinosad) followed by T_5 (Spodolure + SNPV) whereas the lowest % decrease (28.26) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

4.4.3 Marketable cabbage head plot^{-1}

Different treatments on marketable cabbage head plot^{-1} (kg) showed significant variation (Table 5). Results indicated that the highest marketable cabbage head plot^{-1} (19.48 kg) was found in T_4 (Spodolure + Spinosad) treatment. The lowest marketable cabbage head plot^{-1} (8.30 kg) was found in control treatment T_6. but under treated plants the lowest marketable cabbage head plot^{-1} (12.34 kg) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment. Different treatments on marketable cabbage head ha^{-1} (kg) showed significant variation (Table 5). Results indicated that the highest marketable cabbage head ha^{-1} (45.08 t) was found in T_4 (Spodolure + Spinosad) treatment whereas the lowest marketable cabbage head ha^{-1} (19.24 t) was found in control treatment

T_6. but under treated plants the lowest marketable cabbage head ha^{-1} (28.57 t) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

4.4.4 Marketable cabbage head ha^{-1}

Different treatments on marketable cabbage head ha^{-1} (kg) showed significant variation (Table 5). Results indicated that the highest marketable cabbage head ha^{-1} (45.08 t) was found in T_4 (Spodolure + Spinosad) treatment whereas the lowest marketable cabbage head ha^{-1} (19.24 t) was found in control treatment T_6. but under treated plants the lowest marketable cabbage head ha^{-1} (28.57 t) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

Table 5. Management of major insect pest by bio-pesticides on yield parameters of cabbage during October 2018 to March 2019 at SAU research field, SAU, Dhaka

Treatment	**Yield parameters**					
	Weight of healthy cabbage head/plant (kg)	**Percent increase of healthy head plant^{-1} over control**	**Weight of infested cabbage head/plant (kg)**	**Percent decrease of infested head plant^{-1} over control**	**Cabbage yield/plot (Marketable) (kg)**	**Cabbage yield/ha (Marketable) (t)**
T_1	1.03 bc	17.05	0.80 b	13.04	13.68 d	31.65 d
T_2	0.97 cd	10.23	0.66 c	28.26	12.34 e	28.57 e
T_3	1.10 ab	25.00	0.60 d	34.78	15.35 c	35.54 c
T_4	1.20 a	36.36	0.52 e	43.48	19.48 a	45.09 a
T_5	1.18 a	17.05	0.55 e	40.22	17.38 b	40.23 b
T_6	0.88 d	--	0.92 a	--	8.31 f	19.24 f
LSD	**0.12**	**--**	**0.05**	**--**	**1.29**	**2.99**
CV(%)	**7.49**	**--**	**8.94**	**--**	**5.94**	**6.94**

In a column, means followed by same latter(s) are not differ significantly at 5% level by DMRT. DAT= Days After Transplanting.

[T_1 = Spinosad, T_2 = SNPV, T_3 = Spodolure, T_4 = Spodolure + Spinosad, T_5 = Spodolure + SNPV, T_6 = Control]

CHAPTER V

SUMMARY AND CONCLUSION

The current study was carried out with six treatments namely T_1= Spinosad, T_2= SNPV (*Spodoptera litura* nuclear polyhedrosis virus), T_3= Spodolure trap, T_4= Spodolure + Spinosad, T_5= Spodolure + SNPV and T_6 untreated control.

There were five insect pests *viz*. flea beetle, aphid, semi-looper, diamondback moth and cabbage caterpillar/tobacco caterpillar identified in the field. Regarding, occurrence of insect pest, the lowest number of cabbage flea beetle (0.33/ 5 plants), Semi-looper (0.33/ 5 plants), Tobacco cutworm (0.33/ 5 plants) Diamondback moth (1.33/ 5 plants) and Aphid (7.50 / 5 plants) was found from T_4 (Spodolure + Spinosad) whereas the highest number of cabbage Semi-looper (4.36), flea beetle (5.28), Tobacco cutworm (5.28), Diamondback moth (6.33) Aphid (26.44), number was found from control treatment T_6. Under treated plot, the highest number of Semi-looper (2.50), flea beetle (3.00), Tobacco caterpillar (4.00), Diamondback moth (4.00) and Aphid (23.60) were found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

It was found that the highest percent (%) number of healthy plants (100, 97.22, 94.44, 93.06 and 91.67% at 30, 50, 70, 90 DAT and at harvest, respectively) and highest number of healthy leaves plant^{-1} (14.36, 18.99, 20.70, 19.88 and 17.35 at 30, 50, 70, 90 DAT and at harvest, respectively) were found in T_4 (Spodolure trap + Spinosad) treatment whereas the lowest percent (%) number of infested plants (0, 2.78, 5.56, 6.94 and 8.33% at 30, 50, 70, 90 DAT and at harvest, respectively) and lowest number of infested leaves plant^{-1} (0.88, 1.05, 1.70, 2.18 and 2.63 at 30, 50, 70, 90 DAT and at harvest, respectively) was also found in T_4 (Spodolure trap + Spinosad) treatment. On the other hand, the lowest percent (%) number of healthy plants (90.28, 79.17, 69.44, 59.72 and 52.78% at 30, 50, 70, 90 DAT and at harvest, respectively) and lowest number of healthy leaves plant^{-1} (13.48, 14.90, 15.40, 14.63 and 12.68 at 30, 50, 70, 90 DAT and at harvest, respectively) were observed found in control treatment T_6 whereas the highest percent (%) number of infested plants (9.72, 20.83, 30.56, 40.28 and 47.22% at 30, 50, 70, 90 DAT and at harvest, respectively) and highest number of infested leaves plant^{-1} (3.43, 4.10, 4.63, 5.38 and 6.38 at 30, 50, 70, 90 DAT and at harvest, respectively) were also found in control treatment T_6.

In case of incidence of natural enemies, the highest number of lady bird beetle (8.00) and number of spider (8.60) was found from T_4 (Spodolure + Spinosad) treatment whereas the lowest number of lady bird beetle (6.75) and number of spider (7.48) was found from control treatment T_6. The lowest number of lady bird beetle (6.50) and spider (6.80) was found from T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment.

In terms of yield performance, the highest weight of healthy head (1.20 kg), marketable healthy weight of cabbage head plot^{-1} (19.48 kg) and highest marketable yield of cabbage head (45.08 t ha^{-1}) was found in T_4 (Spodolure + Spinosad) treatment . On the other hand, the lowest weight of healthy head (0.88 kg), marketable healthy weight of cabbage head plot^{-1} (8.30 kg) and lowest marketable yield of cabbage head (19.24 t) was found in control treatment T_6.

But under treated plants, the lowest percent (%) number of healthy plants (91.67, 84.72, 77.7, 73.61 and 70.83% at 30, 50, 70, 90 DAT and at harvest, respectively) and lowest number of healthy leaves plant^{-1} (13.85, 16.05, 16.85, 16.13 and 14.23 at 30, 50, 70, 90 DAT and at harvest, respectively) was found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment whereas the highest percent (%) number of infested plants (8.33, 15.28, 22.22, 26.39 and 29.17% at 30, 50, 70, 90 DAT and at harvest, respectively) and highest number of infested leaves plant^{-1} (2.80, 3.25, 3.50, 4.25 and 4.75 at 30, 50, 70, 90 DAT and at harvest, respectively) were also found in T_2 (SNPV; *Spodoptera* *litura* nuclear polyhedrosis virus) treatment. Again, under treated plants, the lowest healthy cabbage head plant^{-1} (0.97 kg) marketable cabbage head plot^{-1} (12.34 kg) and marketable cabbage head ha^{-1} (28.57 t) were found in T_2 (SNPV; *Spodoptera litura* nuclear polyhedrosis virus) treatment and highest infested cabbage head plant^{-1} (0.66 kg) was also found in T_2.

From the above findings it can be concluded that the treatment, T_4 (Spodolure + Spinosad) showed the best performance against insect pest of cabbage and the highest healthy cabbage yield also found from this treatment. So, this treatment [T_4 (Spodolure + Spinosad)] can be considered as best among the treatments.

Further experiment can be conducted at different AEZ (Agro Ecological Zone) of Bangladesh regarding different bio-pesticides application against insect pest of cabbage and also healthy yield of cabbage for building final recommendations.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

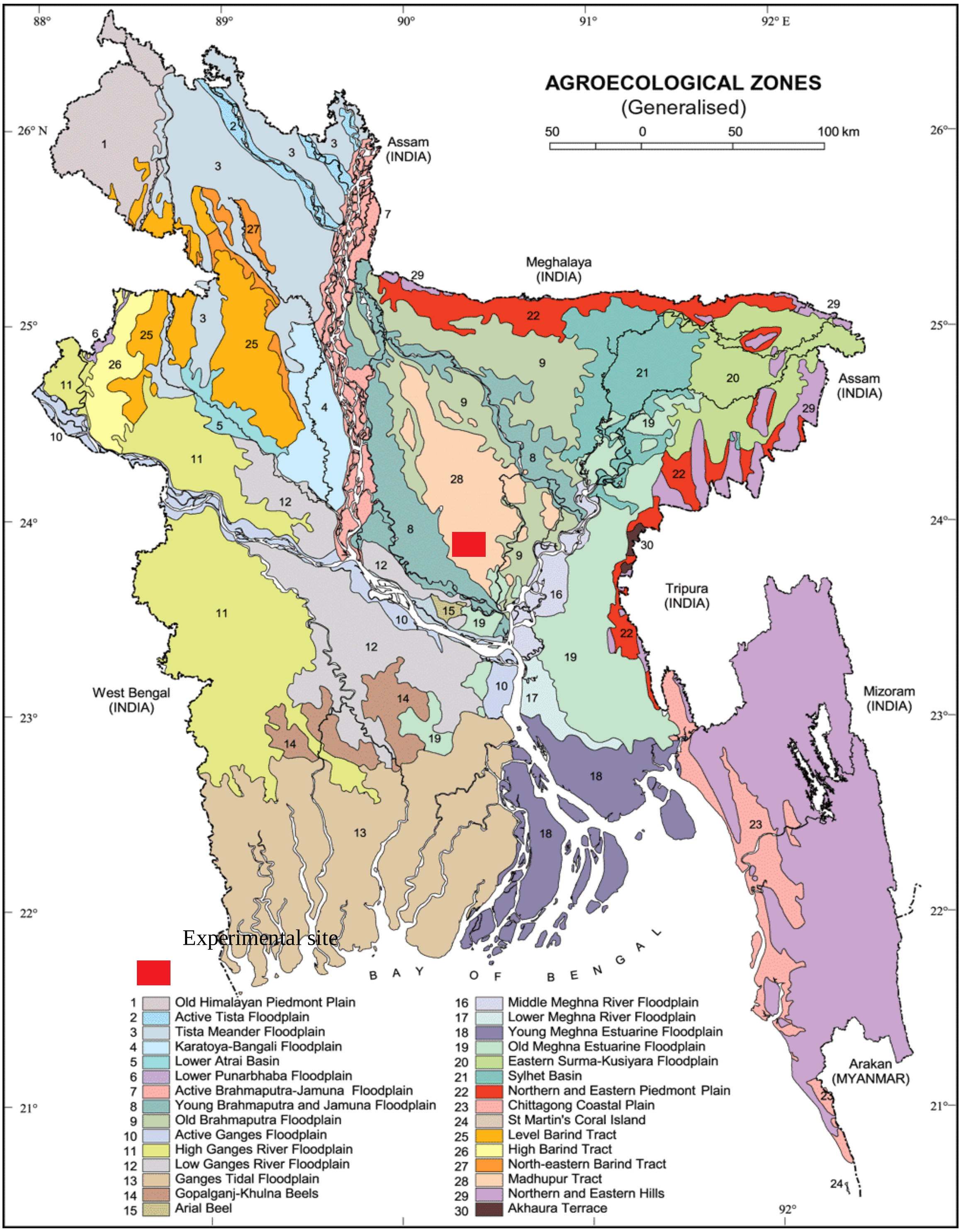

Fig. 9. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from January 2018 to December 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	October	30.42	16.24	23.33	68.48	52.60
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	37.90	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
Ph	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Incidence of insect pest by number in cabbage field affect by different management practices

Sources	df	Mean square of average incidence of insect pest in cabbage field				
		Flea beetle	Aphid	Semi-looper	Diamondback moth	Tobacco cutworm
Replication	2	0.056	0.103	0.014	0.117	0.046
Factor A	5	14.25**	48.64*	26.32*	16.43*	21.66*
Error	10	0.402	0.614	0.136	0.247	0.324

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Incidence of natural enemies in cabbage field affect by different management practices

Sources	df	Mean square of average incidence of natural enemies in cabbage field	
		Lady bird beetle	Spider
Replication	2	0.523	0.614
Factor A	5	11.36*	13.28*
Error	10	1.042	1.136

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Management of major insect pest by bio-pesticides on percent (%) number of healthy plants plot^{-1} in cabbage

Sources	df	Mean square of percent (%) number of healthy plants				
		30 DAT	50 DAT	70 DAT	90 DAT	At harvest
Replication	2	0.551	1.169	1.041	1.377	0.267
Factor A	5	1.702**	4.710*	9.552*	16.88*	21.96*
Error	10	0.263	0.234	0.274	0.176	0.234

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Management of major insect pest by bio-pesticides on percent (%) number of infested plants plot^{-1} in cabbage

Sources	df	Mean square of percent (%) number of infested plants				
		30 DAT	50 DAT	70 DAT	90 DAT	At harvest
Replication	2	0.556	1.167	1.042	1.375	0.264
Factor A	5	1.700**	4.703*	9.542*	16.84*	21.94*
Error	10	0.256	0.233	0.275	0.175	0.231

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Management of major insect pest by bio-pesticides on number of healthy leaves plant^{-1} of cabbage

Sources	df	Mean square of number of healthy leaves plant^{-1}				
		30 DAT	50 DAT	70 DAT	90 DAT	At harvest
Replication	2	0.984	0.563	2.617	3.503	1.844
Factor A	5	0.533**	8.610**	13.94*	14.48*	10.55*
Error	10	0.305	0.173	0.122	0.144	0.148

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Management of major insect pest by bio-pesticides on number of infested leaves plant^{-1} of cabbage

Sources	df	Mean square of number of infested leaves plant^{-1}				
		30 DAT	50 DAT	70 DAT	90 DAT	At harvest
Replication	2	5.145	3.420	1.747	1.543	0.944
Factor A	5	3.375**	4.367**	3.989*	5.155*	7.017*
Error	10	0.251	0.170	0.062	0.138	0.094

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Management of major insect pest by bio-pesticides on yield parameters of cabbage

Sources	Df	Mean square of yield parameters			
		Weight of healthy cabbage head/plant	Weight of infested cabbage head/plant	Cabbage yield/plot (Marketable)	Cabbage yield/ha (Marketable)
Replication	2	0.004	0.002	1.010	5.398
Factor A	5	0.059**	0.082**	61.92*	331.90*
Error	10	0.006	0.001	0.733	3.928

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level