EFFECTIVENESS OF SOME BIOPESTICIDES IN MANAGING MAJOR LEPIDOPTERAN INSECT PESTS OF CABBAGE

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CERTIFICATE

*This is to certify that the thesis entitled, "**EFFECTIVENESS OF SOME BIOPESTICIDES IN MANAGING MAJOR LEPIDOPTERAN INSECT PESTS OF CABBAGE**" submitted to the* **Faculty of Agriculture**, *Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **Md. Masudunnabi Choyon**, Registration No. **18-09223** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

December, 2020
Dhaka, Bangladesh

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2019 to January, 2020 to evaluate some biopesticides applied against major insect pests of cabbage. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Seven treatments, viz. T_1 (Abamectin 1.2EC @ 1 ml/L of water at 7 days interval); T_2 (Azadirachtin 1EC @ 1 ml/L of water at 7 days interval); T_3 (Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval); T_4 (Spinosad 45SC @ 1 ml/L of water at 7 days interval); T_5 (*Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval); T_6 (Abamectin + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval) and T_7 (untreated control) were used. Among the management practices, the lowest mean infestation of cabbage leaf by cabbage caterpillar (6.00 leaves/5 plants) and diamond back moth larvae (4.48 leaves/5 plants) was found in T_4 treated plot that reduced the highest leaf infestation over control (62.02% and 49.85 % respectively); whereas the highest infestation by cabbage caterpillar (15.80 leaves/5 plants) and diamond back moth larvae (8.93 leaves/5 plants) was found in un treated plot (T_7). The lowest mean incidence of cabbage caterpillar (6.82 larvae/5 plants) and diamondback moth (4.87 larvae/5 plants) was found in T_4 that reduced highest incidence over control (50.33% and 51.90% respectively); whereas the highest values of all these parameters were achieved from untreated control treatment (T_7).The lowest cabbage head infestation (21.37%) was recorded in T_4, that gave the highest yield of cabbage (36.40 t/ha) followed by T_1 (34.07 t/ha). From the above study it was found that , the treatment T_4 comprised of Spinosad 45SC @ 1 ml/L of water at 7 days interval gave the highest performance compared to all other treatments used under the present study.

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ABBREVIATIONS AND ACRONYMS

Abbreviation		Acronyms
%	=	Parcentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAT	=	Days After Transplanting
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
RCBD	=	Randomized Complete Block Design
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Mili gram
ml	=	Mili Litre
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
µg	=	Microgram

CHAPTER I

INTRODUCTION

Cabbage, *Brassica oleracea var. capitata* L., is one of the most common winter vegetable crop grown from seed locally called as ‘Bhadha Kopi’ or ‘Pata Kopi’ in Bangladesh. It is widely grown in tropical and temperate regions of the world (Sarker *et al.*, 2002). It is also a well-known and widely distributed crop within Asia and has been introduced successfully into parts of Central America, West Africa, America, Canada and Europe (Talekar and Selleck, 1982).

Vegetable production in Bangladesh is very low as compare to the actual requirements. In 2018-2019, total vegetable (summer and winter season) production area was 434 thousand ha with total production of 4.32 million tons (BBS, 2019).

Cabbage is one of the five leading vegetables in the country which belong to the Cruciferae family. In 2018-2019, 2320 thousand metric tons of cabbage was produced in 19008 ha of land, which ranked fifth among the vegetables produced in the country (BBS, 2019). In our country the consumption rate of vegetables is 33 kg/head/yr. but in developed countries it is 7-8 times higher (FAO, 2015).

Cabbage can play an important role to fulfill the nutritional status of Bangladesh. It is full of vitamins such as vitamin K and C and the dietary fibres and full of potassium and manganese (Norman and shealy, 2007) and it has antioxidant and anti-inflammatory properties (Steinbrecher and Linseisen 2009) in the body of human being. Moreover, it has detoxifying effect due to its high Sulphur and vitamin C contents (Kusznierewicz *et al.,* 2008).

Also, it is a rich source of vitamins A and C (Prabhakar and Srinivas, 1990, Rashid, 1993 and Tiwari *et al.*, 2003). Cabbage is commonly used all over the world and can be prepared in a number of ways for eating and most frequently, it is included as either a cooked or raw part of many salads.(Baidoo and Mochiah, 2016) .

The production of cabbage in Bangladesh is 75-100 ton/ha depending on selection of variety and season (Rashid *et al.*, 2006). These yields are lower as compare to other developing countries. However, a number of reasons may be attributed to low yield viz., lack of quality seeds, unavailability of high yielding varieties, poor fertilizer management, delayed sowing after the harvest of transplanted aman rice, lack of irrigation facilities and due to the attack of insect pests.

The reduction in cabbage production and yield is strongly related with insect herbivory (Tolman and Harris, 2004). Like other vegetables, cabbage is also vulnerable to the attack of several pests such as diamondback moth (*Plutella xylostella*), cabbage butterfly (*Pieris brassicae*), cabbage semi-looper (*Trichoplusia ni*), tobacco caterpillar/prodenia caterpillar (*Spodoptera litura*), cutworm (*Agrotis ipsilon*), are major limiting factors (Butani and Jotwani, 1984, Bhat *et al.*, 1994).

Diamondback moth, *Plutella xylostella* L., is the most destructive pest of cabbage (Mahla *et al.*, 2005; Kumar *et al.*, 2007). It is a primary pest causing heavy loss of the cabbage field by larval feeding (Parajuli and Paudel, 2019). About 50-80% yield losses is occured by *P. xylostella* during severe infestation (Kumar *et al.*, 1983, Ayalew, 2006; Grzywacz *et al.*, 2010, Krishnamoorthy, 2004, Prashant *et al.*, 2007). First instars are leaf quarrying and after moulting feed on the lower surface of plant leaves. Second and third instars chew the host parts and results in asymmetrical patches (Golizadeh *et al.*, 2009).

Tobacco caterpillar (*Spodoptera litura*) is also the most destructive pest, which destroys the leaves of cabbage by making holes in the cabbage head and greatly reduces the market value (Butani and Jotwani, 1984) and it can reduce more than 50% yield in some cabbage genotypes (Bhat *et al.*, 1994). It is a polyphagous pest that cause considerable damage to vegetables (Srivastava *et al.,* 2018) and distributed throughout the world (Thompson *et al.*, 2000, Maqsood *et al.*, 2017). Tobacco caterpillar causes damage 3.99% to 13.44% on leaves and 23.33% to 58.33% on plants depending of the varieties in Bangladesh (Ahmed, 2008).

Various methods have been used to control the insect pests like cultural, physical, botanical, biological, entomopathogens and chemicals. Among them, chemical control is very popular to the farmers and excessively use on small and large scale to control the pests. The tendency because insecticides are considered to be reliable because of their quick and effective action (Adejumo, 2005, Seal *et al.*, 2006).

In Bangladesh ,the farmers use chemical insecticides indiscriminately to control these insect pests of cabbage without considering doses and harmful impact of insecticides on non-target organisms, and economic injury level of the pests.

Indiscriminate use of chemical can cause environmental pollution and resistance in insect pest (Saxena *et al.*, 1989, Karuppaiah *et al.*, 2017, Rehan & Freed, 2014, Vastrad *et al.*, 2003; Shankar *et al.*, 1996).

Moreover, Frequent use of chemical insecticides at higher doses results in depredation of natural enemies (Haseeb *et al.*, 2004).

The indiscriminate and excessive use of pesticides has created various problems, which came to limelight with the publication of “Silent Spring” by Rachel Carson. Therefore, future pest problems will have to be undertaken in an environmentally benign manner as a part of a sustainable crop production technology (Dhaliwal and Heinrichs, 1998; Koul *et al.*, 2004, Koul, 2008).

The use of bio-pesticides as an alternative to chemical insecticides has been studied throughout the world. The term “biopesticide”embraced a wide diversity of both chemical and microbial active ingredients (Joseph *et al.*, 2012).

Biopesticides may be as a form of pesticide based on micro-organisms or natural products and these include naturally occurring substances (biochemical pesticides), microorganisms (microbial pesticides) that have an ability to control pests, and pesticidal substances prepared by plants containing added genetic material (plant incorporated protectants).

According to the United States Environmental Protection Agency (EPA), Three major classes of biopesticides are available such as microbial pesticides consisting of entomopathogenic bacteria (e.g., *Bacillus thuringiensis*), fungi (e.g., *Trichoderma spp.*), or viruses (e.g., Baculovirus) including their metabolites sometimes, entomopathogenic nematodes and protozoa.

The feeding and oviposition deterrence, growth disruption, repellency, reduced fitness, and sterility are collectively the diverse biological activities of bio-pesticides (plant extracts) (Schmutterer, 1990; Nzanza, 2012).

Among the biopesticides viz. Abamectin, Azadirachtin, Spinosad, *Bacillus thuringiensis*, *Beauveria bassiana*, NPV etc. are widely used for controlling the insect pests of cabbage.

These are safe for environment, human health & beneficial insects. But these biopesticides are used in vegetable cultivation without the optimum doses because of having no knowledge of optimum doses to the farmers.

In this case it was strongly felt to assess their present relative status for biopesticides against major insect pests of cabbage under natural field conditions of the cabbage field. However, for achieving high effective results from bio-pesticides, the users need to know about practices of managing pests (Adalbert *et al.*, 2013).

The study was carried out to manage the major Lepidopteran insect pests with eco-friendly manner for profitable cabbage yield.

Considering the above facts this experiment has been undertaken with the following objectives:

- To assess the level of infestation caused by major Lepidopteran insect pests of cabbage, and
- To find out the efficacy of biopesticides in managing major Lepidopteran insect pests of cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important leafy vegetable in Bangladesh. Vegetable production cannot fulfill the actual requirements for increasing population, so the demand of vegetables is increasing day by day. But the vegetable production faces various problems including the insect pests management.

A large number of insect pests attack in the cabbage field every year, which causes significant yield loss to the vegetable growers. Among the insect pests, Lepidopteran insects like diamondback moth, tobacco caterpillar are the major insect pests of cabbage. Use of biopesticides is the modern approaches for pest control that was commonly practiced but the information was not available used in Bangladesh as well as the developed world. Some of the important and informative works related to the information of damaging cabbage caused by pest and research findings related to their control measures through bio-pesticides so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.1. General review of insect pest of cabbage

2.1.1. Diamondback moth

The diamondback moth, *Plutella xylostella* belongs to the order Lepidoptera and the family Plutellidae.

2.1.1.1 Systematic position

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Plutellidae

Genus: Plutella

Species: *Plutella xylostella*

2.1.1.2 Origin and distribution

The diamondback moth (*Plutella xylostella*), sometimes called cabbage moth, is a European moth believed to originate in the Mediterranean region that has since extent worldwide. The moth has a short life cycle (14 days at 25°C), highly fecund and capable of migrating long distances. It is one of the most important pests of cole crops in the world and will usually only feed on plants that produce glucosinolates (Talekar and Shelton, 1993).

2.1.1.3 Life cycle

Eggs are laid singly or in groups of two or three on the underside of lower leaves or stems. After hatching, larvae pass through four instars stages over a period of 14-30 days. The pupa progresses within a loosely spun cocoon attached to the leaves and stems of plants. Adults emerge in 7-15 days. Four to six generations can occur per season. Hot dry conditions favor survival and reproduction, making control difficult (Moyer, 1999).

2.1.1.4 Nature of damage

It usually devours only a small portion of leaf. Larvae work on the underside and eat many small holes. Frequently they leave only the upper epidermis, which has an isinglass-like effect (Janmaat, 2003).

Larvae of *P. xylostella* is feed on the all parts of host plants and make unfit for consumption. First instars are leaf mining and after moulting feed on the lower surface of plant leaves. Late instars chew the host parts and results in irregular patches (Golizadeh *et al.*, 2009).

2.1.2 Tobacco caterpillar (*Spodoptera litura*)

The tobacco caterpillar/Cabbage caterpillar, *Spodoptera litura* belongs to the order Lepidoptera of the family Noctuidae.

2.1.2.1 Systematic position

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: Spodoptera

Species: *Spodoptera litura*

2.1.2.2 Origin and distribution

The tobacco caterpillar is found throughout the tropical and subtropical parts of the world. It is wide spread in India (Atwal, 1986). This pest has been reported from India, Pakistan, Srilanka, Mayanmar, Thailand, Malaysia, Cambodia, Laos, Vietnam, Sabah, Indonesia, the Philippines, Taiwan, Queensland, New South Wales, New Guinea, Papua, West Iran, Solomon Islands, Gilbert Islands, New Caledonia, Fiji, Samoa, Tonga, Society Islands, Gilbert Islands and Micronesia (Grist and Lever, 1989).

2.1.2.3 Life cycle

Egg stage duration of the noctuid *S. litura* on sunflower in the laboratory was 3 days in May-June and 5.4 days in October. The duration of the larval stage averaged 15.09 days in June and 16.67 days in October. Larval survival varied from 72 to 92% in May October. The duration of the pupal stage averaged 7.49 days in September and 12.26 days in October. The adult life span averaged 4.1-6.2 days in males and 5.1-7.8 days in females. Studies at constant temperature of 20, 25 and 30°c showed the egg stage last for 5, 4 and 3 days, respectively (Kumar *et al.*, 1992).

2.1.2.4 Nature of damage

Tobacco caterpillar Spodoptera litura attack the tender leaves, larva cause the damage only. The female moth of tobacco caterpillar laid eggs on the lower surface of the leaves. After hatching of the eggs, the tiny caterpillar starts feeding on host plant. In the early stage of cabbage that was the head forming stage the infestation was found to occur which caused a greater damage. In this stage caterpillars bored the new forming head and reached to the newly emerging little leaf and consumed it. As a result, main head of cabbage could not form. Due to the cosmetic nature of cabbage, a hole is enough to devaluate it. In market it is sold in reduced price.

Because of the excreta was left at the damaged site sometimes it causes rotting in the inner portion of cabbage. The nature of damage and extent of damage differed with age of the caterpillars. The young caterpillar along with mature caterpillar also cause greater damage if the infestation occurs at the head forming stage.

In field, later stage of cabbage was not found to be infested. Succeeding generations can do greater damage and later instars larvae remained outside the cabbage head, can come out as a serious phase of infestation for their voracious eating habit (Tofael, 2004).

2.2 Insect pests Management technique of cabbage

2.2.1 Cultural control

Cultural controls that can reduce pest populations by using various management practices such as crop rotation, cultivation, weed management, water management, and proper fertilizer use etc. Always destroy plant debris and control weeds because they attract insects that may feed on vegetables. Intercropping is the practice of' increasing crop diversity' by growing more than one crops in a field to reduce insect pest outbreak problems associated with monocultures.

Dempster (1969) studied the effects of weed control in brussels sprouts on *P. rapae* and found that weeds provide a habitat for predators of the caterpillar. However, yield reduction due to weed competition outweighed the advantageous effects of insect control obtained in the weedy plots.

Buranday and Rarest (1975) compared the abundance of adults and oviposition of *P. xylostella* in a cabbage field and in a field with cabbage and tomato intercropped. Both factors were lower in the intercropped field and it was suggested that volatile compounds emitted by the tomatoes repelled the adult moths. The recommended planting pattern is two cabbage rows between two rows of tomato. The pest control benefits' with respect to reduction in larval feeding damage were not assessed as plots were sprayed regularly with *B. thuringiensis*, masking any affect of tomato on larvae. In another study,: numbers of *P. xylostella* larvae and pupae were reduced by intercropping cabbage with tomato, barley, dill, garlic, oats or safflower (Talekar et al., 1986). Kenny and Chapman (1988) assessed an intercrop of cabbage and dill(*Anethum graveolens* L.). The number of cabbage aphids on cabbages planted near dill was lower than those planted without dill. Results for numbers of *P. rapae* and *Plutella xylostella* and damage measurement were inconsistent due to low pest populations. Competition from dill was found to reduce yield, but a different planting arrangement could overcome this problem.

Tilling land before planting, which helps to expose and kill overwintering larvae. Tilling also removes plant residue, which helps to discourage egg laying. Avoid using green manure as this may encourage egg laying, instead use compost. Tilling land in the fall; this helps to destroy or expose overwintering larvae or pupae (Hahn and Burkness, 2015).

2.2.2 Mechanical control

The use of physical means to reduce the number of insects or insect damage or to exclude insect pests from the crop field is called Mechanical control. Mechanical control methods include the use of barriers, high pressure water sprays, covers, and hand picking of pests. Barriers have many shapes and sizes. They prevent the movement of pests from one to another plants. Cardboard or plastic cylinders around the base of transplants are an example of a barrier that protect transplants from attacking cutworms and other soil-inhabiting pests. Screening is useful for young plants and seedlings that are the most susceptible to pest attack. High pressure water sprays are useful mechanical control method. Sprays are the most effective against small, soft-bodied pests like aphids. Talekar *et al.*, (1986) found that sprinkler irrigation applied to cabbage for five minutes at dusk throughout the life of the crop physically disrupted diamondback moth flying activity and oviposition and drowned larvae and adults. Such a modification of a cultural practice could be a valuable component of a pest management system. The use of lightweight netting row covers, as a barrier to oviposition, is another effective non-chemical insect control technique. Row covers are mainly used to extend the growing season and by protecting against frosts provide early vegetables by decreasing time to maturity (Mansour, 1989) and they are also effective as barriers against *P. rapae* and *P. xylostella*.

Cutworms can control by placing aluminum foil or cardboard collars around transplants. This creates a barrier that physically prevents cutworm larvae from feeding on plants. When placing these collars around plants, make sure one end is pushed a few inches into the soil and the other end extends several inches above ground. This should prevent most species of cutworms from getting to plants (Hahn and Burkness, 2015).

2.2.3 Chemical control

For controlling moths still mostly used organic phosphorus esters. In this group classified active compounds are chlorine pyrifos-methyl, phenitrothion and acephate (Pelosini, 1999). Sufficient efficacy in this relation can attain also with pyrethroids (cypermethrin, deltamethrin, lambda-cyhalothrin, beta-cyfluthrin and tefluthrin). In Slovenia registered products for controlling cabbage moth are from a group of pyrethroids, a product on the basis of pyrethrin, a product which corresponds to oxadiazine and one from the group of insect development inhibitors (IRI). Pyrethroids which are registered in Slovenia are Fastac 10% SC (alfacypermethrin) and Karate Zeon 5 CS (lambda-cyhalothrin). Two products are also used when controlling cabbage moth, namely pyrethrin (Spruzit powder) and indoxacarb (Steward). Active ingredient indoxacarb refers to the group of oxadiazines which is also advanced one. Insecticides from the oxadiazines group block Na-channels in nerve fibers. Target insects stop feeding, stay paralyzed and die soon. Product Steward is suitable for integrated production. Chitinase inhibitors display minor danger for human being and are suitable especially for controlling eggs and young larvae (Corvi and Nardi, 1998).

Khan *et al.* (2011) evaluvated new and conventional insecticides against the armyworm under laboratory conditions. All the evaluated insecticides proved toxic to S. litura under laboratory conditions, but chlorpyrifos, profenofos, emamectin benzoate, spinosad, indoxacarb, methoxyfenozide and lufenuron proved highlytoxic as the exposure time was extended. After 3 days of the insecticide treatment, 100% mortality was observed in emamectin benzoate @ 100 and 110 ml/acre treatment, followed by chlorpyrifos @ 1100 ml/acre (96.56%), leufenuron @ 55 ml/acre (86.67%) and Methomyl @ 440 ml/acre (83.34%). However, chlorpyrifos and emamectin benzoate, at all the three doses, leufenuron at the higher and recommended dose and thiodicarb, spinosad and methoxyfenozide, at higher doses, were ranked highly toxic-as these insecticides caused thehighest mortality (>90%) in *S. litura*.

Hole *et al.* (2009) informed that ,The treatment with profenofhos 0.1% gave maximum protection when recorded up to 7 days after application and reported 6.5% foliage damage. The highest residual toxicity to tobacco caterpillar at 24, 48, 72 hrs and one week after application was exhibited in the treatment of profenofhos 0.1%

under laboratory to field weathered deposits. Among the different insecticidal treatments tested in field, profenofhos 0.1% alone showed significantly superiority in controlling larval population and thereby, reduction in leaf damage and increasing the grain yield.

In case of cabbage moth control, Fenos® (Flubendiamide) and Prevathon® (Chlorantraniliprole) are novel diamide products thus providing growers excellent rotation partners to manage insecticide resistance development in vegetables. These products quickly became very popular among growers since they were very effective against diamondback moth and other lepidopteran larvae (Edralin, *et al.*, 2011).

Tariq *et al*. (2005) observed that *Helicoverpa armigera* was resistant to conventional insecticides, so there should be new insecticides which can manage the pest in more efficient and economical manner. Deltaphos 360 EC, Tracer 240 SC, Steward 150 EC, Emamectin 1.9 SC, Lorsban 40 EC and Curacron 500 EC were used to control Helicoverpa armigera. According to the result, Tracer 240 SC was found to be the most effective for the control of *Helicoverpa armigera*.

Meena, K.A. (2018) observed that, The field bio-efficacy of four insecticides in different doses was assessed against diamondback moth on cabbage crop. It was found that even the smallest dose of cypermethrin 10 AF, indoxacarb and acetamiprid were significantly effective in reduction of a pest population compared to the untreated check. The order of bio-efficacy against diamondback moth was cypermethrin 10 AF > cypermethrin 10 EC > indoxacarb 14.5 SC > acetamiprid 20 SP. Cypermethrin 10 AF synthetic pyrethroid can be used for effective control of diamondback moth .

The three new insecticides such as emamectin benzoate, lufenuron and profenofos was conducted against two lepidopteran insect pests; *Spodoptera litura* and *Plutella xylostella* at different larval instars during 2018 under laboratory conditions. For this purpose, randomized complete design and leaf dip technique was used. The current study was resulted that Emamectin benzoate proved to be effective one with significantly higher level of mortality followed by profenofos and lufenuron after 48 and 72 hours respectively. Emamectin benzoate can be recommended as the most toxic insecticides against both *Spodoptera litura* and *Plutella xylostella* populations along with profenofos.(Ramzan *et. al*. 2019).

Gupta *et al.* (2004) have determined relative susceptibility of 5days old larvae of *S. litura* by Potter's tower method. On the basis of LC50 value, the order of toxicity of different insecticides with relative toxicity in parenthesis was: emamectin benzoate (6.93) > fenvalerate (1.82) > indoxacarb (1.62) > cypermethrin (1.00) > abamectin (0.94) > quinalphos (0.67) > bifenthrin (0.51) > spinosad (0.44) > endosulfan (0.28) > betacyfluthrin (0.23) > lambda cyhalothrin (0.19).

2.2.4 Biopesticidal control

Jagdish *et al.* (2014) conducted a field experiment to evaluate the relative efficacy of eight biopesticides against gram pod borer legume pod borer. Significant effect of bio-pesticides on percent webbing by *M. vitrata*, at First spray application showed minimum in NSKE.The pod borer *M. vitrata* was found lowest in Spinosad, followed by NSKE and *B. bassiana* as compared to control. Grain yield varied from maximum in Spinosad followed by as compared to untreated control condition.

Simmonds *et al.* (1992) reported that seeds and leaves of the neem tree comprehend terpenoids with potent anti-insect activity. One of the most active terpenoids in neem seeds is "azadirachtain" which acts as an antifeedant and growth disrupter against a wide range of insect pests.

Better performance exhibited by neem product may be due to repellency of the larvae of different instars on the leaves from the treated plants and secondly due to antifeedant effect on the larvae (Rajput *et al.*, 2003).

The insecticidal effect of a liquid of *Bacillus thuringiensis* applied to the egg stage in *Plutella xylostella*, *Spodoptera litura*, and *Pieris rapae* was estimated under laboratory conditions. In all of the three insect pests tested, Bt applied to the egg stage had no effect on eclosion, but caused substantial mortality of the larvae coming out of the Bttreated eggs. With the recommended rates of concentration for field application, the rates of newly-emerged larvae reached 42%, 91% and 54% in the three insects, respectively. In *Plutella xylostella*, it was further determined that, rates of mortality of larvae increased with increase of Bt dosage, but decreased with the age of eggs at treatment. The results of this study suggested that very high effect of Bt against these insect pests could be obtained in the field with applications timed at peaks of oviposition and eclosion.(Sheng and Guang, 2002)

Thakur and Sharma (2014) observed against key insect pests of cabbage, Using eight treatments by leaf dip technique against neonate larvae of *Pieris brassicae*, *Baccillus thuriengiensis* gave complete mortality andit was followed by neem oil with 66.7% mortality. Diamondback moth (*Plutella xylostella*) pupae were exposed to eight treatments to assess anti juvenoid effect where neem oil caused 60% reduction compared to 20% reduction in Melia extract. As per controlled conditions neem oil can effectively manage cabbage aphid and DBM while Bt can shield cabbage butterfly.

Spinosad is a new generation pesticide. It was reported effective against wide range of arthropod pests and especially effective against the order Lepidoptera (Sparks *et al.* 1999). Safety of spinosad to non-target beneficial organisms was proved (Schmutterer, 1990, Thompson *et al.* 2000, Me´ndez *et al.*, 2002, Singh *et al*. 2006). Spinosad was reported having low mammalian toxicology (Cleveland *et al.* 2001) and classified as bioinsecticides (Copping and Menn, 2000). However, phytotoxicity of spinosad was proved (Harris and Maclean. 1999).

Field trial was conducted to determine the selected botanicals and bio-pesticides, NSKE, neem leaf extract, *lantana camara* leaf extract and *Bacillus thurigeinsis* (Delfin). Beauveria bassiana, spinosad respectively with recommended insecticide Chlorpyriphos against diamondback moth, *Plutella xylostella* (L.). All the insecticides tested significantly reduced the pest population compared to control. The overall highest mean per cent reduction of P. *xylostella* in cabbage was noted in insecticide molecules, Chlorpyriphos (74.9%), Spinosad (70.8%) and *Bacillus thuringiensis* (51.7%). Chlorpyriphos recorded the highest yield followed by Spinosad, *Bacillus thurigiensis* (Delfin), *Beauveria bassiana*, NSKE 2%, neem leaf extract 10% and *Lantana camara* leaf extract 10% and untreated control.

Debbarma *et al. (*2017). Reported that, A field trial was carried out to evaluate the efficacy of certain bio-rational insecticides against *Plutella xylostella* and *Pieris brassicae* on cabbage under Manipur valley. The study revealed that due to the Diamondback moth pre-treatment mean extent of leaf damage reached 90.67 percent and whereas it reached 91.11 percent due to the cabbage butterfly, *Pieris brassicae*. Spinosad was found most effective to control both these pests registering lower extent of mean leaf damage by 14.22 percent and 24.30 percent respectively. It was followed by mycojaal (*Beauveria bassiana*) with 15.11 percent and 26.59 percent and differs significantly from untreated control 69.18 percent. The yield harvested in the bio-rational treatment were spinosad, myco-jaal, malathion, racer (*Beauveria bassiana*), achook (Azadirachtin 1500 ppm), lipel (*Bacillus thuringiensis* var. *kurstaki*), shakti (Azadirachtin 300 ppm), and untreated control respectively.

Potassium salt of fatty acids are horticultural soap. It is successfully targets soft bodied insect pest population and control through physical mode of action. It is Produced by Adding potassium hydroxide to fatty acids from plant oil and animal fats, which are saponified by the potassium hydroxide that disrupt insect cuticle and ultimately cause die.

CHAPTER III

MATERIALS AND METHODS

The present study regarding the effectiveness of some biopesticides in managing major lepidopteran insect pests of cabbage particularly diamondback moth (*Plutella xylostella*) and tobacco caterpillar (*Spodoptera litura*) has been conducted in the experimental fields of Sher-e- Bangla Agricultural University, Dhaka. Required materials and methodology are described below under the following sub-headings-

3.1 Experimental period

The experiment was conducted during the period from October, 2019 to January, 2020.

3.2 Location of the experimental field

The experiment was performed in the central Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh and which is situated in 23º74´´N latitude and 90º35´´E longitude and an elevation of 8.2 m from sea level (Anon., 1989) that has been presented in Appendix I.

3.3 Climate of the experimental field

Subtropical, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). The average maximum and minimum temperature were 31.6ºC and 12.7º C respectively, during the experimental period. In our country rabi season is characterized by plenty of sunshine and cool. Meteorological data which are related to the temperature, relative humidity and rainfall during the study period were collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix II.

3.4 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.,* 1991).The land of the selected experimental plot is medium high under the Tejgaon series (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Dhaka and has been represented in Appendix III

3.5 Planting material

The test crop used in the experiment was cabbage variety Magic-65. It is an imported high yielding variety with average yield 45-55 t/ha-1. The seeds were collected from Lal Teer Seed Limited, Tejgaon, Dhaka.

3.6 Experimental Design and Layout

The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. The field with good tilth was divided into 3 blocks. The layout of the experiment was prepared for well distributing all of the treatments randomly. The experiment consists of total 21 plots of size 3 m × 2 m. The layout of the experiment is shown in Figure 1.

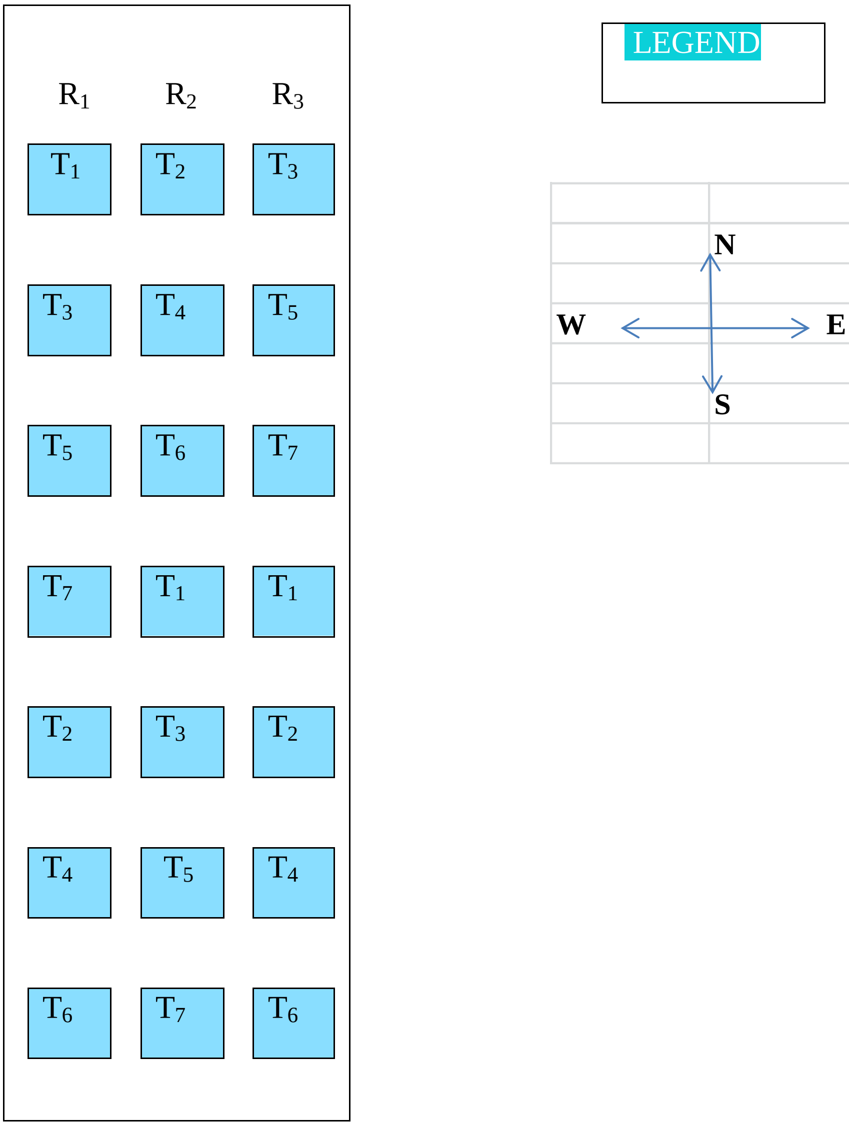

Figure 1. Layout of the experimental plot.

3.7 Land preparation

The selected plot of the experiment was opened in the last week of October, 2019 with a power tiller and exposed to the sun for a week. Several times cross ploughing was done with a country plough followed by harrowing and laddering to make the land suitable for growth and development of cabbage seedlings. All weeds, stubbles and residues were destroyed from the experimental field. Finally, a good tilth was found for proper growth and development of cabbage. The Field layout was prepared on according to the design, after land preparation.

3.8 Manuring and fertilization

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers were applied according to the recommended fertilizer doses for cabbage production per hectare by BARC (2012).

Table 1. Dose and method of application of fertilizers in cabbage field.

Fertilizers and manure	Dose (kg/ha)	Application (%)		
		Basal	Top dressing	
			15 DAT	35 DAT
Cowdung	5000	100		
Urea	370		50	50
TSP	250	100		
MoP	250		50	50

The total amount of cow-dung, TSP and was applied as basal dose at the time of land preparation. The total amount of Urea and MoP was applied in two equal installments at 15 and 35 days after transplanting (DAT) as ring method under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization.

3.9 Raising of seedlings

Before sowing the cabbage variety magic-65, the germination test of seeds was done and on an average, 90% germination was found. The seedlings were raised in 3 m × 1 m size seed bed under special care at Sher-e-Bangla Agricultural University central farm, Dhaka. The soil of the seed bed was well ploughed with a spade and prepared into loose dried masses and obtained good tilth to provide a favorable soil condition for the vigorous growth of young seedlings. Weeds, stubbles were removed. The seedbed was dried in the sun to destroy the soil borne insect and protect the young seedlings from of damping off disease. Cupravit fungicide were applied to control damping off disease. Decomposed cow dung was applied in prepared seedbed. Ten (10) grams of seeds were sown in seedbed on October 01, 2019. After sowing, the seeds were covered with fine light soil.

At the end of germination shading was done by bamboo mat over the seed bed to protect the young seedlings from burning sunshine and heavy rainfall. Light irrigation and weeding were done when needed.

Plate 1. Cabbage seedlings in the seedbed.

3.10 Transplanting

Healthy and uniform seedlings of 35 days old were transplanting in the experimental plots on 5 November, 2019. The seedlings were transferred carefully from the seed bed to experimental plots to evade damage to the root system. To reduce the damage to the roots of seedlings, the seed beds were irrigated one hour before uprooting the seedlings. Transplanting was prepared in the afternoon. The seedlings were watered instantly after transplanting. There were 7 seedlings in each row and a total of 21 seedlings were transplanted in each plot. Seedlings were transplanted in the plot with distance between row to row was 60 cm and plant to plant was 40 cm. The young transplanted seedlings were provided shade by banana leaf sheath during day to protect them from burning sunshine and continued up to 7 days until they were set in the soil. Plants were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots if these were required for gap filling.

Plate 2. Cabbage seedling transplanting in the experimental plot

3.11 Intercultural operations

Various intercultural operations such as gap filling, weeding, earthing up, irrigation etc. were accomplished after transplanting seedlings for better growth and development of the cabbage.

3.11.1 Gap filling

In the experimental plot, the transplanted seedlings were kept under careful observation. At the time of each transplanting few seedlings were transplanted in the border of the experimental plots for gap filling. Very few numbers of the seedlings were damaged after transplanting and such seedlings were replaced by healthy seedlings from the same planted earlier on the border of the experimental plot . The transplanted seedlings were provided shading and watering for 7 days for their proper development.

3.11.2 Weeding

The land of each plot was kept free from weeds and three times weeding was done. The first weeding was done after 20 days of transplanting and the remaining weeding was done after 40 and 55 days of transplanting. Weeding was done by using with mechanical weed control method and uprooting.

3.11.3 Irrigation

After transplanting light irrigation was done to each plot by a watering can at every morning and afternoon. It was continued for a week for rapid growth and well establishment of the transplanted seedlings. Supplementary irrigation was given at 7 days interval. Stagnant water was drained out successfully at the time of excess irrigation.

3.11.4 Earthing up

Earthing up was done at 30 and 55 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.12 Treatments used for management

The experiment was evaluated to determine the efficacy of different botanical products against major Lepidopteran insect pests of summer cabbage. The botanical based treatments as well as their doses were used in the study are given bellow: -

T_1 = Spraying of Abamectin 1.2 EC @ 1 ml/L of water

T_2 = Spraying of Azadirachtin 1 EC @ 1 ml/L of water

T_3 = Spraying of Potassium salt of fatty acid @ 1 ml/L of water

T_4 = Spraying of Spinosad 45 SC @ 1 ml/L of water

T_5 = Spraying of *Bacillus thuringiensis* @ 1 ml/L of water

T_6 = Spraying of Abamectin + *Bacillus thuringiensis* @ 1 ml/L of water

T_7 = Untreated control.

3.13 Treatments application

T_1: Abamectin 1.2 EC @ 1.0 ml/L of water of water was sprayed at 7 days intervals. Under this treatment, Abamectin was applied @ 5 ml/5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 15 DAT.

T_2: Azadirachtin 1 EC @ 1.0 ml/L of water was sprayed at 7 days interval. Under this treatment, Azadirachtin was applied @ 5 ml/5L of water. After proper shaking, the prepared spray was applied with knapsack sprayer at 7 days intervals commencing from 15 DAT.

T_3: Potassium salt of fatty acid @ 1 ml/L of water was sprayed at 7 days interval. Under this treatment, Potassium salt of fatty acid was applied @ 5 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 15 DAT.

T_4: Spinosad 45 SC @ 1 ml/L of water was sprayed at 7 days interval. Under this treatment, Spinosad was applied @ 5 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 15 DAT.

T_5: *Bacillus thuringiensis* @ 1 ml/L of water was sprayed at 7 days. Under this treatment *Bacillus thuringiensis* was applied @ 5 ml/5L of water. After proper shaking, the prepared spray was applied with knapsack sprayer at 7 days intervals commencing from 15 DAT.

T_6: Abamectin + *Bacillus thuringiensis* @ 1 ml/L of water was sprayed at 7 days interval. Under this treatment, Abamectin + *Bacillus thuringiensis* was applied @ 5 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 15 DAT.

T_7: Untreated control treatment. There was no any control measure applied in cabbage field.

3.14 Data collection

Five plants per plot were randomly selected and tagged for data collection. The cabbage plants were closely examined at regular intervals commencing from 15 days after transplanting (DAT) to harvesting of cabbage head. Infestation by different major insects were recorded at 15, 25, 35, 45 and 55 DAT. The data were recorded on number of cabbage diamondback moth larvae, tobacco caterpillar, infested leaves by the insects. The following parameters were considered during data collection:

Plate 3. The experimental plot during the study period

3.14.1 Counting of insect pests of cabbage and infested leaves

Data were collected on the number of tobacco caterpillar and diamondback moth larvae and number of infested leaves caused by tobacco caterpillar and diamondback moth larvae from randomly earlier selected 5 tagged plants per plot and counted individually for each treatment.

Plate 4. A healthy cabbage

Plate 5. A damaged cabbage

3.14.2 Number, weight of healthy and infested cabbage head

Data were collected on the number of healthy and infested cabbage head per plot which was harvested at fully mature head (upto 20th January) stage of cabbage and weighted individually for each treatment.

Data of the yield contributing characters of cabbage like diameter of head, height/thickness of head, weight of head and yield tha^{-1} was also recorded after harvesting.

3.15 Level of infestation

The number of uninfested and infested leaves and plants of cabbage caused by the larvae of major insect pests was counted. The observations were recorded at the first observation of damage leaves and plants and were continued up to harvesting stage of the cabbage at 10 days interval. The data on the yield was also measured. The level of leaf and plant infestations per plant and plot respectively was then calculated using the following formula:

% leaf or plant infestation = $\frac{\text{No.of infested leaves or plants}}{\text{Total no.of leaves or plants}} \times 100$

3.16 Insect infestation percentage on head

The infested heads were calculated at different stages using the following formulae:

% head infestation by number = $\frac{\text{No.of infested heads}}{\text{Total no.of heads}} \times 100$

% head infestation by weight = $\frac{\text{weight of infested head}}{\text{Total head weight}} \times 100$

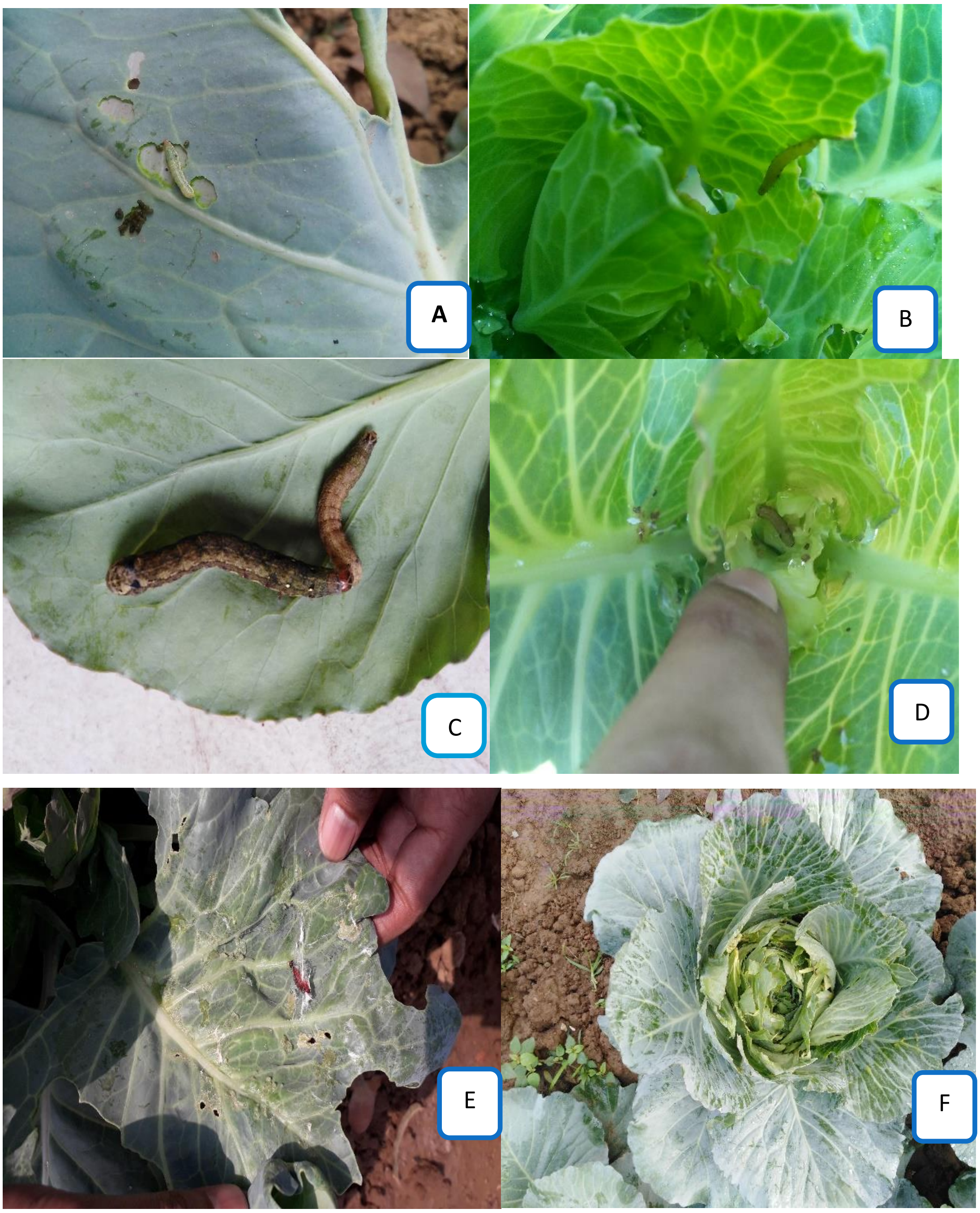

Plate 6. (A) Diamondback(*Plutella xylostella*) moth larvae, (B) Diamondback moth larvae in cabbage head, (C) Tobacco caterpillar (*Spodoptera litura*), (D) Tobacco caterpillar (*Spodoptera litura*) in cabbage head, (E) Pupa of Tobacco caterpillar, (F) Damage caused by Tobacco caterpillar

3.17 Yield

Yield $plot^{-1}$ was noted from the experiment field and then it was converted to total yield (t/ha). Percent increase or decrease of yield over control was calculated by using the following formula:

$$\text{Percent increase of yield over control} = \frac{\text{Yield of treated plots} - \text{Yield of control plot}}{\text{Yield of control plots}} \times 100$$

$$\text{Percent decrease of yield over control} = \frac{\text{Yield of control plots} - \text{Yield of treated plot}}{\text{Yield of control plots}} \times 100$$

3.18 Harvesting

Harvesting of the cabbage was not possible on a particular date because the initiation of head as well as attaining the head at marketable size in different plants were not uniform. Only the compact marketable heads were harvested by using sharp knife. Compactness of the head was tested by pressing with thumbs, before harvesting of the cabbage head.

3.19 Statistical analysis

The data collected on different parameters were accumulated and tabulated for statistical analysis. Statistically analysis was prepared by using the Statistix 10 computer package program. Mean values were graded and compared by Least Significant Difference (LSD) test at 5% level of significance.

CHAPTER IV
RESULTS AND DISCUSSION

The study was conducted to evaluate the effectiveness of some biopesticides for eco-friendly management of some major insect pests of cabbage in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2019 to January, 2020. The results have been presented by using different tables and discussed with possible interpretations have been given under the following sub-headings:

4.1. Leaf infestation of cabbage

4.1.1. Leaf infestation by tobacco caterpillar

Significant variations were observed ($p>0.05$) among different treatments used for the management practices in terms of leaf infestation due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 2). Significally, At 15 DAT, the highest leaf infestation (14.33 leaves/5 plants) was recorded in untreated control plot (T_7) which was different from all other treatments followed by T_3 (11.33 leaves/5 plants) and T_5 (10.33 leaves/5 plants) but they were statistically different. On the other hand, the lowest leaf infestation was recorded in T_4 (6.33 leaves/5 plants) treated plot which was significally different from all other treatments followed by T_1 (7.67 leaves /5 plants), T_6 (8.33 leaves /5 plants) and T_2 (9.33 leaves /5 plants) and they were statistically different.

At 25 DAT, the highest leaf infestation (15.67 leaves/5 plants) was recorded in untreated control untreated control plot T_7 and which was significally different from all other treatments followed by T_3 (11.00 leaves /5 plants) and T_5 (10.67leaves /5 plants) but they were statistically different. Conversely, the lowest leaf infestation (6.33 leaves/5 plants) was recorded in Spinosad 45EC treated plot ($T_{4)}$ which was statistically different from all other treatments followed by T_1 (7.67leaves /5 plants), T_6 (8.67leaves /5 plants) and T_2 (9.67 leaves /5 plants). More or less similar trends of leaf infestation by number were also recorded at 35 DAT, 45 DAT and 55 DAT (Table 2).

In case of mean infestation, the highest number of leaf infestation (15.80 leaves/5 plants) was recorded in control plot (T_7) which was significantly different from all other treatments followed by T_3 (10.33 leaves/5 plants) and T_5 (10.20 leaves/5 plants) but they were statistically identical. On the other hand, the lowest infestation was recorded in T_4 (6.00 leaves/5 plants) which was significally different from all other treatments and followed by T_1 (7.07 leaves/5 plants) and T_6 (8.07 leaves/5 plants) and T_2 (9.07 leaves/5 plants) but they were statistically not similar (Table 2).

Considering the percent reduction of leaf infestation over control, the highest 62.02 reduction over control was achieved in T_4 followed by T_1 (55.27%) and T_6 (48.94 %) and T_2 (42.61%). And the minimum reduction of leaf infestation over control was found in T_3 (30.99%) which was very close to T_5 (35.44%) (Table 2).

From the above mentioned findings it was revealed that among the different treatments, Spinosad @ 45EC (T_4) showed the best result in reducing the leaf infestation of cabbage (62.02%) by number due to attack of tobacco caterpillar than the other treatments, whereas, T_3 showed the least performance results in reducing the leaf infestation of cabbage (34.60%) by number over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent leaf infestation of cabbage by number reduction over control was $T_4 > T_1 > T_6 > T_2 > T_5 > T_3$.

More or less similar result was found by Debbarma *et al.* (2017) by using Spinosad, mycojaal (*Beauveria bassiana*), malathion, lipel (*Bacillus thuringiensis var. kurstaki*), Azadirachtin. Spinosad was found most effective to control tobacco caterpillar registering lower extent of mean leaf damage by 24.30 percent.

Table 2. Effect of biopesticides on leaf Infestation of cabbage caused by tobacco caterpillar at different days after transplanting (DAT).

Treatments	Number of infested leaves per five plants					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	7.67 f	7.67 e	7.33 de	6.67 ef	6.33 ef	7.07 e	55.27
T_2	9.33 d	9.67 c	9.33 bc	8.67 cd	8.33 cd	9.07 c	42.61
T_3	11.33 b	11.00 b	10.33 b	9.67 bc	9.33 bc	10.33 b	34.60
T_4	6.33 g	6.33 f	6.33 e	5.67 f	5.33 f	6.00 f	62.02
T_5	10.33 c	10.67 b	10.33 b	10.00 b	9.67 b	10.20 b	35.44
T_6	8.33 e	8.67 d	8.33 cd	7.67 de	7.33 de	8.07 d	48.94
T_7	14.33 a	15.67 a	16.00 a	16.33 a	16.67 a	15.80 a	
LSD (0.05)	0.67	0.90	1.16	1.25	1.00	0.62	
CV%	3.93	5.06	6.74	7.59	6.26	3.64	

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.1.2 **Leaf infestation by diamondback moth larvae**

Significant variations (p>0.05) were observed among different treatments (Table 3) for different management practices in terms of leaf infestation by Diamondback moth larvae at different days after transplanting (DAT). At 15 DAT, the highest leaf infestation (8.33 leaves/5 plants) was recorded in control plot ($T_{7)}$ which was significally different from all other treatments followed by T_3 (6.33 leaves/5 plants) and T_6 (5.90 leaves/5 plants). On the other hand, the lowest leaf infestation was recorded in T_4 (4.60 leaves/5 plants) which was significally different from all other treatments followed by T_1 (5.00 leaves /5 plants), and T_2 (5.60 leaves /5 plants) and they statistically different (Table 3).

At 25 DAT, the highest leaf infestation was recorded in T_7 (8.67 leaves/5 plants) which was significally different from all other treatments followed by T_3 (6.63 leaves /5 plants) and T_5 (6.03 leaves /5 plants) and they statistically different. On the other hand, the lowest leaf infestation was recorded in T_4 (4.70 leaves /5 plants) which was significantly different from all other treatments followed by T_1 (5.00 leaves /5plants), T_6 (5.43 leaves /5 plants) and T_2 (5.73 leaves /5 plants) and they were statistically similar. Regarding lowest similar trends of leaf infestation were also recorded at 35 DAT, 45 DAT and 55 DAT (Table 3).

In case of mean infestation, statistically the highest number of leaf infestation was recorded in T_7 (8.93leaves/5 plants) which was significantly different from all other treatments followed by T_3 (6.52 leaves/5 plants), T_2 (5.59 leaves/5 plants) and T_5 (5.8 leaves/plants). Here T_2 and T_5 statistically similar. And the lowest infestation was recorded in T_4 (4.48 leaves/5 plants) followed by T_1 (4.89 leaves /5 plants) and T_6 (5.31 leaves /5 plants) and they were statistically not similiar.

Considering the percent reduction of leaf infestation over control, the highest reduction over control was achieved in T_4 (49.85%) followed by T_1 (45.23%) and T_6 (40.52%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (27.01%) followed by T_2 (37.46%) and T_5 (35.01%) (Table 3).

From these above findings it was revealed that among the different treatments, T_4 showed the best result in reducing the leaf infestation of cabbage (49.85%) by number due to attack of Diamond back moth larvae than the other treatments; whereas, T_3 showed the least performance results in reducing the leaf infestation of cabbage (27.01%) by number over control. As a result, the order of rank of efficacy among the different treatments in terms of percent leaf infestation of cabbage by number reduction over control was $T_4 > T_1 > T_6 > T_2 > T_5 > T_3 > T_7$.

More or less similar result was found by Debbarma et al. (2017) by using Spinosad, mycojaal (*Beauveria bassiana*), malathion, lipel (*Bacillus thuringiensis var. kurstaki*), Azadirachtin. Spinosad was found most effective to control diamondback moth larvae registering lower extent of mean leaf damage by 14.22 percent.

Sharma, *et al.* (2017) found the similar findings of his research. who also reported that spinosad was found to be most effective reduced up to 94.33 percent diamondback moth population followed by indoxacarb (91.00%) and Flubendiamide (78.66%).

Table 3.Effect of biopesticides on leaf Infestation caused by diamondback moth larvae at different days after transplanting (DAT) of cabbage.

Treatments	Number of infested leaves per five plants					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	5.00 de	5.00 f	4.90 f	4.83 d	4.73 de	4.89 e	45.23
T_2	5.60 cd	5.73 d	5.63 d	5.53 c	5.43 c	5.59 c	37.46
T_3	6.33 b	6.63 b	6.53 b	6.43 b	6.67 b	6.52 b	27.01
T_4	4.60 e	4.70 g	4.60 g	4.37 e	4.13 e	4.48 f	49.85
T_5	5.90 bc	6.03 c	5.93 c	5.63 c	4.13 e	5.81 c	35.01
T_6	5.90 bc	5.43 e	5.33 e	5.30 c	5.13 cd	5.31 d	40.52
T_7	8.33 a	8.67 a	8.67 a	9.33 a	9.67 a	8.93 a	
LSD(0.05)	0.67	0.23	0.23	0.38	0.66	0.23	
CV%	6.41	2.14	2.17	3.64	6.34	2.19	

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.2 Incidence of insect pest population

4.2.1 Incidence of tobacco caterpillar

Significant variations (p>0.05) were observed among different treatments used for the management practices in terms of number of tobacco caterpillar larvae (Table 4) at different days after transplanting (DAT). At 15 DAT, the highest number of tobacco caterpillar larvae per five plants was recorded in T_7 (12.67 larvae/5 plants) which was significantly different from all other treatments followed by T_3 (10.33 larvae/5 plants) and T_2 (9.67 larvae/5 plants), T_6 (9.33 larvae/5 plants) and T_5 (9.50 larvae/5 plants) where last three assessed number were statistically similiar. On the other hand, the lowest number of tobacco caterpillar larvae per five plants was recorded in T_4 (7.83 larvae/5 plants) which was significally different from all other treatments followed by T_1 (8.67 larvae/5 plants), (Table 4).

At 25 DAT, the highest number of tobacco caterpillar larvae per five plants was recorded in T_7 (13.33 larvae /5 plants) which was significally different from all other treatments followed by T_3 (9.77 larvae /5 plants) and T_2 (9.17 larvae /5 plants), T_6 (8.87larvae /5 plants) and T_5 (8.97 larvae /5 plants) here last three are statistically identical. And the lowest number of tobacco caterpillar larvae per five plants was recorded in T_4 (7.33larvae /5 plants) which was signifycally different from all other treatments followed by T_1 (8.33 larvae/5 plants), (Table 4).

More or less similar trends of number of tobacco caterpillar per five plants were also recorded at 35 DAT, 45 DAT and 55 DAT.

In case of mean number of tobacco caterpillar larvae, the highest number of tobacco caterpillar larvae was recorded in T_7 (13.73 larvae /5 plants) which was significantly different from all other treatments followed by T_3 (9.64 larvae /5 plants) and T_2 (8.86 larvae /5 plants), T_5 (8.53 larvae /5 plants) and T_6 (8.34 larvae /5 plants) where last two were statistically identical On the other hand, the lowest number of tobacco caterpillar larvae was recorded in T_4 (6.82 larvae /5 plants) followed by T_1 (7.89 larvae /5 plants), (Table 4).

Considering the percent reduction of number of tobacco caterpillar larvae among different management practices over control, the highest reduction over control was achieved in T_4 (50.33%) followed by T_1 (42.52%), T_6 (39.27%) and T_5 (37.90%).

On the other hand, the minimum reduction of number of tobacco caterpillar larvae over control was found in T_3 (29.80%) followed by T_2 (35.48%) (Table 4).

From these above findings it was revealed that among the different treatments, T_4 showed the best result in reducing the number of tobacco caterpillar larvae (50.33%) than the other treatments; whereas, T_3 showed the least performance results in reducing the number of tobacco caterpillar larvae (29.80%) over control. As a result, the order of rank of efficacy of the treatments applied against tobacco caterpillar in terms of reducing number of caterpillar over control was $T_4 > T_1 > T_6 > T_5 > T_2 > T_3$.

Table 4. Effect of biopesticides on incidence of tobacco caterpillar per five plants.

Treatments	Number of tobacco caterpillar per five plants					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	8.67 d	8.33 d	7.90 e	7.57 e	7.00 d	7.89 e	42.52
T_2	9.67 c	9.17 c	8.93 c	8.53 c	8.00 c	8.86 c	35.48
T_3	10.3 b	9.77 b	9.53 b	9.40 b	9.17 b	9.64 b	29.80
T_4	7.83 e	7.33 e	6.83 f	6.33 f	5.77 e	6.82 f	50.33
T_5	9.50 c	8.97 c	8.50 d	8.07 d	7.60 cd	8.53 d	37.90
T_6	9.33 c	8.87 c	8.33 d	7.83 de	7.33 d	8.34 d	39.27
T_7	12.67 a	13.33 a	13.66 a	14.33 a	14.67 a	13.73 a	
LSD(0.05)	0.49	0.48	0.37	0.37	0.66	0.33	
CV%	2.86	2.88	2.28	2.38	4.35	2.05	

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.2.2 Incidence of diamondback moth larvae

Significant variations (p>0.05) were observed among different treatments used for the management practices in terms of number of diamondback moth larvae at different days after transplanting (DAT). At 15 DAT, statistically the highest number of diamond back moth larvae per five plants was recorded in T_7 (8.67 larvae /5 plants) which was statistically similar with T_3 (8.67 leaves /5 plants) and different from all other treatments followed by T_2 (7.67 larvae /5 plants) and T_5 (7.00 larvae /5 plants). Conversely, the lowest number of diamond back moth larvae per five plants was recorded in T_4 (5.43 larvae /5 plants) followed by T_1 (6.33 larvae /5 plants), T_6 (6.77 larvae /5 plants) which was statistically different (Table 5).

At 25 DAT, Significally the highest number of diamond back moth larvae per five plants was recorded in T_7 (9.33 larvae /5 plants) which was statistically similar with T_3 (8.63 leaves /5 plants) followed by T_2 (7.23 leaves /5 plants) and T_5 (6.60 larvae /5 plants). And the lowest number of diamond back moth larvae per five plants was recorded in T_4 (5.27 larvae /5 plants) which was statistically different from all other treatments and followed by T_1 (6.00 larvae /5 plants). More or less similar trends of number of tobacco caterpillar per five plants were also recorded at 35 DAT, 45 DAT and 55 DAT.

In case of mean infestation, the highest number of leaf infestation was recorded in T_7 (10.13 leaves /5 plants) which was significally different from all other treatments followed by T_3 (8.29 leaves /5 plants) and T_2 (6.88 leaves /5 plants) and they were statistically not similiar. On the other hand, the lowest infestation was recorded in T_4 (4.87 leaves /5 plants) followed by T_1 (5.63 leaves /5 plants) T_6 (5.97 leaves /5 plants) and T_5 (6.11 leaves /5 plants) and they were statistically identical.(Table 5).

Considering the percent reduction of leaf infestation over control, the highest 51.92% reduction over control was achieved in T_4 followed by T_1 (44.42%) and T_6 (41.05%) and T5 (39.67%). On the other hand, the minimum reduction of leaf infestation over control was found in T_3 (18.22%) followed by T_2 (32.10%) (Table 5).

Table 5. Effect of biopesticides on incidence of diamondback moth larvae per five plants of cabbage.

Treatments	Number of diamondback moth larvae per five plants					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	6.33 d	6.00 cd	5.63 de	5.30 d	4.90 d	5.63 d	44.42
T_2	7.67 b	7.23 b	6.83 c	6.50 c	6.17 c	6.88 c	32.10
T_3	8.67 a	8.63 a	8.43 b	8.03 b	7.67 b	8.29 b	18.22
T_4	5.43 e	5.27 d	5.0 e	4.50 e	4.13 e	4.87 e	51.92
T_5	7.00 c	6.60 bc	6.10 cd	5.60 d	5.27 d	6.11 d	39.67
T_6	6.77 cd	6.37 c	6.03 cd	5.53 d	5.17 d	5.97 d	41.05
T_7	8.67 a	9.33 a	10.00 a	10.33 a	12.33 a	10.13 a	
LSD (0.05)	0.51	0.74	0.80	0.61	0.61	0.59	
CV%	4.00	5.86	6.56	5.24	5.28	4.82	

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.3 Effect of biopesticides on cabbage head infestation

The highest number (11.67) of healthy cabbage head was recorded in T_4, which was statistically different from all other treatments followed by T_1 (10.67) and T_6 (10.33). On the other hand, the lowest number of healthy cabbage head was recorded in T_7 (4.33) which was statistically different from all other treatments and followed by T_3 (7.33) (Table 6). The highest number of cabbage head infestation was recorded in T_7 (7.42) which was significally different from all other treatments. But the lowest number of cabbage head infestation was recorded in T_4 (3.17) which was statistically similar with T_1 (3.33) followed by T_6 (3.83). Considering the percent cabbage head infestation, the highest 55.77% infestation was recorded in T_7 which was statistically different from all other treatments and followed by T_3 (41.35%). On the other hand, the minimum cabbage head infestation by number was recorded in T_4 (21.37%) which was statistically similar with T_1 (23.80%) followed by T_6 (26.80%).

From these above findings it is revealed that among different treatments, the spinosad (T_4) reduced the highest infestation of cabbage head (61.68%) in the cabbage field. The lowest infestation reduction over control was found in T_3 (25.84%).

Table 6. Effect of biopesticides on cabbage head infestation.

Treatments	Healthy head/plot		Infested head/plot		Infestation (%)		Infestation reduce over control (%)
T_1	10.67	b	3.33	de	23.80	ef	57.32
T_2	8.67	d	4.33	c	33.14	c	40.56
T_3	7.33	e	5.17	b	41.35	b	25.84
T_4	11.67	a	3.17	e	21.37	f	61.68
T_5	9.67	c	4.17	c	30.09	cd	53.95
T_6	10.33	bc	3.83	cd	26.80	de	51.94
T_7	4.33	f	7.42	a	55.77	a	
LSD (0.05)	0.95		0.61		5.18		
CV (%)	5.97		7.59		8.78		

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.4 Effect of biopesticides on yield and yield contributing characteristics of cabbage

4.4.1 Diameter of cabbage head

Significally the highest diameter of head (23.50 cm) was recorded in T_4 which was statistically different from all other treatments followed by T_1 (22.17 cm) and T_6 (21.43cm). On the other hand, the lowest head diameter (14.83) was found in T_7 which was significantly different from all other treatments followed by T_2 (20.47cm) and T_5 (20.87 cm) where they were statistically identical. The gradually decreased trend was observed in case of diameter of head as $T_4 > T_1 > T_6 > T_5 > T_2 > T_3 > T_7$ (Table 7).

In terms of % increase of diameter over control, the highest increase over control on head diameter was observed with the treatment of T_4 (58.43%) where the lowest was achieved from T_3 (22.24%).

From the above-mentioned findings, it was revealed that among the different treatments, T_4 performed best results in percent increasing diameter of head (58.43%) at harvesting than the other treatments; whereas, T_3 showed the least performance results in percent increasing diameter of head (22.24%) at harvesting over control.

4.4.2 **Height of cabbage head**

The highest height of head (10.70 cm) was recorded in T_4 which was statistically similar with T_1 (10.34 cm).

On the other hand, the lowest height of head (7.33 cm) was found in T_7 which was significantly different from all other treatments. But among the treated plots, the lowest height of head (8.93cm) was found in T_3 which was statistically similar with T_2 (9.33) followed by T_5 (9.97cm) and T_6 (10.10 cm) .The gradually decreased trend was observed in case of height of head as $T_4 > T_1 > T_6 > T_5 > T_2 > T_3 > T_7$.

In terms of % increase over control, the highest increase over control on head height was observed with the treatment of T_4 (45.91%) followed by T_1 (40.91%) where the lowest was achieved from T_3 (21.8%) which was close to T_2 (27.27 %) (Table 7).

From the above-mentioned findings, it was revealed that among the different treatments, T_4 performed best results in percent increasing height of head (45.91%) at harvesting than the other treatments; whereas, T_3 showed the least performance results in percent increasing height of head (21.8 %) at harvesting over control.

Table 7. Effect of biopesticides on yield contributing characters of cabbage

Treatments	Diameter of head (cm)	% increase over control	Height of head (cm)	% increase over control
T_1	22.17 b	49.44	10.34 ab	40.91
T_2	20.47 c	37.98	9.33 c	27.27
T_3	18.13 d	22.24	8.93 c	21.8
T_4	23.50 a	58.43	10.70 a	45.91
T_5	20.87 c	40.68	9.97 b	35.91
T_6	21.43 bc	44.49	10.10 b	37.73
T_7	14.83 e		7.33 d	
LSD (0.05)	1.12		0.56	
CV (%)	3.11		3.32	

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.4.3 Single head weight (kg) during harvesting

The highest single head weight (1.50kg) was recorded in T_4 which was significally different from all other treatments and followed by T_1 (1.39kg) and T_6 (1.34kg). On the other hand, the lowest single head weight (0.92 kg) was found in T_7 which was significantly different from all other treatments. But in the treated plots, the lowest single head weight (1.12 kg) was found in T_3 which was statistically similar with T_2 (1.17 kg) followed by T_5 (1.23 kg) .The gradually decreased rank was observed in case of single head weight as $T_4 > T_1 > T_6 > T_5 > T_2 > T_3 > T_7$. (Table 8).

In terms of % increase over control, the highest increase over control on single head weight was observed with the treatment of T_4 (63.27%) where the lowest was achieved from T_3 (22.53%) (Table 8).

4.4.4 Total yield (t/ha)

The highest yield (36.40 t/ha) was recorded in T_4 which was significally different from all other treatments followed by T_1 (34.07 t/ha) and T_6 (32.37 t/ha). The lowest yield (22.97 t/ha) was found in T_7 which was significantly different from all other treatments. But in the treated plots, the lowest yield (26.63 t/ha) was found in T_3 which was followed by T_2 (29.57 t/ha) and T_5 (30.37 t/ha). The gradually decreased trend was observed in case of total yield as $T_4 > T_1 > T_6 > T_5 > T_2 > T_3 > T_7$.

In terms of % increase over control, the highest increase over control on total yield (t/ha) was observed with the treatment of T_4 (58.48%) which followed by T_1 (48.33%) and T_6 (40.92%) whereas the lowest was achieved from T_3 (15.94%) followed by T_2 (28.73%) (Table 8).

The higher yield in Spinosad in present investigation were compareable with the findings of Debbarma, *et al*. 2017, Dey, *et al.* 2001, Walunj, *et al.* 2001.

Table 8. Individual head weight and yield (ton/ha) of cabbage in different treatments during harvesting.

Treatments	Single head wt. (kg)	% increase over control	Yield(ton/ha)	% increase over control
T_1	1.39 b	51.27	34.07 b	48.33
T_2	1.17 cd	27.27	29.57 d	28.73
T_3	1.12 d	22.53	26.63 e	15.94
T_4	1.50 a	63.27	36.40 a	58.48
T_5	1.23 c	34.53	30.37 cd	32.22
T_6	1.34 b	45.81	32.37 bc	40.92
T_7	0.92 e		22.97 f	
LSD (0.05)	0.0933		2.0033	
CV (%)	4.24		3.71	

[DAT= Days after transplanting, in a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Spraying of Abamectin 1.2EC @ 1 ml/L of water at 7 days interval; T_2: Spraying of Azadirachtin 1EC @ 1 ml/L of water at 7 days interval; T_3: Spraying of Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval; T_4: Spraying of Spinosad 45SC @ 1 ml/L of water at 7 days interval; T_5: *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_6: Abamectin 1.2EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval; T_7: Untreated control]

4.5 Relationship between leaf infestation by tobacco caterpillar and yield of cabbage

Significant relationship was found between leaf infestation by caterpillar and yield of cabbage when correlation was fitted between these two parameters. There was a very strong (R^2=0.896) and negative (slope =-1.344) correlation found between leaf infestation by caterpillar and yield of cabbage, i.e. yield of cabbage decreased with the increasing of cabbage leaf infestation by caterpillar. Tobacco caterpillar infestation on leaf indirectly prevented plants to produce and supply nutrient and water. The plants growth and development became stunted with a reduced yield.

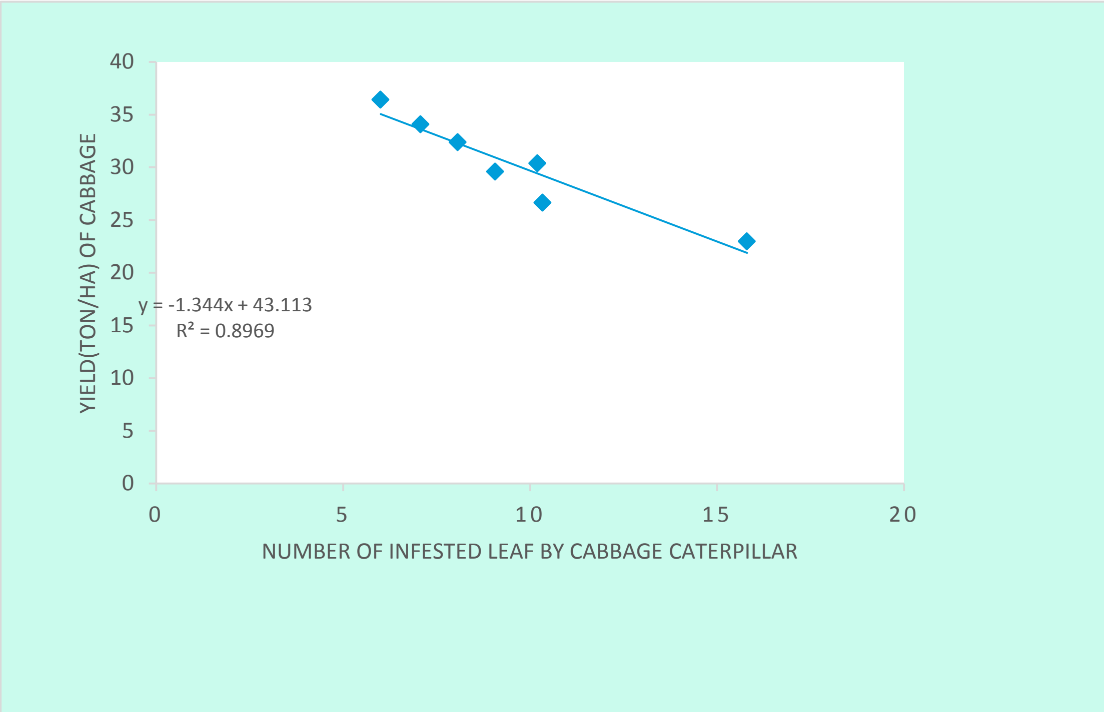

Figure 2. Relationship between leaf infestation by tobacco caterpillar and yield of cabbage.

4.6 Relationship between leaf infestation by diamondback moth larvae and yield of cabbage

Significant relationship was observed when correlation was made between leaf infestation by diamondback moth larvae and yield of cabbage. The highly significant ($p<0.05$), very strong (R^2=0.8945) and negative (slope =-2.907) correlation was found between these two parameters, i.e. yield of cabbage decreased with the increasing of leaf infestation by diamondback moth larvae. From the present study, it is revealed that leaf infestation by diamond back moth larvae indirectly prevented plants to produce and supply nutrient and water. The plants growth and development became stunted with a reduced yield.

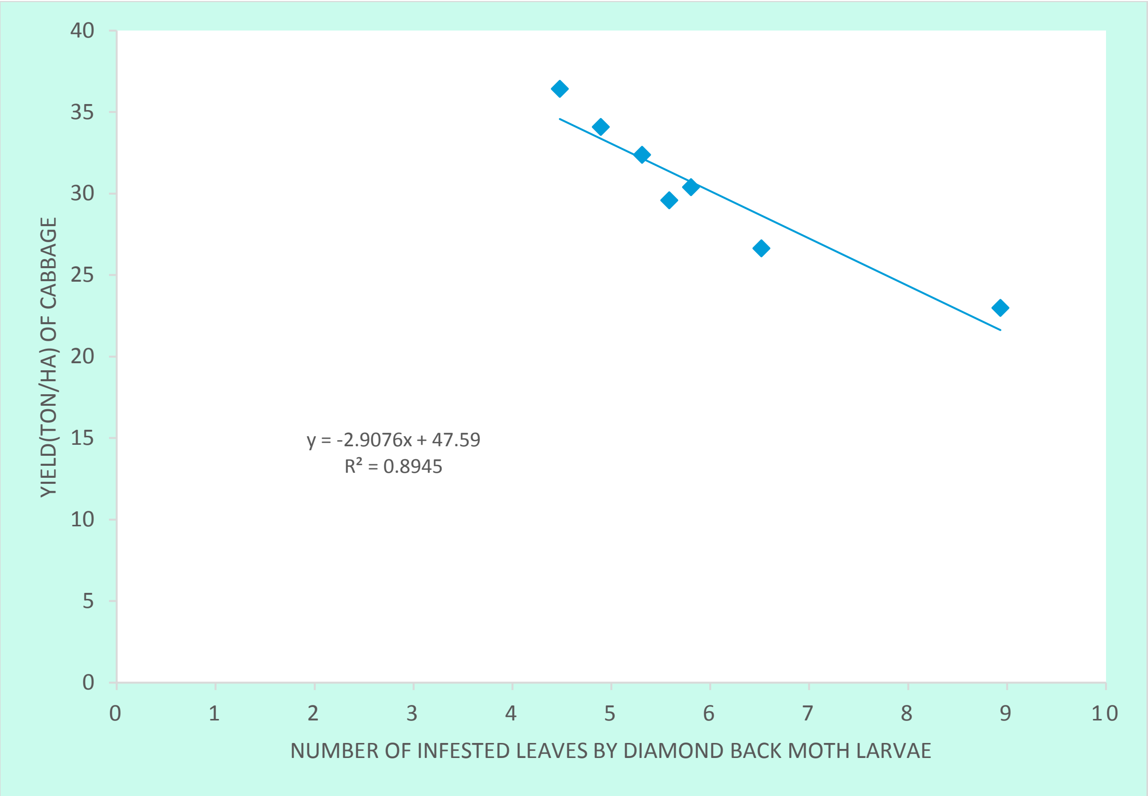

Figure 3. Relationship between leaf infestation by diamondback moth larvae and yield of cabbage.

4.7 Relationship between incidence of tobacco caterpillar and yield of cabbage

When a linear regression was fitted between these two parameters, a highly significant ($p<0.05$), very strong ($R^2=0.8603$) and negative (slope =-1.9013) correlation was found between incidence of caterpillar and yield of cabbage, i.e. yield of cabbage decreased with the increasing incidence of tobacco caterpillar. From the present study, it may be revealed that higher number of tobacco caterpillar larvae increased the leaf infestation of cabbage which indirectly prevented plants to produce and supply nutrient and water. The plants growth and development became stunted with a reduced yield.

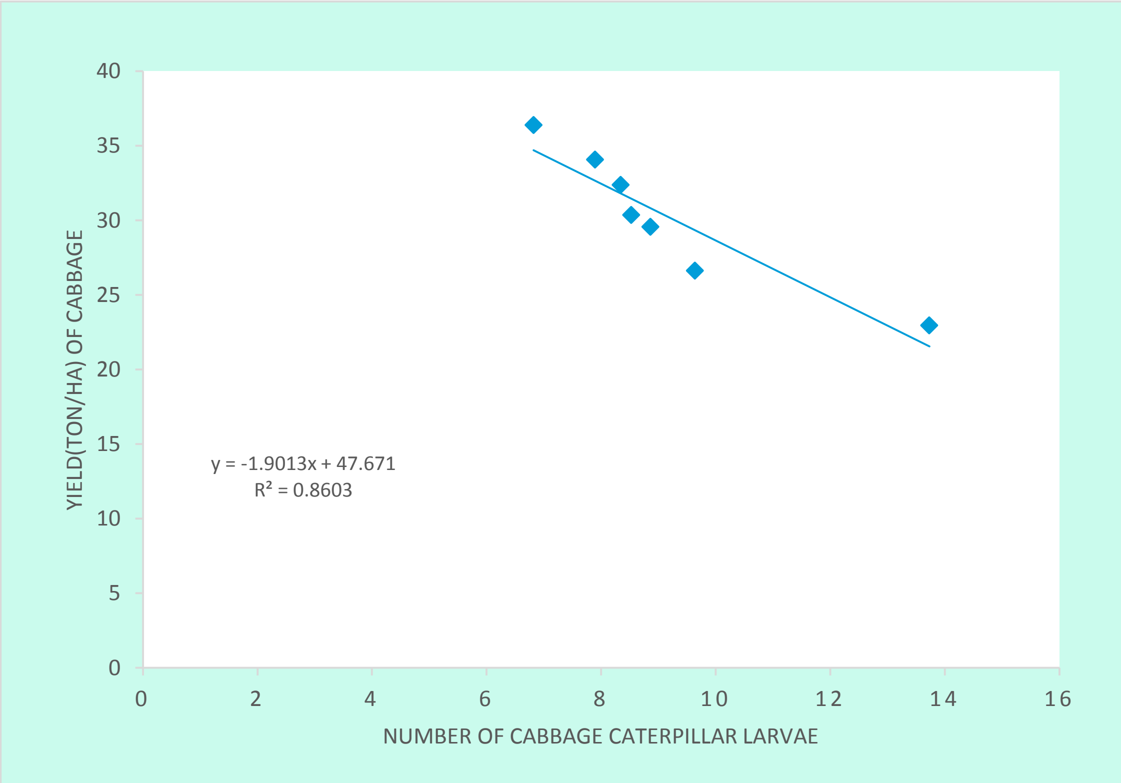

Figure 4. Relationship between incidence of tobacco caterpillar and yield of cabbage.

4.8 Relationship between incidence of diamondback moth larvae and yield of cabbage

A linear regression was fitted between the incidence of diamondback moth larvae and yield of cabbage (t/ha). A highly significant ($p<0.05$), very strong ($R^2=0.9499$) and negative (slope =-2.4492) correlation was found between these two parameters, i.e. yield of cabbage decreased with the increasing number diamondback moth larvae. In this study, it was revealed that the higher number of diamondback moth larvae led to the higher leaf infestation of cabbage.

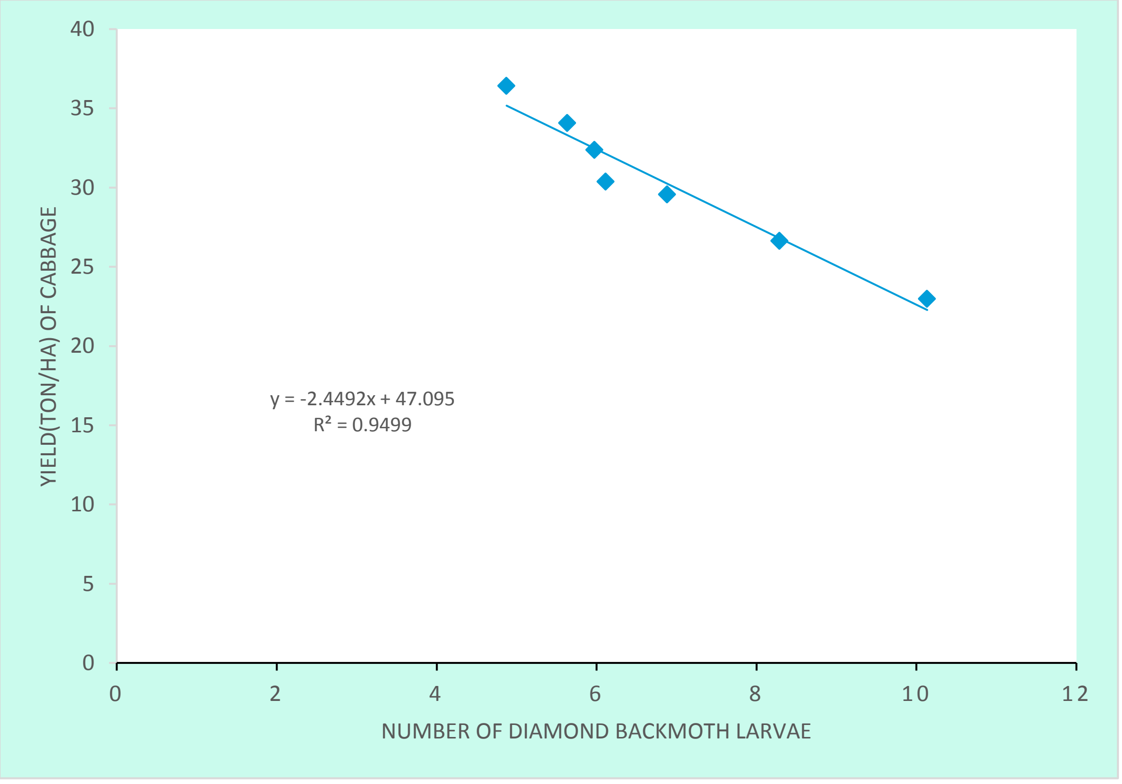

Figure 5. Relationship between incidence of diamondback moth larvae and yield of cabbage.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2019 to January, 2020 to evaluate some management practices applied against major lepidopteran insect pests of cabbage. The experiment consisted of control measures with biopesticides.

Seven treatments, viz. T_1 (Abamectin 1.2EC @ 1 ml/L of water at 7 days interval); T_2 (Azadirachtin 1EC @ 1 ml/L of water at 7 days interval); T_3 (Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval); T_4 (Spinosad 45SC @ 1 ml/L of water at 7 days interval); T_5 (*Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval); T_6 (Abamectin 1.2 EC + *Bacillus thuringiensis* @ 1 ml/L of water at 7 days interval) and T_7 (untreated control) were included in this study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Results demonstrated that the significant variations were observed among different ages of the cabbage plant in terms of percent leaf infestation and percent head infestation by number. From beginning of head formation stage to at harvest, significant results were also observed in terms of leaf infestation intensity, percent head infestation by number, percent head infestation by weight, height of head, diameter of head, single head weight (kg), healthy head weight ($kgpot^{-1}$) and yield (tha^{-1}).

Results showed that the lowest number of infested leaves by tobacco caterpillar (6.33, 6.33, 6.33, 5.67 and 5.33 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean =6.00) was observed in T_4 where the highest (14.33, 15.67, 16.00,16.33 and 16.67 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean =15.80) was obtained from T_7. But among the treated plots, the highest leaf infestation by number (11.33, 11.00, 10.33, 9.67 and 9.33 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean =10.33) was achieved from T_3. In terms of percent reduction of leaf infestation among different treatments, the highest reduction over control was found in T_4 (62.02%) and the lowest was found in T_3 (34.60%).

In case of diamondback moth larvae, the lowest number of infested leaves (4.60, 4.70, 4.60, 4.37 and 4.13 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean =4.48) was observed in T_4 where the highest (8.33, 8.67, 8.67, 9.33 and 9.67 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean =8.93) was obtained from T_7. But among the treated plots, the highest leaf infestation by number (6.33, 6.63, 6.53, 6.43 and 6.67 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean =6.52) was achieved from T_3. In terms of percent reduction of leaf infestation among different treatments, the highest reduction over control was found in T_4 (49.85%) and the lowest was found in T_3 (27.01%).

In case of incidence of different insects, the lowest mean number of different insects larvae per five plants was found in T_4 (6.82 and 4.87 for tobacco caterpillar and diamondback moth respectively). On the other hand, the highest mean number of tobacco caterpillar and diamondback moth larvae per five plants was found in T_7 (13.73 and 10.13 respectively). In terms of percent reduction over control among different treatments,T_4 showed the highest incidence reduction over control (50.33% and 51.90%) against tobacco caterpillar and diamondback moth respectively. The lowest reduction over control was found in T_3 (29.80% and 18.22%) against tobacco caterpillar and diamondback moth respectively.

Again, during harvesting period the lowest number infested head (3.17), percent infestation of head (21.37%), highest height of head (10.70 cm), diameter of head (23.50 cm), single head weight (1.50 kg) and highest yield (36.40 tha^{-1}) were observed in T_4 where as the highest number of infested head (7.42), percent infestation of head (55.77%), lowest height of head (7.33 cm), diameter of head (14.83 cm), single head weight (0.92 kg) and lowest total yield (22.97 tha^{-1}) were obtained from T_7. But in the treated plots, the highest number of infested head (5.17), percent infestation of head (41.35%), lowest height of head (8.93 cm), diameter of head (18.13 cm), single head weight (1.12 kg) and lowest yield (26.63 tha^{-1}) were obtained from T_3.

In terms of percent reduction or increase over control the highest percent reduction of head infestation over control (61.68%), percent increase of height of head over control (45.91%), percent increase of diameter of head over control (58.43%) and percent increase of Total yield over control (58.48%) were achieved by T_4 where the lowest percent reduction of head infestation over control (25.84%), percent increase of height of head over control (21.8%), percent increase of diameter of head over control (22.24%) and percent increase of total yield over control (15.94%) were achieved by T_3.

From the above discussion on summary, it may be concluded that, the treatment T_4 comprised of Spinosad 45SC @ 1 ml/L of water at 7 days interval gave the highest performance compared to all other treatments used under the present study where the lowest performance was achieved by untreated control. On the other hand, the lowest performance among the treated plots was obtained by T_3 (Potassium salt of fatty acid @ 1 ml/L of water at 7 days interval).

RECOMMENDATIONS

Considering the findings of the present experiment, further studies in the following areas may be suggested:

1.To determine the effectiveness by applying new biopesticides in future.

2. Further trials with effective biopesticides may be done at different locations of the country.

CHAPTER VI

REFERENCES

Adalbert, B., Szla, L. A., Feren C. Z. and Gupta, J. A. (2013). Managing Thrips on Roses with Combinations of Neonicotinoide and Biological Insecticides. *J. Agric. Urban Entomol.* **29**: 16-24.

Adejumo, T. O. (2005). Crop protection strategies for major diseases of cocoa, coffee and cashew nut in Nigeria. *Africa J. Biotechnol*. **4**: 143-150.

Ahmed, T. (2008). Study on the biology and management of tobacco caterpillar, *Spodoptera litura*. An MS thesis, Bangladesh Agricultural University, Mymensingh, Bangladesh. pp. 42-43.

Andersen, C. R. (2000). Cabbage home gardening series. University of Arkansas.

Atwal, A. S. (1986). Agricultural Pests of India and South-East Asia. Kollany publishers, India.p. 251.

Ayalew, G. (2006). Comparison of yield loss on cabbage from Diamondback moth, *Plutella xylostella* L.(Lepidoptera: Plutellidae) using two insecticides. *Crop Protect.* **25**(9): 915-919.

Baidoo, P. and Mochiah, M. (2016). Comparing the effectiveness of garlic (*Allium sativum* L.) and hot pepper (*Capsicum frutescens* L.) in the management of the major pests of cabbage (*Brassica oleracea* L.). *Sustain. Agric. Res.* **5**: 83–91.

BARC. (2012). Fertilizer Recommendation Guide-2012. Bangladesh Agricultural Research Council, Farmgate, New Airport Road, Dhaka-1215. p. 113.

BBS. (2019). Year book of Agricultural Statistics of Bangladesh. Statistics Division, Bangladesh Bureau of Statistics (Monthly Statistical Bulletin, Bangladesh, May, 2020). Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p. 295.

Bhat, M. G., Joshi, A. B. and Singh, M. (1994). Relative losses of cotton yield by insects in some cotton genotypes (*Gossypium hirsutum* L.). *Indian J. Entomol.* **46**: 169-172.

Buranday, R. P. and Rarest, R. S. (1975). Effects of cabbage-tomato intercropping on the incidence and oviposition of the diamondback moth *Plutella xylostella* (L.). *Philippine Entomologist*.**2** :369-374.

Butani, D. K. and Jotwani, M. G. (1984). Insects in vegetable. Periodical Expert Book Agency. Vivek-Vihar, Delhi, India. pp: 69-79.

Cleveland, C. B., Mayes, M. A., Cryer, S. A. (2001). An ecological risk assessment for spinosad use on cotton. *Pest Manage. Sci.* **58**: 70-84.

Copping, L. G., Menn, J. J. (2000). Biopesticides: a review of their action, applications and efficacy. *Pest Manage. Sci.* **56**: 651-676.

Corvi, F. and Nardi, S. (1998). Combattere la nottua del cavolfiore. Terra e vita. **47**: 76-78. Dedes. J. (2003). Insectarium Supervisor. Canadian Forest Service, Great Lakes Forestrv Centre. pp. 541-567.

Debbarma, A., Singh, K. I., Gupta, M. K., Sobitadevi, P. (2017). Bio-rational management of major lepidopterous pests and their influence on yield of cabbage crop under Manipur valley. *J. Entomol. and Zool. Stud.* **5**(5): 1546-1551.

Dempster, J. P. (1969). Some effects of weed control of the numbers of small cabbage white (*Pieris rapae* L.) on brussels sprouts. *Appl. Ecol*. **6**: 339-345.

Dey, P. K., Somchoudhary, A. K. (2001). Evaluation of spynosis A + D (spinosad 48 EC) against Lepidopteran pest complex of cabbage and its effect on natural enemies of diamondback moth under field conditions of West Bengal. Pestology. **25**: 54-58.

Dhaliwal, G. S. and Heinrichs, E. A. (1998). Critical Issues in Insect Pest Management. Commonwealth Publishers, New Delhi.

Edralin, O. D., Vasquez, F., Cano, A., Anico, A., Saavedra, N., Suiza, R., Macatula, R., Subagan, R. and Arabit, R. (2011). Update on DBM diamide resistance from the Philippines: causal factors and findings. In: Proceedings of the 5th International Workshop on the Management of Diamond back moth and other crucifer pests. 21-25, March 2011. Shelton *et al.* (Eds). Kasetsart University, Nakhon Pathom, Thailand. AVRDC – The World Vegetable Center, Publication No. 11-755. AVRDC – The World Vegetable Center, Taiwan. p. 321 pp. 199-201.

Edris, K. M., Islam, D. K., Chowdhury, M. S. and Haque, A. K. M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People’s Republic of Bangladesh. pp. 118.

FAO. (1988). Production Year Book. Food and Agricultural of the United Nations Rome, Italy. 42: 190-193.

FAO. (2015). Report of a joint FAO/WHO workshop on fruit and vegetables for health. Food and Agricultural Organization. P. 25.

Golizadeh, A., Kamali, K., Fathipour, Y., and Abbasipour, H. (2009). Life table of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) on five cultivated brassicaceous host plants.

Grist, D, H. and Lever, R. J. A. W. (1989). Pest's of Rice. Published by Longmans, Green and Company Limited, London, Great Britain. pp. 139-140.

Grzywacz, D., Rossbach, A., Rauf, A., Russell, D. A., Srinivasan, R. and Shelton, A. M. (2010). Current control methods for diamondback moth and other brassica insect pests and the prospects for improved management with lepidopteran-resistant Bt vegetable brassicas in Asia and Africa. *Crop protect.* **29**(1): 68-79.

Gupta, G. P., Rani, S., Ajanta, B. and Raghuraman, M. (2004). Relative toxicity of certain new insecticides against *Spodoptera litura* (Fabricius). *Pesticide Res. J.* **16**: 45-47.

Haider, J., Marutomo, K. and Azad, A. K. (1991). Estimation of microbial biomass carbon and nitrogen in Bangladesh. *Soil Sci. Plant Nutr.* **37**(4): 591-599.

Harris, B. M., Maclean, B. (1999). Spinosad: control of lepidopterous pests in vegetable Brassicas. Proc. 52nd N. Z. Pl. *Prot. Conf*. pp. 65-69.

Hahn, J. and Burkness, S. W. (2015). Cutworms in home garden. http://shop.extension.umn.edu

Haseeb, M., Liu, T. X. and Jones, W. A. (2004). Effects of selected insecticides on *Cotesia plutellae* (Hymenoptera: Braconidae), an endolarval parasitoid of *Plutella xylostella* (Lepidoptera:Plutellidae). *Biocontrol*. **49**: 33-46.

Hole, U. B., Jadhav, S. R. and Teli, V. S. (2009). Bio-efficacy of Insecticides against *Spodoptera litura* (Fab.) infesting Soybean. *Ann. Pl. Protec. Sci.* **17**(2): 322-324.

Jagdish, J., Agnihotri, M. and Sharma, R. (2014). Evaluation of some Bio- pesticides against some Important Lepidopteron Pests of Pigeonpea (*Cajanus cajan* L.) at Pantnagar, Uttarakhand, India. *Greener J. Agril. Sci.* **4**(6): 232-237.

Janmaat, A. F. (2003). Rapid evolution and the cost of resistance to *Bacillus tlturingicnsis* in greenhouse populations of cabbage loopers, Trichoplusia nt. *Proc. Biol. Sci*. pp. 63- 70.

Joseph, B., Sowmya and Sujatha, S. (2012). Insight of botanical based biopesticides against economically important pest. *Int. J. Pharm. Life Sci.* **3**(11): 2138-2148.

Karuppaiah, V., Srivastava, C., Subramanian, S. and Čupr, P. (2017). Variation in insecticide detoxification enzymes activity in *Spodoptera litura* (Fab.) of different geographic origin. *J. Entomol. Zool. Stud.* **5**(3): 770-773.

Kenny, G. J. and Chapman, R. B. (1988). Effects of an intercropp on the insect pests, yield and quality of cabbage. *New Zealand Exper*. **16**: 67-72.

Khan, R. R., Ahmed, S. and Nisar, S. (2011). Mortality responses of *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae) against some conventional and new chemistry insecticides under laboratory conditions. *Pakistan Entomol*. **33**(2): 147-150.

Koul, O. (2008). Phytochemicals and insect control: an antifeedant approach. *Crit. Rev. Plant Sci.* **27**: 1–24.

Koul, O., Multani, J. S., Goomber, S., Daniewski, W. M. and Berlozecki, S. (2004). Activity of some non-azadirachtin limonoids from *Azadirachta indica* against lepidopteran larvae. *Australian J. Ento.* **43**: 189– 195.

Krishnamoorthy, A. (2004). Biological control of diamondback moth *Plutella xylostella* L., an Indian scenario with reference to past and future strategies. In Proceedings of the International Symposium (Kirk, A. A and Bordat, D. eds.), Montpellier, France, CIRAD. pp. 204-11.

Kumar, K., Srinivasan, N. K. and Suman, C. L. (1983). Optimum control strategy of cabbage pests from a chemical control trial. *Prog. Hort.* **18**: 104-110.

Kumar, D., Singh, R. and Mahal, M. S. (1992). Biology of *Spodoptera litura* (Fab.) on sunflower. *J. Insect Sci*. **5**(l): 33-36.

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

Kusznierewicz, B., Bartoszek, A., Wolska, L., Drzewiecki, J., Gorinstein, S. and Namies´nik, J. (2008). Partial characterization of white cabbages (*Brassica oleracea* var. *capitata* f. *alba*) from different regions by glucosinolates, bioactive compounds, total antioxidant activities and proteins. LWT *Food Sci. Technol.* **41**: 1–9.

Mahla, R. S., Singh, S. and Chaudhary, P. (2005). Management of diamondback moth, *Plutella xylostella* L. larvae by entomopathogenic fungus, Metarhizium anisopliae. *Indian J. Entomol*. **67**: 342-344.

Mansour, N. S. (1989). Versatile row and field cover American Vegetable Grower March 1989. *pp*. 72-78.

Maqsood, S., Sabri, M. A., Ali, A., Abbas, M., and Aziz, A. (2017). Comparative toxicity of some insecticides against army worm, *Spodoptera litura* L. (Lepidoptera: Noctuidae) under laboratory conditions.

Me´ndez, W. A., Valle, J., Ibarra, J. E., Cisneros, J., Penagos, D. I. and Williams, T. (2002). Spinosad and nucleopolyhedrovirus mixtures for control of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize. *Biol. Control*. **25**: 195-206.

Meena, K. A. (2018). Bio-efficacy of some newer insecticides against insect pests of cabbage. *J. Entomol. and Zool. Stu.* **6**(5): 1102-1106.

Moyer, D. (1999). Pest Management Recommendations for Commercial Vegetable and Potato Production, Cornell Cooperative Extension, Cornell University. *pp*. 206-209.

Norman, C. and Shealy, M. (2007). Illustrated encyclopedia of healing remedies. Elements book inc. Toledo, OH, USA.

Nzanza, B., (2012). Control of whiteflies and aphids in tomato (*Solanum lycopersicum* L.) by fermented plant extracts of neem leaf and wild garlic. *African J. Biotechnol*. **3**: 45-53.

Parajuli, S. and Paudel, S. (2019). Eco-Friendly Management of Diamondback Moth (*Plutella xylostella* L.) of Cabbage (*Brassica oleracea* var. *capitata*) in Nepal. *Int. J. App. Sci. Biotechnol.* **7**(3): 304-308.

Pelosini, P. (1999). La lotta integrata. *Terra e vita*. **24**: 76-78.

Prabhakar, B. S. and Srinivas, K. (1990). Effect of spacing and fertilizer on head yield of cabbage. *Prog. Hort.* **22**(1-4): 112-116.

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

Rajput, A. A., Sarwar, M., Bux, M. and Tofique, M. (2003). Evaluation of synthetic and some plant origin inseticides against *Helicoverpa armigera* (Hubner) on chickpea. *Pak. J. Biol. Sci.* **6**(5): 496-499.

Ramzan, M., Murtaza, G., Javaid, M., Iqbal, N., Raza, T., Arshad, A. and Awais, M. (2019). Comparative Efficacy of Newer Insecticides against *Plutella xylostella* and *Spodoptera litura* on Cauliflower under Laboratory Conditions. *Ind. J. Pure App. Biosci.* **7**(5): 1-7.

Rashid, M. A., Ahmed, S., Halim, G. M. A., Rahman, M. T., Shaha, S., Rahman, A. S. M. M., Masud, M. A. T., Quamruzzaman, A. K. M., Goffer, M. A., Rahaman, M. A., Masumder, S., Rahman, M. A. and Alom, S. N. (2006). Improved Technology of Vegetable Production (Bangla). BARI, Gazipur. P. 158.

Rashid, M. M. (1993). Sitayer Sabji. In: Sabji Biggan (in Bangla). 1st edition. Bangla Academy, Dhaka, Bangladesh. pp. 254-356.

Rehan, A. and Freed, S. (2014). Selection, mechanism, cross resistance and stability of spinosad resistance in *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *Crop Protect.* **56:** 10-15.

Sarker, M. Y., Azad, A. K., Hasan, M. K., Nasreen, A., Naher, Q. and Baset, M. A. (2002). Effect of plant spacing and source of nutrients on the growth and yield of cabbage. *Pakistan J. Biol. Sci.* **5**(6): 636-639.

Saxena, J. D., Rai, S., Srivastava, K. M. and Sinha, S. R. (1989). Resistance in the field populations of the diamondback moth to some commonly used synthetic pyrethroids (No. RESEARCH).

Schmutterer, H. (1990). Properties and potential of natural pesticides from the neem tree. *Azadirachta indica*. *Ann. Rev. Entomol.* **35**: 271-297.

Seal, D. R., Ciomperlik, M., Richard, M. L. and Klassen, W. (2006). Comparative effectiveness of chemical insecticides against the chilli pod borer, on pepper and their compatibility with different natural enemies. *Crop Protect.* **25**: 949-955.

Shankar, G., Arjuna, M., Bhatt, U. G., Kendappa, G. N. and Miphyantha, M. S. (1996). Bt Berliner Subsp. kurstaki in the management of DBM in India. In Proc. 3rd Int. Workshop, Kuala Lumpur, Malaysia. 29th Oct.-1st Nov. pp. 104-108.

Sharma, P., Kumawat, K. C., Khinchi, S. K., Kumar, V., Prasad, B. (2017). Bioefficacy of different insecticides against diamondback moth. *Int. J. Che. Stud.* **5**(3): 891-893.

Sheng, L. and Guang, M. Z. (2002). Effects of *Bacillus thuringiensis* on eggs of three lepidopterous pests of crucifer vegetable crops. Biologically-based technologies 109-112 Proceedings: The Management of Diamondback Moth and Other Crucifer Pests.

Simmonds, M. S. J., Vans, H. C. and Blaney, W. M. (1992). Pesticides for the year 2000: Chemicals and botanicals. Pest management and the effect of environment in 2000. p. 127-164.

Singh SS, Tiwari BC, Rao VK. (2003). Comparative efficacy of some modern insecticides and neem based formulations against cabbage butterfly, *Pieris brassicae*. *Indian J. Entomol.*; 65(2):264-267.

Singh, S. S., Mayank, K. R., Singh, V. B. (2006). Field efficacy of Punjab Agril. Univ. **14**: 66-69.

Sparks, T. C., Thompson, G. D., Kirst, H. A., Hertlein, M. B., Mynderse, J. S., Turner J. R. (1999). Fermentation-derived insect control agents, In F. R. Hall and J. J. Menn [Eds.], Biopesticides: Use and Delivery. Humana Press, Totowas, N. J, pp.171-188.

Srivastava, K., Sharma, D., Anal, A. K. D. and Sharma S. (2018). Integrated Management of *Spodoptera litura*: A Review. *Int. J. Life-Sci. Scient. Res.* **4**(1): 1536-1538.

Steinbrecher, A. and Linseisen, J. (2009). Dietary intake of individual glycosinolates in participants of the EPIC-Heidelberg cohort study. *Ann. Nutr. Metab*. **54**: 87-96.

Talekar, N. S. and Selleck, G. W. (1982). Fareward. In: N.S. Talekar and T.D. Griggs, (eds.). Cabbage. AVRDC, Shanhua, Taiwan, China.

Talekar, N. S., Lee, S. T. and Huang, S. W. (1986). Intercropping and modification of irrigation method for the control of diamondback moth. In Diamond back Moth Management. pp. 145-151.

Talekar, N. S. and Shelton, A. M. (1993). Biology, ecology and management of the diamond backmoth.*Ann. Rev. Entomol.* **38**: 275-301.

Tariq, C. h., Malik, M., Asghar M. and Naveed I. (2005). Management of *Helicoverpa armigera* with different insecticides. *Pak. J. Agri. sci.* **42**(12): 124.

Thakur, N. and Sharma, S. K. (2014). Evaluation for effectiveness of organic inputs against insect-pests of cabbage. *The Ecoscan*. **8**(3-4): 305-308.

Thompson, G. D., Dutton, R., and Sparks, T. C. (2000). Spinosad-a case study: an example from a natural products discovery programme. Pest Management Science: formerly Pesticide Science. **56**(8): 696-702.

Thompson, G. D., Dutton, R., Sparks, T. C. (2000). Spinosad - a case study: an example from a natural products discovery programme. *Pest Manage. Sci.* **56**: 696-702.

Thompson, H. C. and Kelly, W. C. (1988). Cole Crops. In: Vegetables crops. McGraw Hill Book Co. pp. 278-279.

Tiwari, K. N., Singh, P. K. and Mal, P. K. (2003). Effect of drip irrigation on yield of cabbage (*Brassica oleracea* L. var. *capitata*) under mulch and non-mulch conditions. *Agric. Water Manag.* **58**: 19-28.

Tofael, A. (2004). Study on the biology and management of tobacco caterpillar *Spodoptera litura*. M. S. thesis, BAU, Mymensingh, Bangladesh.

Tolman, J. H. and Harris, M. (2004). Cost of crop losses in processing tomato and cabbage in southwestern Ontario due to insects, weeds and/or diseases. *Canadian J. Plant Sci.* **84**: 915-921.

Vastrad, A. S., Lingappa, S. and Basavanagoud, K. (2003). Management of insecticide resistant populations of diamond back moth, *Plutella xylostella* L. (Yponomeutidae:Lepidoptera). Pest management in Horticultural Ecosystem. **9**(1): 33-40.

Walunj, A. R., Pawar, S. A., Darckar, K. S. (2001). Evaluation of a new molecule, spinosad 2.5 SC for the control of DBM (*Plutella. xylostella* L.) on cabbage. Pestology. **25**: 56- 57.

CHAPTER VII

APPENDICES

Appendix I. Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207.

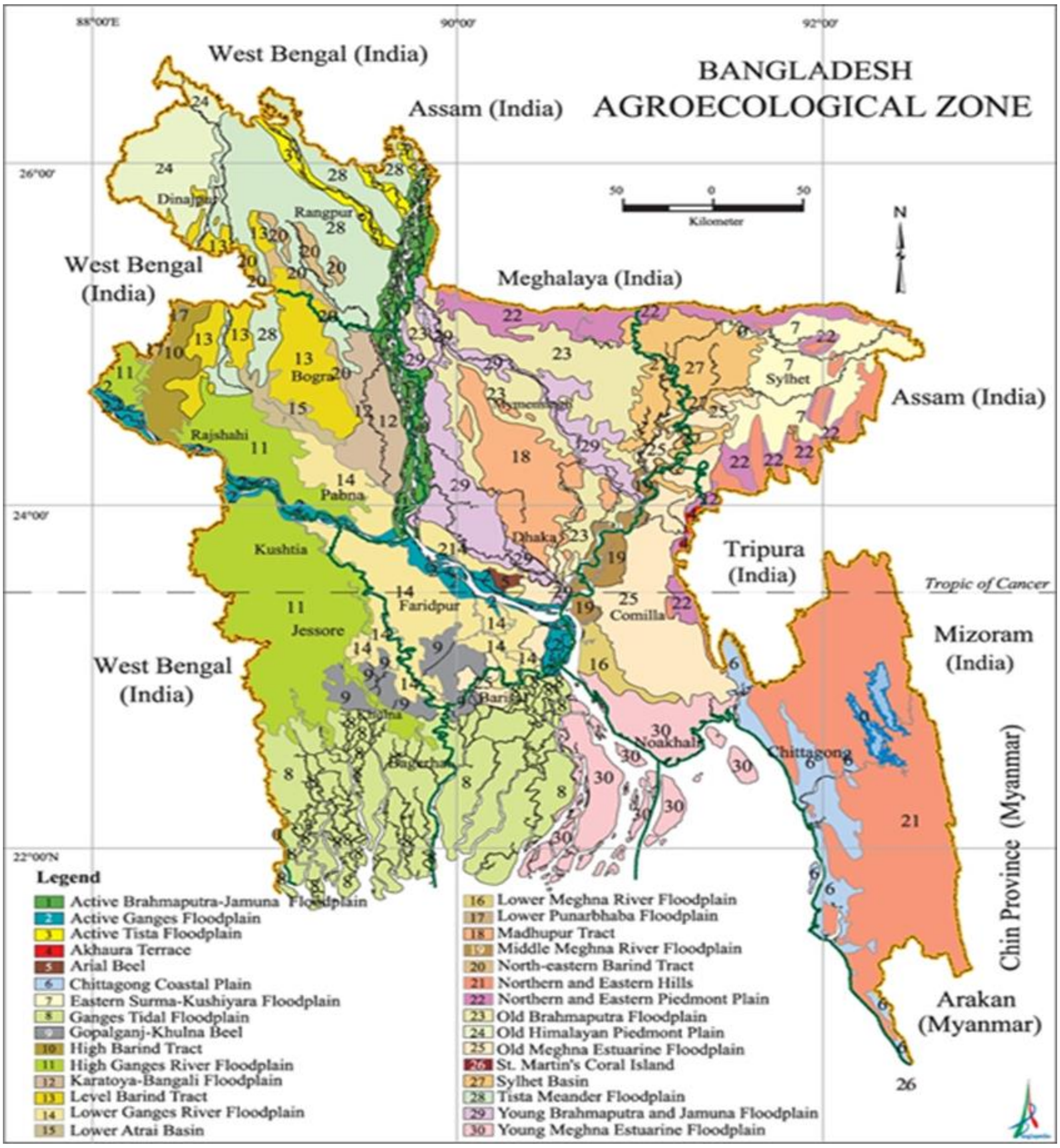

Figure: The map of Bangladesh showing experimental site.

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (October, 2019 to January2020,) at Sher - e - Bangla Agricultural University campus.

Month	Air temperature (ºc)		Average Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
October, 2019	32	23.4	75	203
November,2019	31.82	14.04	81	22
December,2019	23.40	10.50	87	5
January,2020	20.18	7.07	88	0

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1212.

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot.

Soil Characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	5.47 – 5.63
Organic matter	0.82
Total N (%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq / 100 g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix IV. Analysis of variance of the data on the leaf infestation of cabbage due to attack of Tobacco Caterpillar as influenced by different treatments.

Source of variance	Degrees of Freedom	Mean square of leaf infestation by number					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	1.4762	1.4762	0.4286	0.0476	0.4286	0.3733
Treatment	6	21.714**	27.158**	29.714**	36.635**	41.556**	30.644**
Error	12	0.1429	0.2540	0.4286	0.4921	0.3175	0.1200

** Significant at 0.01 level of probability;

Appendix V. Analysis of variance of the data on the leaf infestation of cabbage due to attack of diamondback moth larvae as influenced by different treatments.

Source of variance	Degrees of Freedom	Mean square of leaf infestation by number					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	0.18905	0.98714	0.98714	0.87190	0.5243	0.64013
Treatment	6	4.489**	5.294**	5.563**	8.062**	10.099**	6.529**
Error	12	0.14183	0.01659	0.01659	0.04635	0.1398	0.01696

** Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on the incidence of tobacco caterpillar by number as influenced by different treatments.

Source of variance	Degrees of Freedom	Mean square of leaf infestation by number					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	1.53571	1.2033	1.2186	0.0430	1.6233	1.3396
Treatment	6	6.964**	10.770**	14.298**	20.047**	25.307**	14.688**
Error	12	0.0773	0.0733	0.0430	0.0444	0.1367	0.0351

** Significant at 0.01 level of probability

Appendix VII.Analysis of variance of the data on the incidence of diamondback moth larvae by number as influenced by different treatments.

Source of variance	Degrees of Freedom	Mean square of leaf infestation by number					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	1.80048	1.69905	1.80762	0.9657	0.6605	1.30870
Treatment	6	4.308**	6.352**	9.219**	12.108**	23.478**	9.771**
Error	12	0.08325	0.17127	0.20317	0.1174	0.1183	0.10888

** Significant at 0.01 level of probability

Appendix VIII . Analysis of variance of the data on yield and yield contributing characters of Cabbage due to attack of different Lepidopterous insect pests at harvesting as influenced by different treatments

Source of variance	Degrees of Freedom	Mean square			
		Height of head	Diameter of head	Single head weight (kg)	Total yield (t/ha)
Replication	2	1.17571	6.4471	0.00081	0.2819
Treatment	6	3.874**	24.93**	0.110*	61.71**
Error	12	0.10016	0.3938	0.00275	1.2680

** Significant at 0.01 level of probability;
* Significant at 0.05 level of probability;