DAMAGE ASSESSMENT OF MAJOR INSECT PEST OF COLE CROPS AND THEIR ECOFRIENDLY MANAGEMENT

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*This is to certify that thesis entitled **"DAMAGE ASSESSMENT OF MAJOR INSECT PEST OF COLE CROPS AND THEIR ECOFRIENDLY MANAGEMENT"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN ENTOMOLOGY** embodies the result of a piece of bona fide research work carried out by **MAHFUZA ANWAR, Registration no. 13-05451** 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.

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DEDICATED
TO
MY BELOVED
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DAMAGE ASSESSMENT OF MAJOR INSECT PEST OF COLE CROPS AND THEIR ECOFRIENDLY MANAGEMENT

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ABSTRACT

The experiment was conducted in the experimental field of SAU, Dhaka, Bangladesh during the period from November 2019 to February 2020 to evaluate the damage assessment of major insect pest of cole crops and their ecofriendly management. The experiment was laid out in Randomized Complete Block Design (2 factor) in three replication. For this study, factor A were V_1: BARI phulkopi 2 and V_2: BARI bandhakopi 2 and factor B were T_1: Using Pheromone traps (@ 2 traps/ plot at 30 days interval); T_2: Neem seed solution (@ 3ml/L of water at 7 days interval); T_3: Neem leaf extract (@ 3ml/L of water at 7 days interval), T_4: Neem oil (@ 3ml/L of water at 7 days interval), T_5: Spinosad-45 (@ 3ml/L of water at 7 days interval); T_6: Admire 200SL (@ 3ml/L of water at 7 days interval) and T_0: Control. The incidence of insect pests like diamond back moth, cabbage semi-looper, cabbage worm and tobacco caterpillar, insect pest infestation (i.e. leaves and plants) were lowest and highest in yield attributing characteristics (i.e. curd height, curd diameter, perimeter of curd and yield/ha) for BARI bandhakopi 2. The incidence of diamond back moth, cabbage semi-looper, cabbage worm and tobacco caterpillar, the percent leaf and plant infestation caused by insect pests were low and high in case of curd height, curd diameter, perimeter of curd and yield/ha for spraying neem oil @ 3ml/L of water. Again, BARI bandhakopi 2 along with spraying neem oil @ 3ml/L of water showed the best performance in reducing the number of insect incidence, insect infestation (i.e. leaves and plants) and yield contributing characteristics. The order of rank was $V_1T_7 < V_2T_7 < V_1T_1 < V_1T_5 < V_2T_1 < V_2T_5 < V_1T_6 < V_2T_2 < V_1T_3 < V_2T_6 < V_1T_4 < V_2T_3 < V_2T_4$.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
%	Percent
^0C	Degree celsius
AEZ	Agro-ecological Zone
AVOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
CV	Coefficient of variation
DAT	Days after transplanting
df	Degrees of freedom
et al.	And others
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
ml	Milliliter
MoP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate

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CHAPTER I

INTRODUCTION

"Cole" refers to any of various plants belonging to the Cruciferae. The mustard family includes cool season crops such as Brussels sprout (*Brassica oleracea* var. *gemmifera*), cabbage (*Brassica oleracea* var. *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*), collards (*Brassica oleracea* var. *acephala*), kale (*Brassica oleracea* var. *acephala*), kohlrabi (*Brassica oleracea* var. *gongylodes*), mustard (*Brassica juncea*), broccoli (*Brassica oleracea* var. *italica*), turnips (*Brassica rapa* var. *rapa*), knol khol (*Brassica oleracea* var. *gongylodes*) and watercress (*Nasturtium officinale*) (Roy and Chakrabarti 2003). All of these are also familiar as garden crops. Cabbage and cauliflower are the important cole crops, member of the family Cruciferae. Cole crops, including cabbage and Cauliflower are important fresh and processing vegetable crops in most of the countries of the world like USA, UK, New Zealand, Italy, China, India, Egypt, Israel, Thailand and Bangladesh etc. Cole crops are biennials, but are generally grown as annuals. Cabbage is a vegetable crop and generally grown in Rabi season in Bangladesh. Cabbage is believed to have originated in Western Europe and it was the first cole crop to be cultivated. Prior to cultivation and use as food, cabbage was mainly used for medicinal purposes (Silva 1986). The first description of cauliflower appeared in 1544. Brussels sprouts, named after the city in Belgium, did not occur until the beginning of the 19th century. The sprouting broccoli of today originated in the Mediterranean area (Advisory committee of vegetable crops 2012). Cabbage is an excellent source of Vitamin C. In addition to containing some B vitamins, vitamin E and tryptophan, potassium and calcium (Rashid 1993). It is an important and nutritious winter leafy vegetable in our country. It contains a range of essential vitamins and minerals as well as small amount of protein and good caloric value (Anon. 2006). Cauliflower is also a very tasty and much popular vegetable in Bangladesh as well as all over the world, being cultivated in large area in the growing period. It also contains 8.0g carbohydrate, 2.3g protein, 40 IU carotene, 0.13 mg B1, 0.11 mg B2, 50 mg vitamin C, 30 mg calcium and 0.8 mg iron respectively (Rashid 1999). Broccoli is good source of Vitamins A and C; rich in potassium, calcium and phosphorus, folate; contains some iron. 250 mL (1 cup) cooked broccoli contains about 45 kilocalories. Brussels sprouts is very good source of Vitamins A and C; rich in potassium and folate. Contains other nutrients in small amounts. 250 mL (1 cup) serving contains 58 kilocalories (Advisory committee of vegetable crops 2012). Growth and yield of these vegetable crops remarkably influenced by organic and inorganic nutrients management. It is an established fact that use of inorganic fertilizer for the crops is not so good for health because of residual effect but in the case of organic fertilizer such problem does not arise and on the other hand it increase the productivity of soil as well as crop quality and yield (Tindall 2000).

Vegetables sub-sector plays an important role for development of Bangladesh. The consumption rate of vegetables in our country is 33Kg/head/yr, but in developed countries it is 6-7 times higher (FAO 2015). Vegetables are herbaceous plant whose fruits, seeds, roots, tubers, leaves etc. are used as food. Nearly 100 different types of vegetables comprising both of local and foreign origins are grown in Bangladesh. Vegetable is important for nutrition, economy and food security. Vegetables can be identified as a significant one for this economy for its noteworthy contribution in raising the foreign exchange earnings and occupies an important position among the items exported from Bangladesh. Vegetables contribute 3.6% of the agricultural Gross Domestic Product (BBS 2019).

In Bangladesh, but the crop cultivation faces various problems including the pest management. There are several reasons for low production of cole crops in Bangladesh such as insect pests, diseases, qualities of variety, soil nutrients and weather factors etc. Among the insect pests, Lepidopteran insects like cabbage semi-looper, diamond back moth, tobacco caterpillar, cabbage worm, cabbage butterfly, cut worm are the major pests of cabbage as well as cole crops. There are several methods to combat insect pests of cole crops comprising cultural, mechanical, chemical, biological, botanicals and host plant resistance. Considering the hazards impact of chemical insecticides, the utilization of botanicals are the safe and hazards free tactics for the environmental pollution free management of insect pests (Hasan *et al.* 1960). Botanicals like neem oil, neem leaf extract, neem seed karnel extract, garlic extract, thuja leaf extract etc. are very limited. There is renewed interest in the application of botanical pesticides for crop protection. There have been a large number of plant-products, which possess pesticidal properties are alkaloid, flavonoids, quinones, tanines, azadiractin, terpinoids and have been used successfully for controlling various pests in field (Pedigo 2002, Bajpai and Sehgal 2000). Botanical products like neem oil and kernel extract etc. which can be easily and cheaply collected in rural Bangladesh, have been found promising and useful for pest control in squash. Mode of action of plant derivatives is as stomach poison, feeding deterrent, repellent and confusants which paralyze nerve activity to convulsions and death of insect. Considering of these issues some objective are taken in this study and they are as follows:

- To find out the incidence and damage severity of four major insect pests of cole crops
- To find out the eco-friendly safe control measure for their management.

CHAPTER II

REVIEW OF LITERATURE

Cole crops are most important vegetable crops in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests, Lepidopteron insects like cabbage semi-looper, diamond back moth, tobacco caterpillar, cabbage worm, cabbage butterfly, cut worm are the major pests of cole crops. Botanicals like neem oil, neem leaf extract, neem seed carnel extract, garlic extract, thuja leaf extract etc. are very limited and useful to manage these insect pests. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings.

2.1. General review of insect pest of cabbage

2.1.1. Cabbage semi-looper

The cabbage semi-looper (*Trichoplusia ni*) is a member of the moth family Noctuidae belongs to the order of Lepidoptera.

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Trichoplusia*

Species: *Trichoplusia ni*

B. Nature of damage

Capinera (1999a) mentioned in his study that, cabbage semi-looper larvae damage plants by chewing holes in leaves. Smaller larvae remain on the lower leaf surface, while larger larvae produce larger holes throughout the leaf. In addition to feeding on the wrapper leaves, cabbage loopers may bore into the developing head. Some defoliation can be tolerated before head formation, but feeding damage and excrement left behind on heads make cabbage unmarketable. Cabbage with damage confined to wrapper leaves is marketable but with reduced value. Control has been shown to the justified in Texas when population densities reach 0.3 larvae per plant. In Florida, an action threshold of 0.1 medium to large cabbage looper larvae per plant was developed for cabbage (Leibee 1996).

2.1.2. Diamond back moth

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

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Plutellidae

Genus: *Plutella*

Species: *Plutella xylostella*

B. Nature of damage

Walsh and Furlong (2008) reported that, from May to September, *Plutella xylostella* (L.) (diamondback moth) poses the greatest threat to production.

Janmaat (2003) observed that, the larval stage of the diamondback moth (DBM) makes numerous small holes in the leaves, and sometimes leaves fine webbing in the center of the plant. Foliar injury lowers the quality of the crop, and weakens the plant. The larvae themselves can be a contaminant of the final product. Of the three lepidopteron pests of cabbage, DBM is by far the most difficult to control in NY (Moyer 1999). 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.

2.1.3. Tobacco caterpillar / cabbage caterpillar

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

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Spodoptera*

Species: *Spodoptera litura*

B. Nature of damage

Tobacco caterpillar *Spodoptera litura* attacked the tender leaves, larva caused the damage only. The female moth of cabbage 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 and at that time it was not economical to replace it with another new seedling. 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 caused 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 caused greater damage if the infestation occurred 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).

2.1.4. Cabbage worm

The term cabbage worm is primarily used for any of four kinds of lepidopteran whose larvae feed on cabbages and other cole crops. Favorite foods include broccoli, cauliflower, Brussels sprouts, collards, kale, mustard greens, turnip greens, radishes, turnips, rutabagas and kohlrabi. This small group of similar pest species is known to agriculturists as the cabbage worm complete butterflies

A. Nomenclature

Phylum: Arthropod

Class: Insecta

Order: Lepidoptera

Family: Pieridae

Genus: *Pieris*

Species: *Pieris rapae*

B. Nature of damage

Larvae of *Pieris rapae* damage cruciferous crops by chewing leaves, hearts and curds. Young larvae hatch on the outer leaves and feed on them superficially leaving the upper leaf surface intact. Older larvae make holes in the leaves and are more likely to eat through small veins, they also damage the outer leaves of the hearts of cabbages or the curd or cauliflowers. They often bore into the center of the head damaging the edible portion of the plant. Heavily infested plants become ragged and stunted but no webbing occurs. The presence of masses of wet greenish-brown excrement deep among leaves is indicative of this pest. In large infestations of *P. rapae* the plant may be reduced to a partial or complete skeleton, in which all the leaf tissue except the veins has been eaten (CABI 2021, Hely *et al.* 1982).

2.2. Management of insect pests of cole crops

2.2.1. Cultural control

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 of tomato and 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.

Remove weeds and plant resi-due to help reduce egg-laying sites and seedling weeds that nourish small cutworms. Tilling land before planting, which helps 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 com-post. Tilling land in the fall; this helps destroy or expose overwintering larvae or pupae (Hahn and Burkness 2015).

2.2.2. Mechanical control

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

Pelosini (1999) reported that, in controlling moths still mostly are used organic phosphorus esters. In this group classified active compounds are chlorine pirifos-methil, phenitrotion and acephate. Sufficient efficacy in this relation can attain also with pyrethroids (cypermethrin, deltamethrin, lambda-cyhalothrin, betacyfluthrin 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 (alfa-cypermethrin) 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 controling eggs and young larvae (Corvi and Nardi 1998). Among inhibitors of insect development active ingredients are teflubenzuron, esaflumuron and lufenuron (Pelosini 1999). The last one is registered in Slovenia and represents an active ingredient of product Match 050 EC.

If there are caterpillars of various developmental stages on the ground, Corvi and Nardi (1998) recommend the application of pyretroids or carbamates. Both groups of insecticides belong to neurotoxins and act as a contact or stomach insecticides. In case of cabbage moth control in autumn, Corvi and Nardi (1998) advice double treatment with synthetic insecticides (pyretroids, carbamates, organic phosphorus esters and growth regulators) and at least spraying with microbiological products on the basis of *Bacillus thuringiensis* var. *kurstaki.*

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).

Flubendiamide (Takumi® 20WDG) is a novel insecticide, representing the IRAC Mode of Action Group 28 (ryanodine receptor modulator) within the IRAC (Insecticide Resistance Action Committee) mode of action classification scheme. Flubendiamide is the first member of phthalic acid diamides, and is active against abroad range of lepidopteran insects (Nauen 2006, Tohnishi *et al.* 2005). Chlorantraniliprole (Prevathon® 5%SC) is also a novel insecticide from a new class of chemistry, the IRAC Mode of Action Group 28. Chlorantraniliprole is the first member of anthranilic diamides, and is potent within the insect order Lepidoptera (Temple *et al*. 2009). Chlorantranilprole is relatively harmless to beneficial arthropods, and has not been found to exhibit cross resistance with existing insecticides (Lahm *et al.* 2009).

Fipronil has been used for control of diamondback moth (DBM), *Plutella xylostella* (L.), on *Brassica* vegetables in Australia since its registration as Regent® 200 SC in 1997 (Ridland and Endersby 2011).

The efficacy of spinetoram against *Plutella xylostella*, *Trichoplusia ni*, *Spodoptera exigua*, *Pieris* spp., and other crucifer pests has been demonstrated in field trials and under conditions of commercial use around the world. It activates certain nicotinic acetylcholine receptors which excites the insect central nervous system, causing paralysis and death of pest insects. Because spinetoram works directly on the insect nervous system, it is fast-acting. Larvae stop feeding and crawling within minutes of first exposure, and death occurs within 24 to 72 hours (Huang *et al.* 2011).

For controlling cutworms several insecticides are effective. All of them are contact insecticide like Carbaryl, Cyfluthrin Permethrin etc. But carbaryl shows great result for controlling cutworms in the field condition (Hahn and Burkness 2015).

2.2.4. Biological control

In order to develop sustainable pest management programs for *Brassica* crops, an effective biological control program for *P. xylostella* must be integrated with effective control measures for *C. pavonana* (e.g. selective insecticides, manipulation of endemic predator complexes, trap crops and other means of host plant manipulation). Biological control can form the foundation for IPM strategies for the management of *P. xylostella* and other crucifer pests (Furlong *et al*. 2008a, Furlong *et al*. 2004a) but in order to take this approach, a detailed understanding of pest and natural enemy ecology is required (Furlong *et al.* 2008b).

The program is based on a cost-effective crop scouting system and uses action thresholds for cabbage, broccoli and cauliflower. It includes a DBM insecticide resistance management strategy that emphasises the rotation of products with selective activity and different modes of action to maximise the impact of existing biological control agents (Walker *et al.* 2009).

In the 2009-10 year, weekly pheromone trap catches of DBM were compared with corresponding larval infestations in five crops. Results show that increases in DBM larval infestations were detected 1–3 weeks (most between 2 and 3 weeks) after increases in pheromone trap catches. These results indicate the potential of DBM pheromone trap monitoring as a pest management tool for forecasting damaging larval infestations in a cold-winter climate (Walker *et al.* 2011).

Building on and expanding earlier work reported in (Grzywacz *et al.* 2010, Russell *et al*. 2008) reviewed current control methods for brassica pests in Asia and Africa and concluded that effective Bt transgenics could play a very useful role.

Bioassays with pure Cry1B and Cry1C proteins in India, USA, Australia, Indonesia, Taiwan and China (Shelton *et al*. 2009) using leaf dip assays showed the LC50 values for both Cry1B and Cry1C against diamondback moth to be <1.3 ppm in all field populations tested. *C. binotalis* had LC50s of >1.07 ppm for Cry1B and <1.89 ppm for Cry1C. The prospects for control of these species with transgenic Bt brassicas was therefore good. However, *S. litura*, an increasing pest of brassicas in Asia showed less susceptibility with LC50s >10 ppm to both proteins (Russell *et al.* 2011).

Currently, entomopathogenic nematodes are used as effective biological control agents against many different kinds of soil-dwelling insect pests of many economically important crops and turfgrasses. These nematodes are commercially available and are not harmful to humans, animals and even beneficial insects like honeybees. Canadian researchers have demonstrated that the entomopathogenic nematodes including *Steinernema carpocapsae*, *S. feltiae* and *S. riobrave* can cause 76 to 100% mortality of cabbage butterflys *Artogeia rapae* if applied at temperatures ranging from 25 to 30 °C and their LC50 values were ranged from 4 to 18 infective juveniles (Bélair *et al*. 2003).

Mahar *et al.* (2005) also reported that in addition to the above stated species of entomopathogenic nematodes, *Heterorhabditis bacteriophora* and *H. indica* nematodes can infect and kill both larvae and pupae of cabbage butterflies. Recently, another insect-parasitic nematode, *Rhabditis blumi* also been shown to be effective against cabbage butterfly (Park *et al*. 2012).

The natural enemies including *Diadegma semiclausum, Cantheonidea furcellata* and *Erigonidium graminicola* and the cropping systems including rotating rice, corn and shallot in summer were effective in managing the Diamond back moth (Xia *et al.* 2011). The parasitoids *Diadegma* (for the highlands) and *Cotesia* (for the lowlands) were imported, mass reared and released in the field with almost 85% parasitization (Colting and Cardona 2011).

The larval parasitoids like ichneumonid, braconids etc. and the pupal parasitoids like *Diadromus collaris, Diadromus subtilicornis* etc. are the most effective natural enemies of *P. xylostella* (Karimzadeh and Wright 2008, Sarfraz *et al.* 2005, Talekar and Shelton 1993).

Many studies revealed that different host-plant species or cultivars have differential effects on *P. xylostella* parasitism success by parasitoids, in particular, *Cotesia plutellae* (Kurdjumov) and *Diadegma semiclausum* (Hellen) (Karimzadeh and Wright 2008, Karimzadeh *et al*. 2004, Liu and Jiang 2003, Haseeb *et al*. 2001, Verkerke and Wright 1997, Talekar and Yang 1991).

Prasad *et al*. (2009) observed that, monitoring aphids and their natural enemies in brassicas in British Columbia (Canada), observed a lag of several weeks in colonization by syrphids and other aphid predators. These authors concluded that syrphids act on aphids in a density-dependent manner, and hence they are often unable to control populations before damage exceeds threshold levels.

Previous sampling studies in Australian brassica crops found Lycosidae to be the most abundant predator in pitfall catches (Hosseini *et al*. 2008; Furlong *et al*. 2004b).

Although Formicidae formed a large proportion of trap catch, activity was highly localized; large catches often occurred in a single trap at each site. Therefore, although results for Formicidae are presented, they were excluded from the calculation of relative abundance. The contribution of ants to biological control is uncertain: although they prey on a variety of pest species, they may also have a negative impact on some beneficial species, and can actively protect honeydew-producing hemipteran pests from natural enemies (Chong *et al*. 2010).

Predators included species of Araneae (Theridiidae, Clubionidae, Miturgidae, Lycosidae, Salticidae, Oxyopidae, Araneidae, Tetragnathidae, Thomisidae), Coleoptera (Coccinellidae, Carabidae, Staphylinidae), Diptera (Syrphidae), Neuroptera (Hemerobiidae), Hemiptera (Miridae, Anthocoridae, Lygaeidae, Reduviidae, Nabidae), Dermaptera (Labiduridae) and Hymenoptera (Formicidae). Spiders were the most abundant predators, found consistently at all sampling sites from transplanting onwards. In comparison, populations of predatory insects varied between sampling sites, and foliage-dwelling predatory insects were generally absent from plants for the first two weeks post-transplanting (Senior and Healey 2011).

2.2.5. Botanical control

A botanical pesticide can be employed as an alternative source to control pests with biodegradable concern, reductive contamination in environment and human health hazards (Devlin and Zettel 1999, Grainge and Ahmed 1988). 2121 plant species was listed which were possessing pest control property which include neem, sweetflag, cashew, custard apple, sugar apple, derris, lantana, tayanin, indian privet, agave, crow plant etc. 1005 species of plants having biological properties against insect pests including 384 species as antifeedants, 297 as repellents, 97 as attractants and 31 as growth inhibitors.

Roy *et al*. (2005) discussed on his study that, botanical pesticides are also special because they can be produced easily by farmers for sustainable agriculture and small industries.

Pyrethrins, rotenone and nicotine were among the first compounds from plants used to control agricultural insect pests (Grainge and Ahmed 1988).

Many plant species are being investigated for their natural products to be used for *P. xylostella* control. For instance,*Azadirachta indica* A. Juss. (Meliaceae), *Melia azedarach* L. (Meliaceae) and *Acorus calamus* L. (Araceae) treatments were found to inhibit feeding of *P. xylostella* 24 h after treatment (Patil and Goud 2003).

About 413 different species/sub-species of insect pest have been listed by (Schmutterer 1995) found to be susceptible to neem products. The listed species/sub-species belongs to different insect orders most of them were Lepidoptera (136) and Coleopteran (79).

The use of neem based insecticides as a source of biologically active substances for pest control is increasing worldwide, and have recently gained popularity as components of integrated pest management (Banken and Stark 1997).

Azadirachtin is the most potent growth regulator and antifeedant (Warthen *et al.* 1978, Butterworth and Morgan 1968). The triterpenoid azadirachtin was first isolated from the seeds of the tropical neem tree by Butterworth and Morgan (1968). Its definite structural formula, which resembles somewhat that of ecdysone, was finally explained in 1985 by Kraus *et al.* and Bilton *et al.*

Azadirachtin is a limonoid alleliochemical (Broughton *et al.*1986, Butterworth and Morgan 1968) present in the fruits and other tissues of the tropical neem tree (*Azadirachta indica*). The fruit is the most important aspect of neem that affectsinsects in various ways. The leaves, which may also be used for pest control, may reach a length of 30 cm.

Crude neem extracts deters settling and reduces feeding in *M. persicae* (Griffiths *et al*. 1989, 1978).

The study was conducted to know the biology and the effect of neem *Azadirachta indica* oil on the food consumption of lemon butterfly *Papilio demoleus*. The 5th instar larvae consumed the highest amount of lemon leaves. Among the treatments, 1.5% neem oil showed strong antifeedant effect on food consumption (Karim *et al.* 2007).

Azadirachtin is a potent insect antifeedant. Antifeedancy is the result of effects on deterrent and other chemoreceptors. The antifeedant effects of azadirachtin have been reported for many species of insects. Reduction of feeding was also observed after topical application or injection of neem derivatives, including AZA and alcoholic neem seed kernel extract. This means that the reduction of food intake by insects is not only gustatory which means that sensory organs of the mouth parts but also non- gustatory regulate it. These two phagodeterrent/antifeedant effects were called primary and secondary (Schmutterer 1985).

Azadirachtin has different influence on the metamorphosis of the insects resulting in various morphogenetic defects as well as mortality, depending on the concentration applied. The IGR effect of neem derivatives such as methanolic neem leaf extract and azadirachtin in larvae and nymphs of insects was first observed in 1972 in Heteroptera (Leuschner 1972) and Lepidoptera.

Molting, if it occurred, was incomplete and resulted in the death of the tested insects. Botanicals possess an array of properties including insecticidal activity and insect growth regulatory activity against many insect pests and mites (Prakash *et al*. 1990, 1987, Rajasekaran and Kumaraswami 1985).

Repellent activity of neem against oviposition by Lepidopterous pests has also been reported for *Spodoptera litura* (Joshi and Sitaramaiah 1979), *Cnaphalocrocis medinalis* (Saxena *et al*. 1981) and *E. vittella* (Sojitra and Patel 1992). Extracts of neem and bakain caused maximum adverse effects on fecundity and hatching.

Lakshmanan (2001) reported that effectiveness of neem extract alone or in combination with other plant extracts in managing lepidopteran pest's viz., *E. vittella, Chilo partellus* Swinhoe, *H. armigera* and *S. litura.*

Maximum reduction in bollworm infestation (65.7%) was observed in garlic treated plot. Garlic extract and NSKE both at 10 percent were found to be superior. Lowest bollworm incidence was observed with NSKE (10.3%), datura and neem oil emulsion (Anonymous 1987).

Sardana and Krishnakumar (1989) studied the efficacy of neem oil, karanj oil (both at 0.5, 1.0 and 2.0%) and garlic oil (0.25, 0.5 and 1.0%) in comparison with monocrotophos (0.05%). Among the oils, neem oil and karanj oil offered effective control against okra fruit borers. It was concluded that weekly application of neem oil at two per cent concentration was effective in controlling fruit borer in okra and was safe to natural enemies.

Analysis of *Thuja occidentalis* L. essential oil used for insect fumigation by phase gas chromatography revealed the presence of 22 compounds including α-thujone (49.64%), fenchone (14.06%), and β-thujone (8.98%). When insects were treated with aromatized powder, significant differences were also found between treatments and control. Application of 100 mg of powder aromatized at 3 μL essential oil g^{-1} on bruchid pairs lead to 95% mortality of females and 100% of males with 0% of mortality in the control after 6 h exposure. Five days after their deposit, egg hatching was 1.2% (treated with kaolin powder aromatized with *T. occidentalis* essential oil), 41% (with kaolin alone) and 44% of eggs (control without kaolin). In the same experiment, adult emergence of 80% (in treatments with kaolin alone), 100% in control (without kaolin) and 0% (with kaolin aromatized with *T. occidentalis* essential oil) were recorded 30 days after treatment. Germination of cowpea seeds was not significantly affected by the treatments. Five days after sowing, germination was 88, 97 and 97%, respectively, when cowpea grains were treated and exposed, treated and unexposed, untreated and unexposed, respectively, while those untreated and exposed had 15% germination (Keita *et al.* 2001).

CHAPTER III

MATERIALS AND METHODS

Damage assessment of major insect pest of cole crops and their ecofriendly management for controlling is the main focus point of this present study which has been conducted during November 2019 to February 2020 in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka. Required materials and methodology are described below under different sub-headings:

3.1. Location

The central field of the experimental farm of SAU, Dhaka was the site for this study at latitude 23.46 N and longitude 90.23 E with an elevation of 8.45 m from the sea level.

3.2. Climate

The experimental area is characterized by subtropical rainfall during the month of May to September (Annon. 1988) and scattered rainfall during the rest of the year.

3.3. Soil

Soil was medium high land, clay loam in texture belonging to Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.* 1991).

3.4. Land preparation

The soil was well prepared and good tilth ensured for commercial crop production. The target land was divided into 42 equal plots (3m×1m) with plot to plot distance of 0.50 m and block to block distance is 0.75 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment were followed immediately after land preparation.

3.5. Manure and fertilizer

Recommended fertilizers were applied at the rate of 370 kg urea, 250kg triple super phosphate (TSP) and 250kg muriate of potash (MoP) per hectare were used as source of nitrogen, phosphorus and potassium, respectively. Moreover, well-decomposed cow dung (CD) was also applied at the rate of 10 ton/ha to the field at the time of land preparation (BARC 2012).

3.6. Design of experiment and layout

The experiment was laid out in a two factor Randomized Complete Block Design (RCBD) with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 14 unit plots. The size of the unit plot was 3m × 1m. The block to block and plot-to-plot distance was .75m and 0.5m, respectively.

3.7. Collection of seed, seedling raising

The seeds of BARI phulkopi-2 and BARI badhakopi-2 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing, the germination test of seeds was done and on an average, 90% germination was found for these varieties. Seeds were then sown on the 7th November, 2019 in seedbed containing a mixture of equal proportion well decomposed cow dung and loam soil. After sowing seeds, the seedbeds were irrigated regularly. After germination, the seedlings were sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

3.8. Seedling transplanting

The 30 days old healthy and uniform sized seedlings of cauliflower and cabbage varieties were transplanted on December 6th, 2020 in the main field. Each plot contains 12 seedlings with 2 rows followed by 50cm x 50cm (row to row and plant to plant distance, respectively).

Plate 2: Seedlings transplants in the main field

3.9. Cultural practices

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. Various intercultural operations like gap filling, weeding, earthen up, drainage etc. was done as and when necessary to cultivate cabbage and cauliflower.

Plate 1: Cauliflower in main field

3.10. Treatments

The experiment was evaluated to damage assessment of major insect pest of cole crops and their ecofriendly management for controlling. The treatments were used in this study are given bellow:-

Facror A

V_1= BARI phulkopi-2
V_2= BARI badhakopi-2

Factor B

Sl. No.	Treatments	Dose
1	Using Pheromone traps	@ 2 traps/ plot at 30 days interval
2	Neem seed solution	@ 3ml/L of water at 7 days interval
3	Neem leaf extract	@ 3ml/L of water at 7 days interval
4	Neem oil	@ 3ml/L of water at 7 days interval
5	Spinosad-45	@ 4ml/L of water at 7 days interval
6	Admire 200SL	@ 1ml/L of water at 7 days interval

7	Untreated Control	Spraying just water at 7 days interval

3.11. Treatment preparation

3.11.1. Pheromone traps

Sex pheromone trap designed by BARI with cue-lure and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, 60 cm above the ground. The soap water was replaced by new soap water at an interval of 4 days. After four days interval the number of insects trapped was recorded. In case of trapping, number of trapped fruit flies was counted. Total fruit and infested fruits were recorded and percentage of infested fruit was calculated.

Plate 3: Pheromone traps in the main field

3.11.2. Neem seed solution

The neem seeds were collected from Siddic Bazar, Gulistan, Dhaka. Dried seed were collected and again dried in the sun and after that crashed using electric grinder, of which 1000 gm dried broken neem seeds were taken into a 30L bucket. Mixture it throughly and keep it for 12 hrs. After that the mixture was filtered and the water was collected. Then the neem seed solution was prepared for field application and preserved the aqueous extracts of neem seed solution in the refrigerator at 4^0c for spraying in the field.

3.11.3. Neem leaf extract

The fresh neem leaves were collected from the neem tree found in the Horticulture Garden of SAU. Leaves were sun dried and crashed using electric grinder, of which 500 gm dried neem leaf powder was taken into a 1000 ml beaker. 500 ml water was taken into the beaker and then the beaker was shaken with the magnetic stirrer to make the extracts of neem leaves. The aqueous extract then filtered using Whatmen paper filter and preserved the aqueous extracts of neem leaf in the refrigerator at 4^0c for spraying in the field.

3.11.4. Neem oil

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. For neem oil application, 25 ml neem oil (@ 5.0 ml/L of water was used. The mixture was sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant.

3.12. Treatment application

T_1: Use pheromone trap @ 2 traps/plot with detergent mixed water for capturing insect pests. The lure of this pheromone trap was changed after 30 days intervals commencing from 20 DAT.

T_2: Neem seed solution @ 3ml/L of water was sprayed at 7 days interval. Under this treatment, neem seed solution was applied @ 15ml/5L of water. After proper shaking with the detergent as a trix, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_3: Neem leaf extract @ 3ml/L of water was sprayed at 7 days interval. Under this treatment, neem leaf extract was applied @ 15ml/5L of water mixed with detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_4: Neem oil @ 3ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 15ml/5L of water mixed with detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_5: Spinosad-45 @ 4ml/L of water was sprayed at 7 days interval. Under this treatment, spinosad was applied @ 20ml/5L of water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_6: Admire 200SL @ 1ml/L of water was sprayed at 7 days interval. Under this treatment, Admire was applied @ 5ml/5L of water mixed thoroughly. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Plate 4: Treatment application in the main field

T_7: Untreated control which was sprayed @ 5L of water to the broccoli plots.

3.13. Data collection

For data collection five plants per plot were randomly selected and tagged. Data collection was started at vegetative stage to head harvesting stage. The following parameters were considered during data collection:

Plate 6: Healthy cauliflower head

3.13.1. Number of insect pests of cole crops

Data were collected on the number of cabbage worm, diamondback moth, cabbage semi-looper, and tobacco caterpillar per 5 tagged plants per plot and counted separately for each treatment.

3.13.2. Number of infested leaves caused by different insect pests

Plate 5: Bore on cabbage head

Data were collected on the number of infested leaves caused by cabbage worm, diamondback moth, cabbage semi-looper and tobacco caterpillar randomly selected 5 tagged plants per plot and counted separately for each treatment.

3.13.3. Number of infested plants caused by different insect pests

Data were collected on the number of infested plants caused by cabbage worm, diamondback moth, cabbage semi-looper and tobacco caterpillar randomly selected 5 tagged plants per plot and counted separately for each treatment.

Plate 7: Infested cabbage plant

3.14. Calculation

3.14.1. Percent of infested leaves by insect pests of cole crop

Number of infested leaves was counted from total leaves per five plants and leaf infestation by insect pests of cole crop were calculated as follows:

$$\% \text{ infested leaves} = \frac{\text{Number of infested cole crop leaves}}{\text{Total number of cole crop leaves}} \times 100$$

3.14.2. Percent of infested plants by insect pests of cole crop

Number of infested plants was counted from total plants per plot and plant infestation by insect pests of cole crop were calculated as follows:

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

3.15. Statistical analysis

Data statistically analyzed by two factors Randomized Complete Block Design through MSTAT-C software and LSD and Duncan's multiple range tests were used to determine the incidence and damage assessment of insect pest of cole crops.

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate damage assessment of major insect pest of Cole crops and their ecofriendly management in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during November, 2019 to February, 2020. The results have been presented and discussed under the following sub-headings:

4.1. Performance of cole crops against major insect pests

4.1.1. Cabbage semi-looper

The average number of cabbage semi-looper per five tagged plants was ranged from 4.27 to 4.87. The highest number of cabbage semi-looper per five tagged plants was recorded in V_1 (4.87 cabbage semi-looper/five tagged plants). On the other hand, the lowest number of cabbage semi-looper per five tagged plants was recorded in V_2 (4.27 cabbage semi-looper/five tagged plants). But it was observed that there was no statistical variation among the varieties in terms of average number of cabbage semi-looper per five tagged plants (Figure 1).

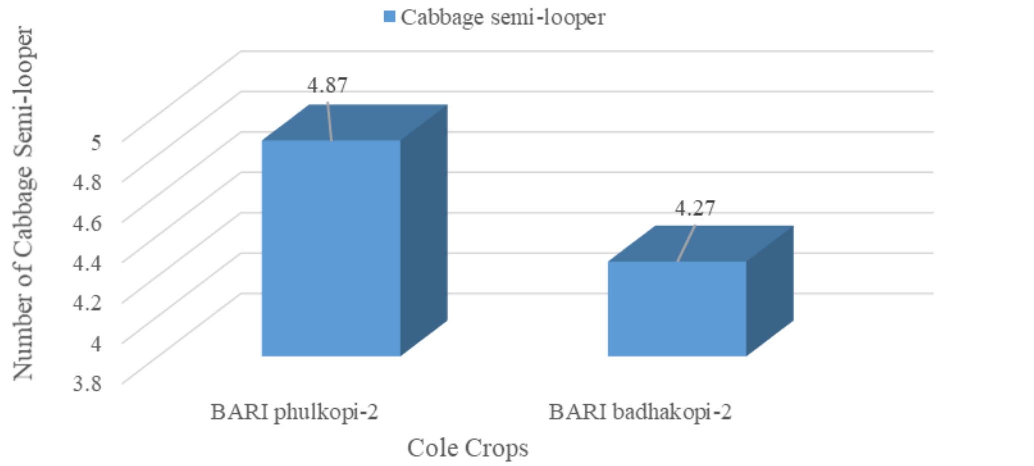


Figure 1: Effect of cole crops on average number of cabbage semi-looper per five tagged plants

4.1.2. Diamondback moth

The average number of diamondback moth caterpillar per five tagged plants was ranged from 4.88 to 5.50. The highest number of diamondback moth caterpillar per five tagged plants was recorded in V_1 (5.50 DBM caterpillar/five tagged plants). On the other hand, the lowest number of diamondback moth caterpillar per five tagged plants was recorded in V_2 (4.88 DBM caterpillar/five tagged plants). But it was observed that there was no statistical variation among the cole crops in terms of average number of diamondback moth caterpillar per five tagged plants (Figure 2).

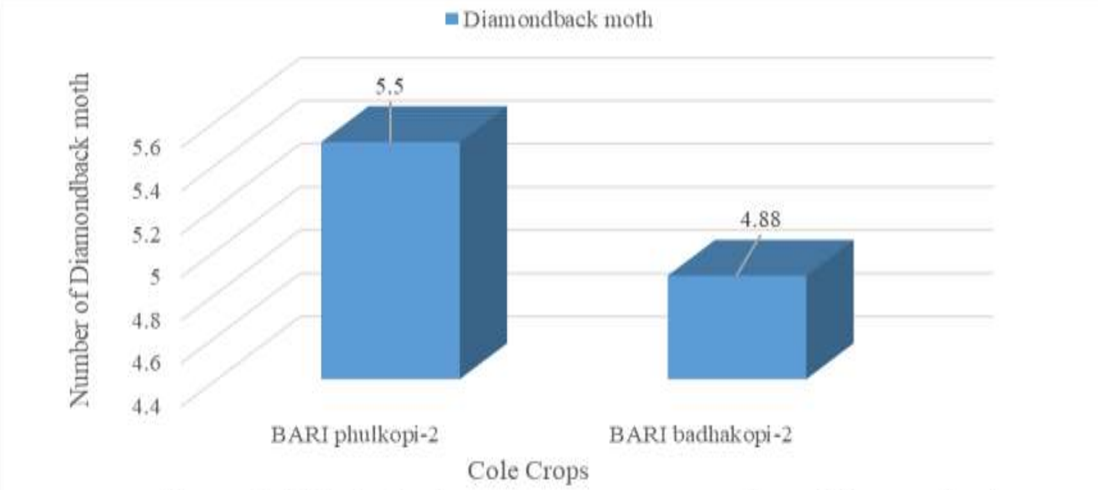


Figure 2: Effect of cole crops on average number of diamondback moth caterpillar per five tagged plants

4.1.3. Cabbage worm

The average number of cabbage worm per five tagged plants was ranged from 2.17 to 2.54. The highest number of cabbage worm per five tagged plants was recorded in V_1 (2.54 cabbage worm/five tagged plants). On the other hand, the lowest number of cabbage worm per five tagged plants was recorded in V_2 (2.17 cabbage worm/five tagged plants). But it was observed that there was no statistical variation among the cole crops in terms of average number of cabbage worm per five tagged plants (Figure 3).

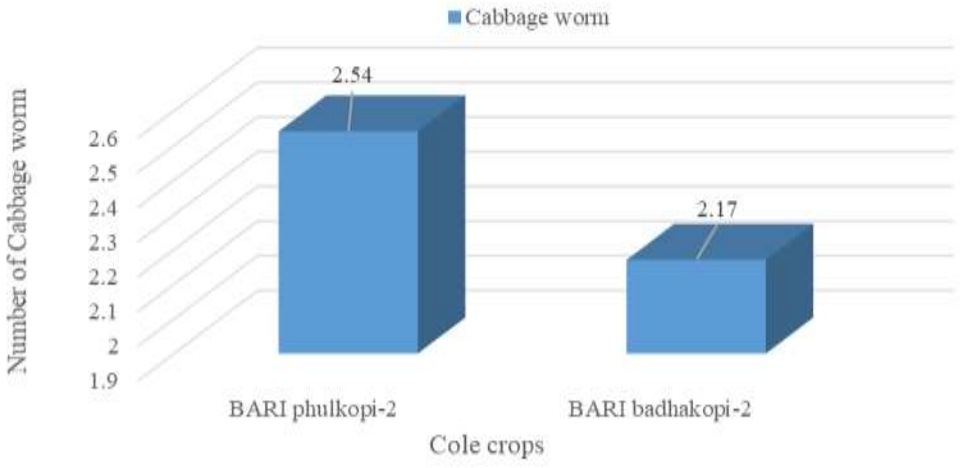


Figure 3: Effect of cole crops on average number of cabbage worm per five tagged plants

4.1.4. Tobacco caterpillar

The average number of tobacco caterpillar per five tagged plants was ranged from 2.63 to 3.03. The highest number of tobacco caterpillar per five tagged plants was recorded in V_1 (3.03 tobacco caterpillar/five tagged plants). On the other hand, the lowest number of tobacco caterpillar per five tagged plants was recorded in V_2 (2.63 tobacco caterpillar/five tagged plants). But it was observed that there was no statistical variation among the cole crops in terms of average number of tobacco caterpillar per five tagged plants (Figure 4).

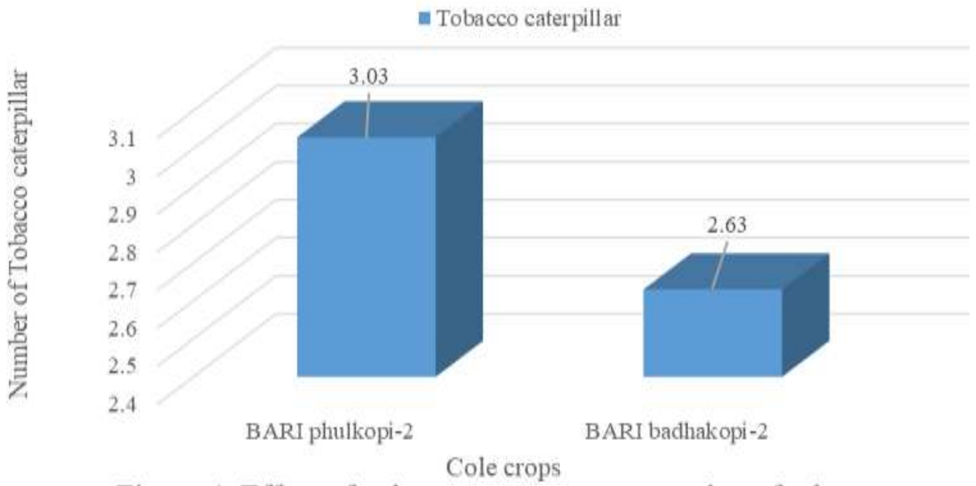
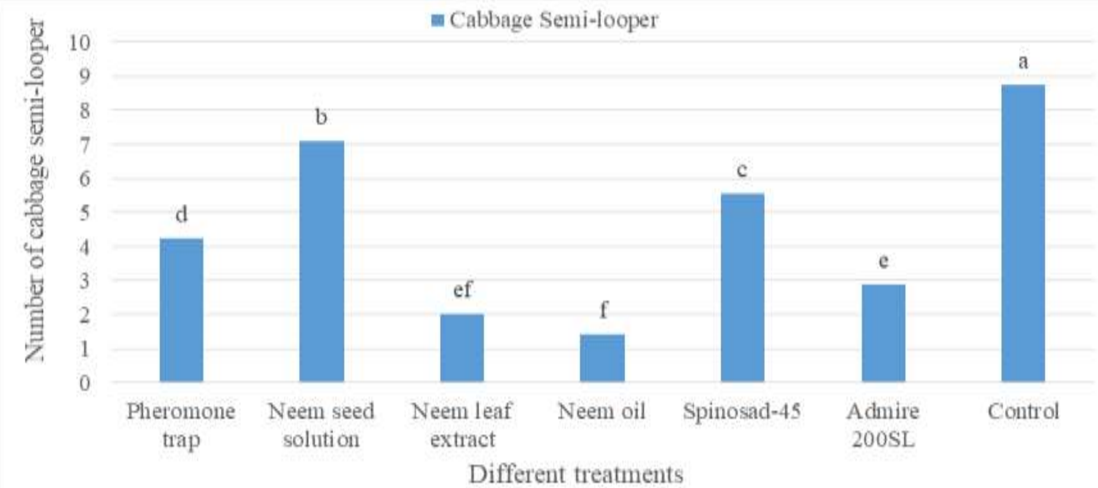


Figure 4: Effect of cole crops on average number of tobacco caterpillar per five tagged plants

4.2. Performance of different treatments against major insect pests

4.2.1. Cabbage semi-looper

The average number of cabbage semi-looper per five tagged plants was ranged from 1.43 to 8.75. The lowest number of cabbage semi-looper per five tagged plants was recorded in T_4 (1.43 cabbage semi-looper/five tagged plants). On the other hand, the highest number of cabbage semi-looper per five tagged plants was recorded in T_7 (8.75 cabbage semi-looper/five tagged plants). But it was observed that there was statistical variation among the treatments in terms of average number of cabbage semi-looper per five tagged plants (Figure 5).



Fugure 5: Effect of different treatments on average number of cabbage semi-looper per five tagged plants

4.2.2. Diamondback moth

The average number of diamondback moth caterpillar per five tagged plants was ranged from 2.51 to 7.67. The lowest number of diamondback moth caterpillar per

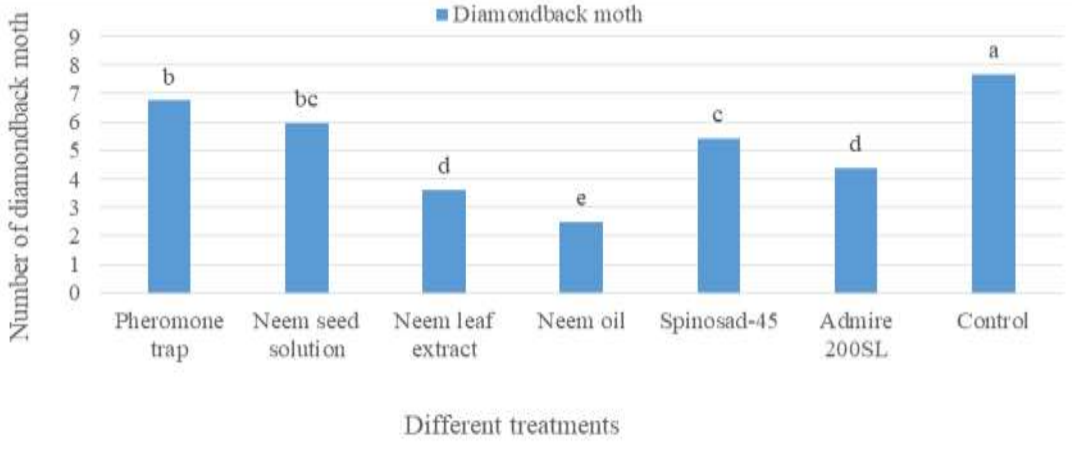


Figure 6: Effect of different treatments on average number of diamondback moth caterpillar per five tagged plants

five tagged plants was recorded in T_4 (2.51 DBM caterpillar/five tagged plants). On the other hand, the highest number of diamondback moth caterpillar per five tagged plants was recorded in T_7 (7.67 DBM caterpillar/five tagged plants). But it was observed that there was statistical variation among the treatments in terms of average number of diamondback moth caterpillar per five tagged plants (Figure 6).

4.2.3. Cabbage worm

The average number of cabbage worm per five tagged plants was ranged from 0.57 to 4.22. The lowest number of cabbage worm per five tagged plants was recorded in T_4 (0.57 cabbage worm/five tagged plants). On the other hand, the highest number of cabbage worm per five tagged plants was recorded in T_7 (4.22 cabbage worm/five

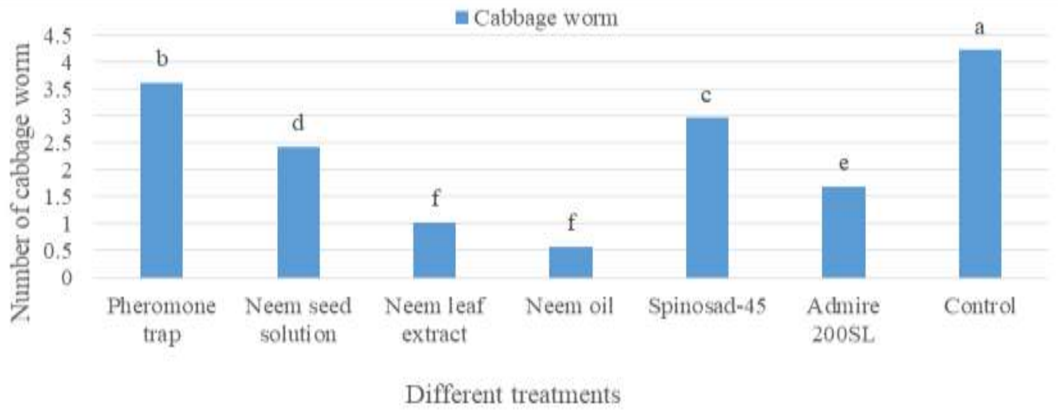


Figure 7: Effect of different treatments on average number of cabbage worm per five tagged plants

tagged plants). But it was observed that there was statistical variation among the treatments in terms of average number of cabbage worm per five tagged plants (Figure 7).

4.2.4. Tobacco caterpillar

The average number of tobacco caterpillar per five tagged plants was ranged from 0.92 to 5.27. The lowest number of tobacco caterpillar per five tagged plants was recorded in T_4 (0.92 tobacco caterpillar/five tagged plants). On the other hand, the highest number of tobacco caterpillar per five tagged plants was recorded in T_7 (5.27 tobacco caterpillar/five tagged plants). But it was observed that there was statistical variation among the treatments in terms of average number of tobacco caterpillar per five tagged plants (Figure 8).

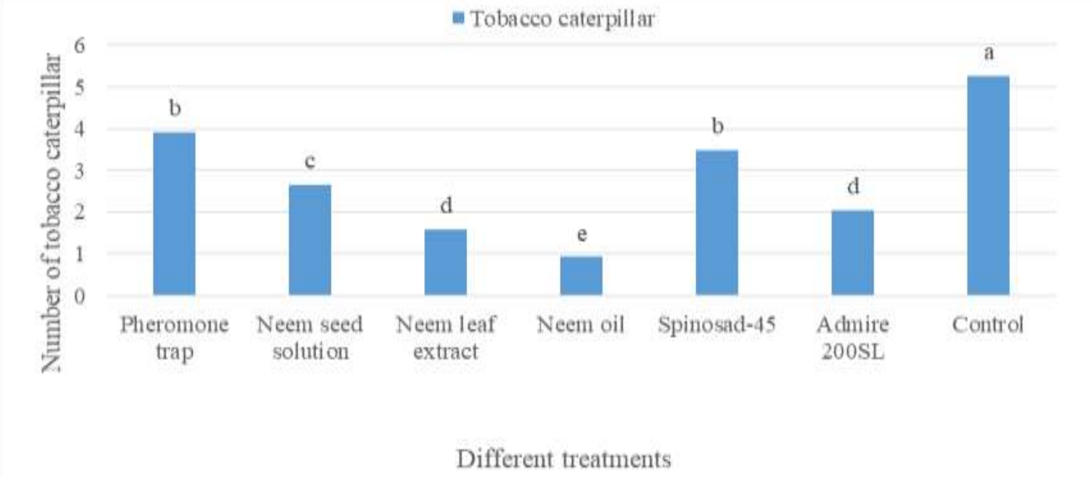


Figure 8: Effect of different treatments on average number of tobacco caterpillar per five tagged plants

4.3. Combined effect of Cole crops and different treatments against major insect pests

4.3.1. Cabbage semi-looper

The significant variations were observed among the combination of cole crops and different treatments in terms of the number of cabbage semi-looper per five tagged plants and ranged from 1.19 to 9.33. The lowest number was recorded in V_2T_4 (1.19

cabbage semi-looper/five tagged plants), which was statistically different from others and followed by V_2T_3 (1.67), V_1T_4 (1.87), V_2T_6 (2.19), V_1T_3 (2.63), V_2T_2 (3.13), V_1T_6 (3.89), V_2T_5 (4.61), V_1T_2 (5.23), V_2T_1 (5.85) and V_1T_5 (6.27). On the other hand, the highest number was recorded in V_1T_7 (9.33 cabbage semi-looper/five tagged plants), which was significantly different from others and followed by V_2T_7 (8.16) and V_1T_1 (7.89 cabbage semi-looper/five tagged plants) (Table 1).

4.3.2. Diamondback moth

The significant variations were observed among the combination of cole crops and different treatments in terms of the number of diamondback moth caterpillar per five tagged plants and ranged from 2.34 to 8.46. The lowest number was recorded in V_2T_4 (2.34 DBM caterpillar/five tagged plants), which was statistically similar with V_2T_3 (2.67) and followed by V_1T_4 (3.36), V_2T_6 (3.89), V_1T_3 (4.23), V_2T_2 (4.56), V_1T_6 (5.36), V_2T_5 (5.51), V_1T_2 (5.78), V_2T_1 (6.13) and V_1T_5 (6.23). On the other hand, the highest number was recorded in V_1T_7 (8.46 DBM caterpillar/five tagged plants), which was significantly different from others and followed by V_2T_7 (7.27) and V_1T_1 (6.87 DBM caterpillar/five tagged plants) (Table 1).

4.3.3. Cabbage worm

The significant variations were observed among the combination of cole crops and different treatments in terms of the number of cabbage worm per five tagged plants and ranged from 0.46 to 4.46. The lowest number was recorded in V_2T_4 (0.46 cabbage worm/five tagged plants), which was statistically similar with V_2T_3 (0.67) and V_1T_4 (0.97) and followed by V_2T_6 (1.09), V_1T_3 (1.46), V_2T_2 (1.89), V_1T_6 (2.20), V_2T_5 (2.65), V_1T_2 (2.78), V_2T_1 (3.13) and V_1T_5 (3.33). On the other hand, the highest number was recorded in V_1T_7 (4.46 cabbage worm/five tagged plants), which was significantly similar with V_2T_7 (3.98) and followed by V_1T_1 (3.89 cabbage worm/five tagged plants) (Table 1).

4.3.4. Tobacco caterpillar

The significant variations were observed among the combination of cole crops and different treatments in terms of the number of tobacco caterpillar per five tagged plants and ranged from 0.87 to 5.67. The lowest number was recorded in V_2T_4 (0.87 tobacco caterpillar/five tagged plants), which was statistically similar with V_2T_3 (0.96) and V_1T_4 (1.46) and followed by V_2T_6 (1.67), V_1T_3 (1.87), V_2T_2 (2.19), V_1T_6 (2.30), V_2T_5 (2.97), V_1T_2 (3.33), V_2T_1 (3.63) and V_1T_5 (3.67). On the other hand, the highest number was recorded in V_1T_7 (5.67 tobacco caterpillar/five tagged plants), which was significantly different from others and followed by V_2T_7 (4.87) and V_1T_1 (4.12 tobacco caterpillar/five tagged plants) (Table 1).

Table 1: Effect of different combinations of cole crops and different treatments on average number of major insect pests

Cole Crops	**Treatments**	**Cabbage Semi-looper**	**Caterpillar of DBM**	**Cabbage worm**	**Tobacco caterpillar**
BARI phulkoei-2 (V_1)	T_1	7.89 b	6.87 bc	3.89 b	4.12 c
	T_2	5.23 cd	5.78 d	2.78 d	3.33 de
	T_3	2.63 gh	4.23 fg	1.46 gh	1.87 fg
	T_4	1.87 hi	3.36 gh	0.97 hij	1.46 gh
	T_5	6.27 c	6.23 cd	3.33 c	3.67 cd
	T_6	3.89 ef	5.36 de	2.20 ef	2.30 f
	T_7	9.33 a	8.46 a	4.46 a	5.67 a
BARI badhakopi-2 (V_2)	T_1	5.85 c	6.13 cd	3.13 cd	3.63 cd
	T_2	3.13 fg	4.56 ef	1.89 fg	2.19 f
	T_3	1.67 hi	2.67 hi	0.67 ij	0.96 h
	T_4	1.19 i	2.34 i	0.46 j	0.87 h
	T_5	4.61 de	5.51 d	2.65 de	2.97 e
	T_6	2.19 ghi	3.89 fg	1.09 hi	1.67 fg
	T_7	8.16 b	7.27 b	3.98 ab	4.87 b
CV (%)		13.35	9.87	12.59	12.60
$LSD_{(0.05)}$		1.00	0.84	0.49	0.59

[Here, T_1= Using Pheromone traps; T_2= Neem seed solution; T_3= Neem leaf extract; T_4= Neem oil; T_5= Spinosad-45; T_6= Admire 200SL and T_7= Untreated Control]

4.4. Leaf infestation caused by major insect pests

4.4.1. Effect of cole crops

The percent leaf infestation per five tagged plants was ranged from 33.71 to 44.27. The lowest percent infested leaves per five tagged plants was recorded in V_2 (33.71%). On the other hand, the highest percent leaves per five tagged plants was recorded in V_1 (44.27%). But it was observed that there was statistical variation among the cole crops in terms of percentage of infested leaves per five tagged plants (Table 2).

4.4.2. Effect of different treatments

The percent leaf infestation per five tagged plants was ranged from 12.12 to 81.25%. The lowest percent infested leaves per five tagged plants was recorded in T_4 (12.12%). On the other hand, the highest percent leaves per five tagged plants was recorded in T_7 (81.25%). But it was observed that there was statistical variation among the different treatments in terms of percentage of infested leaves per five tagged plants (Table 2).

4.4.3. Combined effect of cole crops and different treatments

The significant variations were observed among the combination of cole crops and different treatments in terms of percent leaf infestation per five tagged plants and ranged from 11.77 to 100.00 %. The lowest percent leaf infestation was recorded in V_2T_4 (11.77%), which was statistically similar with V_2T_3 (12.50), V_1T_4 (20.00), V_2T_6 (28.57), V_1T_3 (30.77), V_2T_2 (34.42), V_1T_6 (41.67), V_2T_5 (43.98), V_1T_2 (50.00), V_2T_1 (51.70) and V_1T_5 (62.70). On the other hand, the highest percent leaf infestation was recorded in V_1T_7 (100.00%), which was significantly different from others and followed by V_2T_7 (66.67) and V_1T_1 (66.67%) (Table 2).

Table 2: Effect of cole crops on leaf infestation per five tagged plants

Cole crops	Treatments	% leaf infestation
Effect of cole crops		
BARI phulkopi-2 (V_1)	-	44.27 a
BARI badhakopi-2 (V_2)	-	33.71 b
Effect of different treatments		
-	T_1	57.90 b
-	T_2	39.14 c
-	T_3	24.14 d
-	T_4	12.12 e
-	T_5	55.00 b
-	T_6	36.00 c
-	T_7	81.25 a
Effect of combination of cole crops and different treatments		
BARI phulkopi-2 (V_1)	T_1	66.67 b
	T_2	50.00 c
	T_3	30.77 ef
	T_4	20.00 g
	T_5	62.70 b
	T_6	41.67 d
	T_7	100.00 a
BARI badhakopi-2 (V_2)	T_1	51.70 c
	T_2	34.42 e
	T_3	12.50 h
	T_4	11.77 h
	T_5	43.98 d
	T_6	28.57 f
	T_7	66.67 b
CV (%)		5.33
$LSD_{(0.05)}$		1.63

[Here, T_1= Using Pheromone traps; T_2= Neem seed solution; T_3= Neem leaf extract; T_4= Neem oil; T_5= Spinosad-45; T_6= Admire 200SL and T_7= Untreated Control]

4.5. Plant infestation caused by major insect pests

4.5.1. Effect of cole crops

The percent plant infestation per plot was ranged from 53.81 to 62.18. The lowest percent infested plants per plot was recorded in V_2 (53.81%). On the other hand, the highest percent plants per plot was recorded in V_1 (62.18%). But it was observed that there was statistical variation among the cole crops in terms of percentage of infested plants per plot (Table 3).

4.5.2. Effect of different treatments

The percent plant infestation per plot was ranged from 29.17 to 87.50%. The lowest percent infested plants per plot was recorded in T_4 (29.17%). On the other hand, the highest percent plants per plot was recorded in T_7 (87.50%). But it was observed that there was statistical variation among the different treatments in terms of percentage of infested plants per plot (Table 3).

4.5.3. Combined effect of cole crops and different treatments

The significant variations were observed among the combination of cole crops and different treatments in terms of percent plant infestation per plot and ranged from 25.00 to 91.67%. The lowest percent of plant infestation per plot was recorded in V_2T_4 (25.00%), which was statistically different from others and followed by V_2T_3 (33.33), V_1T_4 (41.67), V_2T_6 (50.00), V_1T_3 (50.00), V_2T_2 (51.67), V_1T_6 (58.33), V_2T_5 (58.33), V_1T_2 (60.28), V_2T_1 (66.67) and V_1T_5 (66.67). On the other hand, the highest percent of plant infestation per plot was recorded in V_1T_7 (91.67%), which was significantly different from others and followed by V_2T_7 (83.33) and V_1T_1 (75.00%) (Table 3).

Table 3: Effect of combination of cole crops and different treatments on plant infestation per five tagged plants

Cole crops	Treatments	% plant infestation
Effect of Cole crops		
BARI phulkopi-2 (V_1)	-	53.83 a
BARI badhakopi-2 (V_2)	-	62.17 b
Effect of different treatments		
-	T_1	70.83 b
-	T_2	56.00 d
-	T_3	45.83 e
-	T_4	29.17 f
-	T_5	62.50 c
-	T_6	54.17 d
-	T_7	87.50 a
Effect of combination of cole crops and different treatments		
BARI phulkopi-2 (V_1)	T_1	75.00 c
	T_2	60.28 e
	T_3	50.00 f
	T_4	41.67 g

	T_5	66.67 d
	T_6	58.33 e
	T_7	91.67 a
BARI badhakopi-2 (V_2)	T_1	66.67 d
	T_2	51.67 f
	T_3	33.33 h
	T_4	25.00 i
	T_5	58.33 e
	T_6	50.00 f
	T_7	83.33 b
CV (%)		3.31
$LSD_{(0.05)}$		1.63

[Here, T_1= Using Pheromone traps; T_2= Neem seed solution; T_3= Neem leaf extract; T_4= Neem oil; T_5= Spinosad-45; T_6= Admire 200SL and T_7= Untreated Control]

4.6. Yield contributing characteristics

4.6.1. Effect of cole crops

Card height: The average card height per plot was ranged from 8.66 to 17.32 cm. The highest average card height per plot was recorded in V_1 (17.32 cm). On the other hand, the lowest average card height per plot was recorded in V_2 (8.66 cm). But it was observed that there was statistical variation among the cole crops in terms of average card height per plot (Table 4).

Card diameter: The average card diameter per plot was ranged from 18.63 to 18.77 cm. The highest average card diameter per plot was recorded in V_2 (18.77 cm). On the other hand, the lowest average card diameter per plot was recorded in V_1 (18.63 cm). There was no statistical variation among the cole crops in terms of average card diameter per plot (Table 4).

Yield: The yield was ranged from 16.41 to 15.20 ton/ha. The highest yield was recorded in V_2 (16.41 ton/ha). On the other hand, the lowest yield was recorded in V_1 (15.20 ton/ha). But it was observed that there was no statistical variation among the cole crops in terms of yield (Table 4).

4.6.2. Effect of different treatments

Card height: The average card height per plot was ranged from 10.11 to 15.81 cm. The highest average card height per plot was recorded in T_4 (15.81 cm). On the other hand, the lowest card height per plot was recorded in T_7 (10.11 cm). But it was observed that there was statistical variation among the different treatments in terms of average card height per plot (Table 4).

Card diameter: The average card diameter per plot was ranged from 16.01 to 21.34 cm. The highest average card diameter per plot was recorded in T_4 (21.34 cm). On the other hand, the lowest card diameter per plot was recorded in T_7 (16.01 cm). But it was observed that there was statistical variation among the different treatments in terms of average card diameter per plot (Table 4).

Yield: The yield was ranged from 17.52 to 19.94 ton/ha. The highest yield was recorded in T_4 (19.94 ton/ha). On the other hand, the lowest yield was recorded in T_7 (17.52 ton/ha). But it was observed that there was statistical variation among the different treatments in terms of yield (Table 4).

4.6.3. Combined effect of cole crops and different treatments

Card height: The significant variations were observed among the combination of cole crops and different treatments in terms of the card height per plot and ranged from 6.56 to 21.29 cm. The lowest card height was recorded in V_2T_4 (21.29 cm), which was statistically different from other treatments and followed by V_2T_3 (19.46), V_1T_4 (19.18), V_2T_6 (17.56), V_1T_3 (15.33), V_2T_2 (14.78), V_1T_6 (13.67), V_2T_5 (10.33), V_1T_2 (9.76), V_2T_1 (9.23) and V_1T_5 (9.07). On the other hand, the highest card height was recorded in V_1T_7 (6.56 cm), which was significantly similar with V_2T_7 (7.46) and followed by V_1T_1 (8.19 cm) (Table 4).

Card diameter: The significant variations were observed among the combination of cole crops and different treatments in terms of the card diameter per plot and ranged from 15.45 to 22.46 cm. The highest card diameter was recorded in V_2T_4 (22.46 cm), which was statistically different from other treatments and followed by V_2T_3 (20.78), V_1T_4 (20.23), V_2T_6 (19.87), V_1T_3 (19.45), V_2T_2 (19.41), V_1T_6 (18.94), V_2T_5 (18.56), V_1T_2 (18.33), V_2T_1 (17.67) and V_1T_5 (17.56). On the other hand, the lowest card diameter was recorded in V_1T_7 (15.45 cm), which was significantly similar with V_2T_7 (16.56) and V_1T_1 (16.56 cm) (Table 4).

Yield: The significant variations were observed among the combination of cole crops and different treatments in terms of yield per plot and ranged from 16.82 to 20.13 ton/ha. The highest yield was recorded in V_2T_4 (20.13 ton/ha), which was statistically similar with V_2T_3 (20.00), V_1T_4 (19.96), V_2T_6 (19.76), V_1T_3 (19.71), V_2T_2 (19.02), V_1T_6 (18.82), V_2T_5 (18.67), V_1T_2 (18.63), V_2T_1 (18.43) and V_1T_5 (18.22). On the other hand, the lowest yield was recorded in V_1T_7 (16.82 ton/ha), which was significantly similar with V_2T_7 (17.33) and V_1T_1 (17.78 ton/ha) (Table 4).

Table 4: Effect of cole crops and different treatments on yield attributing characteristics and yield

Cole crops	Treatments	Card height (cm)	Card diameter (cm)	Yield (ton/ha)
Effect of cole crops				
BARI phulkopi-2 (V_1)		17.32 a	18.63 a	18.20 a
BARI badhakopi-2 (V_2)		8.66 b	18.77 a	19.41 a
Effect of different treatments				
	T_1	11.12 cd	17.06 de	18.08 ab
	T_2	13.39 b	19.01 bc	19.07 ab
	T_3	14.61 ab	20.33 ab	19.31 ab
	T_4	15.81 a	21.34 a	19.94 a
	T_5	11.76 c	18.00 cd	18.40 ab
	T_6	14.13 b	19.17 bc	19.31 ab
	T_7	10.11 d	16.01 e	17.52 b
Effect of combination of cole crops and different treatments				
BARI phulkopi-2 (V_1)	T_1	9.23 fg	16.56 fg	17.78 bcd
	T_2	14.78 de	18.33 de	18.63 abcd
	T_3	19.46 b	19.45 bcd	19.71 ab
	T_4	21.29 a	20.23 bc	19.96 a
	T_5	10.33 f	17.56 ef	18.22 abcd

	T_6	17.56 c	18.94 cde	18.82 abc
	T_7	7.46 hi	15.45 g	16.82 d
BARI badhakopi-2 (V_2)	T_1	8.19 gh	17.67 ef	18.43 abcd
	T_2	9.76 f	19.41 bcd	19.02 abc
	T_3	15.33 d	20.78 b	20.00 a
	T_4	19.18 b	22.46 a	20.13 a
	T_5	9.07 fg	18.56 cde	18.67 abcd
	T_6	13.67 e	19.87 bcd	18.82 abc
	T_7	6.56 i	16.56 fg	17.33 cd
CV (%)		5.61	4.90	5.45
$LSD_{(0.05)}$		1.20	1.51	1.69

[Here, T_1= Using Pheromone traps; T_2= Neem seed solution; T_3= Neem leaf extract; T_4= Neem oil; T_5= Spinosad-45; T_6= Admire 200SL and T_7= Untreated Control]

CHAPTER V
SUMMARY AND CONCLUSION

The summary and conclusions of the study were given below:

Effect of cole crops

The highest number of cabbage semi-looper per five tagged plants was recorded in V_1 (4.87 cabbage semi-looper/five tagged plants). On the other hand, the lowest number of cabbage semi-looper per five tagged plants was recorded in V_2 (4.26 cabbage semi-looper/five tagged plants).

The highest number of diamondback moth caterpillar per five tagged plants was recorded in V_1 (5.50 DBM caterpillar/five tagged plants). On the other hand, the lowest number of diamondback moth caterpillar per five tagged plants was recorded in V_2 (4.88 DBM caterpillar/five tagged plants).

The highest number of cabbage worm per five tagged plants was recorded in V_1 (2.54 cabbage worm/five tagged plants). On the other hand, the lowest number of cabbage worm per five tagged plants was recorded in V_2 (2.17 cabbage worm/five tagged plants).

The highest number of tobacco caterpillar per five tagged plants was recorded in V_1 (3.03 tobacco caterpillar/five tagged plants). On the other hand, the lowest number of tobacco caterpillar per five tagged plants was recorded in V_2 (2.63 tobacco caterpillar/five tagged plants).

The lowest percent infested leaves per five tagged plants was recorded in V_1 (11.34%). On the other hand, the highest percent leaves per five tagged plants was recorded in V_2 (12.34%).

The lowest percent infested plants per plot was recorded in V_2 (53.81%). On the other hand, the highest percent plants per plot was recorded in V_1 (62.18%).

The lowest card height per plot was recorded in V_2 (8.66 cm). On the other hand, the highest card height per plot was recorded in V_1 (17.32 cm).

The highest card diameter per plot was recorded in V_2 (18.77 cm). On the other hand, the lowest card diameter per plot was recorded in V_1 (18.63 cm).

The highest yield was recorded in V_2 (16.41 ton/ha). On the other hand, the lowest yield was recorded in V_1 (15.20 ton/ha).

Effect of different treatments

The lowest number of cabbage semi-looper per five tagged plants was recorded in T_4 (1.43 cabbage semi-looper/five tagged plants). On the other hand, the highest number of cabbage semi-looper per five tagged plants was recorded in T_7 (8.75 cabbage semi-looper/five tagged plants).

The lowest number of diamondback moth caterpillar per five tagged plants was recorded in T_4 (2.51 DBM caterpillar/five tagged plants). On the other hand, the average number of diamondback moth caterpillar per five tagged plants was recorded in T_7 (7.67 DBM caterpillar /five tagged plants).

The lowest number of cabbage worm per five tagged plants was recorded in T_4 (0.57 cabbage worm/five tagged plants). On the other hand, the highest number of cabbage worm per five tagged plants was recorded in T_7 (4.22 cabbage worm/five tagged plants).

The lowest number of tobacco caterpillar per five tagged plants was recorded in T_4 (0.92 tobacco caterpillar/five tagged plants). On the other hand, the highest number of tobacco caterpillar per five tagged plants was recorded in T_7 (5.27 tobacco caterpillar/five tagged plants).

The lowest percent infested leaves per five tagged plants was recorded in T_4 (12.12%). On the other hand, the highest percent leaves per five tagged plants was recorded in T_7 (81.25%).

The lowest percent infested plants per plot was recorded in T_4 (29.17%). On the other hand, the highest percent plants per plot was recorded in T_7 (87.50%).

The highest card height per plot was recorded in T_4 (15.81 cm). On the other hand, the lowest card height per plot was recorded in T_7 (10.11 cm).

The highest card diameter per plot was recorded in T_4 (21.34 cm). On the other hand, the lowest card diameter per plot was recorded in T_7 (16.01 cm).

The highest yield was recorded in T_4 (19.94 ton/ha). On the other hand, the lowest yield was recorded in T_7 (17.52 ton/ha).

Combined effect of cole crops and different treatments

The lowest number of cabbage semi-looper per five tagged plants was recorded in V_2T_4 (1.19 cabbage semi-looper/five tagged plants). On the other hand, the highest number of cabbage semi-looper per five tagged plants was recorded in V_1T_7 (9.33 cabbage semi-looper/five tagged plants).

The lowest number of diamondback moth caterpillar per five tagged plants was recorded in V_2T_4 (2.34 DBM caterpillar/five tagged plants). On the other hand, the highest number of diamondback moth caterpillar per five tagged plants was recorded in V_1T_7 (8.46 DBM caterpillar/five tagged plants).

The lowest number of cabbage worm per five tagged plants was recorded in V_2T_4 (0.46 cabbage worm/five tagged plants). On the other hand, the highest number of cabbage worm per five tagged plants was recorded in V_1T_7 (4.46 cabbage worm/five tagged plants).

The lowest number of tobacco caterpillar per five tagged plants was recorded in V_2T_4 (0.87 tobacco caterpillar/five tagged plants). On the other hand, the highest number of tobacco caterpillar per five tagged plants was recorded in V_1T_7 (5.67 tobacco caterpillar/five tagged plants).

The lowest percent of leaf infestation was recorded in V_2T_4 (11.77%). On the other hand, the highest percent of leaf infestation was recorded in V_1T_7 (100.00%).

The lowest percent of plant infestation per plot was recorded in V_2T_4 (25.00%). On the other hand, the highest percent of plant infestation per plot was recorded in V_1T_7 (91.67%).

The highest card height was recorded in V_1T_7 (21.29cm). On the other hand, the lowest card height was recorded in V_2T_4 (6.56 cm).

The highest card diameter was recorded in V_2T_4 (22.46 cm). On the other hand, the lowest card diameter was recorded in V_1T_7 (15.45 cm).

The highest yield was recorded in V_2T_4 (20.13 ton/ha). On the other hand, the lowest yield was recorded in V_1T_7 (16.82 ton/ha).

Conclusion

Conclusions of this study are presented below:

i. Cabbage worm, diamondback moth, cabbage semi-looper and tobacco caterpillar affected cole crops in the filed condition. Diamondback moth found in higher incidence.

ii. Among different treatments neem oil played an important role against cabbage worm, diamondback moth, cabbage semi-looper and tobacco caterpillar.

iii. Among the different combinations BARI badhakopi-2 with Neem oil showed the best performance against cabbage worm, diamondback moth, cabbage semi-looper and tobacco caterpillar.

CHAPTER VI

REFERENCES

Advisory committee of vegetable crops. (2012). Cole crops- Vegetable crops production guide for the Atlantic Provinces. Atlantic Provinces Agriculture Services Coordinating Committee.

Anonymous. (1987). Annual Report for (1986-87). Central Institute for Cotton Research, Nagpur. p.: 27.

Anonymous, (1988). *FAO Production Year Book. Food and Agricultural Organization*, United Nation, Rome, Italy. **43**: 190-193.

Anonymous. (2006). Effect of chemical fertilizer and organic manure on the yield and quality of cabbage. *Annual Rep.* BARI, Joydebpur. pp.: 186-189.

Bajpai, N.K. and Sehgal, V.K. (2000). Efficacy of neem, Karanj and tobacco formulations against *Helicoverpa armigera* (Hubner) in chickpea crop. *Indian J. Entom.* **62**: 21-23.

Banken, J.A.O. and Stark, J.D. (1997). Stage and age influence on the susceptibility of *Coccinella septempunctata* after direct exposure to neemix, a neem insecticide. *J. Eco. Entomol.* **90**(5): 1102-1105.

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

BBS. (2019). *Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics*, Statistical Division, Ministry of Planning, Government of the People’s Republic of Bangladesh, Dhaka.

Bélair, G., Fournier, Y. and Dauphinais, N. (2003). Efficacy of steinernematid nematodes against three insect pests of crucifers in Quebec. *J. Nematology*. **35**(3): 259-265.

Bilton, J.N., Broughton, H.B., Ley, S.V., Lidert, Z., Morgan, E.D., Rzepa, H.S. and Sheppard, R.N. (1985). Structural reappraisal of the limonoid insect antifeedant azadirachtin. *J. Chem. Soc. Chem. Commun*. pp.: 968-971.

Broughton, H.B., Bilton, J.N., Ley, S.V., Lidert, Z., Morgan, E.D., Rzepa, H.S. and Sheppard, R.N. (1986). Structural reappraisal of the limonoid insect antifeedant azadirachtin. *J. Chem. Soc. Chem. Commun*. pp. 968-971.

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.

Butterworth, J.H. and Morgan, E.D. (1968). Isolation of substance that suppresses feeding in locusts. *J. Chem. Commun*. pp.: 23-24.

CABI. (2021). Cabbage worm. Plant wise knowledge bank.

Capinera, J.L. (1999a). Cabbage Looper. Featured Creatures EENY-116.Entomology and Nematology Department, University of Florida. pp.: 311-314.

Chong, C.S., D'Alberto, C.F., Thomson, L.J. and Hoffmann, A.A. (2010). Influence of native ants on arthropod communities in a vineyard. *Agric. Forest Entomol.* **12**: 223-232.

Colting, M.L. and Catdona, J.E.V. (2011). Insecticide resistance management: sharing the experience on diamondback moth in the Philippines. **In**: *Proceedings of the 5th International Workshop on the Management of Diamondback 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. pp.: 228-233.

Corvi, F. and Nardi, S. (1998). Combattere la nottua del cavolfiore. *Terra e vita*. **47**: 76-78.

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.

Devlin, J.F. and Zettel, T. (1999). Ecoagriculture: Initiatives in Eastern and Southern Africa. Weaver Press, Harare, Zimbabwe.

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 Diamondback 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. pp.: 199-201.

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

Furlong, M.J., Kim, H.J., Pak, W.S., Jo, K.C., Ri, C.I. and Zalucki, M.P. (2008a). Integration of endemic natural enemies and *Bacillus thuringiensis* to manage insect pests of Brassica crops in North Korea. *Agric. Ecos. Envir.* **125**: 223-238.

Furlong, M.J., Shi, Z.H., Liu, Y.Q., Guo, S.J., Lu, Y.B., Liu, S.S. and Zalucki, M.P. (2004a). Experimental analysis of the influence of pest management practice on the efficacy of an endemic arthropod natural enemy complex of the diamondback moth. *J. Econ. Entomol.* **97**: 1814-1827.

Furlong, M.J., Shi, Z.H., Liu, Y.Q., Guo, S.J., Lu, Y.B., Liu, S.S. and Zalucki, M.P. (2004b). Experimental analysis of the influence of pest management practice on the efficacy of an endemic arthropod natural enemy complex of the diamondback moth. *J. Econ. Entomol.* **97**(6): 1814-1827.

Furlong, M.J., Spafford, H., Ridland, P.M., Endersby, N.M., Edwards, O.R., Baker, G.J., Keller, M.A. and Paull, C.A. (2008b). Ecology of diamondback moth in Australian canola: landscape perspectives and implications for management. *Australian J. Experi. Agric.* **48**: 1494-1505.

Grainge, M. and Ahmed, S. (1988). Handbook of Plants with Pest Control Properties. Wiley, New York.

Griffiths, D.C., Greenway, A.R. and Lioyd, S.L. (1978). The influence of repellent materials and aphid extracts on settling behavior and larviposition of *Myzus piersicae* (Sulzer) (Hemiptera: Aphididae). *Bull. Ent. Res.* **68:** 613-619.

Griffiths, D.C., Pickett, J.A., Smart, L.E. and Woodcock, C.M. (1989). Use of insect antifeedant against aphid vectors of plant virus disease. *Pestic. Sci*. **27**: 269-276.

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 Protec.* **29**: 68-79.

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

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

Hasan, A.S., Moussa, M.A., Sayed, E. and Nasir, A. (1960). Behaviora of larvae, adults of the cotton leaf worm *Prodenia litura* (Feb.) Lepidoptera: Noctuidae. *Bull. Soc. Ent. Egypt.* **44**(1): 337-343.

Haseeb, M., Kobori, Y., Amano, H. and Nemoto, H. (2001). Population dynamics of *Plutella xylostella* (Lepidoptera: Plutellidae) and its parasitoid *Cotesia plutellae* (Hymenoptera: Braconidae) on two varieties of cabbage in an urban environment. *App. Entomol. Zool.* **36**: 353-360.

Hely, P.C., Pasfield, G. and Gellatley, J.G. (1982). Insect Pests of Fruit and Vegetables in NSW. Sydney, New South Wales, Australia: Department of Agriculture, New South Wales. pp.: viii + 312.

Hosseini, R., Keller, M.A., Schmidt, O. and Baker, G.J. (2008). Predators associated with crop pests of *Brassica* spp. in South Australia. **In**: *Proceedings of the Fifth International Workshop*: The Management of Diamondback Moth and Other Crucifer Pests. 24 – 27 October 2006. Shelton *et al.* (Eds.). China Agricultural Science and Technology Press, Beijing, China. pp.: 338 – 344.

Huang, X.P., Drioos, J.E., Quinones, S. and Tsai, T. (2011). Spinetroram, a new spinosyn insecticide for managing diamondback moth and other insect pests of crucifers. **In:** *Proceedings of the 5th International Workshop on the Management of Diamondback moth and other crucifer pests*. Shelton *et al.* (Eds.). China Agricultural Science and Technology Press. pp.: 272-289.

Islam, M.B. (1997). Neem and botanical insecticides: Barriers to commercialization. *Phytoparasitica*. **25**: 339-344.

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

Joshi, B.G. and Sitaramaiah, S. (1979). Seed kernel as an oviposition repellent for *Spodoptera litura* (F.) moths. **7**: 199-202.

Karim, S., Ahad, M.A., Amin, M.R., Iqbal, T.M.T. (2007). Biology of lemon butterfly *Papilio demoleus* (Lepidoptera: Papilionidae): The effect of neem oil on food consumption. *J. Sci. Technol. (Dinajpur)*. **5**: 28-34.

Karimzadeh, J. and Wright, D.J. (2008). Bottom-up cascading effects in a tritrophic system: interactions between plant quality and host-parasitoid immune responses. *Eco. Entomol.* **33**: 45-52.

Karimzadeh, J., Bonsall, M.B. and Wright, D.J. (2004). Bottom-up and topdown effects in a tritrophic system: the population dynamics of *Plutella xylostella* (L.)-*Cotesia plutellae* (Kurdjumov) on different host plants. *Eco. Entomol.* **29**: 285-293.

Keita, S.M., Vincent, C., Schmidt, J.P. and Arnason, J.T. (2001). Insecticidal effects of *Thuja occidentalis* (Cupressaceae) essential oil on *Callosobruchus maculatus* [Coleoptera: Bruchidae]. *Canadian J. Plant Sci*. **81**(1): 173-177.

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

Kraus, W., Bokel, R., Klenk, A. and Pohnl, H. (1985). Constituents of neem and related species: A reversed structure of azadirachtin. Third Int. Conf. of 56 Chemistry and Biotechnology of Biologically Active Natural products (Sofia, Bulgaria, 1985), *Abstr*. pp.: 446-450.

Lahm, G.P., Cordova, D. and Barry, J.D. (2009). New and selective ryanodine receptor activators for insect control. *Bioorg. Med. Chem.* **17**: 4127-4133.

Lakshmanan, K.K. (2001). Neem a natural pesticide. *The Hindu, March* 1. p.: 8.

Leibee, G.L. (1996). Insect pest management in crucifers in Florida. Pest Management in the Subtropics, Integrated Pest Management - A Florida Perspective. Intercept, Andover, UK. pp.: 314-316.

Leuschner, K. (1972). Effects of an unknown substance on a shield bug. *Naturwissenshaften*. **59**: 217.

Liu, S.S. and Jiang, L.H. (2003). Differential parasitism of *Plutella xylostella* (Lepidoptera: Plutellidae) larvae by the parasitoid *Cotesia plutellae* (Hymenoptera: Braconidae) on two host plant species. *Bull. Entomol. Res.* **93**: 65-72.

Mahar, A.N., Jan, N.D., Chachar, Q.I.., Markhand, G.S., Munir, M. and Mahar, A.Q. (2005). Production and infectivity of some entomopathogenic nematodes against larvae and pupae of Cabbage Butterfly, *Pieris brassicae* L. (Lepidoptera: Pieridae). *Entomol.* **2**: 86-91.

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

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

Nauen, R. (2006). Insecticide mode of action: return of the ryanodine receptor. *Pest Manag. Sci.* **62**: 690-692.

Park, H.W., Kim, H.H., Youn, S.H., Shin, T.S., Bilgrami, A.L., Cho, M.R. and Shin, C.S. (2012). Biological control potentials of insect-parasitic nematode

Rhabditis blumi (Nematoda: Rhabditida) for major cruciferous vegetable insect pests. *Appl. Entomol. Zool.* **47**: 389-397.

Patil, R.S. and Goud, K.B. (2003). Efficacy of methanolic plant extracts as ovipositional repellents against diamondback moth *Plutella xylostella* (L.). *J. Entomol. Res.* **27**: 13-18.

Pedigo, L.P. (2002). Entomology and Pest Management (Third ed.). Prentice-Hall, Englewood Cliffs, NJ.

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

Prakash, A., Rao, J., Jevari, S.N. and Gupta, S.P. (1990). Rice agro ecosystem management by pesticides and its consequences. *Nat con. Publ. in Growth Develop. Natural Res. Conservations*. pp.: 131-137.

Prakash, A., Rao, J., Pasalu, I.C. and Mathur, K.C. (1987). Rice Storage and Insect Management. B.R. Publishing Corporation, New Delhi. p.: 337.

Prasad, R.P., Kabaluk, J.T., Meberg, H.P., Bevon, D.A. and Henderson, D.E. (2009). Seasonal and spatial occurrence of aphid natural enemies in organic *Brassica* fields: diversity, phenology, and reproduction. *J. Sustainable Agric.* **33**: 336–348.

Rajasekaran, B. and Kumarswami, Y. (1985). Antifeedent properties of certain plant products against *Spodoptera litura* (F.). **In:** *Proceedings of National Seminar on Behavioral Physiology Appr*. Mrmt. Crop pests, Tamil Nadu Agricultural University. pp.: 25-28.

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

Rashid, M.M. (1999). SabjiBijnan. Text Book Division, Bangla Academy, Dhaka, Bangladesh. p.: 221.

Ridland, P.M. and Endersby, N.M. (2011). Some Australian populations of diamondback moth, *Plutella xylostella* (L.) show reduced susceptibility to fipronil. **In**: *Proceedings of the 5th International Workshop on the Management of Diamondback 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. pp.: 207-215.

Roy, B., Amin, R., Uddin, M.N., Islam, A.T.M.S., Islam, M.J. and Halder, B.C. (2005). Leaf extracts of Shiyalmutra (*Blumea lacera* Dc.) as botanical pesticides against lesser grain borer and rice weevil. *J. Biol. Sci.* **5**(2): 201-204.

Roy, S.K. and Chakrabarti, A.K. (2003). Vegetables of temperate climates-Commercial and dietary importance. Encyclopedia of Food Science and Nutrition (Second edition).

Russell, D.A., Uijtewaal, B., Shelton, A.M., Mao, C., Srinivasan, R., Gujar, G.T., Rauf, A., Grzywacz, D. and Gregory, p. (2008). Bt brassicas for DBM control: The CIMBAA public/private partnership. **In:** *Proceedings of the 5th International Workshop on the Management of Diamondback moth and other crucifer pests.* Shelton *et al.* (Eds.). China Agricultural Science and Technology Press. pp.: 272-289.

Sardana, H.R. and Krishnakumar, N.K. (1989). Effectiveness of plant oils against leafhopper, shoot and fruit borer in okra. *Indian J. Entomol*. **51**(2): 167- 171.

Sarfraz, M., Keddie, A.B. and Dosdall, L.M. (2005). Biological control of the diamondback moth, *Plutella xylostella*: a review. *Biocontrol Sci. Tech.* **15**: 763-789.

Saxena, R.C., Waldbauer, G.P., Liquido, N.J. and Puma, B.C. (1981). Effects of neem seed oil to the rice leaf folder, *Cnaphalocrocis medinalis*. **In:** *Natural Pesticides from the Neem Tree (Azadirachta indica A. Juss) and Other Tropical Plants*. Schmutterer, H. and Ascher, K.R.S. (eds.) Rottach-Egern, Germany: Eschborn: GTZ. pp.: 189-204.

Schmutterer, H. (1985). Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. *Annu. Rev. Entomol*. **35**: 271-297.

Schmutterer, H. (1995). The neem tree, *Azadirachta indica* A. Juss and other eliaceous plants Sources of unique natural products for integrated pest management, medicines, industry and other purposes. VCH Publishers Inc., New York, USA. p.: 253.

Senior, L.J. and Healey, M.A. (2011). Predators in early season brassica crops in South East Queensland (Australia). **In**: *Proceedings of the 5th International Workshop on the Management of Diamondback 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. pp.: 114-122.

Shelton, A.M., Gujar, G.T., Chen, M., Rauf, A., Srinivasan, R., Kalia, V., Mittal, A., Kumari, A., Kaliaperumal, R., Borkakatti, R., Zhao, J.Z., Endersby, N., Russell, D., Wu, Y.D. and Uijtewaal, B. (2009). Assessing the susceptibility of cruciferous Lepidoptera to Cry1Ba2 and Cry1Ca4 for future transgeneic cruciferous vegetables. *J. Econ. Entomol.* **102**(6): 2217-2223.

Silva, A.A. Jr. (1986). Mineral and organic fertilizing in cabbage. Commercial quality and the occurrence of *Xanthomonas campestries* cv. Campestris. *Hort. Bras*. **4**(2): 10-12.

Sojitra, I.R. and Patel, J.R. (1992). Effects of plant extracts (including *Azadirachta indica*, *Ricinus communis* and *Pongamia pinnata*) on ovipositional behavior of spotted bollworm (*Earias vittella*) infesting okra (*Abelmoschus esculentus*). *Indian J. Agric. Sci.* **62**: 848-849.

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

Talekar, N.S. and Yang, J.C. (1991). Characteristics of parasitism of diamondback moth by two larval parasites. *Entomophaga.* **36**: 95–104.

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

Temple, J.H., Pommireddy, P.L., Cook, D.R., Marcon, P. and Leonard, B.R. (2009). Susceptibility of selected lepidopteran pests to Rynaxypyr®, a novel insecticide. *J. Cotton Sci.* **13**: 23-31.

Tindall, M. (2000). Mineral and organic fertilizing in cabbage. Residual effect for commercial cultivation on yield and quality performance with organic farming. *Hort. Bras*. **6**(1): 15-20.

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

Tohnishi, M., Nakao, H., Furuya, T., Seo, A., Kodama, H., Tsubata, K., Fujioka, S., Kodama, H., Hirooka, T. and Nishimatsu, T. (2005). Flubendiamide, a novel class insecticide highly active against lepidopterous insect pests. *J. Pestic. Sci.* **30**: 354-360.

Verkerk, R.H.J. and Wright, D.J. (1997). Field-based studies with the diamondback moth tritrophic system in Cameron Highlands of Malaysia: implications for pest management. *Inter. J. Pest Manag.* **43**: 27-33.

Walker, G., Wright, P., Cameron, P. and Berry, N. (2009). Information guide for integrated pest management in vegetable brassicas: an information guide. Fresh Vegetable Product Group, Horticulture New Zealand. ISBN 978-0-473-14901-7.

Walker, M.K., Davidson, M.M., Wallace, A.R. and Walker, G.P. (2011). Monitoring of diamondback moth in a cold-winter climate, South Island, New Zealand. **In**: *Proceedings of the 5th International Workshop on the Management of Diamondback moth and other crucifer pests*. Shelton *et al.* (Eds.). 21-25, March 2011, Kasetsart University, Nakhon Pathom, Thailand. AVRDC – The World Vegetable Center, Publication No. 11-755. AVRDC – The World Vegetable Center, Taiwan. pp.: 51-55.

Walsh, B. and Furlong, M.J. (2008). Imidacloprid treatment of seedling roots as a component of integrated pest management in Brassica crops. **In:** *The Management of Diamondback Moth and Other Crucifer Pests*. Proceedings of the Fifth International Workshop. Shelton *et al.* (Eds.). China Agricultural Science and Technology Press, Beijing, China. pp.: 338–344.

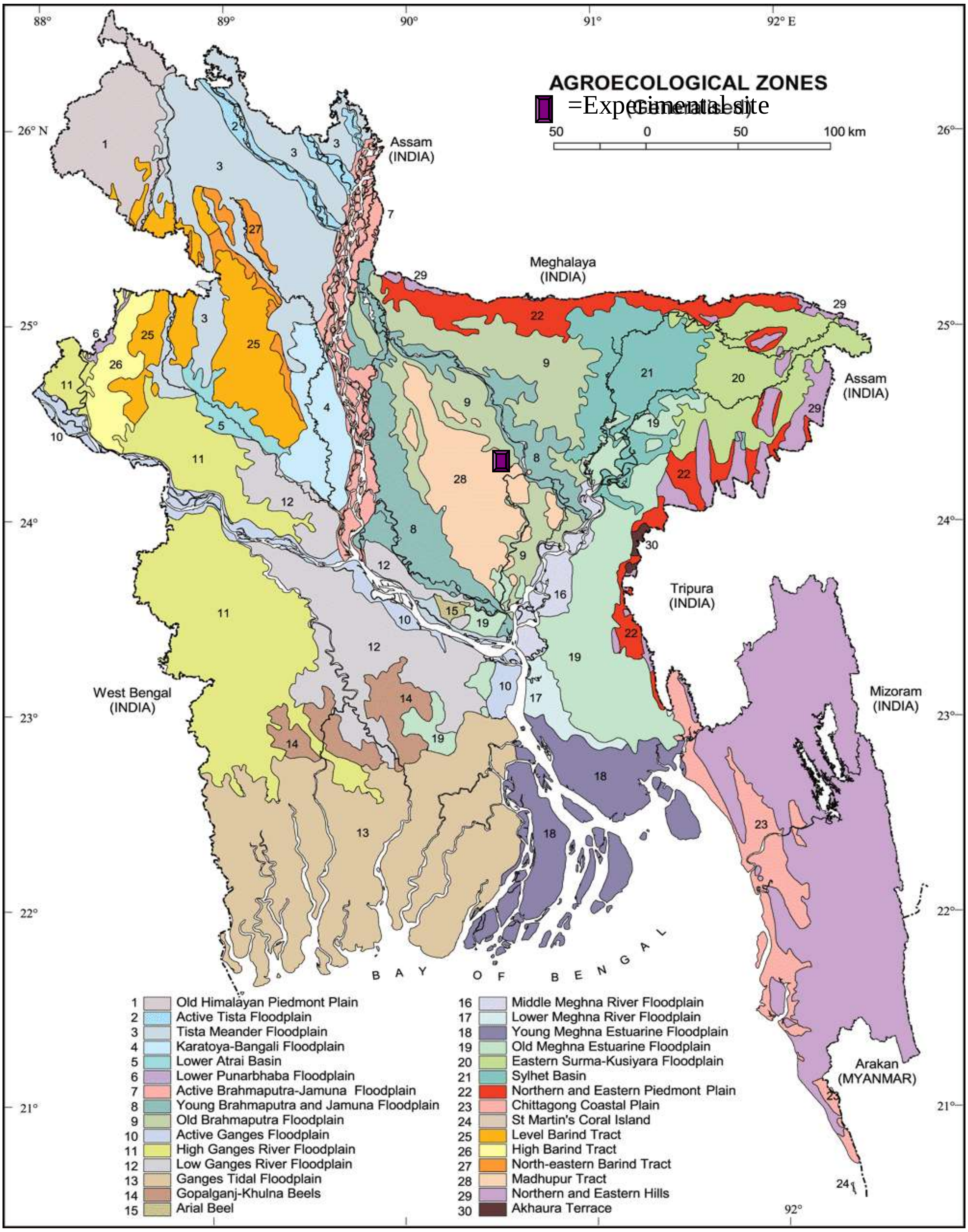
Warthen, J.D., Uebel, J., Dutky, E.C., Luspy, S.R. and Finegold, W.R. (1978). Adult house fly feeding deterrent from neem seeds. *USDA/SEA Agric. Res. Results Northeast.* **2**: 1-11.

Xia, F., Zhen-Yu, L., Huan-Yu, C., Quing-Jun, W., Ai-Dong, C., Yi-Dong, W., You-Ming, H., Yu-Rong, H., Jain-Hong, L., Sheng-Hua, X., Jin-Ming, Z., Wei, F. and Chun-Sen, M. (2011). Raising to the challenge: a national project on sustainable control of DBM in China. **In**: *The sixth International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests*. Srinivasan *et al.* (Eds.). Kamphaeng Saen Campus, Kasetsart University. Nakhon Pathom, Thailand. pp.: 15-18.

CHAPTER VII

APPENDIXES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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