ECO-FRIENDLY MANAGEMENT OF MAJOR INSECT PESTS OF CABBAGE

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SHER-E-BANGLA NAGAR, DHAKA-1207, BANGLADESH

DECEMBER, 2015

ECO-FRIENDLY MANAGEMENT OF MAJOR INSECT PESTS OF CABBAGE

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REGISTRATION NO. 14-06305

A Thesis

Submitted to the Department of Entomology, Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JULY-DECEMBER, 2015

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CERTIFICATE

This is to certify that thesis entitled **"ECO-FRIENDLY MANAGEMENT OF MAJOR INSECT PESTS OF CABBAGE"** 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 **KAZI MD. ABDULLAH-AL-MAHMUD, Registration no. 14-06305** 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.

Dated: December, 2015
Place: Dhaka, Bangladesh

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DEDICATED
TO
MY BELOVED
PARENTS

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah, Who enabled the author to pursue his education in Agriculture discipline and to complete this thesis for the degree of Master of Science (M.S.) in Entomology.

The author is proud to express his deepest gratitude, deep sense of respect and immense in debtedness to his Supervisor, Dr. Md. Razzab Ali, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his constant supervision, invaluable suggestion, scholastic guidance, continuous inspiration, constructive comments and encouragement during his research work and guidance in preparation of manuscript of the thesis.

He expresses his sincere appreciation, profound sense, respect and immense in debtedness to his respected Co-supervisor, Dr. S. M. Mizanur Rahman, Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for providing him with all possible help during the period of research work and preparation of the thesis.

The author would like to express his deepest respect and boundless gratitude to his honorable teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and research work.

Cordial thanks are also due to all field workers of SAU farm for their co-operation to complete his research work in the field.

He would like to express his last but not least profound and grateful gratitude to his beloved parents, friends and all of his relatives for their inspiration, blessing and encouragement that opened the gate of his higher studies in his life.

Dated: December, 2015 **The Author**

SAU, Dhaka

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2014 to March, 2015 to evaluate some management practices applied against major insect pestsof cabbage. The experiment was laid out in Randomized Complete Block Design replicated with three times. The management practices were six botanicals, two synthetic insecticides and one untreated control. Those were T_1 (spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval); T_2 (Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval); T_3 (Neem oil @ 3.0 ml/L of water at 7 days interval); T_4 (Garlic extract @ 3.0 ml/L of water at 7 days interval); T_5 (Thuza leaf extract @ 3.0 ml/L of water at 7 days interval); T_6 (Sevin 85 WP @ 2.0 g/L of water at 7 days interval); T_7 (Admire 200 SL @ 1.0 ml/L of water at 7 days interval); T_8 (Phytoclean @ 3.0 ml/L of water at 7 days interval) and T_9 (untreated control). Among the management practices, the lowest mean infestation of cabbage leaf by semi-looper (2.0 leaves/5 plants), cabbage caterpillar (1.95 leaves/5 plants) and diamond back moth larvae (1.5 leaves/5 plants) was found in T_7 that reduce highest leaf infestation over control (85.72%, 86.02% and 89.66%, respectively); whereas the highest infestation by semi-looper (14.01 leaves/5 plants), cabbage caterpillar (13.93 leaves/5 plants) and diamond back moth larvae (14.21 leaves/5 plants) was found in T_9. Among the botanicals the lowest infestation of cabbage leaf by semi-looper (3.76 leaves/5 plants), cabbage caterpillar (3.33 leaves/5 plants) and diamond back moth (2.12 leaves/5 plants) was found in T_3. No cutworm infestation (0.0) was recorded at 3 days after transplanting (DAT) of cabbage seedlings and the cutworm infestation was initiated at 5 DAT. The maximum infestation (2.0 to 3.0 infested seedlings/plot) was recorded at 7 DAT, and then infestation declined gradually with the increase of time. But no infestation was recorded at 13 DAT. The lowest cabbage head infestation was recorded (6.08%) in T_7, that gave the highest yield of cabbage (19.96 t/ha) followed by T_3 (19.71 t/ha). The cutworm infestation on cabbage seedlings was ranged from 47.62 to 57.14% in the field, where the highest infestation was recorded in T_5, which statistically similar with all other treatments. On the contrary, the lowest cutworm infestation (47.62%) was recorded in T_2 and T_6. Therefore, that management practice particularly for cutworm should be applied between 3 to 13 DAT of cabbage seedlings in the field. Considering the number of beneficial arthropods, the highest mean incidence of ants (4.53 ants/plot/inspection) was recorded in T_3 but the lowest in T_7 (1.73 ants/plot/inspection). The highest incidence of spiders was recorded in T_9 (4.53 spiders/plot/inspection) and the lowest in T_7 (1.47 spiders/plot/inspection). The highest incidence of lady bird beetles (4.75 beetles/plot/inspection) was recorded in T_3 and the lowest in T_7 (1.00 beetles/plot/inspection); i.e. the highest reduction of infestation was achieved by the application of Admire 200 SL treatment (T_7), but it also reduced highest level beneficial arthropod population than botanical based treatments.

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CHAPTER I

INTRODUCTION

Cabbage (*Brassica pleracea var. capitata* L.) locally known as 'Bhadha Kopi' or 'Pata Kopi' is a popular and most common winter vegetable crop in Bangladesh. It is one of the five leading vegetables in the country which belongs to the Cruciferae family. In Bangladesh, cabbage is cultivated usually in winter. The cabbage head is the edible portion of cabbage plants, which is formed by the fleshy leaves overlapping one another in compact. Cabbage is a leafy vegetable contains rich in vitamin C, vitamin E and tryptophan; an important amino acid for our body (Rashid, 1993). The consumption rate of vegetables in our country is 33Kg/head/yr, but in developed countries it is 6-7 times higher (FAO, 2015). In 2014-2015, 259 thousand metric tons (BBS, 2015) of cabbage was produced, which ranked fifth among the vegetables produced in Bangladesh. The yield of cabbage in Bangladesh is 75-100 ton/ha depending on selection of variety and season (Rashid *et al.,* 2006). These yields are low comparing with other developing countries.

There are several reasons for low production of cabbage in Bangladesh such as insect pests, diseases, qualities of variety, soil nutrients and weather factors etc. Among them, insect pests are important such as cabbage butterfly (*Pieris brassicae*), cabbage semi-looper (*Trichoplusia ni*), diamond back moth (*Plutella xylostella*), tobacco caterpillar/ prodenia caterpillar (*Spodoptera litura*), cutworm (*Agrotis ipsilon*), cabbage worm (*Hellula undalis*) etc. (Bhat *et al.,* 1994; Butani and Jotwani, 1984). Among these insect pests, *Pieris brassicae* is the most destructive pest, which destroys leaves of cabbage by voraciously feeding (Guan-soon and Yuan-Ba, 1990). They deposited eggs in clusters of 20 to 100 on the leaves of the host plants (Hashmi, 1994; Subramanian, 1987). The large caterpillars are extremely voracious and perforate the foliage and made more damage to the leaves, often leaving only the large veins (Hashmi, 1994). *Spodoptera litura* Fab. (tobacco caterpillar/ prodenia caterpillar) is also the most destructive pest, which destroys the leaves of cabbage by making holes in the cabbage head and greatly reduces the market value (Butani and Jotwani, 1984). With the other polyphagous insects such as *Plutella xylostella, Artogeia rape crucevora* become an important pest of vegetable in southern Taiwan (Lee, 1986). Among these insect pests, tobacco caterpillar can cause reduce more than 50% yield in some cabbage genotypes (Bhat *et al.*, 1994). In Bangladesh, Ahmed (2008) reported that cabbage caterpillar cause damage 3.99% to 13.44% on leaves and 23.33% to 58.33% on plants depending of the varieties. Damage caused by the diamondback moth (*Plutella xylostella* L.) on head cabbage was assessed and yield losses up to 12 and 20.7 tons/ha in the first season and 27 and 48.7 tons/ha, respectively in the second season (Bhatia, 1994). Yield loss (up to 30%) due to competition may be tolerable as an alternative to severe pest damage, in situations where infestation levels are high (Andrea, 2006). These insect pests cause more serious damage on cabbage in summer season.

There are several methods to combat insect pests of cabbage comprising cultural, mechanical, chemical, biological, botanicals and host plant resistance. Traditionally, the farmers of Bangladesh use chemical insecticides indiscriminately to combat these pests of cabbage without considering doses and negative impact of insecticides on non-target organisms and economic injury level of the pests. These chemical control of the insect pests of cabbage is not only expensive but also left over residues on the sprayed surface of the crops and/or in the soil, destroying natural enemies have become a matter of great concern of human health and environmental pollution (Rikabdar, 2000). Considering the hazards 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).

Among the botanicals viz. neem oil, neem leaf extract, neem seed kernel extract, garlic extract etc. are widely used for controlling the insect pests of cabbage. These are safe for environment, human health & beneficial insects and also cheap. But these botanicals are used in vegetable cultivation without the optimum botanicals as well as their doses. In such a situation it was strongly felt to assess their present relative status for botanicals against major insect pests in comparison with traditional chemical insecticide(s) under natural field conditions of the cabbage field.

Objectives

- To assess the level of infestation caused by major insect pests of cabbage.
- To find out the efficacy of botanicals as compared with chemical insecticides in controlling major insect pests of cabbage.
- To find out the impact of management practices on the beneficial arthropods in the field of cabbage.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests, Lepidopteran insects like cabbage semi-looper, diamond back moth, tobacco caterpillar, cut worm are the major pests of cabbage. Botanicals like neem oil, neem leaf extract, neem seed karnel extract, garlic extract, thuja leaf extract etc. are very limited. An attempt has been taken in this chapter to review the pertinent literatures 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. It is found throughout the southern palaearctic ecozone, all of North America, part of Africa and most of the Oriental and Indo-Australian region.

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Trichoplusia*

Species: *Trichoplusia ni*

B. Origin and distribution

The cabbage semi-looper (*Trichoplusia ni*) is native to the United States and feeds on many vegetable plants including all members of the cabbage family (Brassicaceae). This insect cannot over winter in the Midwest. Adult cabbage semi-looper moths annually migrate to the

North United States and Canada from early July to late August, depending on the weather and airflow patterns. There can be 1 to 3 generations during on the growing season in the northern states depending on arrival time and late summer temperatures (Hutchison *et al.,* 1999).

The cabbage semi-looper (*Trichoplusia ni*) is found throughout North America. It is a major pest of crucifer crops including cabbage, broccoli and cauliflower may also be found feeding on the agricultural crops such as beets, celery, lettuce, peas, spinach, tomatoes and flowers including camations and nasturtiums. Cabbage semi-looper cannot survive Canadian winters. Every year, they migrate from the Southern US and arrive here in July and August depending on temperatures and wind patterns. Although they normally produce two to three overlapping generations in a growing season, the actual number depends on when they arrive in Canada. And it takes approximately one month of worm weather for the cabbage semi-looper to complete its life cycle and produce the next generation of offspring (Dedes, 2003).

Cabbage semi-looper is one of the most important annual pests for Florida cabbage growers. It is less of a problem in southern Florida, where it is considered a minor pest. In that part of the state, pheromone trap data show that adult populations tend to be highest during the late spring and summer months and in some years in the late fall (Nuessly and Hentz, 1999). Cabbage semi-looper does not enter diapauses and cannot survive prolonged cold weather. The insect remains active and reproduces throughout the winter months only in the southern part of Florida (South of Orlando) (Capinera, 1999a). In central Florida, cabbage semi-looper populations peak during early fall and again during late spring (Leibee, 1996). In general, cabbage semi-looper is more of a problem on Florida cabbage during the fall than during the winter or spring months.

The cabbage semi-looper, *Trichoplusia ni,* Hub., (Lepidoptera: Noctuidae) is a cosmopolitian insect pest that causes damage in more than 160 species of plants (Sutherland and Greene, 1984), and has become a chronic pest of Canadian greenhouse vegetable crops.

C. Nature of damage

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 (Capinera, 1999a). 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. Origin and distribution

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

C. Nature of damage

From May to September, *Plutella xylostella* (L.) (diamon dback moth) poses the greatest threat to production (Walsh and Furlong, 2008).

The larval stage of the diamond back 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 comparatively difficult to control in New Yourk (Moyer, 1999). It usually devours only a small portion of leaf. Larvae work on the underside and eat many small holes. Frequently they live only the upper epidermis, which has an isinglass-like effect (Janmaat, 2003).

2.1.3. Tobacco caterpillar / cabbage caterpillar

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

A. Nomenclature

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Spodoptera*

Species: *Spodoptera litura*

B. Origin and distribution

The tobacco caterpillar is found throughout the tropical and subtropical parts of the world. It is wide spread in India (Atwal, 1986). This pest has been reported from India, Pakistan, Ceylon, Burma, Thailand, Malaysia, Cambodia, Laos, Vietnam, Sabah, Indonesia, the Philippines, Taiwan, Queensland, New South Wales, New Guinea, Papua, West Iran, Solomon Islands, Gilbert Islands, New Caledonia, Fiji, Samoa, Tonga, Society Islands, Gilbert Islands and Micronesia (Grist and Lever, 1989). The two old world cotton leaf worm species *Spodoptera litura* and *Spodoptera littoralis*, are allopatric, their ranges covering Asia and Africa, respectively (Hill, 1983).

C. 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. 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. Cutworm

Cutworms are the larvae of several species of night-flying moths (Order- Lepidoptera, Family- Noctuidae).

A. Nomenclature

Phylum: Arthropod

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Agrotis*

Species: *Agrotis ipsilon*

B. Origin and distribution

The origin of cutworm is uncertain, though it is now found in many regions of the world, being absent principally from some tropical regions and cold areas. Long distance dispersal of adults has long been suspected in Europe, China and North America. The basic pattern is to move north in the spring, and south in the autumn (Capinera, 2015).

D. Nature of damage

Cutworms are common pest of many vegetable crops including carrots, celery, lettuce, onion, tomato, pepper, eggplant, cole crops, rutabaga, beans, cucurbit crops, sweet corn and others. Most species of cutworms are solitary feeders found in the soil; however some species occasionally attack the foliage and/or fruit of some vegetable crops (Bentley *et al.* 1996).

All instars of *A. ipsilon* feed on the leaves of corn seedlings, but the most serious damage results from leaf and stem cutting by late instars (Clement and McCartney 1982).

Young larvae feed on the foliage or small roots of weeds or crops until they reach about 1/2 inch in length. At this stage, they can begin feeding on seedling stems, either cutting through them or burrowing into them. Corn, peppers, tomatoes, beans, and the crucifer family are common hosts, but they will attack many kinds of herbaceous plants (Hahn and Burkness, 2015).

Cutworms feed at night causing serious damage to stems and foliage of young plants. Stalks of plants may be cut. The variegated cutworm climbs the plants to feed on foliage and the bud (Benssin, 2011).

2.2. Management of insect pests of cabbage

2.2.1. Cultural control

Cultural controls that can reduce pest populations consist of a variety of management practices such as crop rotation, cultivation, weed management, water management, and proper fertilizer use. Using fallow periods and crop rotation can interrupt the life cycles of pests whenever possible. Always destroy plant debris that can harbor pests and control weeds because they attract insects that may feed on vegetables.

Intercropping is the practice of' increasing crop diversity' by growing more than one plant species in a field to overcome insect pest outbreak problems associated with monocultures.

Dempster (1969) studied the effects of weed control in brussels sprouts on *P. rapae* and found that weeds provide a habitat for predators of the caterpillar. However, yield reduction due to weed competition outweighed the advantageous effects of insect control obtained in the weedy plots. Buranday and Rarest (1975) compared the abundance of adults and oviposition of *P. xylostella* in a cabbage field and in a field with cabbage and tomato intercropped. Both factors were lower in the intercropped field and it was suggested that volatile compounds emitted by the tomatoes repelled the adult moths. The recommended planting pattern is two cabbage rows between two rows of tomato. The pest control benefits' with respect to reduction in larval feeding damage were not assessed as plots were sprayed regularly with *B. thuringiensis*, masking 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 residue 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 compost. Tilling land in the fall; this helps destroy or expose overwintering larvae or pupae (Hahn and Burkness, 2015).

2.2.2. Mechanical control

Mechanical control is the use of physical means to reduce the number of insects or insect damage or to exclude pests from the crop field. Mechanical methods include the use of barriers, covers, high pressure water sprays, and hand picking of pests. Barriers come in many shapes and sizes. They prevent the movement of pests onto the plants. Cardboard or plastic cylinders around the base of transplants are an example of a barrier that discourages cutworms and other soil-inhabiting pests from attacking transplants. Cloth or plastic row covers can serve as a cover to keep out pests in a crop field. Screening may increase the temperature of a planting bed, so additional benefits of temperature management may be achieved. Screening is useful for young plants and seedlings that are the most susceptible to pest attack. High pressure water sprays are also a mechanical control method. Sprays are most effective against small, soft-bodied pests like aphids. High pressure water sprays may help remove webbing, dissolve droppings, and quickly reduce the number of pests.

Talekar *et al.,* (1986) found that sprinkler irrigation applied to cabbage for five minutes at dusk throughout the life of the crop physically disrupted diamond back moths flying activities 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

In controlling moths still mostly used organic phosphorus esters. In this group classified active compounds are chlorine pirifos-methil, phenitrotion and acephate (Pelosini, 1999). 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 50 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) adviced 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 diamond back moth and other lepidopteran larvae (Edralin, *et al.,* 2011).

Flubendiamide (Takumi® 20 WDG) is a novel insecticide, representing the IRAC (Insecticide Resistance Action Committee). Mode of Action Group 28 (ryanodine receptor modulator) within the IRAC 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. Botanical control

Botanical pesticides 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). Ahmed (2008) enlisted 2121 plant species, possessing pest control properties which include neem, sweetflag, cashew, custard apple, sugar apple, derris, lantana, tayanin, indian privet, agave, crow plant etc. Among these, 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.

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

Botanical pesticides are also special because they can be produced easily by farmers for sustainable agriculture and small industries (Roy *et al*. 2005).

Many plant species are being investigated for their natural products to be used for *P. xylostella* control. For instancet, *Azadirachta indica* A. Juss. (Meliaceae), *Melia azedarachta* 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) and found 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 (Kraus *et al.* 1985 and Bilton *et al.* 1985) (Figure 2).

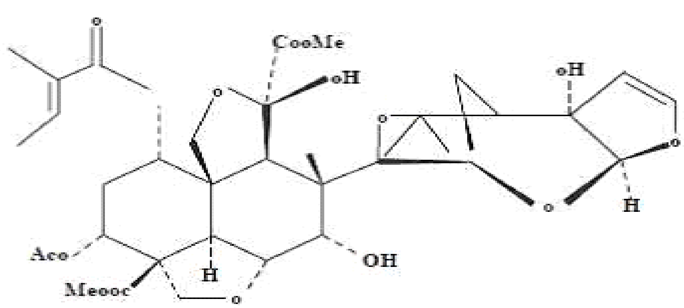

Figure 1. Structural formula of azadirachtin (Butterworth and Morgan,1968)

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 affects insects in various ways.

Crude neem extracts deters settling and reduces feeding in *M. persicae* (Griffiths *et al*. 1989). The females of some lepidopterous insects are repelled by neem treated plant products or other substrates and not laid eggs on them under laboratory conditions.

The study 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 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 part 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 (Rajasekaran and Kumaraswami, 1985; Prakash *et al*., 1987 and 1990).

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 *Earies vittella* (Sojitra and Patel, 1992). Extracts of neem and bakain caused maximum adverse effects on fecundity and hatching.

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

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

Sardhana and Krishna Kumar (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 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 treated with aromatized powder, significant differences were also found between treatments and control. Germination of cowpea seeds 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

The present study regarding ecofriendly management of some insect pests of cabbage particularly cabbage semi-looper (*Trichoplusia ni*), diamond back moth (*Plutella xylostella*), tobacco caterpillar/prodenia caterpillar (*Spodoptera litura*) and cutworm (*Agrotis ipsilon*) has been conducted during October 2014 to March 2015 in the experimental fields of Sher-e-Bangla Agricultural University, Dhaka. Required materials and methodology are described below under the following sub-headings.

3.1. Location

The experiments were conducted in the experimental farm of SAU, Dhaka situated at latitude 23.46 N and longitude 90.23 E with an elevation of 8.45 meter above 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 of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.*, 1991).

3.4. Land preparation

The soil was well prepared and good tilth ensured for commercial crop production. The target land was divided into 27 equal plots (2.5 m×1.5 m) with plot to plot distance of 0.50 m and block to block distance 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 experiments were followed immediately after land preparation.

3.5. Manure and fertilizer

Recommended fertilizers were applied at the rate of 370 kg urea, 250 kg triple super phosphate (TSP) and 250 kg muriate of potash (MP) per hectare used as source of nitrogen, phosphorus and potassium, respectively. Moreover, well-decomposed cow dung (CD) was also applied at the rate of 5 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 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 9 unit plots. The size of the unit plot was 2.5 m×1.5 m. The block to block and plot-plot distance was .75 m and 0.5 m, respectively.

3.7. Collection of seed, seedling raising

The seeds of selected cabbage variety Atlas-70 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. Seeds were then sown on the 28th October, 2014 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 from the nursery bed was transplanted on November 28th, 2014 in the main field. Each plot contained 10 seedlings of cabbage with 2 rows followed by 60 cm x 40 cm (row to row and plant to plant distance, respectively).

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. were done as and when necessary to cultivate cabbage.

3.10. Treatments

The experiment was evaluated to determine the efficacy of different botanical products and two chemical insecticides to compare with each other in considering the less hazardous but effective control measures against major insect pests. The botanical based treatments and chemical insecticides as well as their doses were used in the study are given bellow:-

T_1= Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval

T_2= Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval

T_3= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval

T_4= Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval

T_5= Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval

T_6= Spraying of Sevin 85 WP @ 2.00 g/L of water at 7 days interval

T_7= Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval

T_8= Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval

T_9= Untreated control.

3.11. Treatment preparation

3.11.1. Neem leaf extract

The fresh neem leaves were collected from the neem tree from the Horticulture Garden of SAU. Leaves were sun dried 2 to 3 days and crashed using electric grinder, of which 250 gm dried neem leaf powder was taken into a 500 ml beaker. 250 ml water was taken into the beaker and then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of neem leaves. The aqueous extract then filtered using Whatmen no. 1 paper filter and preserved the aqueous extract as flock solution in the refrigerator at 4^0c for experimental use.

3.11.2. Neem seed kernel

The mature and dried neem seeds were collected from the neem tree found in the Horticulture Garden of SAU. Then seeds were roasted at 60ºC to 80ºC for 1 to 2 days by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of this powder was taken into a beaker and 250 ml water was added into it. Then the beaker was shaken by electric stirrer for 30 minutes thoroughly the mixture. The aqueous mixture then filtered using Whatmen no. 1 paper filter and preserved the aqueous extracts in the refrigerator at 4^0c for future experimental use.

3.11.3. Neem oil

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazar, Dhaka. All sprays were made according to the methods described earlier. For each neem oil application, 15 ml neem oil (@ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture within the spray machine (knapsack sprayer) was shacked well and sprayed on the upper and lower surface of the plants until the drop run off from the plant. Three liters spray material was required to spray in three plot of each replication.

3.11.4. Garlic extract

Fresh garlic bulbs were collected from the local market and chopped the bulbs in small size by sharp knife. Then 250 gm chopped garlic bulbs were taken into electric blender for blending. Then the blended garlic was taken into the beaker and 250 ml water was added with the garlic extract. Then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of garlic. The aqueous extract then filtered using Whatmen no.1 paper filter and preserved the aqueous extracts of garlic in the refrigerator at 4^0c for experimental use.

3.11.5. Thuza leaf extract

The fresh thuza leaves were collected from the thuza plant found in the Horticulture Garden of SAU. Leaves were sun dried for 2-3days and crashed using electric grinder, of which 250 gm dried thuza leaf powder was taken into a 500 ml beaker. 250 ml water was taken into the beaker and then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of thuza leaves. The aqueous extract then filtered using Whatmen no.1 paper filter and preserved the aqueous extracts of thuza leaf in the refrigerator at 4^0c for experimental use.

3.12. Treatments application

T_1: Neem leaf extract @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem leaf extract was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_2: Neem seed kernel extract @ 3.0 ml/L of water was sprayed at 7 days. Under this treatment, neem seed kernel extract was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_3: Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 15 ml /5L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_4: Garlic extract @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, garlic extract was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_5: Thuza leaf extract @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, thuza leaf extract was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_6: Sevin 85WP @ 2.00 gm/L of water was sprayed at 7 days interval. For this treatment 10.0 gm of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_7: Admire 200 SL @ 1.0 ml/L of water was sprayed at 7 days interval. For this treatment 5.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_8: Phytoclean @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, Phytoclean was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_9: Untreated control treatment. There was no any control measure applied in cabbage field.

3.13. Data collection

For data collection five plants per plot were randomly selected and tagged. Data collection was started at vegetative stage at 20 DAT to cabbage head harvest. The data were recorded on number of cabbage semi-looper, diamondback moth, cabbage butterfly, infested leaves by the insects, beneficial insects. The following parameters were considered during data collection.

3.13.1. Counting of insect pests of cabbage and infested leaves

Data were collected on the number of cabbage semi-looper, cabbage butterfly and diamond back moth and number of infested leaves caused by cabbage semi-looper, cabbage butterfly and diamond back moth from randomly previously selected 5 tagged plants per plot and counted separately for each treatment.

3.13.2. Number of infested plants by cutworm

Data were collected at morning on the number of infested plants by cutworms per plot and counted separately for each treatment.

3.13.3. Beneficial arthropod

Data were collected on the number of beneficial arthropods such as ant, spider etc. per plot and counted separately for each treatment through visual observation in the field.

3.13.4. Number, weight of healthy and infested cabbage head

Data were collected on the number of healthy and infested cabbage head per plot which was harvested at fully mature head (upto 15th February) stage of cabbage and weighted separately for each treatment.

3.14. Calculation

3.14.1. Percent of infested leaves

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

$$\text{Infested leaves (\%)} = \frac{\text{Number of infested cabbage leaves}}{\text{Total number of cabbage leaves}} \times 100$$

3.14.2. Percent Cutworm infested plant

Number of infested plant was counted from total plants per plot and percent plant infestation by Cutworm was calculated as follows:

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

3.14.3. Percent head infestation

Infested cabbage heads were counted from total harvested head and the percent infestation was calculated by using the following formula:

$$\text{Head infestation (\%) (number)} = \frac{\text{Number of the infested head}}{\text{Total number of head}} \times 100$$

3.14.4. Percent cabbage head infestation

Weight of the infested cabbage head was recorded from total weight of the harvested cabbage head and the percent cabbage head infestation by weight was calculated using the following formula:

$$\text{Head infestation (\%) (weight)} = \frac{\text{Weight of the infested head}}{\text{Total weight of head}} \times 100$$

3.14.5. Reduction head infestation over control

The number and weight of infested cabbage head, total cabbage head and untreated control plot were recorded for each treated plot and the reduction of infestation in number and weight basis were calculated using the following formulae:

$$\text{Head infestation (\%) reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = Mean value of the treated plot

X_2 = Mean value of the untreated plot

3.14.6. Percent yield loss

The weight of infested cabbage head was recorded from the total weight of the harvested cabbage head for each plot and the percent yield loss was calculated considering the following formula:

$$\text{Yield loss (\%)} = \frac{\text{Avg. wt. of healthy head} - \text{Avg. wt. of whole plot}}{\text{Average weight of healthy head per plot}} \times 100$$

3.14.7. Statistical analysis

Data were statistically analyzed by randomized complete block design through MSTAT-C software and mean were separated using Duncan's Multiple Range Tests to determine the levels of significant differences among different treatments.

Plate 1: Maintenance of seedbed of cabbage

Plate 2: Transplanted cabbage in main field

Plate 3: Treatment application in cabbage field

Plate 4: Infested cabbage head

Plate 5: Bored cabbage head by Cabbage semi-looper

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate the effectiveness of botanicals for eco-friendly management of some insect pests of cabbage in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2014 to March, 2015. The analysis of variance (ANOVA) of the data on cabbage leaf and head infestation and different yield contributing characters of cabbage are given in Appendix. The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.1. Leaf infestation of cabbage

4.1.1. Cabbage semi-looper

The significant variations ($p>0.05$) were observed among different treatments (Table 1) for different management practices in terms of leaf infestation by cabbage semi-looper at different days after transplanting (DAT). At 20 DAT, the highest leaf infestation was recorded in T_9 (11.93 leaves/5 plants), and statistically similar with T_8 (11.60 leaves/5 plants) and T_4 (10.87 leaves/5 plants) but different from all other treatments. On the other hand, the lowest leaf infestation was recorded in T_7 (3.87 leaves/5 plants), and statistically different from others treatments. More or less similar trends of leaf infestation by number were also recorded at 30 DAT, 40 DAT, 50 DAT and 60 DAT (Table 1).

In case of mean infestation, the highest number of leaf infestation was recorded in T_9 (14.01 leaves/5 plants), which significantly different from all other treatments. On the other hand, the lowest infestation was recorded in T_7 (2.00 leaves/5 plants), which was significantly similar with T_3 (3.76 leaves/5 plants) followed by T_6 (5.23 leaves/5 plants) (Table 1). Considering the percent reduction of leaf infestation, the highest 85.72% reduction over control was achieved in T_7 followed by T_3 (73.16%) and T_6 (62.69%). Nevertheless, the minimum reduction of infestation over control was found in T_8 (16.99%) followed by T_4 (27.27%).

Table 1: Infestation of cabbage caused by semi-looper at different DAT of cabbage

Treatments	Number of leaf infestation per five plants						
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Mean	Reduction over control (%)
T_1	9.00 b	8.47 c	8.13 d	7.73 d	7.47 d	8.16 c	41.76
T_2	10.40 ab	10.07 bc	9.73 c	9.27 cd	9.13 cd	9.72 bc	30.62
T_3	4.87 cd	4.07 d	3.67 f	3.27 e	2.93 e	3.76 de	73.16
T_4	10.87 a	10.47 b	10.07 c	9.87 c	9.67 c	10.19 bc	27.27
T_5	10.73 ab	10.13 bc	9.80 c	9.53 c	9.07 cd	9.85 bc	29.67
T_6	6.13 c	5.40 d	5.40 e	4.80 e	4.40 e	5.27 d	62.69
T_7	3.87 d	2.00 e	1.80 g	1.33 f	1.00 f	2.00 e	85.72
T_8	11.60 a	11.53 b	11.80 b	11.67 b	11.53 b	11.63 b	16.99
T_9	11.93 a	13.80 a	14.33 a	14.87 a	15.13 a	14.01 a	-
$LSD_{(0.05)}$	1.66	1.59	1.58	1.64	1.59	1.91	-
CV(%)	13.23	13.20	13.37	14.32	14.29	13.33	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it is revealed that among the different treatments, T_7, Admire 200 SL @ 1.0 ml/L of water at 7 days in reducing leaf infestation over control (85.72%) caused by cabbage semi-looper. Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best treatment in terms of reducing the leaf infestation over control (73.16%). As a result, the order of ranks of efficacy of the treatments applied against cabbage semi-looper including untreated control in terms of reducing leaf infestation was $T_7 > T_3 > T_6 > T_1 > T_2 > T_5 > T_4 > T_8 > T_9$.

4.1.2. Cabbage caterpillar

The significant variations were observed among different treatments of leaf infestation by cabbage caterpillar at different DAT (Table 2). At 20 DAT, the highest leaf infestation was recorded in T_9 (12.33 leaves/5 plants), which statistically similar with T_8 (11.40 leaves/5 plants) and T_4 (10.80 leaves/5 plants) but different from all other treatments. Contrary, the lowest leaf infestation was recorded in T_7 (3.53 leaves/5 plants) which statistically similar with T_6 (4.00 leaves/5 plants) and T_3 (4.60 leaves/5 plants). More or less similar trends of leaf infestation by number were also recorded at 30 DAT, 40 DAT, 50 DAT and 60 DAT (Table 2).

The highest mean number of leaf infestation was recorded in T_9 (13.93 leaves/5 plants) comprised of untreated control, which significantly different from all other treatments. Nonetheless, the lowest mean leaf infestation was recorded in T_7 (1.95 leaves/5 plants), which significantly similar with T_6 (2.45 leaves/5 plants), T_3 (3.33 leaves/5 plants) and followed by T_1 (5.92 leaves/5 plants) (Table 2). Considering the percent reduction of leaf infestation, the highest 86.02% reduction over control was achieved in T_7 followed by T_6 (82.39%) and T_3 (76.07%). On the other hand, the minimum reduction of leaf infestation over control was found in T_8 (20.17%) followed by T_2 (26.78%).

From these above findings it is revealed that among the different treatments, T_7, Admire 200 SL @ 1.0 ml/L of water at 7 days in reducing leaf infestation over control (86.02%). Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best treatment in terms of reducing the leaf infestation over control (76.07%). As a result, the order of rank of efficacy of the treatments applied against cabbage caterpillar including untreated control in terms of reducing leaf infestation was T_7> T_6> T_3> T_1> T_5> T_4> T_2> T_8> T_9.

Table 2:- Infestation of cabbage caused by cabbage caterpillar at different DAT

Treatments	Number of leaf infestation per five plants						
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Mean	Reduction over control (%)
T_1	6.60 c	6.07 d	6.00 d	5.60 d	5.33 d	5.92 d	57.50
T_2	10.80 ab	10.40 bc	10.27 bc	9.93 bc	9.60 bc	10.20 bc	26.78
T_3	4.60 d	3.73 e	3.40 e	2.80 e	2.13 e	3.33 e	76.07
T_4	10.00 b	9.40 c	9.40 bc	8.93 c	8.47 c	9.24 c	33.67
T_5	10.07 b	9.33 c	9.13 c	8.73 c	8.20 c	9.09 c	34.72
T_6	4.00 d	2.73 e	2.33 e	1.67 e	1.53 e	2.45 e	82.39
T_7	3.53 d	2.33 e	1.87 e	1.20 e	0.80 e	1.95 e	86.02
T_8	11.40 ab	11.27 b	11.13 b	10.87 b	10.93 b	11.12 b	20.17
T_9	12.33 a	13.67 a	14.07 a	14.60 a	15.00 a	13.93 a	-
$LSD_{(0.05)}$	1.53	1.71	1.78	1.67	1.85	1.66	-
CV(%)	11.01	12.91	13.71	13.53	15.53	12.80	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

4.1.3. Diamond back moth larvae

The significant variations were observed among different treatments at different days after transplanting (DAT). At 20 DAT, the highest leaf infestation caused by diamond back moth larvae was recorded in T_9 (13.07 leaves/5 plants), which statistically different from all other treatments. On the other hand, the lowest leaf infestation was recorded in T_7 (3.13 leaves/5 plants), which statistically similar with T_6 (3.73 leaves/5 plants) and T_3 (3.73 leaves/5 plants). More or less similar trends of leaf infestation by number were also recorded at 30 DAT, 40 DAT, 50 DAT and 60 DAT (Table 3).

The highest number of mean leaf infestation was recorded in T_9 (14.21 leaves/5 plants) comprised of untreated control, which significantly different from all other treatments. On the other hand, the lowest mean leaf infestation was recorded in T_7 (1.47 leaves/5 plants), which significantly different with T_3 (2.12 leaves/5 plants) and T_6 (2.83 leaves/5 plants) and followed by T_1 (3.83 leaves/5 plants) (Table 3). Considering the percent reduction of leaf infestation, among different management practices, the highest (89.66%) reduction was achieved over control in T_7 followed by T_3 (85.09%) and T_6 (80.12%). Nonetheless, the minimum reduction of leaf infestation over control was found in T_8 (23.47%) followed by T_4 (50.48%).

Table 3:- Infestation of cabbage caused by diamond back moth larvae at different DAT

Treatments	Number of leaf infestation per five plants						
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Mean	Reduction over control (%)
T_1	4.27 f	3.80 e	3.87 e	3.73 e	3.47 e	3.83 f	73.08
T_2	4.87 e	4.13 e	4.47 e	3.87 e	4.20 e	4.31 e	69.71
T_3	3.73 g	2.73 f	1.93 g	1.33 g	0.87fg	2.12 h	85.09
T_4	7.47 c	7.00 c	6.93 c	7.00 c	6.80 c	7.04 c	50.48
T_5	6.93 d	5.73 d	6.00 d	6.20 d	5.67 d	6.11 d	57.05
T_6	3.73 g	3.73 e	2.87 f	2.13 f	1.67 f	2.83 g	80.12
T_7	3.13 h	1.35 g	1.60 g	0.87 g	0.40 g	1.47 i	89.66
T_8	10.13 b	10.67 b	11.20 b	11.20 b	11.20 b	10.88 b	23.47
T_9	13.07 a	14.13 a	14.27 a	14.60 a	15.00 a	14.21 a	-
$LSD_{(0.05)}$	0.40	0.75	0.77	0.78	0.82	0.44	-
CV(%)	3.60	7.28	7.54	8.01	8.68	4.31	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it revealed that among the different treatments, T_7, Admire 200 SL @ 1.0 ml/L of water reducing leaf infestation over control (89.66%) caused by diamond back moth larvae. Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best treatment of reducing the leaf infestation over control (85.09%). As a result, the order of rank of efficacy of the treatments applied against diamond back moth larvae including untreated control in terms of reducing leaf infestation was $T_7 > T_3 > T_6 > T_1 > T_2 > T_5 > T_4 > T_8 > T_9$.

4.1.4. Cutworm infestation

The level of infestation of cabbage seedlings caused by cutworm at different days after transplanting (DAT) was evaluated in this study. From the study it was observed that there was a numerical variation found at different DAT in terms of number of cutworm infested cabbage seedlings per plot, but there was no statistical variation found in number of infested seedlings per plot at different DAT of cabbage seedlings (Figure 2). At the initial stage of seedling transplanting (3 DAT), no cutworm infestation (0.0) was recorded in the field, but the number of cutworm infested cabbage seedlings was increased with increase of time. And it was reached the highest at 7 DAT depending on the treatments (2.0 to 3.0 infested seedlings/plot). Afterward the cutworm infestation was decreased gradually and declined and no infestation (0.0) occurred at 13 DAT.

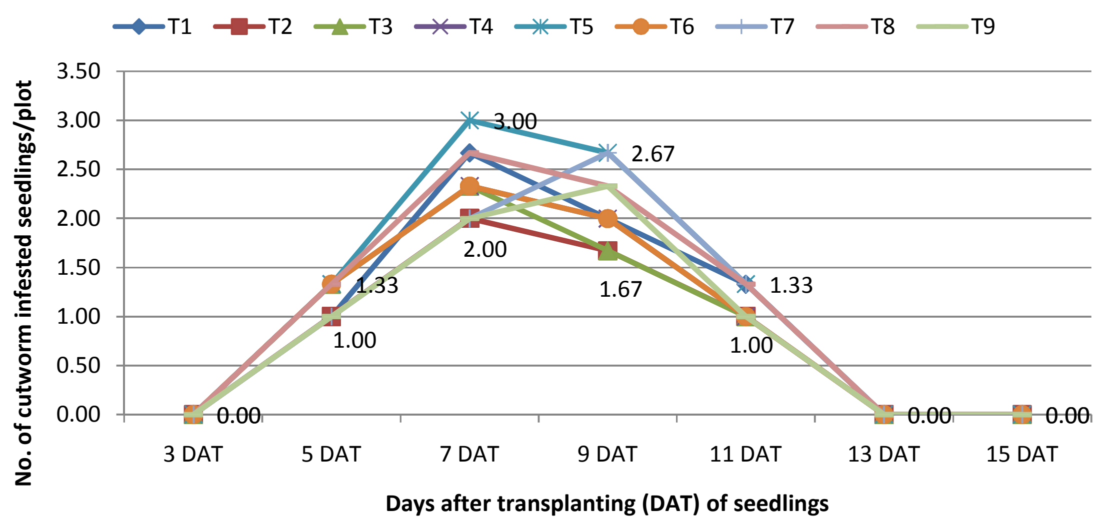

Figure 2. Cutworm infested seedlings at different DAT of cabbage in the field

The total number of cutworm infested seedlings per plot was ranged from 6.67 to 8.0 infested seedlings/plot. The highest total number of cutworm infested seedlings per plot was recorded in T_5 (8.0), which provided 57.14% seedling infestation. On the other hand, the lowest total number of cutworm infested seedlings per plot was recorded in T_2 and T_6 (6.67 infested seedlings/plot), which was 47.62% seedling infestation. But it was observed that the numerical variation found among the treatments of cutworm infested seedlings per plot (Figure 3).

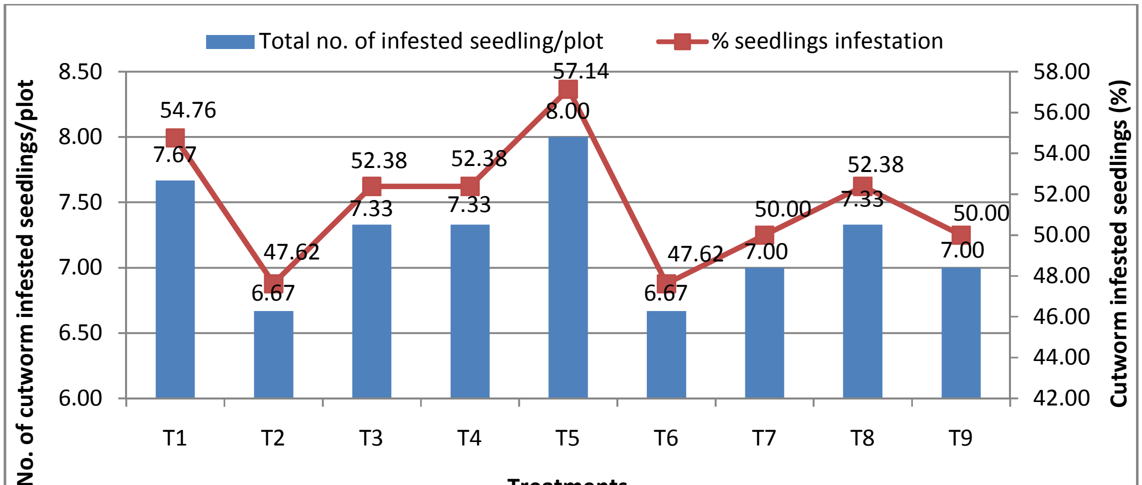

Figure 3. Cutworm infestated seedlings of cabbage due to application of different treatments

From the above findings it was revealed that the cutworm infested seedlings ranged from 47.62 to 57.14%, where the highest infestation was recorded in T_5, which statistically similar with all other treatments. On the other hand, the lowest cutworm infestation (47.62%) was recorded in T_2 and T_6. It was also observed that the no cutworm infestation (0.0) was recorded at 3 DAT. But the cutworm infestation was initiated in the cabbage field at 5 DAT and the maximum infestation (2.0 to 3.0 infested seedling/plot) was recorded at 7 DAT, whereas the infestation was declined gradually with the increase of time and no infestation was recorded at 13 DAT. Therefore, it is concluded that management practice particularly for cutworm should be applied between 3 to 13 DAT of cabbage seedlings in the field.

4.2. Incidence of insect pest population

4.2.1. Cabbage semi-looper

Significant variations were observed among different treatments of number of cabbage semi-looper at different days after transplanting (DAT). At 20 DAT, the highest number of cabbage semi-looper per five plants was recorded in T_9 (13.00 larvae/5 plants) which statistically different with all other treatments and followed by T_8 (10.67 larvae/5 plants), and similar to T_5 (10.67 larvae/5 plants), T_2 (10.67 larvae/5 plants), T_1 (10.33 larvae/5 plants), and T_4 (10.00 larvae/5 plants). Contrary, the lowest number of cabbage semi-looper per five plants was recorded in T_7 (7.67 larvae/5 plants) which statistically similar with T_3 (8.00 larvae/5 plants) (Table 4). More or less similar trends of number of cabbage semi-looper per five plants were also recorded at 30 DAT, 40 DAT, 50 DAT and 60 DAT.

The highest number of cabbage semi-looper per five plants was recorded in T_9 (13.73 larvae/5 plants) which significantly different from all other treatments. Nonetheless, the lowest mean number of cabbage semi-looper per five plants was recorded in T_7 (4.80 larvae/5 plants), which significantly similar with T_3 (5.00 larvae/5 plants) followed by T_6 (5.73 larvae/5 plants) (Table 4). Considering the different management practices, the highest 65.04%

reduction over control was in T_7 followed by T_3 (63.58%) and T_6 (58.24%). On the other hand, the minimum reduction of number of cabbage semi-looper per five plants over control was found in T_8 (26.66%) followed by T_4 (52.42%).

Table 4:- Effect of treatments on incidence of cabbage semi-looper per five plants

Treatments	Incidence of cabbage semi-looper per five plants						
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**	**Mean**	**Reduction over control (%)**
T_1	10.33 b	6.67 c	3.33 d	2.67 de	1.33 e	6.33 c	53.87
T_2	10.67 b	7.67 c	5.67 c	3.67 bcd	1.67 de	6.33 c	53.87
T_3	8.00 c	3.67 d	2.67 d	1.67 ef	1.00 e	5.00 de	63.58
T_4	10.00 b	7.67 c	5.67 c	4.33 bc	3.67 c	6.53 c	52.42
T_5	10.67 b	7.33 c	5.33 c	3.67 cd	2.33 d	5.93 c	56.79
T_6	9.00 bc	6.33 c	5.00 c	5.00 b	2.33 d	5.73 cd	58.24
T_7	7.67 c	3.33 d	2.67 d	1.33 f	1.00 e	4.80 e	65.04
T_8	10.67 b	12.67 b	11.33 b	9.67 a	7.67 b	10.07 b	26.66
T_9	13.00 a	14.67 a	14.67 a	10.33 a	8.67 a	13.73 a	-
$LSD_{(0.05)}$	1.68	1.72	1.17	1.25	0.83	0.88	-
CV(%)	9.72	12.77	10.76	15.38	14.60	7.73	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it is revealed that among the different treatments, T_7 Admire 200 SL @ 1.0 ml/L of water in reducing number of cabbage semi-looper over control (65.04%). Considering the treatments, T_3 Neem oil @ 3.0 ml/L of water performed as the best treatment in terms of reducing the number of cabbage semi-looper over control (63.58%). As a result, the order of rank of efficacy of the treatments applied against cabbage semi-looper including untreated control in terms of reducing number was $T_7 > T_3 > T_6 > T_5 > T_4 > T_1 > T_2 > T_8 > T_9$.

4.2.2. Cabbage caterpillar

The significant variations were observed among the different treatments of number of cabbage caterpillar at different days after transplanting (DAT). At 20 DAT, the highest number of cabbage caterpillar per five plants was recorded in T_9 (5.33 larvae/5 plants) which statistically similar with T_8 (4.67 larvae/5 plants), T_5 (4.67 larvae/5 plants), T_2 (4.33 larvae/5 plants) and T_4 (4.33 larvae/5 plants). Contrary, the lowest number of cabbage caterpillar per five plants was recorded in T_7 (2.67 larvae/5 plants) which was statistically similar with T_3 (3.33 larvae/5 plants) (Table 5). More or less similar trends of number of cabbage caterpillar per five plants were also experienced at 30 DAT, 40 DAT, 50 DAT and 60 DAT.

In case of mean number of cabbage caterpillar, the highest number of cabbage caterpillar per five plants were recorded in T_9 (7.27 larvae/5 plants) with untreated control, which significantly different from all other treatments. On the other hand, the lowest mean number of cabbage caterpillar per five plants was recorded in T_7 (1.33 larvae/5 plants), which significantly different with all other treatments and followed by T_3 (1.93 larvae/5 plants) and T_6 (2.07 larvae/5 plants) (Table 5). Considering the percent reduction of number of cabbage caterpillar per five plants, among different management practices, the highest 81.66% reduction over control was achieved in T_7 followed by T_3 (73.40%) and T_6 (71.56%). Nonetheless, the minimum reduction of cabbage caterpillar per five plants over control was found in T_8 (27.52%) followed by T_4 (54.14%).

Table 5:- Effect of management practices on incidence of caterpillar per five plants of cabbage

Treatments	Number of Cabbage Caterpillar per five plants						
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Mean	Reduction over control (%)
T_1	3.67 bcd	3.33 b	3.33 c	2.00 c	1.00 d	2.67 d	63.30
T_2	4.33 abc	3.67 b	3.67 c	2.00 c	1.67 cd	3.07 cd	57.80
T_3	3.33 cd	2.33 c	2.00 d	1.00 d	1.00 d	1.93 e	73.40
T_4	4.33 abc	4.00 b	4.00 c	2.33 c	2.00 c	3.33 c	54.14
T_5	4.67 ab	3.67 b	3.33 c	2.00 c	1.67 cd	3.07 cd	57.80
T_6	4.33 abc	2.00 c	2.00 d	1.00 d	1.00 d	2.07 e	71.56
T_7	2.67 d	1.00 d	1.00 d	1.00 d	1.00 d	1.33 f	81.66
T_8	4.67 ab	4.00 b	5.33 b	6.00 b	6.33 b	5.27 b	27.52
T_9	5.33 a	5.33 a	7.33 a	8.67 a	9.67 a	7.27 a	-
$LSD_{(0.05)}$	1.01	0.78	1.00	0.46	0.70	0.40	-
CV(%)	14.11	13.85	15.90	9.12	14.30	6.93	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it is revealed that among the different treatments, T_7 Admire 200 SL @ 1.0 ml/L of water in reducing number of cabbage caterpillar over control (81.66%). Considering the botanical treatments, T_3 Neem oil @ 3.0 ml/L of water performed as the best treatment in terms of reducing the number of cabbage caterpillar over control (73.40%). As a result, the order of rank of efficacy of the treatments applied against cabbage caterpillar including untreated control in terms of reducing number was $T_7 > T_3 > T_6 > T_1 > T_5 > T_2 > T_4 > T_8 > T_9$.

4.2.3. Diamond back moth larvae

The significant variations were observed among the different treatments the number of diamond back moth larvae at different days after transplanting (DAT). At 20 DAT, the highest number of diamond back moth per five plants was recorded in T_9 (16.67 larvae/5 plants) which statistically similar with T_8 (16.33 larvae/5 plants), T_4 (16.00 larvae/5 plants) and T_5 (15.67 larvae/5 plants). On the other hand, the lowest number of diamond back moth larvae per five plants was recorded in T_7 (12.33 larvae/5 plants) which statistically similar with T_3 (13.00 larvae/5 plants) and T_6 (13.00 larvae/5 plants) (Table 6). More or less similar trends of number of diamond back moth larvae per five plants were also recorded at 30 DAT, 40 DAT, 50 DAT and 60 DAT.

In case of mean number of diamond back moth larvae, the highest number of diamond back moth larvae per five plants was recorded in T_9 (19.27 larvae/5 plants) untreated control, which significantly different from all other treatments. On the other hand, the lowest mean incidence of diamond back moth larvae per five plants was recorded in T_7 (5.33 larvae/5 plants), which significantly different with all other treatments and followed by T_6 (7.27 larvae/5 plants) and T_3 (7.33 larvae/5 plants) (Table 6). Considering the percent reduction of number of diamondback moth larvae, among different management practices, the highest 72.32% reduction over control was found in T_7 followed by T_6 (62.29%) and T_3(61.95%). But, the minimum reduction of number of diamondback moth over control was found in T_8 (32.90%) followed by T_4 (39.80%).

Table 6:- Effect of treatments on incidence of diamond back moth larvae per five plants

Treatments	Incidence of Diamond back moth larvae per five plants						
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Mean	Reduction over control (%)
T_1	14.33 bc	13.00 bc	11.67 c	9.67 b	5.33 cd	10.80 d	43.95
T_2	14.33 bc	11.00 d	10.00 d	8.00 c	4.33 de	9.53 e	50.53
T_3	13.00 cd	10.33 d	8.33 e	4.00 e	1.00 f	7.33 g	61.95
T_4	16.00 ab	14.33 b	11.67 c	10.00 b	6.00 c	11.60 c	39.80
T_5	15.67 ab	10.33 d	8.00 e	6.00 d	3.67 e	8.73 f	54.68
T_6	13.00 cd	8.67 e	8.33 e	4.67 e	1.67 f	7.27 g	62.29
T_7	12.33 d	8.33 e	4.00 f	1.00 f	1.00 f	5.33 h	72.32
T_8	16.33 a	13.00 bc	14.67 b	9.00 bc	11.67 b	12.93 b	32.90
T_9	16.67 a	18.33 a	19.33 a	20.00 a	22.00 a	19.27 a	-
$LSD_{(0.05)}$	1.60	1.30	1.10	1.22	1.24	0.76	-
CV(%)	6.33	6.30	5.95	8.76	11.33	4.23	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From the above findings it is revealed that among the different treatments, T_7 Admire 200 SL @ 1.0 ml/L of water in reducing number of diamondback moth over control (72.32%). Considering the botanical treatments, T_3 Neem oil @ 3.0 ml/L of water performed as the best treatment in terms of reduction (61.95%) the number of diamondback moth over control. As a result, the order of rank of efficacy of the treatments applied against diamondback moth including untreated control in terms of reducing number was T_7> T_6> T_3> T_5> T_2> T_1> T_4> T_8> T_9.

4.3. Incidence of beneficial arthropods

4.3.1. Ants

The significant variations were observed among the different treatments due to management practices in terms of number of ants. At 20 DAT, there was no significantly variation found among the treatments. But at 30 DAT, the highest number of ants per five plants was recorded in T_1 (3.67 ants/plot/inspection) which statistically similar with T_3 (3.33 ants/plot/inspection), T_9 (3.33 ants/plot/inspection), T_2 (3.00 ants/plot/inspection), T_5 (3.00 ants/plot/inspection) and T_8 (3.00 ants/plot/inspection). But, the lowest number of ants per five plants was recorded in T_7 (2.00 ants/plot/inspection) which statistically similar with T_6 (2.33 ants/plot/inspection) and T_4 (2.67 ants/plot/inspection) (Table 7). More or less similar trends of number of ants per five plants were also recorded at 40 DAT, 50 DAT and 60 DAT. In case of mean number of ants, the highest number of ants per five plants was recorded in T_3 (4.53 ants/plot/inspection) neem oil @ 3.0 ml/L of water, which significantly similar with T_9 (4.40 ants/plot/inspection) and T_1 (4.07 ants/plot/inspection). On the other hand, the lowest number of ants per five plants was recorded in T_7 (1.73 ants/plot/inspection), which significantly similar with T_6 (2.00 ants/plot/inspection) and followed by T_8 (3.87 ants/plot/inspection) (Table 7). Considering the percent reduction of number of ants per five plants, among different management practices, the highest 60.61% reduction over control was achieved in T_7 followed by T_6 (54.55%). On the other hand, the minimum reduction of number of ants over control was found in T_3 (-3.02%) followed by T_1 (7.5%).

Table 7:- Effect of management practices on incidence of ants

Treatments	Incidence of ants						
	20 DAT	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**	**Mean**	**Reduction (+) over control (%)**
T_1	3.67 a	3.67 a	3.67 ab	4.67 bc	4.67 b	4.07 abc	7.57
T_2	3.00 a	3.00 abc	4.00 a	4.00 de	4.33 b	3.67 cd	16.66
T_3	3.33 a	3.33 ab	4.33 a	5.33 a	6.33 a	4.53 a	-3.02
T_4	3.00 a	2.67 bcd	3.00 b	3.67 e	4.33 b	3.33 d	24.25
T_5	3.00 a	3.00 abc	4.00 a	4.00 de	4.33 b	3.67 cd	16.66
T_6	3.67 a	2.33 cd	2.00 c	1.00 f	1.00 c	2.00 e	54.55
T_7	3.67 a	2.00 d	1.00 d	1.00 f	1.00 c	1.73 e	60.61
T_8	3.00 a	3.00 abc	4.00 a	4.33 cd	5.00 b	3.87 bcd	12.11
T_9	3.33 a	3.33 ab	4.33 a	5.00 ab	6.00 a	4.40 ab	-
$LSD_{(0.05)}$	0.78	0.67	0.76	0.61	0.68	0.55	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it was revealed that among different treatments the Admire 200 SL based treatment (T_7) reduced the highest incidence of ants (60.61%) in the cabbage field. Conversely, the neem oil based treatment (T_3)performed as the least hazard. Management practices, which increased (3.02%) the cabbage field rather than reducing as like as synthetic treatments as well as other botanicals.

4.3.2. Field spiders

The significant variations were observed among the different treatments used for the management practices in terms of number of field spiders per five plants recorded from the cabbage field. At 20 DAT, the highest number of field spiders per five plants was recorded in T_9 (3.00 spiders/plot/inspection) which statistically similar with T_8 (3.00

spiders/plot/inspection), T_3 (3.00 spiders/plot/inspection) and T_2 (3.00 spiders/plot/inspection). But, the lowest number of field spiders per five plants was recorded in T_1 (2.00 spiders/plot/inspection) which was statistically similar with T_4 (2.33 spiders/plot/inspection), T_6 (2.67 spiders/plot/inspection) and T_7 (2.67 spiders/plot/inspection) (Table 8). More or less similar trends of number of field spiders per five plants were also recorded at 30 DAT, 40 DAT, 50 DAT and 60 DAT.

In case of mean number of field spiders, the highest number of field spiders per five plants was recorded in T_9 (4.53 spiders/plot/inspection) comprised of untreated control, which was significantly similar with T_3 (4.47 spiders/plot/inspection). On the other hand, the lowest mean number of field spiders was recorded in T_7 (1.47 spiders/plot/inspection), which significantly different from all other treatments and followed by T_1 (3.80 spiders/plot/inspection) and T_4 (3.33 spiders/plot/inspection) (Table 8). Considering the percent reduction of number of field spiders, the highest 67.64% reduction over control was achieved in T_7 which statistically similar with T_6 (67.64%). On the other hand, the minimum reduction of number of field spiders over control was found in T_3 (1.46%) followed by T_8 (16.17%).

Table 8:- Effect of treatments on incidence of spider

Treatments	Incidence of spider						
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	Mean	Reduction (+) over control (%)
T_1	2.00 b	2.33 bc	3.00 d	3.67 b	4.00 c	3.00 d	33.82
T_2	3.00 a	3.33 a	3.67 bcd	4.33 b	4.67 b	3.80 b	16.17
T_3	3.00 a	3.67 a	4.33 ab	5.33 a	6.00 a	4.47 a	1.46
T_4	2.33 ab	3.00 ab	3.33 cd	4.00 b	4.00 c	3.33 cd	26.47
T_5	3.00 a	3.00 ab	3.67 bcd	4.00 b	4.33 bc	3.60 bc	20.58
T_6	2.67 a	1.67 c	1.00 e	1.00 c	1.00 d	1.47 e	67.64
T_7	2.67 a	1.67 c	1.00 e	1.00 c	1.00 d	1.47 e	67.64
T_8	3.00 a	3.00 ab	4.00 abc	4.33 b	4.67 b	3.80 b	16.17
T_9	3.00 a	3.67 a	4.67 a	5.33 a	6.00 a	4.53 a	-
$LSD_{(0.05)}$	0.60	0.70	0.73	0.71	0.56	0.37	-
CV(%)	12.66	14.30	13.17	11.13	8.23	6.51	-

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it is revealed that among different treatments, the Admire 200 SL treatment (T_7) reduced the highest number of field spiders (67.64%) in the cabbage field. Conversely, the neem oil (T_3) performed as the least hazard to spider. Management practices, which increased (1.46%) the cabbage field rather than reducing as like as synthetic treatments as well as other botanicals.

4.3.3. Lady bird beetle

The significant variations were observed among the different treatments of number of lady bird beetle. At 20 DAT, no incidence of lady bird beetle was observed in the cabbage field. But at 30 DAT, the highest number of Lady bird beetle per five plants was recorded in T_3

(3.00 Beetles/plot/inspection), which statistically similar with T_1 (2.67 Beetles/plot/inspection), T_2 (2.33 Beetles/plot/inspection), T_4 (2.33 Beetles/plot/inspection), T_8 (2.00 Beetles/plot/inspection) and T_9 (2.00 Beetles/plot/inspection). On the other hand, the lowest number of lady bird beetle per five plants was recorded in T_7 (1.00 Beetles/plot/inspection), which statistically similar with T_6 (1.33 Beetles/plot/inspection) and T_5 (1.67 Beetles/plot/inspection) (Table 9). More or less similar trends of number of lady bird beetle per five plants were also recorded at 40 DAT, 50 DAT and 60 DAT.

The highest number of lady bird beetle per five plants was recorded in T_3 (4.75 Beetles/plot/inspection) comprised of untreated control, which was significantly different with other treatments. Nonetheless, the lowest mean number of Lady Bird beetle per five plants was recorded in T_7 (1.00 Beetles/plot/inspection), which significantly similar with T_6 (1.08 Beetles/plot/inspection) (Table 9). Considering the reduction of lady bird beetle per five plants, the highest 75.00% reduction over control was achieved in T_7 followed by T_6 (73.00%). On the other hand, the minimum reduction of number of lady bird beetle over control was found in T_3 (-18.75%) followed by T_1 (-6.25%).

Table 9:- Effect of treatments on incidence of lady bird beetle

Treatments	Incidence of lady bird beetle					Reduction (+) over control (%)
	30 DAT	40 DAT	50 DAT	60 DAT	Mean	
T_1	2.67 ab	3.33 ab	4.00 b	7.00 a	4.25 b	-6.25
T_2	2.33 abc	3.33 ab	3.67 b	6.00 bc	3.83 b	4.25
T_3	3.00 a	4.00 a	4.67 a	7.33 a	4.75 a	-18.75
T_4	2.33 abc	2.33 b	3.67 b	5.00 d	3.33 c	16.75
T_5	1.67 bcd	2.67 b	3.00 c	5.67 cd	3.25 c	18.75
T_6	1.33 cd	1.00 c	1.00 d	1.00 e	1.08 d	73
T_7	1.00 d	1.00 c	1.00 d	1.00 e	1.00 d	75
T_8	2.00 abcd	2.33 b	3.00 c	5.00 d	3.08 c	23
T_9	2.00 abcd	3.33 ab	4.00 b	6.67 ab	4.00 b	0
$LSD_{(0.05)}$	0.99	0.97	0.50	0.88	0.45	
CV	28.15	21.64	9.28	10.26	8.07	

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From these above findings it is revealed that among different treatments the Admire 200 SL (T_7) reduced the highest incidence of lady bird beetle (75.00%) in the cabbage field. Conversely, the neem oil treatment (T_3) performed as the least hazard. Management practices, which increased (18.75%) the cabbage field rather than reducing as like as synthetic treatments as well as other botanicals.

4.4. Effect of treatments on cabbage head infestation

The highest number of healthy cabbage head was recorded in T_7 (18.75), which statistically similar with T_3 (18.38). On the other hand, the lowest number of healthy cabbage head was recorded in T_9 (15.77) which statistically similar with T_8 (16.09) followed by T_5 (16.61) (Table 10). The highest number of cabbage head infestation was recorded in T_9 (2.45), which statistically similar with T_8 (2.27). But the lowest number of cabbage head infestation was recorded in T_7 (1.22) which statistically similar with T_3 (1.32). Considering the percent cabbage head infestation the highest 13.42% infestation was recorded in T_9 which statistically similar with T_8 (13.20%). On the other hand, the minimum cabbage head infestation by number was recorded in T_7 (6.08%) which was similar with T_3 (6.70%) and followed by T_6 (7.64%).

From these above findings it is revealed that among different treatments, the Admire 200 SL (T_7) reduced the highest infestation of cabbage head (54.69%) in the cabbage field. Beside neem oil treatment (T_3) performed as the least hazard. Management practices, which reduced the infestation of cabbage head (50.07%) in the cabbage field rather than reducing as like as synthetic treatments as well as other botanicals.

Table 10:- Effect of management practices on cabbage head infestation

Treatments	Healthy head	Infested head	Infestation (%)	Infestation reduce over control (%)
T_1	17.21 c	1.63 cd	8.83 de	34.20
T_2	16.97 c	1.73 c	9.41 d	29.88
T_3	18.38 ab	1.33 ef	6.70 fg	50.07
T_4	16.79 c	2.03 b	10.74 c	19.97
T_5	16.61 cd	2.12 b	11.28 bc	15.95
T_6	17.87 b	1.48 de	7.64 ef	43.07
T_7	18.75 a	1.22 f	6.08 g	54.69
T_8	16.09 de	2.27 ab	12.30 ab	8.35
T_9	15.77 e	2.45 a	13.42 a	-
$LSD_{(0.05)}$	0.59	0.25	1.20	
CV(%)	1.97	8.05	7.21	

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

4.5. Effect of treatments on yield and yield contributing characteristics of cabbage

4.5.1. Diameter of cabbage head

Maximum diameter of cabbage head was recorded in T_7 (21.29 cm/head) which statistically different with all other treatments followed by T_3 (20.61 cm/head), T_6 (19.69 cm/head) and T_1 (18.95 cm/head). On the other hand, minimum diameter of cabbage head was recorded T_9 (15.45 cm/head) which statistically different with all other treatments followed by T_8 (16.71 cm/head), T_5 (17.75 cm/head), T_4 (17.35cm/head) and T_2 (18.29 cm/head) (Table 11). The trend was $T_7 > T_3 > T_6 > T_1 > T_2 > T_4 > T_5 > T_8 > T_9$.

4.5.2. Height of cabbage head

Maximum height of cabbage head was recorded in case of T_7 (10.37 cm/head) which statistically similar with T_3 (10.24 cm/head) and T_6 (9.60 cm/head) followed by T_1 (8.907 cm/head) and T_2 (8.600 cm/head). On the other hand, minimum height of cabbage head was recorded in case of T_9 (6.560 cm/head) which statistically similar with T_4 (7.500 cm/head) and T_8 (7.267 cm/head) followed by T_5 (8.007 cm/head) (Table 11). The trend was $T_7 > T_3 > T_6 > T_1 > T_2 > T_5 > T_8 > T_4 > T_9$.

4.5.3. Yield of cabbage head

Statistically significant variation was recorded in yield (ton/ha) of cabbage head for different control measures under the present trial presented in table 11. Highest yield was recorded from T_7 (19.96 ton/ha) which significantly similar with T_3 (19.71 ton/ha) followed by T_6 (19.35 ton/ha) and T_1 (19.02 ton/ha). Contrary, the lowest yield was recorded in T_9 (18.22 ton/ha) which significantly similar with T_8 (18.35 ton/ha) followed by T_4 (18.82 ton/ha), T_2 (18.75 ton/ha) and T_5 (18.74 ton/ha) (Table 11). From these results it is revealed that the trend of the yield of cabbage was observed due to application of the different management practices against cabbage fruit borer is $T_7 > T_3 > T_6 > T_1 > T_5 > T_2 > T_4 > T_8 > T_9$.

Table 11:- Effect of management practices on yield and yield attributes of cabbage as controlling different insects of cabbage

Treatment	Diameter of head (cm)	Height of head (cm)	Yield (Kg/ha)	Yield (ton/ha)
T_1	18.95 d	8.91 bcd	19020 c	19.02 c
T_2	18.29 e	8.60 cde	18750 cd	18.75 cd
T_3	20.61 b	10.24 ab	19710 ab	19.71 ab
T_4	17.35 f	7.50 ef	18820 cd	18.82 cd
T_5	17.75 ef	8.01 de	18740 cd	18.74 cd
T_6	19.69 c	9.60 abc	19350 bc	19.35 bc
T_7	21.29 a	10.37 a	19960 a	19.96 a
T_8	16.71 g	7.27 ef	18350 d	18.35 d
T_9	15.45 h	6.56 f	18220 d	18.22 d
$LSD_{(0.05)}$	0.56	1.29	569.2	0.57
CV(%)	1.76	8.72	1.73	1.73

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

[T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval; T_2 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval; T_3: Spraying of Neem oil @ 3.0 ml/L of water at 7 days; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval; T_6 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days; T_8 : Spraying of Phytoclean @ 3.0 ml/L of water at 7 days interval; T_9 : Untreated control.]

From the above finding it was revealed that the highest percent of yield increased over control found in T_7 (9.55%) comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the treatments, Neem oil treatments (T_3) performed the treatment in increasing of cabbage yield (8.18%) as compare to control.

4.6.1. Relationship between leaf infestation by semi-looper and yield of cabbage

Significant relationship is found between leaf infestation by cabbage semi-looper and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.980) and negative (slope =-0.148) correlation was found between leaf infestation by cabbage semi-looper and yield of cabbage, i.e. yield of cabbage decreased with the increasing of cabbage leaf infestation.

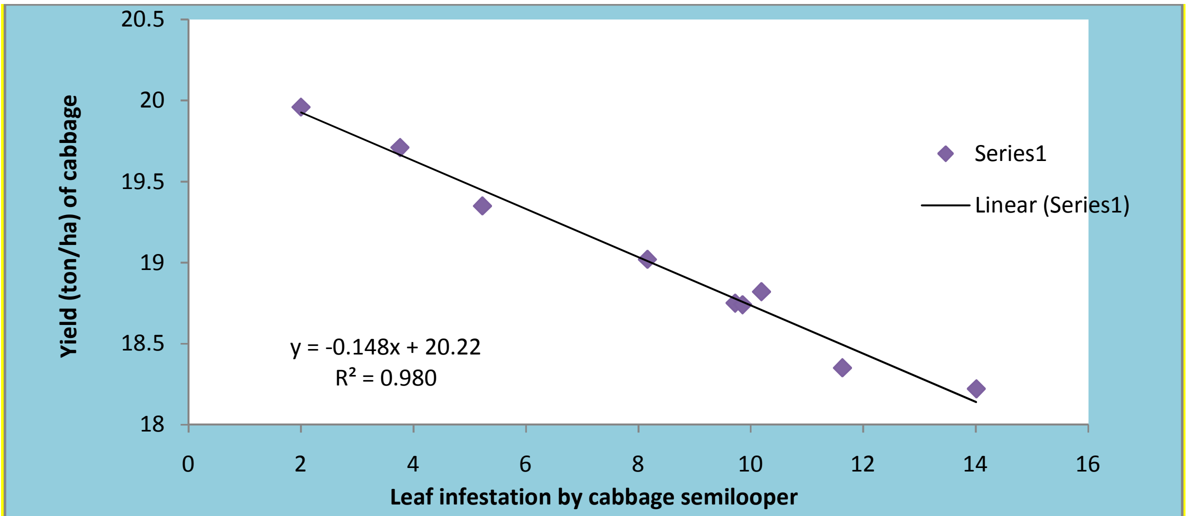

Figure 4: Relation between leaf infestation by semilooper and yield of cabbage

4.6.2. Relationship between leaf infestation by caterpillar and yield of cabbage

Significant relationship is found between leaf infestation by caterpillar and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.904) and negative (slope =-0.131) correlation was found between leaf infestation by caterpillar and yield of cabbage, i.e. yield of cabbage decreased with the increasing of cabbage leaf infestation by caterpillar.

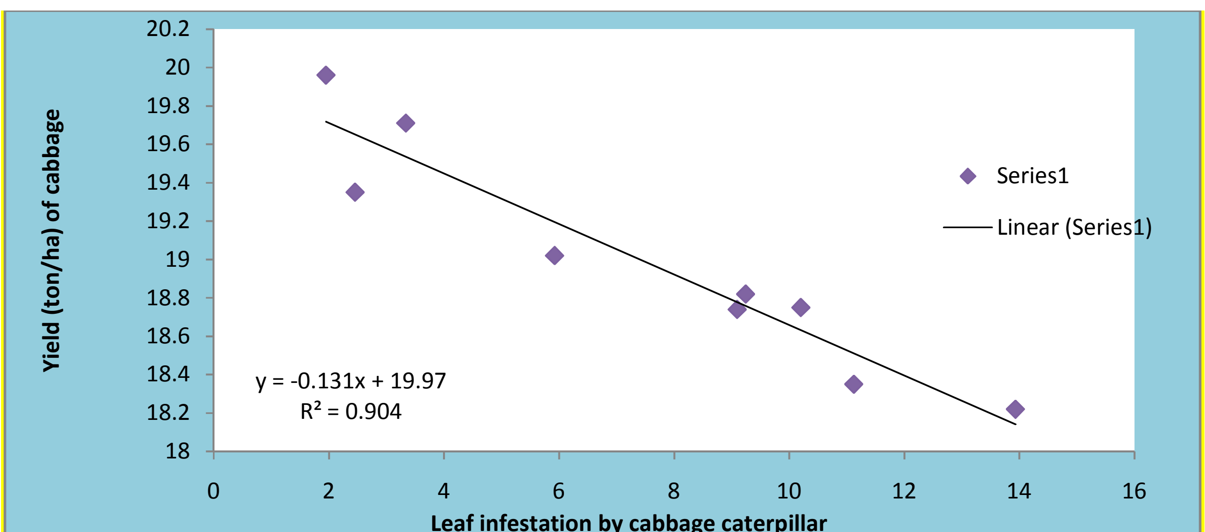

Figure 5: Relation between leaf infestation by caterpillar and yield of cabbage

4.6.3. Relationship between leaf infestation by diamondback moth and yield of cabbage

Significant relationship was found between leaf infestation by diamondback moth and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.780) and negative (slope =-0.121) correlation was found between leaf infestation by diamondback moth and yield of cabbage, i.e. yield of cabbage decreased with the increasing of leaf infestation.

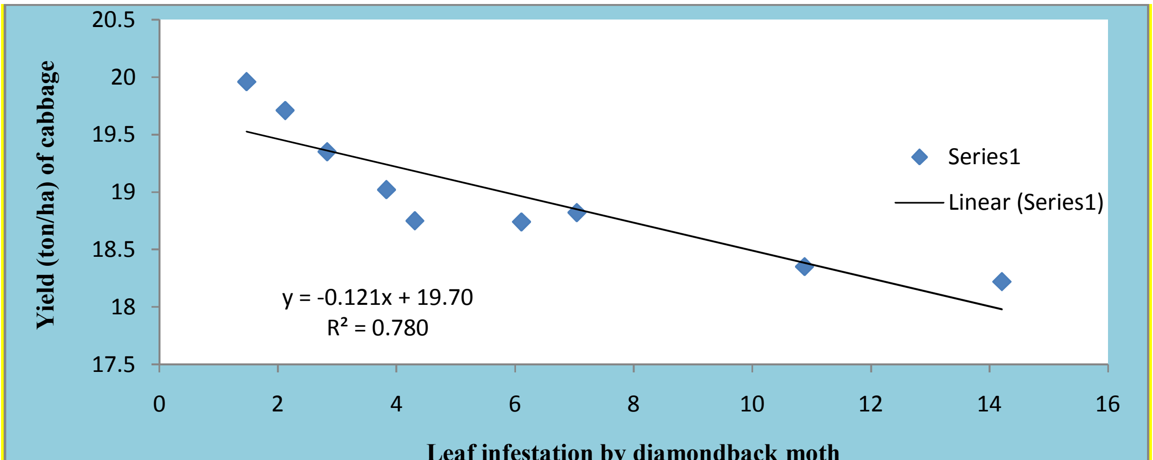

Figure 6: Relation between leaf infestation by diamondback moth and yield of cabbage

4.6.4. Relationship between incidence of semi-looper and yield of cabbage

Significant relationship was found between incidence of semi-looper and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.620) and negative (slope =-0.159) correlation was found between incidence of semi-looper and yield of cabbage, i.e. yield of cabbage decreased with the increasing of incidence.

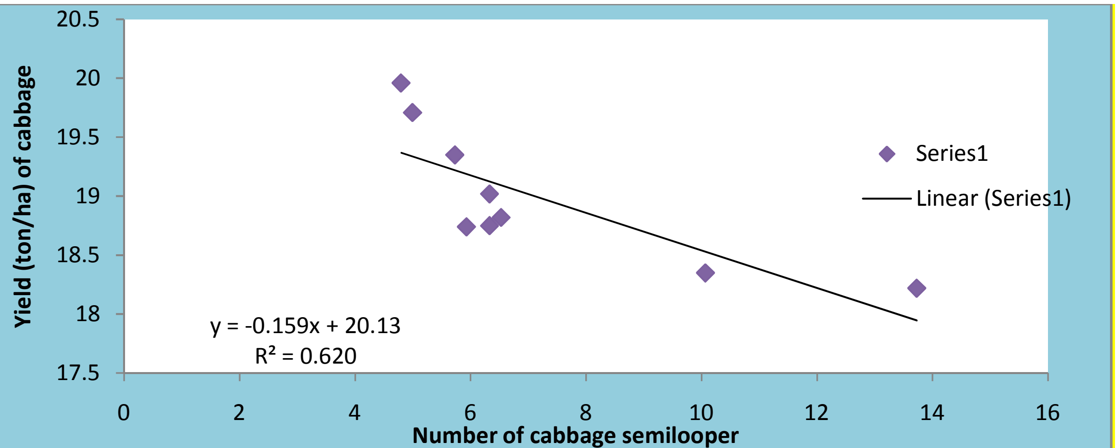

Figure 7: Relation between incidenc of semilooper and yield of cabbage

4.6.5. Relationship between incidence of caterpillar and yield of cabbage

Significant relationship was found between incidence of caterpillar and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong ($R^2=0.762$) and negative (slope =-0.276) correlation was found between incidence of caterpillar and yield of cabbage, i.e. yield of cabbage decreased with the increasing of incidence of cabbage caterpillar.

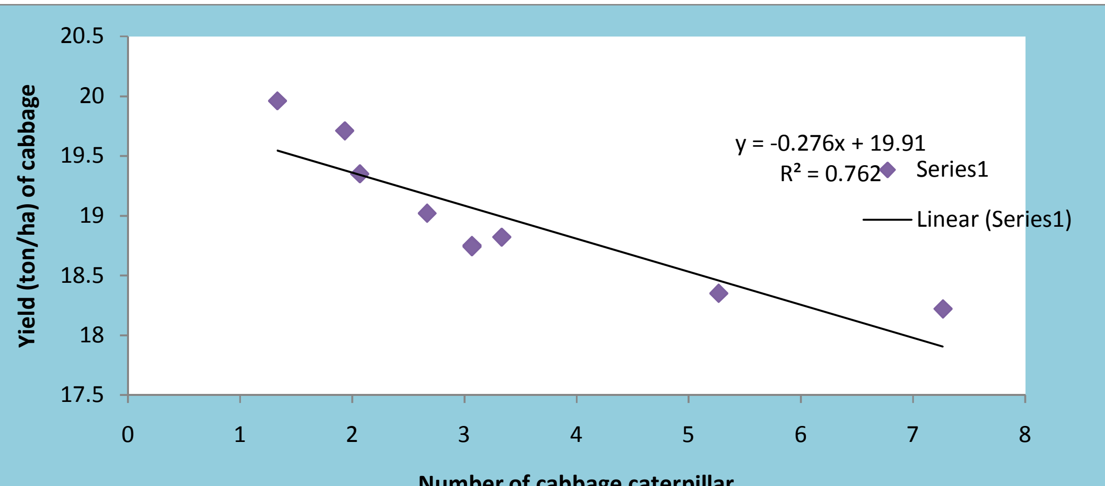

Figure 8: Relation between incidence of caterpillar and yield of cabbage

4.6.6. Relationship between incidence of diamondback moth and yield of cabbage

Significant relationship was found between the incidence of diamondback moth and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.714) and negative (slope =-0.120) correlation was found between the incidence of diamondback moth and yield of cabbage, i.e. yield of cabbage decreased with the increasing of incidence.

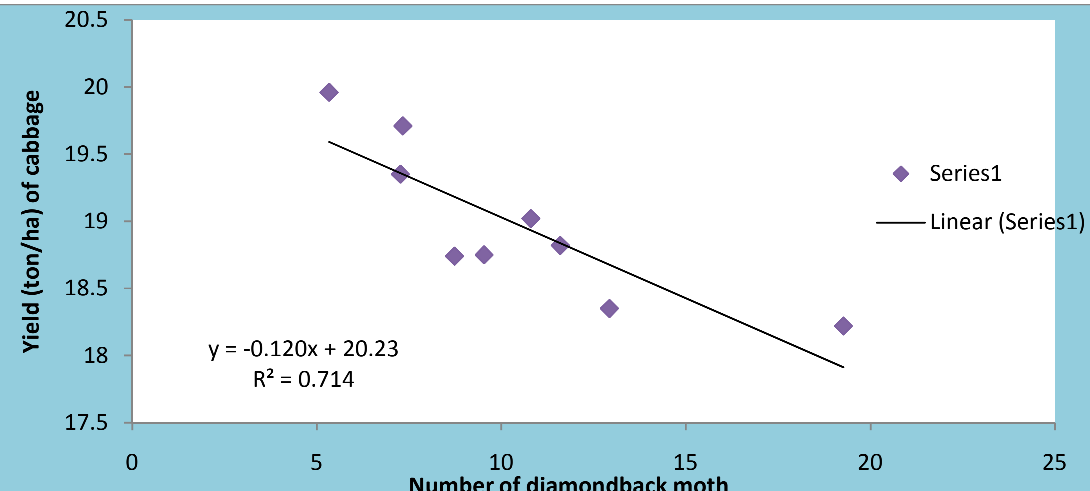

Figure 9: Relation between incidence of diamondback moth and yield of cabbage

4.6.7. Relationship between diameter of cabbage head and yield of cabbage

Significant relationship was found between diameter of cabbage head and yield of cabbage when correlation made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.953) and positive (slope =0.304) correlation was found between diameter of cabbage head and yield of cabbage, i.e. diameter of cabbage head increases with the increasing the yield of cabbage.

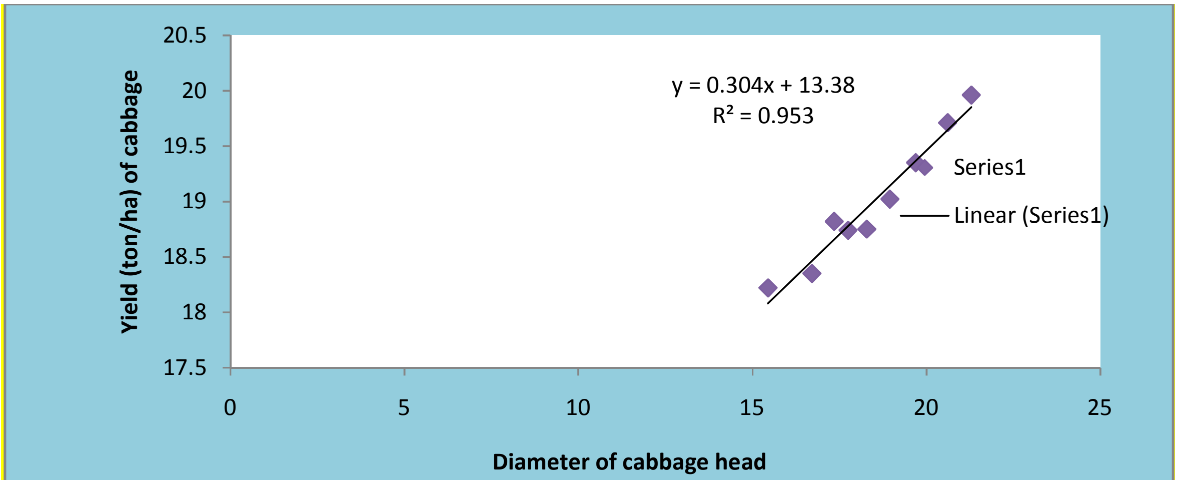

Figure 10: Relation between diameter of cabbage head and yield of cabbage

4.6.8. Relationship between height of cabbage head and yield of cabbage

Significant relationship was found between height of cabbage head and yield of cabbage when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.919) and positive (slope =0.418) correlation was found between height of cabbage head and yield of cabbage, i.e. height of cabbage head increased with the increasing the yield of cabbage.

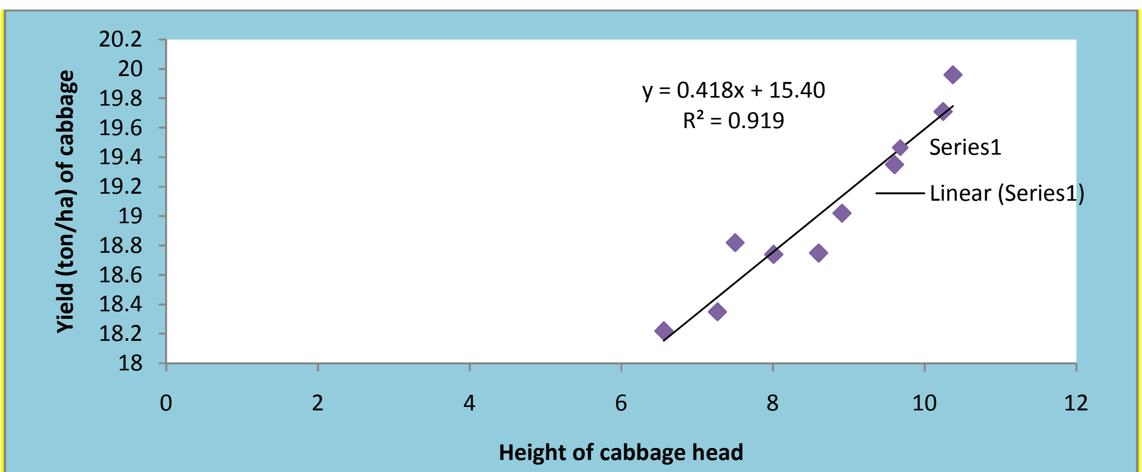

Figure 11: Relation between height of cabbage head and yield of cabbage

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2014 to March, 2015 to evaluate some management practices applied against major insect pests of cabbage. The experiment consisted of control measures with chemical and botanicals.

The highest reduction of leaf infestation over control by cabbage semi-looper was found in T_7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best in reducing the leaf infestation which compare to control (73.16%).

The highest reduction of leaf infestation over control by cabbage caterpillar was found in T_7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best in reducing the leaf infestation which compare to control (76.07%).

The highest reduction of leaf infestation over control by diamond back moth larvae was found in T_7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best in reducing the leaf infestation which compare to control (85.09%).

The cutworm infestation on cabbage seedlings ranged from 47.62 to 57.14% in the field, where the highest infestation was recorded in T_5, which statistically similar with all other treatments. On the other hand, the lowest infestation (47.62%) was recorded in T_2 and T_6. It was also observed that no cutworm infestation (0.0) was recorded at 3 DAT in the cabbage field. But the cutworm infestation was initiated in the cabbage field at 5 DAT and the maximum infestation (2.0 to 3.0 infested seedling/plot) was recorded at 7 DAT, whereas the infestation was declined gradually with the increase of time and no infestation was recorded at 13 DAT and subsequently at 15 DAT. Therefore, it was concluded that management practice particularly for cutworm should be applied between 3 to 13 DAT of cabbage seedlings in the field.

The highest percent of reducing number over control of cabbage semi-looper was founded in T_7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best results in terms of reducing the number of cabbage semi-looper as compare to control (63.58%).

The highest percent of reducing number over control of cabbage caterpillar was founded in T7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best results in terms of reducing the number of cabbage caterpiller as compare to control (73.40%).

The highest percent of reducing number over control of cabbage diamond back moth larvae was founded in T7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best results in terms of reducing the number of cabbage diamond back moth larvae as compare to control (61.95%).

In case of beneficial arthropods e.g. ants, spiders, lady bird beetle etc., the best performing treatment was T_3 comprised with spraying of Neem oil @ 3.0 ml/L of water at 7 days and the lowest performing treatment was T_7 comprised with spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days. For ants, the Admire 200 SL based treatment (T_7) reduced the highest incidence of ants (60.61%) in the cabbage field. Conversely, Neem oil treated plot (T_3) performed as the least hazard management practice, which increased (3.02%) the population of ants in the cabbage field rather than reducing as like as systematic insecticidal treatments as well as other botanicals.

For spiders, treatment (T_7) Admire 200 SL reduced the highest incidence of spiders (67.64%) in the cabbage field. Conversely, the Neem oil (T_3) treated plot performed as the least hazard management practice, which reduced (1.46%) the population of spiders in the cabbage field.

For lady bird beetle, the Admire 200 SL based treatment (T7) reduced the highest incidence (60.61%) in the cabbage field. Conversely, Neem oil treated plot (T3) performed as the least hazard management practice, which increased (3.02%) the population of lady bird beetle in the cabbage field rather than reducing as like as systematic insecticidal treatments as well as other botanicals.

The Admire 200 SL based treatment (T_7) reduced the highest infestation of cabbage head (54.69%) in the cabbage field. Besides this the Neem oil based treatment (T_3) performed as the least hazard. Management practice, which reduced the infestation of cabbage head (50.07%) in the cabbage field rather than reducing as like as systematic insecticidal treatments as well as other botanicals.

Maximum diameter of cabbage head was found in case of T_7 (21.29 cm) and minimum diameter of cabbage head was found in case of T_9 (15.45 cm). And maximum height of cabbage head was found in case T_7 (10.37 cm) and minimum height of cabbage head was found in case of T_9 (6.56 cm). Considering the botanical treatments, T_3 was showed the best performance in case of diameter of cabbage head (20.61 cm), height of cabbage head (10.24 cm). The highest yield was recorded in case of T_7 (19.96 t/ha) which was statistically similar with T_3 (19.71 t/ha) and the lowest yield was recorded in case of T_9 (18.22 t/ha) which was significantly similar with T_8 (18.35 t/ha).

The highest percent of yield increased over control was founded in T_7 spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval. Considering the botanical treatments, T_3 spraying of Neem oil @ 3.0 ml/L of water at 7 days performed as the best results those increasing of cabbage yield over control (8.18%).

Findings of the experiment revealed that insecticidal treatment produced maximum yield among the treatments but keeping the environmental point in view and less hazards botanicals may be recommended as treatment against insect pests of cabbage by sacrificing yield.

CHAPTER: VI

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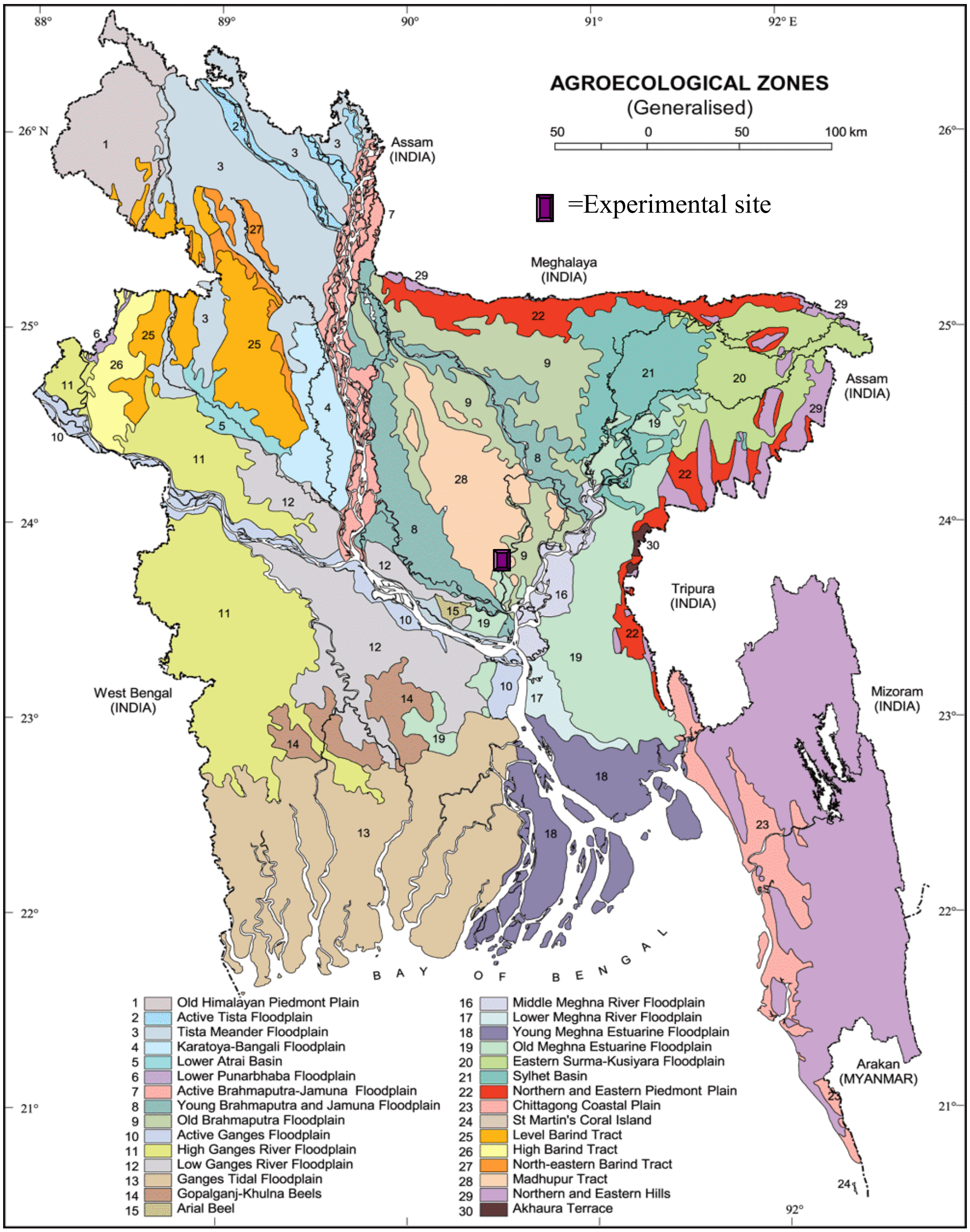
APPENDICES

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

Appendix III. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from October 2014 to March 2015

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2014	25.82	16.04	78	00
November, 2014	22.40	13.50	74	00
December, 2015	24.50	12.40	68	00
January, 2015	27.10	16.70	67	30
February, 2015	31.40	19.60	54	11
March, 2015	33.5	22.6	61	160.4

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207