FIELD EVALUATION OF SOME BIORATIONAL INSECTICIDES AGAINST MAJOR INSECT-PESTS OF CABBAGE AND THEIR IMPACTS ON BENEFICIAL ARTHROPODS

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CERTIFICATE

This is to certify that thesis entitled, **"FIELD EVALUATION OF SOME BIORATIONAL INSECTICIDES AGAINST MAJOR INSECT-PESTS OF CABBAGE AND THEIR IMPACTS ON BENEFICIAL ARTHROPODS"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **Entomology,** embodies the result of a piece of Bonafede research work carried out by **MD. MAHBUB HASAN, Registration No.: 13-05280** 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:June 2020
Place: Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from October, 2018 to March, 2019 to evaluate biochemical insecticides applied against major insect pests of cabbage. The treatments were T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC); T_5: untreated control (no pesticides). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were collected on the insect pest species associated with cabbage crop along with their nature of damage, seasonal incidence, damaging stage, cabbage head length and diameter, yield and data on natural enemies. A statistically significant variation was recorded in terms of all the characters related to growth and yield quality. In terms of leaf infestation by cabbage semi-looper at 20 DAT the highest number (12) of leaf infested by semi-looper was for Untreated control and lowest (4) infestation was observed for flubendiamide (Belt 24 WG). Significant variations were observed among different number of treatments of cabbage semi-looper at 20 DAT the highest (11.66) infestation by Cabbage semi-looper was observed for Untreated control and lowest (6.66) were found for flubendiamide (Belt 24 WG). At 20 DAT the highest (5.33) infestation by Cabbage cutworm was for Untreated control and lowest (2.66) were for flubendiamide (Belt 24 WG). At 20 DAT the highest (16) infestation by Cabbage diamondback moth larvae was for Untreated control and lowest (12) were for flubendiamide (Belt 24 WG). In terms of number of field spiders at 20 DAT, there was no significantly variation found among the treatments. For Lady bird beetle, at 20 DAT, there was no significantly variation found among the treatments. But at 60 DAT the highest (6.66) number of lady bird beetle was observed for untreated control. The highest diameter of cabbage head (22.2cm) was achieved from flubendiamide (Belt 24 WG) and lowest diameter (15.5cm) of cabbage was collected for untreated control. The highest height of cabbage head was achieved from flubendiamide (Belt 24 WG) (11.3cm) and lowest diameter of cabbage for untreated control (6.5cm) and the highest yield (19.97 ton/ha.) of cabbage head was achieved from flubendiamide (Belt 24 WG) and lowest yield (18.22 ton/ha.) of cabbage was collected for untreated control. Number of beneficial Arthropods as natural enemies, was also recorded and data suggested relatively low effect on natural beneficial Arthropods.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agriculture Organization
N	=	Nitrogen
B	=	Boron
et al.	=	And others
TSP	=	Triple Super Phosphate
MoP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Cabbage, *Brassica oleracea* var. *capitata* L., is one of the most important cruciferous winter leafy vegetables grown extensively in tropical and temperate regions of the world. In Bangladesh, cabbage is locally known as 'Bhadha Kopi' and the most common winter vegetable crop grown from seed. Structurally, cabbage has a short-thickened stem surrounded by a series of overlapping expanded leaves which form a compact head (Rice *et al*., 1986). Cabbage is a leafy vegetable rich in vitamin C, vitamin E and tryptophan; an important amino acid for our body (Rashid, 1993). In 2016-2017, 311650 metric tons (BBS, 2018) of cabbage was produced, which ranked fifth among the vegetables produced in Bangladesh. The total area of cabbage cultivation is 45681 acres in *Rabi* season (BBS, 2018). The yield produced by cabbage in Bangladesh is 75-100 ton/ha depending on selection of variety and season (Rashid *et al*., 2006). These yields are low comparing with other developing countries.

Like most of the other vegetables, cabbage is also vulnerable to the attack of several pests such as diamondback moth (*Plutella xylostella*), cabbage butterfly (*Pieris brassicae*), cabbage semi-looper (*Trichoplusia ni*), tobacco caterpillar/prodenia caterpillar (*Spodoptera litura*), cutworm (*Agrotis ipsilon*), are major limiting factors (Butani and Jotwani, 1984; Bhat *et al*., 1994). Damage caused by the Diamondback moth (DBM) (Lepidoptera: Plutellidae) 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 damages on cabbage in summer season. Cabbage caterpillar is the most destructive pest, which destroys leaves of cabbage by voraciously feeding (Guan and Yuan, 1990). 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). 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. Tobacco 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) and it can reduce more than 50% yield in some cabbage genotypes (Bhat *et al.*, 1994).

Many methods can be considered in order to combat insect pests of cabbage comprising cultural, mechanical, chemical, biological, botanicals and host plant resistance. Generally, 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). Among the hazards of chemical insecticides, the utilization of botanicals is the safe and hazards free tactics for the environmental pollution free management of insect pests (Hasan *et al.*, 1960).

The use of insecticides has become indispensable in increasing vegetable crop production because of its rapid effect, ease of application and availability. The management practices against major pests of cabbage have been done elsewhere but a few of them is related to this present study. This study is about the efficacy of some newer pesticides as well as those pesticides would be less harmful for natural enemies. For this purpose, some newer insecticides will be applied and result will be demonstrated. Flubendiamide is initially quickly degraded in soil by indirect photolysis however, further microbial degradation occurs at a slower rate it is eco-friendly also. Belt 24 WG contains flubendiamide which is the first representative of a new chemical insecticide classes - the diamides. In contrast to other insecticide classes targeting the insect nervous system, flubendiamide acts at receptors in insect muscles causing an immediate cessation of feeding and thus avoids crop damage. It is well suited for the control of a broad range of

Lepidoptera pests. The unique mode of action makes the compound well suited as a tool in insect resistance management programs. The other prominent new insecticides spinosad (Success 2.5 SC) and emamectine (Proclaim 5 SG) will be applied and their efficacy will be demonstrated.

Considering the above facts and points, the present research program has been designed with the following objectives;

- To evaluate the field infestation levels of target insect pests of cabbage viz. cabbage cutworm, diamond back moth and cabbage semi-looper
- To demonstrate the efficacy of newer insecticides against major pests of cabbage
- To integrate the best treatment for controlling pest of cabbage; and
- To assess the effect of treatments on beneficiary Arthropod 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, diamondback moth and cutworm are the major pests of cabbage. The efficacy of some newer pesticides as well as those pesticides effects on natural enemies was the subject to study. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings.

2.1. Different aspects of lepidopterous insects are presented below:

2.1.1. General review of 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, parts 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 of cabbage semi-looper

Dedes (2003) reported that, 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 other agricultural crops such as beets, celery, lettuce, peas, spinach, tomatoes and flowers including carnations 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. It takes approximately one month of warm weather for the cabbage semi-looper to complete its life cycle and produce the next generation of offspring.

Hutchison *et al*. (1999) reported that, 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 Northern 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 the growing season in the northern states depending on arrival time and late summer temperatures.

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 studied by, Nuessly and Hentz (1999). Capinera (1999) found that, Cabbage semi-looper does not enter diapause 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). Leibee (1996) found that, In central Florida, cabbage semi-looper populations peak during early fall and again during late spring.

C. Life cycle

Cabbage semi-looper do not require an overwintering period as a part of their life cycle, in fact, conditions colder than 10°C can prove fatal. Once adults migrate into an area, they deposit their eggs on the upper or lower surface of host foliage.

Eggs are hemispherical in shape, yellowish-white to a light green in color, bearing longitudinal ridges and are approximately 0.6mm in diameter. They are usually laid individually but may be found in masses containing 2-10.

Dedes (2003), the length of time required for eggs to hatch is temperature dependent. Eggs hatch after three days at 27°C or 10 days at 15°C into small, green, first-instar larvae that are initially hairy but lose this hair as they develop. They will shed their skins and molt through a total of five larval stages know as instars. Larvae are light green with faint white stripes running dorsally along their bodies. Their torso at the anterior end is narrow, containing three pairs of forelegs, gradually getting wider to the posterior end with three pairs of prolegs. Larvae move by holding on with their prolegs, projecting their front-end forward, grabbing hold with their forelegs and then arching their bodies bringing the prolegs up to meet the forelegs. This method of locomotion is characteristic to semi-loopers, which are also sometimes referred to as "inchworms". Larvae feed for two to three weeks on the underside of leaves, damaging and killing plants by chewing large holes between plant veins. Mature larvae reach lengths of 3-4 cm before they pupate within fragile, thin, white cocoons attached to the stems or undersides of leaves. Pupae are initially green but as they develop, they turn dark-brown or black in color and are about 2cm in length. Development of adults within pupae takes about six days at 27°C after which they emerge as mottled greyish-brown moths with distinctive silvery markings on their forewings. Adults are considered to be semi-nocturnal and may be active at dusk and during cloudy days but are most active late in the evening. Moths are capable of living up to 200 km to locate new crops where females produce 300-600 eggs to initiate next generation.

Eggs arc deposited singly or in small clusters on either leaf surface, although more are found on the lower leaf surface. Each female moth can produce 300 to 600 eggs during the approximately 10 to 12 days it is alive. After the eggs hatch, additional larvae move to the lower leaf surface to feed. Two to four weeks after hatching, the mature lama forms a thin cocoon on the lower leaf surface, or in plant debris or soil.

Capinera (1999) the pupal stage lasts approximately two weeks. Total time required for development from egg to adult can be as little as 18 days at 21ºC (69.8°F) and 25 days at 32°C (89.6°F)

Cabbage semi-looper can be a serious mid- and late season pest of cabbage and other crucifers. They do not over winter in NY; adults migrate into the state during July and August. The adults are about l to l inches across, gray-brown, and fly and lay eggs mostly at night. Eggs are laid singly on the underside of the foliage. The larvae are light green, with a white stripe on each side, about 1 inch long, and move by humping their back like an inch-worm, hence the name “semi-looper”. There may be 2 or 3 generations per year. As the larvae grow, they become more difficult to control (Shelton, 1994).

D. Nature of damage caused by cabbage semi-looper

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

2.1.2. Diamondback moth

The diamondback 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

Nuessly and Hentz (1999) in southern Florida, diamondback moth is most abundant from December to February or March and can attack at any time during the crop cycle. By the end of May, moth counts in pheromone traps fall to near zero. Moth counts may rise in mid-fall through early winter, but activity is limited during that time. Populations build on winter weeds, such as wild mustard, before moving into winter and early spring cabbage plantings. From mid-winter through the spring, when it is a serious pest, diamondback moth may cause losses of up to 70 percent in the absence of control.

Talekar and Shelton (1993) the Diamondback 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.

C. Life cycle

Eggs are laid in groups of 1-6 on the lower surface of the leaf. Moths can lay up to 300 eggs. The eggs are very small and difficult to spot. The larvae that emerge from the eggs, start feeding on the underside of the older leaves of mostly older plants; but will also feed on the young growing points of seedlings.

The larvae can reach maturity in between 10 and 14 days in summer and in winter it takes a bit longer. The larvae can go through up to 5 instars before going over to pupating. Pupation can take place on the underside of the leaf or under debris in the soil. The new generation of moths can emerge as quickly as 1 week after pupating. The whole cycle can be completed in 3 to 4 weeks. Diamondback moth adults can migrate from southern states into NY in late April and May but the majority of the problem appears to be diamondback moth which enters the state on southern-grown transplants. While diamondback moth does not over winter in upstate NY, it does over winter on Long Island in most years.

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

D. Nature of damage

From May to September, *Plutella xylostella* (L.) (diamondback 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 York (Moyer, 1999).

Janmaat (2003) reported that, 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

2.1.4.Cabbage Cutworm

Cabbage 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

Bentley *et al.* (1996) cutworms are a common pest of many vegetable crops including carrots, celery, lettuce, onion, tomato, pepper, eggplant, cole crops, rutabaga, beans, cucurbit crops, sweet corn and several 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, there are many species of cutworms attacking a wide range of cultivated and wild plants. Cutworms commonly found in Canada include the black cutworm, *Agrotis ipsilon*; variegated cutworm, *Pedridroma saucia*; dark-sided cutworm, *Euxoa messoria*; dingy cutworm, *Feltia jaculifera*; glassy cutworm, *Crymodes deva*stator; red-backed cutworm, *Euxoa ochrogaster*; black army cutworm, *Actebia fennica*; and white cutworm, *Euxoa scandens*

Bentley *et al.* (1996) the black cutworm and the variegated cutworm are the 2 most common species attacking vegetables although other species may be present in some areas. Recognizing damage from cutworms is relatively simple when plants are small. Seedlings are often 'cut' off at ground level and if the soil around the plants is dug up to a depth of about 5 cm, the characteristic cutworm larva can often be found. Cutworms generally curl up as illustrated when disturbed. Cutworms feed at night and will not generally be observed on plants or on the soil surface during the day. Black cutworms are grey to black with no striping on the body whereas variegated cutworms are usually brown on the upper surface and cream-coloured on the lower surface. Variegated cutworms also have a row of yellow spots down the back. The red-backed cutworm has a reddish-brown, translucent stripe down its back giving it a distinct appearance. The dark-sided cutworm is a grey-brown cutworm that has distinct striping along the sides giving it a darker appearance. The glassy cutworm has a greenish-white body with a translucent appearance and a pale red head. The black army cutworm feeds in groups unlike the other species and is characterized when small by having a very dark, velvety-black body with faint white striping. As the black army cutworm matures it becomes brown with pale yellow stripes.

C. Life cycle

West *et al., (*1990) Cutworm leads a complete metamorphosis. Most species pass the winter in soil or under garden trash as young larvae. In the spring, as temperatures warm, they become active and begin feeding on plants at night, remaining hidden during the day. The larvae molt several times and when fully grown pupate in the soil (late spring). Within one-week moths emerge and begin laying hundreds of eggs mostly on stems and leaves. One to five generations per year, depending upon the species.

D. Nature of damage

Hutchison and Burkness, (2015) Young larvae feed on the foliage or small roots of weeds or crops until they reach about ½ 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

Benssin (2011) 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.

Bentley *et al. (*1996) 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. Cutworms overwinter as eggs, larvae, pupae or adult moths depending upon the species. Not all cutworm species overwinter in Ontario during normal winters. For instance, a large

West *et al., (*1990) Proportion of the variegated cutworm population is thought to migrate into Ontario each season. Cutworms have 1 to 4 generations per year depending upon the species and location. The majority of cutworm damage occurs to seedling vegetables early in the season and when plants are small. Moths lay eggs on the soil and the larvae hatch to feed on plants. Weedy areas, fields of grasses or pasture are ideal sites for cutworms to overwinter. It is often in these areas and along field borders where problems arise. If weeds are permitted to grow in the fall after crop harvest and the fall and winter seasons are mild, large numbers of cutworms may survive to attack vegetables in the spring. Some species of climbing cutworms lay eggs in groups on the leaves of plants and the larvae hatch out to begin feeding on leaves, flowers and fruit of some vegetables. Late season species, such as the variegated cutworm, often do more damage to mature vegetable plants and their marketable portions. Damage to celery from climbing cutworms can be severe. Variegated cutworms also damage tomatoes when fruit is maturing, leading to serious losses. Damage to other vegetables is normally less severe or noticeable, however peppers, radishes, rutabagas and lettuce may experience limited damage from climbing cutworms.

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).

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.

Hahn and Burkness (2015) 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.

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.

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.

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*., 1993).

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.

Hahn and Burkness (2015) 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.

Talekar *et al.*, (1993) 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.*

2.2.3. Chemical control

In controlling moths still mostly used organic phosphorus esters. In this group classified active compounds are chlorine pirimiphos-methil, phenitrothion 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.

Hahn and Burkness (2015) 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.

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).

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.Cause 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). 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).

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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).

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.

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.

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) advised 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.*

2.3 Natural enemies

From the research of Afrin (2013), the highest number of honeybee (72.65) was found in mustard + onion intercropping system, which was statistically different than all others treatment. Second highest number of honeybees was found (71.97) in mustard + coriander.

According to Majumdar (2012), trap crops also provide a habitat for beneficial insects, such as lady beetles, spiders and hover flies or syrphid flies.

Dempster and Coaker (1974) found that, the predating activities of ground beetle were enhanced when cabbage was under sown with white and red clover resulting in regulation of population of *Brevicoryne brassicae* and Pieris rapae.

Andow and Risch (1985) observed that predaceous coccinellid beetles, *Coleomegilla maculata* (Dey.) and its prey (aphids) were more abundant on sole crops than on mixed maize and beans. Carabid beetles immigrated more rapidly from patches of monoculture of tomatoes and beans from intercrops of the two.

Hansen (1983) clearly demonstrated the increased abundance of several predator species in an intercrop system of maize and cowpea in Southern Mexico, suggesting an explanation for the over yielding of that system as reported by Vandermeer *et al.* (1983).

Altieri *et al.* (1977) reported that a higher abundance of predators in a weedy crop than in a comparable monoculture. Gavarra and Raros (1975) reported spiders to be more effective against corn borers in an intercrop of corn and groundnuts than in monoculture of corn.

CHAPTER III
MATERIALS AND METHODS

The present study regarding evaluate the field infestation levels of target insect pests of cabbage viz. cabbage cutworm (*Agrotis ipsilon*), diamondback moth (*Plutella xylostella*) and cabbage semi-looper (*Trichoplusia ni*) has been conducted during August 2018 to January 2019 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.

3.4. Land preparation

The soil was well prepared and good tilth ensured for commercial crop production. The target land was divided into 15 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 (MoP) 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 5-unit plots. The size of the unit plot was 2.5 m×1.5 m. The block to block and plot-plot distance was 0.75 m and 0.5 m, respectively.

3.7. Collection of seed, seedling raising

The seeds of selected cabbage variety BARI Bandha kopi-2 (Agradut) 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, 2018 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, 2018 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: flubendiamide (Belt 24 WG); @ 10-15 ml/100L water

T_2: spinosad (Success 2.5 SC); @ 1.2ml/L water.

T_3: emamectin Benzoate (Proclaim 5G); @ 0.2 gm/2L water

T_4: Farmer's practice (Cypermethrin @ 2ml/L of water spray)

T_5: untreated (No pesticides)

3.11. 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.

3.11.1. Counting of insect pests of cabbage and infested leaves

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

3.11.2. 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.

3.11.3. Beneficial arthropod

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

3.11.4. 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 (up to 15th February) stage of cabbage and weighted separately for each treatment.

3.12. Calculation

3.12.1. 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:

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

3.12.2. Percent Cutworm infested plant

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

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

3.12.3. Percent head infestation

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

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

3.12.4. 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:

Head infestation (%) (weight) = (Weight of infested heads/Total weight of heads) × 100

3.12.5. 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 formula: Head infestation (%) reduction over control = $\frac{X2-X1}{X2} \times 100$

Where, X1 = Mean value of the treated plot

X2 = Mean value of the untreated plot

3.12.6. 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:

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

3.12.7. Statistical analysis

Data were statistically analyzed by randomized complete block design through STATA-10 software and mean were separated using LSD tests to determine the levels of significant differences among different treatments.

Plate 1: Transplanting of seedling of cabbage in the experimental plot

Plate 2: Watering in cabbage main field during study period

Plate 3: Infested cabbage head due to cabbage cut-worm

Plate 4: semi-looper Bored cabbage head by Cabbage

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate the effectiveness of modern chemicals 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, 2018 to March, 2019. 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 number of leaves infested by semi-looper was 12 for T_5 (untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) where 4 leaves infestation per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT (Table 1).

In case of mean infestation, the highest number of leaf infestation was recorded in T_5 (14) and lowest T_1 (2). Considering the percent reduction of leaf infestation, the highest at T_1 (85.71%) and lowest at T_4 (42.86%).

From these findings it is revealed that among the different treatments T_1: flubendiamide (Belt 24 WG) reduced the leaf infestation the most and T_5: Untreated control the least. 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 $T_1 > T_2 > T_3 > T_4 > T_5$.

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

Treatments	Number of leaf infestation per five plants				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	4 d	2 d	1 d	2	85.71
T_2	5 cd	4 cd	3 c	4	71.43
T_3	6 c	5 c	4 c	5	64.29
T_4	9 b	8 b	8 b	8	42.86
T_5	12 a	15.33 a	16 a	14	00
LSD (0.05)	1.684	2.062	1.113	-	-
CV%	12.42	15.65	9.24	-	-

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

4.1.2. Cabbage cutworm

The significant variations were observed among different treatments of leaf infestation by cabbage cutworm at different DAT (Table 2). At 20 DAT the highest number of leaf infested by Cabbage cutworm was 12 for T_5 (Untreated control) and the lowest for T_1: flubendiamide (Belt 24 WG) was 3.66 which was statistically similar to T_2 (4) leaves infestation per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT in Table 2.

In case of mean infestation, the highest number of leaf infestation was recorded in T_5 (13.89) and lowest T_1 (2.22). Considering the percent reduction of leaf infestation, the highest T_1 (84.01%) and lowest at T_4 (56.80%).

From these findings it is revealed that among the different treatments T_1: flubendiamide (Belt 24 WG) reduced the leaf infestation the most and T_5: Untreated control the least. 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 $T_1 > T_2 > T_3 > T_4 > T_5$.

Table 2: Infestation of cabbage caused by cabbage cutworm at different DAT

Treatments	Number of leaf infestation per five plants				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	3.667 c	2 d	1 d	2.22	84.01
T_2	4 c	2.667 cd	1.667 c	2.78	79.98
T_3	4.667 c	3.667 c	2 c	3.44	75.23
T_4	6.333 b	6 b	5.667 b	6.00	56.80
T_5	12 a	14 a	15.667 a	13.89	00
LSD (0.05)	1.165	1.031	0.595	--	--
CV%	10.09	9.67	6.08	--	--

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

4.1.3. Diamondback moth larvae

The significant variations were observed among different treatments at different days after transplanting (DAT). At 20 DAT the highest number of leaf infested by Cabbage diamondback moth larvae was 13 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 3 which is statistically similar to T_2 (4.33) leaves infestation per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT in Table 3.

In case of mean infestation, the highest number of leaf infestation was recorded in T_5 (14) and lowest T1 (2). Considering the percent reduction of leaf infestation, the highest T_1 (85.71%) and lowest at T_4 (66.64%).

From these findings it is revealed that among the different treatments T_1: flubendiamide (Belt 24 WG) reduced the leaf infestation the most and T_5: untreated control the least. As a result, the order of ranks of efficacy of the treatments applied against cabbage diamondback moth larvae including untreated control in terms of reducing leaf infestation was $T_1 > T_2 > T_3 > T_4 > T_5$.

Table 3: Infestation of cabbage caused by diamondback moth larvae at different DAT

Treatments	**Number of leaf infestation per five plants**				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	3 c	1.667 d	1.333 d	2.00	85.71
T_2	4.333 bc	3 c	2.333 cd	3.22	77.00
T_3	4.667 b	4.333 b	3.667 bc	4.22	69.85
T_4	5.333 b	4.667 b	4 b	4.67	66.64
T_5	13 a	14 a	15 a	14.00	00
LSD (0.05)	1.375	1.002	1.556	--	--
CV%	12.04	9.62	15.70	--	--

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

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 infestation by Cabbage semi-looper was 11.66 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 6.66 infestation incident per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT (Table 4).

In case of mean incidence, the highest number of incidents was recorded in T_5 (11.44) and lowest T_1 (3.33). Considering the percent reduction of leaf infestation, the highest T_1 (70.89%) and lowest at T_4 (45.62%).

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	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	6.667 d	2.333 c	1 c	3.33	70.89
T_2	7.667 cd	2.333 c	1.333 c	3.78	66.95
T_3	8.667 bc	5 b	2.667 b	5.44	52.45
T_4	9.667 b	5.333 b	3.667 b	6.22	45.62
T_5	11.667 a	13.667 a	9 a	11.44	00
LSD (0.05)	1.263	1.140	1.002	--	--
CV%	7.57	10.56	15.06	--	--

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

From these findings it is revealed that among the different treatments T_1: flubendiamide (Belt 24 WG) reduced the leaf infestation the most and T_5: Untreated control the least. 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 $T_1 > T_2 > T_3 > T_4 > T_5$.

4.2.2. Cabbage cutworm

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 infestation by Cabbage cutworm was 5.33 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 2.66 infestation incident per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT (Table 5).

In case of mean incidence, the highest number of incidents was recorded in T_5 (7.11) and lowest T_1 (1.89). Considering the percent reduction of leaf infestation, the highest T_1 (73.41%) and lowest at T_4 (51.62%).

From these findings it is revealed that among the different treatments T_1: flubendiamide (Belt 24 WG) reduced the leaf infestation the most and T_5: untreated control the least. As a result, the order of ranks of efficacy of the treatments applied against cabbage cutworm including untreated control in terms of reducing leaf infestation was $T_1 > T_2 > T_3 > T_4 > T_5$.

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

Treatments	Number of Cabbage cutworm per five plants				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	2.667 d	1.667 d	1.333 c	1.89	73.41
T_2	3.333 c	2.000 cd	1.333 c	2.22	68.77
T_3	3.667 c	3.000 bc	1.667 bc	2.78	60.90
T_4	4.333 b	3.667 b	2.333 b	3.44	51.62
T_5	5.333 a	7.667 a	8.333 a	7.11	00
LSD (0.05)	0.595	1.031	0.972	--	--
CV%	8.18	15.21	17.21	--	--

(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)

4.2.3. Diamondback moth larvae

The significant variations were observed among the different treatments the number of diamondback moth larvae at different days after transplanting (DAT). At 20 DAT the highest infestation by Cabbage diamondback moth larvae was 16 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 12 infestation incidents per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT (Table 6).

In case of mean incidence, the highest number of incidents was recorded in T_5 (18.67) and lowest T_1 (5.67). Considering the percent reduction of leaf infestation, the highest T_1 (69.63%) and lowest at T_4 (44.67%).

From these findings it is revealed that among the different treatments T_1: flubendiamide (Belt 24 WG) reduce the leaf infestation the most and T_5: untreated control the least. As a result, the order of ranks of efficacy of the treatments applied against cabbage diamondback moth larvae including untreated control in terms of reducing leaf infestation was $T_1 > T_2 > T_3 > T_4 > T_5$.

Table 6: Effect of treatments on incidence of diamondback moth larvae per five plants

Treatments	**Incidence of Diamondback moth larvae per five plants**				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	12 d	4 d	1 d	5.67	69.63
T_2	13 c	8 c	1 d	7.33	60.74
T_3	14 b	10 b	3 c	9.00	51.79
T_4	14 b	11.33 b	5.67 b	10.33	44.67
T_5	16 a	19 a	21 a	18.67	00
LSD (0.05)	0.842	1.851	1.286	--	--
CV%	3.24	9.39	10.79	--	--

(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)

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 60 DAT the highest number of ants was observed (6.00) for T_5: Untreated control and lowest 1.33 for T_1: flubendiamide (Belt 24 WG). Which is statistically similar to T_2: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of ants per five plants, among different management practices, the highest 61.34% reduction over control was achieved in T_1 treatment and lowest for (0.06%) T_4 treatment (Table 7).

Table 7: Effect of management practices on incidence of ants

Treatments	Incidence of ants				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	2.667 b	1.667 d	1.333 d	1.89	61.34
T_2	3.333 ab	3.333 c	2.000 d	2.89	40.90
T_3	3.667 ab	3.667 bc	3.333 c	3.56	27.19
T_4	4.333 a	4.667 ab	4.667 b	4.56	0.06
T_5	3.333 ab	5.333 a	6.000 a	4.89	00
LSD (0.05)	1.031	1.190	0.909	--	--
CV%	15.80	16.94	13.93	--	--

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

From these above findings it was revealed that among different treatments the T_1: flubendiamide (Belt 24 WG) reduced highest number of ants as synthetic treatment.

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, there was no significantly variation found among the treatments. But at 60 DAT the highest number of field spider was observed (6.00) for T_5: Untreated control and lowest 1.00 for T_1: flubendiamide (Belt 24 WG). Which is statistically similar to T_2: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of field spider per five plants, among different management practices, the highest 70.11% reduction over control was achieved in T_1 treatment and lowest for (14.94%) T4 treatment (Table 8).

Table 8: Effect of treatments on incidence of spider

Treatments	Incidence of spider				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	2.333 d	1.333 c	1.000 c	1.56	70.11
T_2	3.000 c	1.667 c	1.333 c	2.00	61.68
T_3	3.333 bc	3.667 b	4.333 b	3.78	27.59
T_4	3.667 b	4.333 b	5.333 a	4.44	14.94
T_5	4.333 a	5.333 a	6.000 a	5.22	00
LSD (0.05)	0.643	0.842	0.729	--	--
CV%	10.25	13.69	10.76	--	--

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

From these above findings it was revealed that among different treatments the T_1: flubendiamide (Belt 24 WG) reduced highest number of field spider as synthetic treatment.

4.3.3. Lady bird beetle

The significant variations were observed among the different treatments of number of lady bird beetle. At 20 DAT, there was no significantly variation found among the treatments. But at 60 DAT the highest number of lady bird beetle was observed (6.66) for T_5: untreated control and lowest 1.33 for T_1: flubendiamide (Belt 24 WG). Which is statistically similar to T_2: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of lady bird beetle per five plants, among different management practices, the highest 64.54% reduction over control was achieved in T_1 treatment and lowest for (10.32%) T_4 treatment (Table 9).

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

Treatments	**Incidence of lady bird beetle**				
	20 DAT	**40 DAT**	**60 DAT**	**Mean**	**%Reduction over control**
T_1	2.667 b	1.667 c	1.333 c	1.89	64.54
T_2	3.333 ab	2.667 bc	2.000 c	2.67	49.91
T_3	3.667 ab	3.333 b	4.667 b	3.89	27.02
T_4	4.333 a	4.667 a	5.333 b	4.78	10.32
T_5	3.667 ab	5.667 a	6.667 a	5.33	00
LSD (0.05)	1.031	1.140	1.239	--	--
CV%	15.50	16.82	16.46	--	--

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

From these above findings it was revealed that among different treatments the T_1: flubendiamide (Belt 24 WG) reduced highest number of lady bird beetle as synthetic treatment

4.4. Effect of treatments on cabbage head infestation

The highest number of healthy cabbage head was recorded in T_1 (18.75), which statistically similar with T_3 (18.38). On the other hand, (Table 10)

The highest number of healthy cabbage head was achieved from treatment T_1 (18.66) with lowest infestation (6.08%). And for T_5 (15.66) lowest healthy head cabbage was collected with the highest infestation of (13.40%).

Table 10: Effect of management practices on cabbage head infestation

Treatments	Healthy head	Infested head	Infestation (%)
T_1	18.667 a	1.000 b	6.08 e
T_2	17.667 b	2.000 a	7.64 d
T_3	16.667 c	2.333 a	11.28 c
T_4	16.333 c	2.333 a	12.30 b
T_5	15.667 d	2.667 a	13.40 a
LSD (0.05)	0.486	0.687	0.104
CV%	1.52	17.67	0.54

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

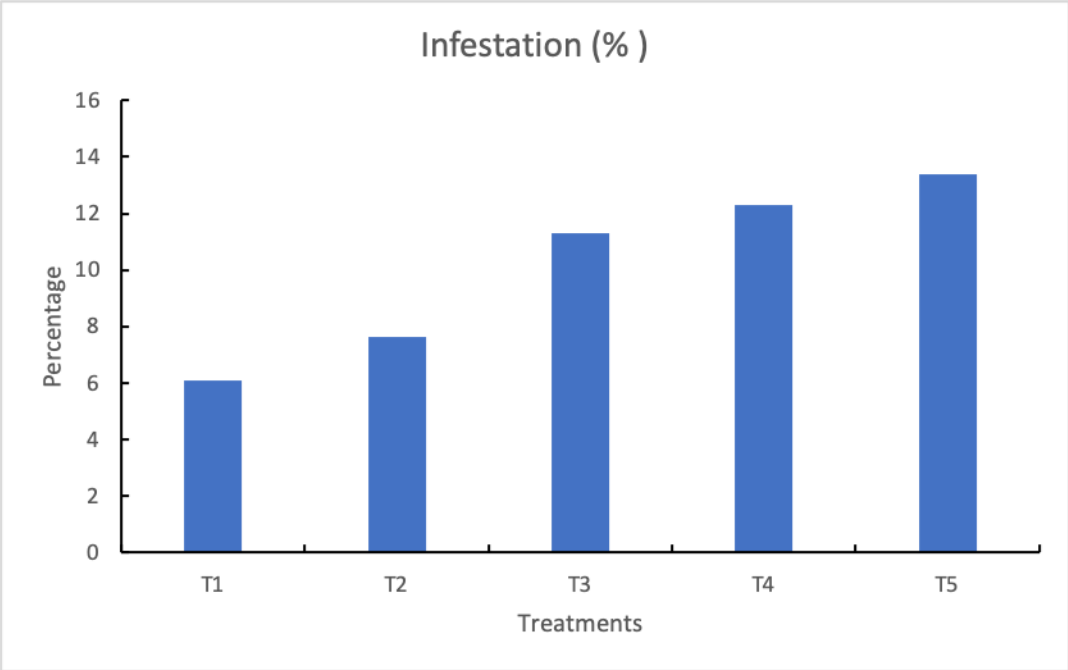

Figure 1: Effect of management practices on cabbage head infestation

From the above data it was revealed that the T_1: flubendiamide (Belt 24 WG) reduced the highest infestation of cabbage head in the cabbage field

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

4.5.1. Diameter of cabbage head

The highest diameter of cabbage head was achieved from treatment T_1 (22.2cm) and lowest diameter of cabbage was collected (Table 11) for T_5 (15.5cm).

4.5.2. Height of cabbage head

The highest height of cabbage head was achieved from treatment T_1 (11.3cm) and lowest diameter of cabbage was collected for T_5 (6.5cm).

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

Treatments	Diameter of head (cm)	Height of head (cm)	Yield (Kg/ha)	Yield (ton/ha)
T_1	22.2 a	11.3 a	19978 a	19.978 a
T_2	21.4 b	10.2 b	19357 b	19.357 b
T_3	20.6 c	10.23 b	19018 c	19.018 c
T_4	19.7 d	9.8 c	18760 d	18.76 d
T_5	15.5 e	6.5 d	18226 e	18.226 e
LSD (0.05)	0.206	0.185	8.804	8.805
CV%	0.55	1.02	0.02	0.02

(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)

[Treatments; T_1: flubendiamide (Belt 24 WG); T_2: spinosad (Success 2.5 SC); T_3: emamectine benzoate (Proclaim 5G); T_4: farmer's practice (cypermethrin 10 EC) T_5: untreated control (no pesticides)]

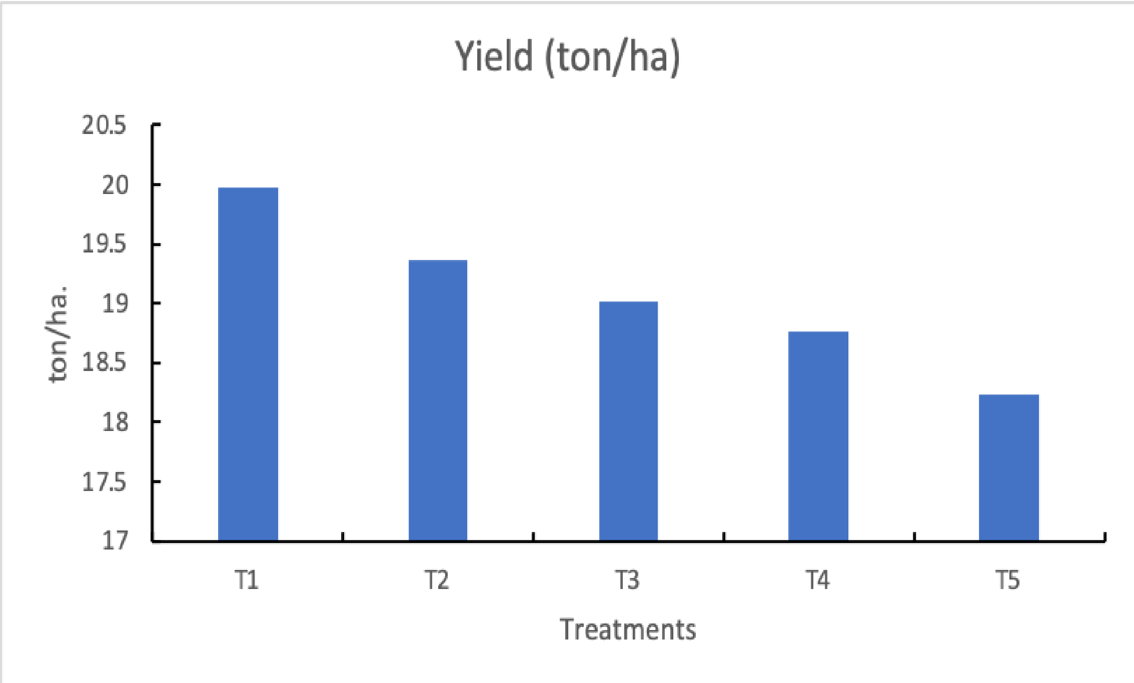

Figure 2: Effect of management practices on yield

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. The highest yield (ton/ha.) of cabbage head was achieved from treatment T_1 (19.97 ton) and lowest yield (ton/ha.) of cabbage was collected for T_5 (18.22 ton). From the above data it was revealed that the T_1: flubendiamide (Belt 24 WG) gives the highest yield (ton/ha.) of cabbage head in the cabbage field.

Findings of the experiment revealed that insecticidal treatment produced maximum yield among the treatments but keeping the environmental point in view less hazards botanicals may be recommended as treatment against insect pests of cabbage by sacrificing yield. The number of beneficial Arthropods count was high mirrors the relatively less effect by the beneficial Arthropods of cabbage by the trial pesticides especially T_1: flubendiamide (Belt 24 WG). In addition to Arthropod Management data on the effects of flubendiamide on several beneficial arthropods, results indicated little to no mortality on many beneficial insects such as ladybird beetles, ant and spider. This study indicated that first instar ladybird beetles were moderately harmed. From the result it was observed that, an early field application of flubendiamide allowed for the build-up of predators and parasitoids which prevents the Lepidopteran pests of cabbage from building up too high populations later in the season**.**

CHAPTER V

SUMMARY AND CONCLUTION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to March, 2019 to evaluate some integrated pest management practices applied against major insect pests of cabbage. The experiment consisted of control measures with modern chemical pesticides.

The significant variations ($p>0.05$) were observed among different treatments for different management practices in terms of leaf infestation by cabbage semi-looper at different days after transplanting (DAT). At 20 DAT the highest number of leaf infested by semi-looper was 12 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 4 leaves infestation per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT. The significant variations were observed among different treatments of leaf infestation by cabbage cutworm at different DAT (Table 2). At 20 DAT the highest number of leaf infested by Cabbage cutworm was 12 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 3.66 which is statistically similar to T_2 (4) leaves infestation per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT. At 20 DAT the highest number of leaf infested by Cabbage diamond back moth larvae was 13 for T_5 (untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 3 which is statistically similar to T_2 (4.33) leaves infestation per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT.

Significant variations were observed among different treatments of number of cabbage semi-looper at different days after transplanting (DAT). At 20 DAT the highest infestation by Cabbage semi-looper was 11.66 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 6.66 infestation incident per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT. In case of mean incidence, the highest number of incident was recorded in T_5 (11.44) and lowest T_1 (3.33). Considering the percent reduction of leaf infestation, the highest T_1 (70.89%) and lowest at T_4 (45.62%). 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 infestation by Cabbage cutworm was 5.33 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 2.66 infestation incident per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT. 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 infestation by Cabbage diamond back moth larvae was 16 for T_5 (Untreated control) and lowest for T_1: flubendiamide (Belt 24 WG) was 12 infestation incident per five plants. More or less similar trends of leaf infestation by number were also recorded at 40 DAT and 60 DAT.

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 60 DAT the highest number of ant was observed (6.00) for T_5: Untreated control and lowest 1.33 for T_1: flubendiamide (Belt 24 WG). Which is statistically similar to T_2: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of ants per five plants, among different management practices, the highest 61.34% reduction over control was achieved in T_1 treatment. And lowest for (0.06%) T_4 treatment. 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, there was no significantly variation found among the treatments. But at 60 DAT the highest number of field spider was observed (6.00) for T_5: Untreated control and lowest 1.00 for T_1: flubendiamide (Belt 24 WG). Which is statistically similar to T_2: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of field spider per five plants, among different management practices, the highest 70.11% reduction over control was achieved in T_1 treatment. And lowest for (14.94%) T_4

treatment. The significant variations were observed among the different treatments of number of lady bird beetle. At 20 DAT, there was no significantly variation found among the treatments. But at 60 DAT the highest number of lady bird beetle was observed (6.66) for T_5: Untreated control and lowest 1.33 for T_1: flubendiamide (Belt 24 WG). Which is statistically similar to T_2: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of lady bird beetle per five plants, among different management practices, the highest 64.54% reduction over control was achieved in T_1 treatment. And lowest for (10.32%) T_4 treatment.

The highest number of healthy cabbage head was recorded in T_1 (18.75), which statistically similar with T_3 (18.38). On the other hand, the highest number of healthy cabbage head was achieved from treatment T_1 (18.66) with lowest infestation (6.08%). And for T_5 (15.66) lowest healthy head cabbage was collected with the highest infestation of (13.40%).

The highest diameter of cabbage head was achieved from treatment T_1 (22.2cm). And for T_5 (15.5cm) lowest diameter of cabbage was collected, the highest height of cabbage head was achieved from treatment T_1 (11.3cm). And for T_5 (6.5cm) lowest diameter of cabbage and the highest yield (ton/ha.) of cabbage head was achieved from treatment T_1 (19.97 ton). And for T_5 (18.22 ton) lowest yield (ton/ha.) of cabbage was collected. From the above data is was revealed that the T_1: flubendiamide (Belt 24 WG) gives the highest yield (ton/ha.) of cabbage head in the cabbage field.

Conclusion

Cabbage growers of Bangladesh use insecticides more frequently. Improper application along with impurity of marketed insecticides is suspected for control and repeated use of insecticides. So, we should create awareness about the proper use of chemical pesticides.

RECOMENDATIONS

Considering the above experimental results of the present study further investigation in the following areas may be recommended as follows.

1. Further study may be needed for ensuring the efficiency of botanical pesticides in relation to growth and yield performance in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

2. More mechanical and botanical treatments against Cabbage fruit borer may be needed to include for future study as sole or different combination to avoid total rely on insecticides.

3. Safe use of pesticides should be practiced in farmer's level to avoid the harmful effect of pesticides.

4. Pesticide companies should be taken different steps to create awareness among the farmers about the harmful effect of pesticides.

CHAPTER VI

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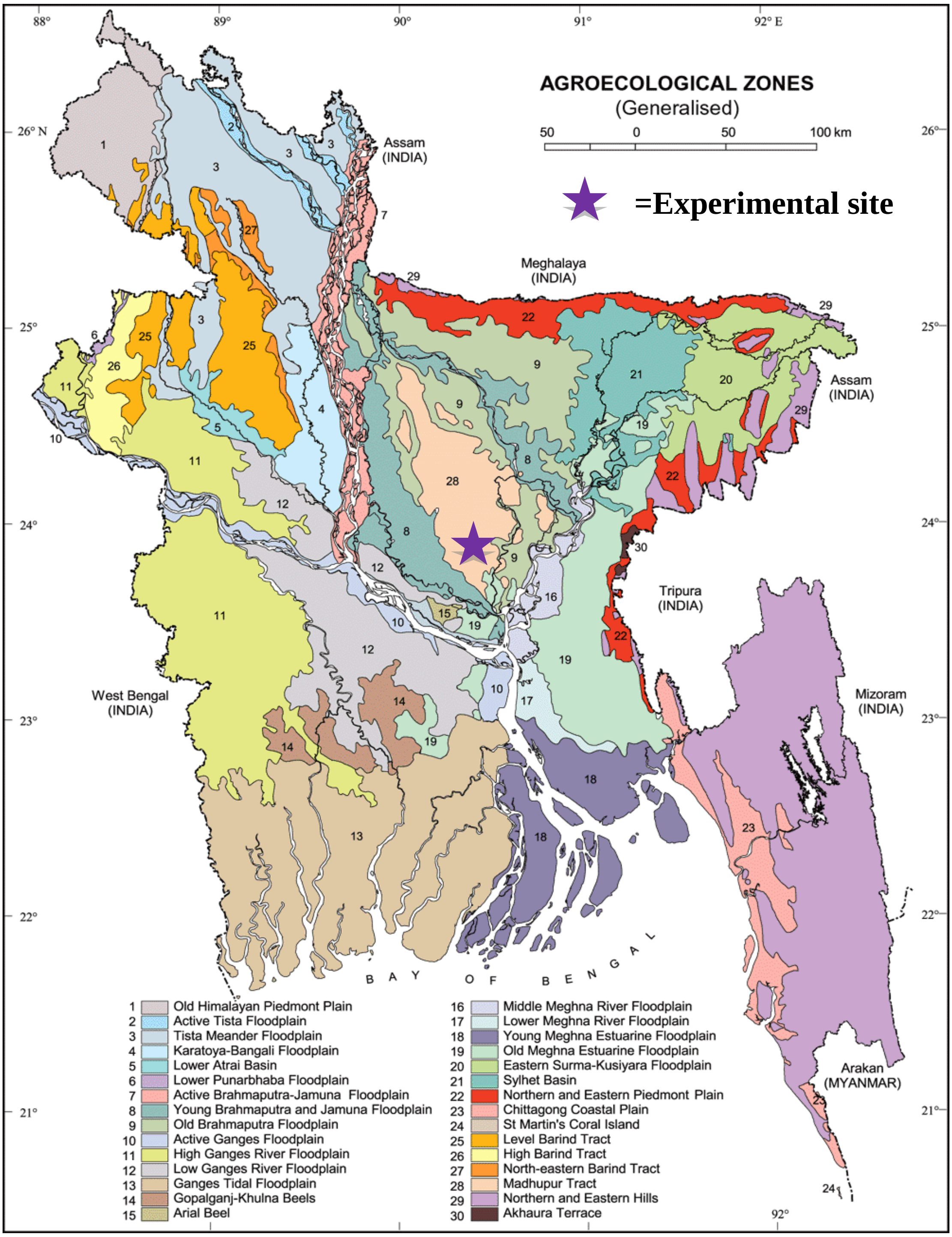
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly meteorological information during the period from November, 2018 to April, 2019

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2019	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	33.50	25.90	64.50	119

Source : Meterological Centre, Agargaon, Dhaka, (Climate Division)

Appendix IV. Layout of the experimental field