SPECIES DIVERSITY OF FLEA BEETLES OF CABBAGE AND ITS MANAGEMENT USING CHEMICAL INSECTICIDES AND BIO-PESTICIDES

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JUNE, 2018

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Reg. No.: 11-04383

A Thesis
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 (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY - JUNE, 2018

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CERTIFICATE

This is to certify that the thesis entitled, "**SPECIES DIVERSITY OF FLEA BEETLES OF CABBAGE AND ITS MANAGEMENT USING CHEMICAL INSECTICIDES AND BIO-PESTICIDES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **Fatima Farhana, Registration No. 11-04383** 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, 2018

Dhaka, Bangladesh

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ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to the almighty Allah Rabbul Al-Amin for His gracious kindness and infinite mercy in all the endeavors to the author to let her successfully complete the research work and the thesis leading to the degree Master of Science in Entomology.

The author would like to express her heartfelt gratitude and most sincere appreciations to her Supervisor **Prof. Dr. Md. Abdul Latif,** Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to her Co-Supervisor **Prof. Dr. Mohammed Ali,** Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, for his constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.

The author would like to express her deepest respect and boundless gratitude to all her respected 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.

The author wishes to extend her special thanks to her class mates and friends and roommates for their keen help as well as heartiest co-operation and encouragement during experimentation.

The authoress is deeply indebted and grateful to her parents, brothers, sisters, and relatives who continuously prayed for her success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

Finally the author appreciates the assistance rendered by the staff members of the Department of Entomology and central farm, Sher-e-Bangla Agricultural University, Dhaka, who have helped her lot during the period of study.

The Author

SPECIES DIVERSITY OF FLEA BEETLES OF CABBAGE AND ITS MANAGEMENT USING CHEMICAL INSECTICIDES AND BIO-PESTICIDES

ABSTRACT

A field experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Bangladesh during the period from October 2017 to March 2018 to evaluate the available species of flea beetles and their management practices in the cabbage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Nine treatments, viz. T_1 (Sevin 85WP @ 2 g L^{-1} of water at 7 days interval), T_2 (Decis 2.5 EC @ 1 ml L^{-1} of water at 7 days interval), (T_3 (Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval), T_4 (Ripcord 10EC @ 1 ml L^{-1} of water at 7 days interval), T_5 (Dursban 20EC @ 1 ml L^{-1} of water at 7 days interval), T_6 (Tobacco leaf extract @ 3 g L^{-1} of water at 7 days interval), T_7 (Neem seed kernel extract @ 3 g L^{-1} of water at 7 days interval), T_8 (Bioneem plus 1 EC @ 1 ml L^{-1} of water at 7 days interval) and T_9 (Untreated Control) were used. Two species of flea beetle were found in the experimental field, stripped flea beetle (*Phyllotreta striolata*) and white-spotted flea beetle (*Monolepta signata*). It was observed that T_4 treatment performed best in managing flea beetles attacking cabbage based on the lowest percentage of leaf infestation (5.84%), lowest number of holes per plant (6.13), lowest percentage of head infestation by number (18.04) and highest percentage of infestation reduction over control on all parameters at vegetative stage of plant. Again, the lowest leaf infestation intensity (5.73%), lowest number of holes per infested head (14.00), lowest percentage of infestation of head by number (6.69), were achieved at harvesting stage from the same treatment (T_4) whereas the highest values of all these parameters were achieved from untreated control treatment (T_9). T_4 treatment provided the best performance in yield where yield was increased (112.51 %) over control, giving maximum yield 75.76 ton ha^{-1}. Form the study it was found that there is a strong negative relationship between leaf infestation intensity and single head weight and between leaf infestation intensity and yield (t ha^{-1}) of cabbage. Moreover a strong negative relationship was observed between number of holes and weight of individual head and between percent head infestation and weight of individual head.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Cabbage, *Brassica oleracea* var. *capitata* L., is one of the most unique cruciferous winter vegetables grown extensively in tropical and temperate regions of the world (Sarker *et al*., 2002). It is also a well known and widely distributed crop within Asia and has been introduced successfully into parts of Central America, West Africa, America, Canada and Europe (Talekar and Selleck, 1982). Vegetable production in Bangladesh is far below the actual requirements. In 2010-2011, total vegetable (summer and winter season) production area was 645.04 thousand hectares with total production of 1.87 million tons (BBS, 2012). The consumption rate of vegetables in our country is 30 kg/head/yr but in developed countries it is 7-8 times higher (FAO, 2004). FAO (2004) claimed that at least 5% of total calories should have come from vegetables and fruits, which may fulfill the requirement of vitamins and minerals of the body.

In Bangladesh, cabbage is locally known as ‘Badha Kopi’ or ‘Pata Kopi’ and the most common winter vegetable crop grown from seed. It is one of the five leading vegetables in the country which belong to the Cruciferae family. It has been recognized as a very important commercial vegetable to the farmers in providing income and nutrition worldwide (Oruku and Ndungu 2001, Kfir 2004, Lohr and Kfir 2004, FAOSTAT 2007). The medicinal values of cabbage include treatment of constipation, stomach ulcers, headache, excess weight, skin disorders, eczema, jaundice, scurvy, rheumatism, arthritis, gout, eye disorders, heart diseases, ageing and Alzeimer’s disease (Tanongkankit *et al*., 2011).

Cabbage can play a vital role in elevating the nutritional status of Bangladesh, as it is rich in vitamins and minerals such as carotene, ascorbic acid and contains appreciable quantities of thiamin, riboflavin, calcium and iron (Thompson and Kelly, 1985). It has been reported that 100 g of edible portion of cabbage contains 92% water, 24 calories of food energy, 1.5 g of protein, 9.8 g of carbohydrate, 40 mg of Ca, 0.6 mg of Fe, 600 IU of Carotene, 0.05 mg of thiamine, 0.05 mg of riboflavin, 0.3 mg of niacin and 60 mg of vitamin E (Rashid, 1993). Moreover, it is a rich source of vitamins A and C (Prabhakar and Srinivas, 1990 and Tiwari *et al.*, 2003). It may be served in slaw, salads or cooked dishes (Andersen, 2000). The yield produced by cabbage in Bangladesh is 5.9 metric ton/acre and total production across the country is 258608 metric ton /acre (BBS, 2015). 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. However, low yield may be attributed to a number of reasons viz., unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, improper or limited irrigation facilities and due to the attack of insect pests.

Insect pests can play an important role for decreasing the production of cabbage in Bangladesh. Like most of the other vegetables, cabbage is also vulnerable to the attack of several insect pests such as cabbage semilooper (*Trichoplusia ni*), flea beetles (*Phyllotreta* sp.*)* diamondback moth (*Plutella xylostella*), tobacco caterpillar/prodenia caterpillar (*Spodoptera litura*), cutworm (*Agrotis ipsilon*), cabbageworm (*Pieris rapae*), cabbage aphids (*Brevicoryne brassicae)* are major limiting factors (Butani and Jotwani, 1984, Bhat *et al*., 1994). Flea beetles are included in the most important pests of cabbage (Haddock, 1986).

Flea beetle is the common name to an insect of the family chrysomelidae and belongs to the coleopteran. There are various genera and species of flea beetles i.e; Pale striped Flea beetle, Elongate Flea beetle, Hop Flea beetle, Red headed Flea beetle, Three spotted flea beetle, Western black Flea beetle, Toothed Flea beetle etc. They occasionally damage vegetables, flowers, and even trees. Adult’s flea beetle, which produce most plant injuries are typically small often shiny, and have larger rear legs that allow them to jump like a flea when disturbed. And also produce characteristics injury known as ‘shot holing”. When occurring in large numbers can rapidly defoliate and kill plants. The pest if left unabated and in severe infestation can result in total crop failure while moderate infestation leads to at least 25 % foliage damage characterized by “shot holes” on the foliage. Certain flea beetles are considered polyphagous, though many of them attack only one or few closely related plant species (Metcalf *et al*., 1993). The importance of flea beetles as pests is aggravated by the fact that several species also vector plant pathogens (Dillard *et al*., 1998). Some species are vectors of serious diseases such as potato blight and bacterial wilt of corn.

Most flea beetle treatments are applied as foliar sprays to protect the foliage against the feeding of the adult beetle. Among the various control practices in cabbage to suppress the prevalence of flea beetle insecticides are the mostly used. Foliar applied insecticides are effective when beetle populations have reached an economic threshold level and treatments are timed properly. There are many insecticides labeled for treating flea beetles. For conventional growers, pesticides containing pyrethroids or carbamates (Sevin) are generally effective (Vern Grubinger, 2003). Rotenone was often used in the past, but it is not ideal because it is has a relatively high mammalian toxicity and its availability has become limited. Other materials often recommended for farming include neem containing insecticides and neo-nicotinoids. Neem-based insecticides are known for their pesticidal activity against more than 400 species of insects (Siddiqui *et al.*, 2003). However, they are not toxic to humans and many beneficial arthropods, and targeted pests are unlikely to develop resistance; therefore, these insecticides have been advocated to replace synthetic insecticides as they are more sensible to be used in most pest management programs (Isman, 2006 and Irigaray *et al*., 2010).

As occurrence of flea beetle is common in cabbage and causes a great damage or losses to the farmer, so proper management should be done to increase the production as well as the quality of cabbage. Researches on flea beetle species diversity and management are very much scanty in Bangladesh.

Therefore, the present study was undertaken to fulfill the following objectives:

- To know the species diversity of flea beetle infesting cabbage in the field,
- To evaluate some chemical insecticides and bio-pesticides against flea beetle.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is one of the most leading vegetables in Bangladesh which is generally grown in the Rabi season. Vegetable production in the country is far below of actual requirements, so the demand of vegetable is increasing day by day. For this reason horizontal expansion of vegetable yield unit^{-1} area should be increased to meet this ever-increasing demand of vegetables. But vegetables cultivation faces various problems including the pest management. Cabbage is infested by large number of insect pests in the field, which causes significant yield loss in every year to the vegetable growers. Among different insect pests, the flea beetle is one of the most serious pests, which causes significant damage to cabbage every year and causes a great loss to the growers. An attempt has been taken in this chapter to review the pertinent research work related to the present study. But the research work in these aspects so far done in Bangladesh and elsewhere, which are not adequate and conclusive. Nevertheless, some of important and informative works and research findings related to the species diversity and management of flea beetle in cabbage so far been done at home and abroads, is presented below under the following sub-headings.

2.1 General review of flea beetle

2.1.1 Nomenclature

The flea beetle synonym is Leaf beetle.

Common name: Flea beetle

Flea beetles belong to the Coleoptera: Chrysomelidae family and are named for their ability to jump quickly when disturbed.

2.1.2 Systematic position

According to Ohno (1980) fifty thousand species of flea beetles distribute throughout the world. Only two species i.e; Stripped flea beetle (*Phyllotreta striolata*) and White-spotted flea beetle (*Monolepta signata*) classifications are given below as they were found in the research field during the experimental period.

Kingdom:	Animalia	
Phylum:	Arthropoda	
Class:	Insecta	
Order:	Coleoptera	
Family:	Chrysomelidae	
Subfamily:	Galerucinae	
Tribe:	Alticini	
Genus:	*Phyllotreta*	
Species:	*P. striolata*	Fabricius, 1801

Kingdom:	Animalia	
Phylum:	Arthropoda	
Class:	Insecta	
Order:	Coleoptera	
Family:	Chrysomelidae	
Subfamily:	Galerucinae	
Tribe:	Luperini	
Genus:	*Monolepta*	
Species:	*M. signata*	(Olivier, 1808)

2.2 Origin and distribution

Flea beetles are thought to have been introduced from Eurasia. The crucifer flea beetle was first reported in the United States in 1923 (Bonnemaison, 1965) and in Aggasiz, BC in the early 1920’s (Burgess, 1977a) while the striped flea beetle is thought to have been introduced into the United States in the 1700s (Bain and Le Sage, 1998).

According to Chamberlin and Tippins (1948) flea beetle was native to South America. But it was first reported in the United States in 1947 on young cabbage plants. It is now widely distributed in the southeastern United States with major field infestations reported in Alabama, Florida, Louisiana, Mississippi, South Carolina, and Texas (Rohwer *et al*. 1953, Oliver 1956, Balsbaugh 1978, Ameen and Story 1997a). Now it is found throughout the tropical and subtropical parts of the world.

Fan and Huang (1991) included *Phyllotreta* species as serious pest in Taiwan. Flea beetles are commonly found in almost all kinds of habitats. The richest flea beetle communities occur in open spaces near forests or scrublands often associated with rivers or lakes and in various kinds of meadows and prairies. Density and species composition of phytophagous beetles are affected by many factors including vegetation, humidity, temperature and host plants (Konstantinov and Vandenberg, 1996). The striped flea beetle i.e, *Phyllotreta striolata* (F.) (Coleoptera: Chrysomelidae), is the most serious insect pests of canola. In North America, the striped flea beetle was reported from "Carolina" in 1801 and is now widespread across Canada, United States, Mexico, and South America. In Hungary it is common of the leaf beetle assemblages in basswood and maple canopies, but only as visiting or "tourist" species (Van and Visser, 2007). Kimoto (2000) stated that the flea beetles are widely distributed to Holarctic region, India, Nepal, Thailand, Cambodia, Vietnam, China, Taiwan, Indonesia, Japan, Korea etc.

2.3 Host range

Flea beetles mainly prefer plants from Brassicaceae and Resedaceae which grow in cultivated areas, roadsides, orchards, and shrubs (Mohr 1966, Furth 1979, Matsuda 1988, Nielsen 1988). The low density of Brassicaceae in moist habitats may be the reason for limited habitat occurrence of flea beetles. According to Furth (1983), all of the flea beetles prefer plant families that produce mustard oil (or allyl isothiocyanate), which is known as aggregation pheromone of the crucifer flea beetle. The most preferred hosts are in the genus *Brassica* (Cruciferae), which include the major agricultural host attacked by flea beetle, oil rapeseed or Argentine canola *(B. napus)* and Polish canola *(B. rapa/campestris).* Mustard (*Brassica* spp.) and crambe *(Crambe abyssinica)* are also susceptible to flea beetle attack but not preferred over canola. Other hosts that flea beetles will attack in the garden setting are cabbage, turnip, cauliflower, kale, Brussel sprouts, horseradish, and radish. Some weeds attacked in the cruciferous group are flixweed, field pennycress, peppergrass, and wild mustard. Although flea beetles are known to feed in the field on a wide range of cruciferous plants, it appears to show preference for certain cruciferous crops over others (Chamberlin and Tippins 1948, Haeussler 1951, Rohwer *et al*. 1953 and Anonymous 1976).

Chen *et al.* (1990) studied an experiment on the ecology and control of *Phyllotreta striolata* (Fab.) and found that the preferable host of flea beetles are many species of cultivated Brassicaceae, such as the radish (*Raphanus sativus* L.), edible rape (*Brassica chinensis* var. *oleifera* Makino), pak-choi or ching-geen (*B. rapa chinensis* L.), mustard (*B. juncea* Cosson), and cabbage (*B. oleracea* var. *capitata* DC.)

2.4 Seasonal abundance

Teodora *et al* (2009) conducted an experiment about the seasonal activity of flea beetle in Bulgaria. They observed the seasonal activity of flea beetle was to be similar in consecutive two years in 2006 and 2007. Low catches of *Phyllotreta sp*. adults of the overwintering generation were recorded from April until the middle of June. The emergence of the beetles of the new generation started at the end of June to beginning of July and the most numerous catches were observed in July. Last catches in the traps located in the cabbage field were recorded at the end of October while a few specimens were caught in the half of November in the traps placed at horse radish plots. The remarkable reduction in the number of the *Phyllotreta sp*. at the end of August 2006, more probably, is due to the heavy rainfalls at the end of August.

In Europe and North America, the majority of *Phyllotreta* have usually one generation per year (Bonnemaison, 1965). However, partial second generations of *Phyllotreta sp.* have been reported for Manitoba and Ontario, Canada (Westdal and Romanow 1972; Kinoshita *et al.* 1979), and Massachusetts, Northeastern United States (Andersen *et al*., 2005) in some particular years.

Kinoshita *et al.* (1979) reported that the patterns of abundance of overwintering and summer generations of *Phyllotreta* sp. in cabbage crop were very similar, with summer generations being more numerous than overwintering ones. These differences in the abundance of overwintering and summer generation flea beetles are due mainly to several reasons. First, unfavourable weather conditions during emergence can influence the population size of the overwintering generation in the spring.

Oliver and Chapin (1983) conducted an experiment on flea beetle seasonal activity and found that the restriction of each flea beetle species to one habitat may be temporary or accidental. In Alabama, flea beetle is a multivoltine cool season pest that typically occurs in vegetable fields from October to May. He also observed that fall activity usually started in early October when adult beetles migrate in mass numbers from summer aestivation sites (wild mustard plants) into cruciferous crops.

Burgess (1981) and Ulmer and Dosdall (2006) stated that the type of the overwintering site also has an important role on *P. stirolata* emergence; significantly higher numbers of flea beetles emerged from sheltered locations than from grassy areas. On the other hand, phenological synchrony of the new generation with growth of late cabbage and the migration of flea beetles from cruciferous weeds to newly planted crops may be factors determining abundance of summer generation flea beetles. Such pest/host plant synchrony was observed between *Ceutorhynchus* *assimilis* (Curculionidae) and *M. aeneus* populations and oilseed rape growth (Veromann *et al*., 2006a, b). Synchrony between the phenology of the insect herbivores and that of the host plant has a major impact on the population densities of many leaf-feeding insects (Eber 2004; Van and Visser 2007).

Temperature and wind orientation had significantly positive correlations with the dispersion of *P. striolata* (Fabricius, 1803) beetles, while humidity weakly influenced their activity (Gao *et al.,* 2005). Low temperatures in the winter and high temperatures in the warm season had a negative effect on populations of flea beetles (Cárcamo *et al*. 2008; Gao *et al*. 2005). However, Shukla and Kumar (2003) showed that, in India, flea beetle population had a negative correlation with mean temperature, while positively correlated with mean relative humidity.

According to Teodora *et al.* (2009), decreasing of the number of the flea beetles in the spring caused by complex environmental factors (weather conditions, emergence habitat, food quality, natural enemies) can be a possible reason for the non-significant relationship between the climatic factors investigated and the catches of the overwintering generation of *Phyllotreta* sp. Flea beetles overwinter as adults and become active during early spring. Field monitoring for flea beetle activity should begin in newly emerged fields during May and June when air temperatures reach 57°F (14°C).

2.5 Infestation status or symptoms

Adults feed on the leaves, creating small, round pits “shot holes” (Al-Doghairi, 1999) that cause most of the damage to the crop, while larvae are root-feeders and do not cause economic damage. There are several species of flea beetles associated with cruciferous crops, of which the most common species found on cruciferous vegetables in northern Italy is *Phyllotreta* sp. (Goeze) (Dalla Montà *et al*., 2005). Adult flea beetles overwinter in weeds or plant debris and emerge from overwintering sites in early spring and this coincides with the seedling stage of the host plants. Flea beetle often feed in groups, responding to a male-produced aggregation pheromone (Peng *et al.*, 1999), and can cause severe damage to young seedlings. Adult feeding on young seedlings results in reduced crop stands and plant growth, delayed maturity, and lower seed yield. When flea beetle populations are large and warm, sunny, dry, calm conditions favor severe infestation in the fields quickly.

The characteristic type of flea beetle injury to plants consists of small holes or pits in the epidermis of leaves. Damage occurs when adults feed on cotyledons and stems of seedlings, resulting in reduced photosynthetic capability, wilting, or host plant mortality (Westdal and Romanow, 1972). This feeding continues as the plant grows but is less detrimental as the plant is able to compensate (Gavloski and Lamb, 2000). Less severe infestations may result in stunted plants, uneven stands and maturation, and harvest problems. When weather conditions are cool, wet, and windy, flea beetles may creep slowly into the field and concentrate feeding on the field edges. The first 20 days after emergence is the most crucial period for canola development, as flea beetle feeding has been shown to reduce yield potential even at low pressure during that time (Bracken and Bucher, 1986).

2.6 Species diversity

The Chrysomelidae are one of the most diverse insect groups, particular in tropical forests. There are at least 35,000 species recorded in this beetle family according to more conservative estimation or more than 60,000 according to more progressive ones (Reid 1995a). Since a long time, this beetle group has drawn a lot of attention in research especially in taxonomy, systematics, ecology and biogeography, as well as molecular studies in present days (Sota & Hayashi 2004, Nokkala & Nokkala 2004, Cox 1996, Gómez- Zurita *et al.* 2007, Stapel *et al.* 2008, Gross & Schmidtberg 2009, Mohamedsaid 2009, 2011). Being phytophagous, chrysomelids include many established and potential agricultural pests. Besides their agricultural significance, the biodiversity of leaf beetles is also a direct indicator of diversity in ambient flora.

Alticinae is the largest subfamily of chrysomelidae, generally know as flea beetles and can be distinguished from other Chrysomelidae by their greatly enlarged hind femora (Furth 1988). It is represented by 59 genera and more than 1,000 species in the Palearctic Region (Konstantinov and Vandenberg, 2010).

According to Ohno (1980) fifty thousand species of flea beetles distribute throughout the world. There are over 4000 species of flea beetles worldwide affecting numerous plant species from vegetables, field crops and weeds (Konstantinov and Vandenberg, 2010). One generation per year is common in the Canadian prairies (Knodel and Olsen, 2002), although multiple generations have been reported in some places such as Ontario (Kinoshita *et al*., 1979). Three species of flea beetles are reported from Nepal: *P. cruciferae, P. nemorum and Monolepta signata* (Vaidya, 1995).

2.7 Morphology of flea beetle

According to Aston (2009) Chrysomelidae beetles can be distinguished by the combination of following characters: tarsi 4 segmented (Pseudo tetramerous), antennae longer than papls, elytra always covering abdomen only occasionally exposing pygidium. The adult of flea beetle is a small, oval-shaped, blackish beetle with a bright blue sheen on the elytra, measuring about 1/32 to 1/8 in. (2-3 mm) in length. Flea beetles have enlarged hind femora (thighs) on their hind legs, which they use to jump quickly when disturbed. Their name flea beetles arose from this behavior.

Phyllotreta cruciferae adults are 2 to 3mm, dorsally flat, elongate oval, black with a bright blue lustre and have enlarged hind femoras (thighs). The eleven antennae segments are similar in both sexes with the fifth segment not much different from the sixth. The Striped flea beetle adults are similar in size and shape to the crucifer flea beetle, but they are black with two yellow stripes on their wing covers (Burgess, 1977a).

Phyllotreta striolata

Phyllotreta striolata adults are 2 to 2.5mm, dorsally flat, elongate oval, black and have enlarged hind femoras. Each elytron, which is a modified hardened forewing, has a distinctive pale yellow stripe that is wavy along its outside margin and curves towards the middle near the ends of the elytra (Tansey, 2007). The yellow stripes do not reach the posterior elytral margins, distinguishing *P. striolata* from another flea beetle, *P. robusta* (Burgess, 1977a). The two species are found to coexist in most areas with similar host preferences and requirements although *P. cruciferae* has been the predominant species (Burgess, 1977a), recently *P. striolata* is becoming more predominant (Tansey *et al.*, 2008).

Monolepta signata

Members of this genus are generally ovate, moderately convex, slightly narrowed in front and behind, dorsal surface smooth, shiny and finely punctured, segment 1 of hind tarsi markedly long and claws are appenndiculate.

General appearance oblong, narrow, small (2.5mm) and pale yellowish, antennae short and extending upto the middle of elytra. Prothorax broader than long, posterior angles rounded, surface is finely punctuates. Elytra pattern similar to signata but its suture being pale yellowish, punctration fine and confused.

General appearance oblong-ovate, moderately convex and dorsa, surface shiny with fine punctures; head, pronotum and abdominal sternites reddish brown, antennae long and blackish with three basal segments brown, elytra usually pale brown with black stripes and a transverse band across the middle.

2.8 Biology and life cycle of the flea beetle

Despite of flea beetles economic importance and impact on vegetable production, very little research has been conducted on the biology and ecology of flea beetle. Most of the present information on the biology flea beetle was compiled from

European literature since the species has been little investigated in North America. In the Europe, flea beetles over winters as adults which emerged at the end of March and the beginning of April when the temperature is 8-9 degrees Celsius. They search for appropriate host plants, and the feeding flea beetle is characterized by numerous small holes bordered by a narrow line of dead brown leaf (Jourdevil, 1993). Both major species of flea beetles have one life cycle per calendar year, however, if the conditions are right, two cycles may be possible (Westdal and Romanow, 1972).

In Taiwan, *P. striolata* (Fabricius) is a notorious pest of cruciferous vegetables. Chen *et al*. (1990) published detailed information on its biology. Adults feed on the foliage of host plant and produce small round holes. The species is multivoltine, and the larvae are generally root feeders. Pupation takes place in the soil.

According to Whiting and Wilson (2002) flea beetles over winter as adults under soil and leaf litter in brushy or woody areas surrounding fields, rather than in grassy areas right next to fields. They emerge in early spring when temperatures reach about 50 degrees, feeding on weeds or crops, if available. Females soon lay their eggs in the soil at the base of these plants. Eggs hatch in a week or two and the larvae feed on plants until fully grown. Then they pupate in the soil for 11 to 13 days before emerging as adults. Delaying the planting dates of susceptible crops until after the over wintering beetles have emerged is one way to reduce damage to young plants.

Phyllotreta sp. overwinters as adults in the soil or leaf litter near damaged cruciferous fields. Early in the spring, the beetles emerge from hibernation sites and feed on leaves of various cruciferous weeds. Later, they migrate to the seedlings of newly planted crops for further feeding (Popov and Nikolova, 1958). According to Mihailova *et al*. (1982), the species of this genus have one or two generation per year in Bulgaria.

According to Popov and Nikolova (1958) and Mihailova *et al.* (1982), the beetles of the overwintering generation of *Phyllotreta sp*. emerge from the end of March to beginning of May, and the most damage occurs in May. When climatic conditions are appropriate, flea beetles can appear as early as February (Gruev and Tomov, 1998). According to Mihailova *et al.* (1982), the emergence of the flea beetles in the spring in Bulgaria starts when the daily temperature exceeds 15°C. Prior to our first inspections of traps in 2007 (no temperature data for March, 2006 were available), daily temperature exceeded 15°C on 5, 18, 19 and 20th March; therefore, According to Grigorov (1972); Gruev and Tomov (1986) and (1998) adults of the new generation of *P. cruciferae*, *P. stirolata* and *P. nigripes* occur from July to the end of October–beginning of November, which corresponds again with our results. When the adult lays eggs in soil from the end of May onwards, the hatched larvae feed on either roots or leaf. Nevertheless, larval damage is not so severe as that of the adults (Evans, 2003). They overwinter as adults in the leaf litter of shelterbelts or grassy areas and are rarely found in canola stubble. Beetles emerge when temperatures warm up to 57°F (14°C) in early spring. They feed on volunteer canola and weeds, such as wild mustard, and move to newly planted canola as it emerges. Depending on the temperature, it may take up to three weeks for the adults to leave their overwintering sites.

Evans (2003) stated that the striped flea beetle adults usually emerge before the crucifer flea beetle. Warm, dry, and calm weather promotes flea beetle flight and feeding throughout the field, while simultaneously slowing canola growth. In contrast, cool, rainy, and windy conditions reduce flight activity, and flea beetles walk or hop leading to concentrations in the field margins. Females oviposit up to 25 eggs in the soil in June. The overwintered adults continue to remain active until late June and begin to die off in early July. Larvae hatch from the eggs in about 12 days and feed on the secondary roots of the plant. Larvae pass through three instars and complete their development in 25 to 34 days by forming small earthen puparium. The pupal stage lasts for about seven to nine days, usually in early to mid-July. The new generation adult emerges from the puparium beginning in late July until early September and feed on the epidermis of green foliage and pods of canola, mustard, and cruciferous weeds. The crop is usually mature enough that feeding damage is minimal. In early fall beetles move to overwintering sites.

Adult flea beetles overwinter primarily in leaf litter and surrounding shelterbelts (Burgess, 1977a, 1981; Wylie, 1979). They emerge in the spring, becoming active at 14ºC. Flea beetle activity is greatest in the spring when the weather is sunny, warm and dry. Cool, damp conditions can reduce the feeding intensity of the beetles and aid plant growth to the point where they can withstand the feeding damage (Burgess, 1977a). After emergence in the spring, flea beetles mate, lay their eggs in or on the soil and then die in late June or early July. The larvae develop in the soil and have been shown to feed on the roots of the host plants (Burgess, 1977a). Damage by larvae has been shown to be significant (Bracken and Bucher, 1986) but has not been studied extensively. Pupation occurs in late June into July with the new generation of adults emerging in late July and August (Westdal and Romanow, 1972). The new generation of flea beetles is known to feed on green, maturing Brassica crops, removing the epidermis of the stems, leaves, and pods, thus stunting the growth of the seeds (Burgess, 1977a). This late season damage is not usually significant but may lend the host plant to increased susceptibility to secondary infection.

Eggs

Eggs are yellow, oval, and about 0.38-0.46 mm long by 0.18-0.25 mm wide, and deposited singly or in groups of three or four adjacent to the host plant's roots.

In spring, one to four eggs, about 0.4mm long by 0.2 mm wide, oval and light yellow, are deposited near the bases of host plants.

Larvae

Larvae are small approximately 1/8 in. or 3 mm, whitish, slender, cylindrical worms. They have tiny legs and a brown head and anal plate.

Mature larvae are approximately 3mm, white to very light brown with a copper-brown head and anal plate and are slender with small legs. Larvae feed on roots and root hairs and pupate in soil, emerging in late summer.

Pupae

Pupae are similar in size to the adult and white in color except for the black eyes and the free body appendages, which are visible later in the pupal development.

2.9 Nature of damage

Whiting and Wilson (2002) conducted an experiment on flea beetle and observed that adult flea beetle feed externally on plants, eating the surface of the leaves, stems and petals. Under heavy feeding the small round holes caused by an individual flea beetles feedings may coalesce into larger areas of damage. Some flea beetles are root feeders. In adverse weather conditions some flea beetles seek shelter in the soil. Some species, such as *Phyllotreta cruciferae* and *striolata*, prefer to leave their hide out only during jumping ability and this behavior of hiding in the soil.

Flea beetles cause direct and indirect damage to cultivated plants. Direct damage is caused by both larvae and adults. Larvae injure roots or mine leaves while adults gnaw small pits or holes on the upper epidermis and parenchyma of the leaves. During the heavy infestations pitted areas merge and form larger holes on the leaves; later such leaves wilt and this can lead to delay in plant growth and yield reduction (Popov and Nikolova, 1958). Flea beetle larvae and adults also cause indirect damage by transmission of plant pathogens from infected cruciferous plants to healthy ones during feeding (Dillard *et al*. 1998; Glits 2000; Ryden 1989, 1990; Saharan *et al*. 2005; Shelton and Hunter 1985 and Stobbs *et al*. 1998).

2.10 Management

Flea beetle causes a serious damage or yield loss when a suitable seed treatment and/or foliar application is not applied (Knodel *et al.*, 2008). Flea beetles have been estimated to cause about a 10% reduction in yield (Lamb and Turnock, 1982). In particular, flea beetle poses a major threat to organic production of cruciferous crops in the southeastern United States because only very few effective organically acceptable management tactics have been identified for flea beetle (Balusu and Fadamiro, 2011).

Flea beetle management involves several aspects of a typical pest management strategy. These include cultural, biological, chemical and genetic control of the pest etc. Current control options for flea beetles consist primarily of seed dressing and the foliage application of broad spectrum insecticides which may create environmental as well as health hazards. Further, since pesticides are not persistent, reinvasion of the host plants after spraying can be rapid and even repeated treatment can fail to give adequate control (Howard & Parker 2000; Hiiesaar *et al*. 2006).

Insecticides application (seed treatments and foliar sprays) is preferred and considered the most efficient control method for the protection of crops from flea beetles infestations. Several alternative control measures have been recommended and developed for flea beetle management. These are determination of the optimal seeding/cropping date, crop rotation, mixed cultures, use of trap crops, row covers, application of natural insecticides (diatomaceous earth, plant extracts or products, buffalo urine, cow urine) and of organic fertilizers, keeping fields free of weeds, destroying plant residues and so on. (Altieri and Nicholls 2003; Andersen *et al*. 2006; Cárcamo *et al*. 2008; Dosdall and Stevenson 2005; Garcia and Altieri 1992; Subedi and Vaidya 2003; Tahvanainen and Root 1972; Trdan *et al.* 2005). One of the important preconditions for a proper and successful insect control in plant protection is knowledge of the life cycle and periods of pest appearance in conjunction with climatic factors.

2.10.1 Management with botanicals

The commonest pest control method is usually by the application of synthetic insecticides that are unfortunately dangerous to the ecosystem. Despite their efficiency in reducing insect pests, synthetic insecticides are associated with major problems such as environmental pollution, soil toxicity, effect on non-target organisms, pest resurgence, pest resistance and residual effects (NRC, 1992). Though decisive in their action against pests, the use of synthetic insecticides apart from being expensive, cause mammalian toxicity, environmental pollutions and in some cases develop genetic resistance in treated insects thereby leading to insect pest emergence and resurgence (Yar' adua *et al.*, 2007). Neem is well known in India and its neighbouring countries where for 2000 years it was one of the most versatile medicinal plants, having a wide spectrum of biological activity (Alves *et al.,* 2009; Atawodi and Atawodi, 2009). Highly concentrated azadirachtin is the main active ingredient in neem and is mainly found in the seed (NRC, 1992). Azadirachtin is extracted from compressed neem seeds, concentrated, and purified, azadirachtin are pest repellent sprayed on to leaves diluted with water.

Kwaifa *et al.,* (2014) conducted a research entitled Insecticidal Effects of Neem Kernel Extracts on Flea Beetle (*Podagrica uniforma* J.) Of Okra (*Abelmoschus esculentus* L.) in Jega, Kebbi, Nigeria and stated that synthetic insecticide conferred more protection on okra against flea beetles, neem kernel extract also significantly reduced infestation and population of beetles on okra in the field by conferring different levels of protection to the leaves, flowers and pods of okra. Therefore, neem kernel extract could be a potential alternative for insect control in okra production.

2.10.2 Management with chemical insecticides

Foliar applied insecticides are effective when beetle populations have reached an economic threshold level and treatments are timed properly. Chemical control is the primary control defense against flea beetles in North America, with more than 99.5%

of the Canadian canola acres treated with systemic insecticidal seed treatments (Sekulic and Rempel, 2016). These seed treatments last up to 40 days. After that, foliar post-emergent sprays are used. Post-emergence sprays applied to plants after some exposure to flea beetle damage are generally less effective in preventing yield loss than in-furrow or seed treatments that provide continuous protection during and after germination (Bracken and Bucher, 1986). Today's options are primarily neonicotinoids where older technology is pyrethrin-based. Recent reports (Tansey *et al*., 2008, 2009) have shown a species differentiation in effectiveness of neonicotinoid seed treatments. With increasing environmental concerns and bans (Health Canada, 2016; Ontario, 2016) along with the persistence of flea beetle pressure, alternate, non-chemical control would be preferred, although seed treatments are relatively easy to apply and highly effective for the time being.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the central farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from October, 2017 to March, 2018. It was conducted to evaluate of the species diversity of flea beetle in cabbage and its management practices in the field. The details materials and methods that were used to conduct this experiment are represented below under the following headings:

3.1 Location of the experimental field

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

3.2 Climate of the experimental field

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). The average maximum and minimum temperature were 29.45ºC and 13.86º C repectively during the experimental period. In our country rabi season in characterized by plenty of sunshine. Meteorological data which are related to the temperature, relative humidity and rainfall during the experimental period was collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and has been presented in Appendix II.

3.3 Soil of the experimental field

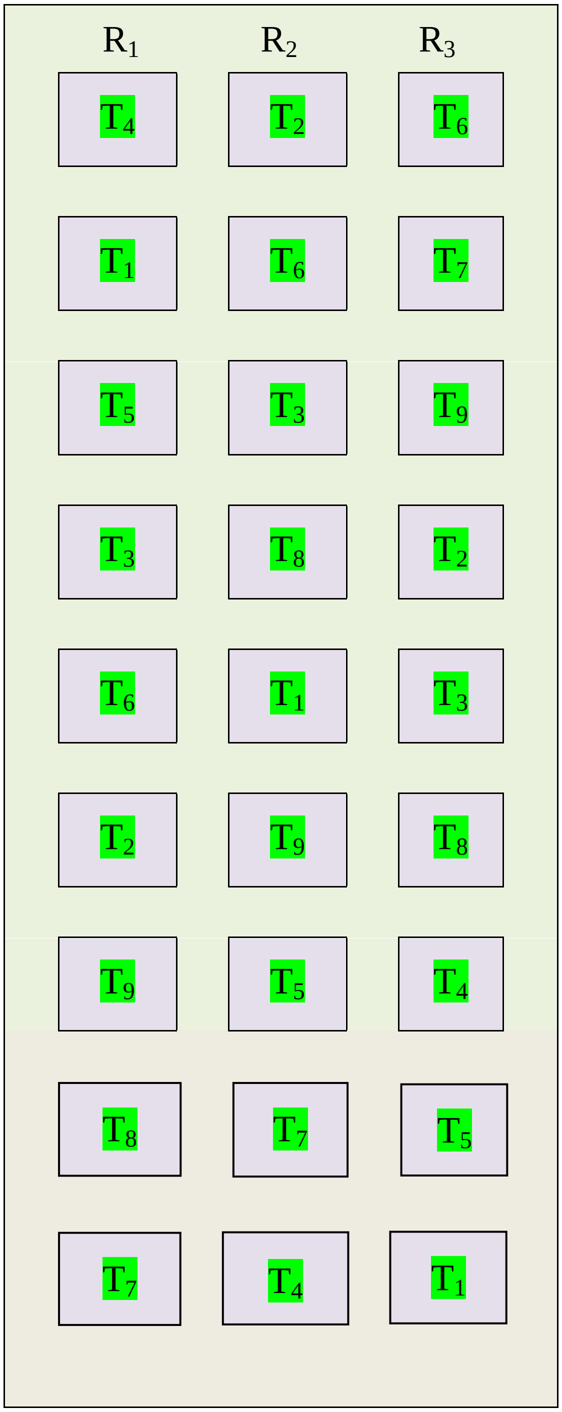
The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) corresponding AEZ No. 28 and is shallow red brown terrace soil. The land of the selected experimental plot is medium high under the Tejgaon series (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Dhaka and has been represented in Appendix III.

3.4 Planting material

The test crop used in the experiment was cabbage variety Atlas-70. It is an imported high yielding variety with average yield 55-60 t/ha^{-1}. The seeds were collected from the local market.

3.5 Experimental Design and Layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in the central farm. The field with good tilth was divided into 3 blocks. The layout of the experiment was prepared for distributing all of the treatments. Each experiment consists of total 27 plots of size 2.5 m × 1.6 m. The layout of the experiment is shown in Figure 1.



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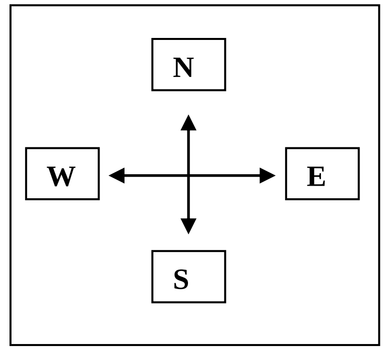

Treatments:

T_1 = Sevin 85WP @ 2.0 g/L of water
T_2 = Decis 2.5 EC @ 1.0 ml/L of water
T_3 = Voliam flexi @ 0.5 ml/L of water
T_4 = Ripcord 10 EC @ 1.0 ml/L of water
T_5 = Dursban 20 EC @ 1.0 ml/Lof water
T_6 = Tobacco leaf extract @ 3.0 g/L of water
T_7 = Neem seed kernel extract @ 3.0 g/L of water
T_8 = Bioneem plus 1 EC @ 1.0 ml/L of water
T_9 = Untreated control

Plot size: 2.5 X 1.6 m^2

Plant spacing 60cm X 40cm

Plot to plot distance = 0.5 m

Block to block distance = 1 m

Replication = 3

Figure 1. Layout of the experimental plot.

Plate 1. Experimental field of cabbage during the study period.

3.6 Land preparation

The selected plot of the experiment was opened in the 1st week of November 2017 with a power tiller and left exposed to the sun for a week. Subsequently several times cross ploughing was done with a country plough followed by harrowing and laddering to make the land suitable for growth of cabbage seedlings. All weeds, stubbles and residues were eliminated from the experimental field. Finally, a good tilth was obtained for proper growth and development of cabbage. The Field layout was done on according to the design, after land preparation. The plots were raised by 10cm from the soil surface keeping the drain around the plots.

3.7 Manuring and fertilization

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers were applied according to the the recommended fertilizer doses for cabbage production per hectare by BARI (2005). (Table 1)

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

Fertilizers and Manures	Dose/ha	Application (%)			
		Basal	10 DAT	30 DAT	50 DAT
Cowdung	20 ton	100	---	---	---
Urea	300 kg	--	33.33	33.34	33.33
TSP	150 kg	100	---	---	---
MoP	150 kg	100	---	---	---

The total amount of cowdung, TSP and MoP was applied as basal dose at the time of land preparation. The total amount of Urea was applied in three installments at 10, 30 and 50 day after transplanting (DAT).

3.8 Raising of seedlings

The seedlings were raised in 3 m × 1 m size seed bed under special care at SAU central farm, Dhaka. The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and to obtain good tilth to provide a favorable condition for the vigorous growth of young seedlings. Weeds, stubbles and dead roots of the previous crop were removed. The seed bed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off disease. To control damping off disease Cupravit fungicide were applied. Decomposed cowdung was applied in prepared seed bed 10 t/ha. Ten (10) grams of seeds were sown in seedbed on October 15, 2017. Before sowing the cabbage seeds were soaked for half an hour in water for rapid and uniform germination. After sowing, the seeds were covered with fine light soil. At the end of germination shading was done by bamboo mat (chatai) over the seed bed to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding was done as and when necessary to provide seedlings with an ideal condition for crop growth.

Plate 2. Cabbage seedlings in the seedbed.

3.9 Transplanting

Healthy and uniform seedlings of 28 days old were transplanting in the experimental plots on 15 November, 2017. The seedlings were transferred carefully from the seed bed to experimental plots to avoid damage to the root system. To minimize the damage to the roots of seedlings, the seed beds were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. A total of 16 seedlings were transplanted in each plot. Seedlings were transplanted in the plot with distance between row to row was 60 cm and plant to plant was 40 cm. The young transplanted seedlings were provided shade by banana leaf sheath during day to protect them from scorching sunshine and continued up to 7 days until they were set in the soil. Plants were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots if these were needed for gap filling.

3.10 Intercultural operations

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

3.10.1 Gap filling

The transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and that seedling were replaced by new seedlings from the stock. Replacement was done with healthy seedling having a boll of earth which was also planted on the same date by the side of the unit plot. The transplanted seedlings were given shading and watering for 7 days for their proper development.

3.10.2 Weeding

The land of the each plot was kept free from weeds and four times weeding was done. The first weeding was done after 15 days of transplanting and the remaining weeding was done after 30, 45 and 60 days of transplanting. Weeding was done by uprooting and using with mechanical weed control method.

3.10.3 Irrigation

Light watering was given by a watering can at every morning and afternoon after transplanting. Following transplanting and it was continued for a week for rapid growth and well establishment of the transplanted seedlings. Beside this, a routine irrigation was given at 3 days intervals.

3.10.4 Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

3.11 Treatments used for management

Treatments used

T_1 = Sevin 85WP (Carbaryl) @ 2.0 g L^{-1} of water at 7 days interval;

T_2 = Decis 2.5 EC (Deltamethrin) @ 1.0 ml L^{-1} of water at 7 days interval;

T_3 = Voliam flexi (Thiomethoxam + Chlorantraniliprole) @ 0.5 ml L^{-1} of water at 7 days interval;

T_4 = Ripcord 10EC (Cypermethrin) @ 1.0 ml L^{-1} of water at 7 days interval;

T_5 = Dursban 20EC (Chloropyriphos) @ 1.0 ml L^{-1} of water at 7 days interval;

T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval;

T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval;

T_8 = Bioneem plus 1 EC (Azadiractin) @ 1.0 ml L^{-1} of water at 7 days interval;

T_9 = Untreated control

3.12 Preperation of Tobacco leaf extract

Tobacco leaves (Plate 3 A) were collected from market. After bringing to the laboratory, they were washed in running water and dried in shade. Dust was prepared by pulverizing the dried leaves in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust (Plate 3 B). The dusts were preserved in airtight condition in polythene bags and were used after mixing with water @ 3 g L^{-1} of water.

3.13 Preparation of neem seed kernel extract

Neem seed kernels were collected from the field of Sher-e-Bangla Agricultural University, Dhaka. After bringing to the laboratory, they were washed in running water and dried in shade (Plate 4 A). Dust was prepared by pulverizing the kernel in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust (Plate 4 B).

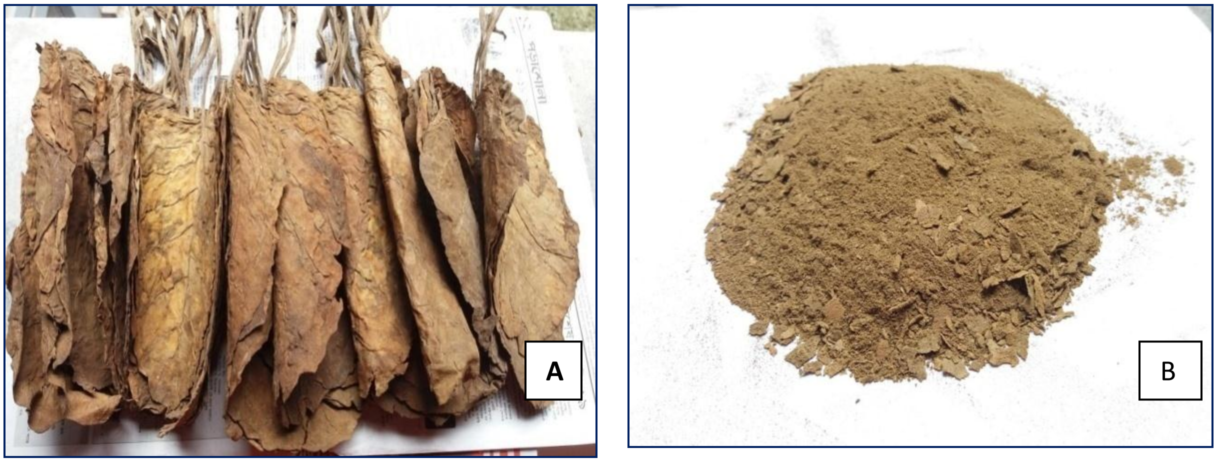

Plate 3. Dried tobacco leaf **(A)** and Tobacco leaf extract **(B)**

Plate 4. Dried neem seed **(A)** and neem seed kernel extract **(B).**

3.14 Sampling

However, sweep net sampling, which is usually applied to assess population size of the harmful stage of many agricultural pests is not suitable for flea beetle monitoring because the beetles can move into the field quickly, which is connected with the presence of meta femoral spring (Furth, 1988). For sampling of flea beetle sweeping net was used due to lack of other sampling method.

3.15 Preservation of insects

The available species of flea beetles were collected from the research field. In the laboratory, specimens were pinned, dried, labeled and kept in collection boxes. The specimens were identified to species under microscope using the taxonomic keys of Maulik (1936) and Aston (2009). The photographs were taken using microscope attached with Samsung J5 mobile camera.

3.16 Species identification

Species identification was according to mainly external marks such as colours and patterns of the elytrae, the shape of the yellow patterns, punctation of the head and the forehead, presence or absence of metallic shade on the back of the prothorax and the elytrae, the specific colour of the elytrae, the shape of the prothorax, the punctation of the elytrae, the colour of the segments of the antenna, the tibia and the tarsus (Kaszab 1962; Gruev and Tomov, 1986).

3.17 Application of insecticides

Different treatments were used after 10 days after transplanting (DAT) following 7 days interval with the recommended doses.

3.18 Data collection

The cabbage plants were closely examined at regular intervals commencing from 15 days after transplanting (DAT) to harvesting of cabbage head. Flea beetles infestation were recorded at 15, 25, 35, 45 and 65 DAT. Data of the yield attributing characters of cabbage like diameter of head, height/thickness of head, weight of head and yield (ton ha^{-1}) was also recorded after harvesting.

3.19 Level of infestation

The number of holes, uninfested and infested leaves and plants of cabbage caused by the flea beetles were counted. The observations were recorded at the first observation of no. of holes, damage leaves and plants and were continued up to harvesting stage of the cabbage at 10 days of interval. The data on the yield was also recorded. The level of leaf and plant infestations per plant and plot respectively was then calculated using the following formula:

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

3.20 Insect infestation percentage on head

The infested heads was calculated at vegetative and harvesting stages using the following formulae:

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

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

3.21 Yield

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

Percent increase of yield over control

$$= \frac{\text{Yield of treated plots - Yield of control plots}}{\text{Yield of control plots}} \times 100$$

Percent decrease of yield over control

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

3.22 Harvesting

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

3.23 Statistical analysis

The data collected on different parameters were compiled and tabulated for statistical analysis. Statistically analysis was done using the MSTAT computer package program. Mean values were ranked and compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

Plate 5. Cabbage plant infested by flea beetle.

Plate 6. Completely healthy head of cabbage.

Plate 7. After harvesting healthy marketable cabbage from the experimental field.

CHAPTER IV

RESULTS AND DISCUSSIONS

The study was conducted to evaluate the species diversity and management practices of flea beetle attacking cabbage in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2017 to March, 2018. The findings of the study have been interpreted and discussed under the following sub-headings:

4.1 Available flea beetle species in the cabbage field:

In the experimental cabbage field two species of flea beetles were identified. They were stripped flea beetle (*Phyllotreta striolata*) and white-spotted flea beetle (*Monolepta signata).*

4.1.1 Stripped flea beetle (*Phyllotreta striolata*)

Phyllotreta striolata belongs to the sub family Alticinae. Insects belong to Alticinae sub-family have the following characters:

General appearance usually oval or elongate, small to medium sized. Head exposed, antennae usually long and selendes, inserted on the frons between the eyes and rather closely situated. Prothorax broad, emarginated in front and lateral sides usually distinctly margined. Front coxae usually not conically prominent and their cavities open or closed behind. Hind leg markedly developed and tibiae with a distinct apical spur. *Phyllotreta striolata* adults are 2 to 2.5mm, dorsally flat, elongate oval, black and have enlarged hind femoras. Each elytron, which is a modified hardened forewing, has a distinctive pale yellow stripe that is wavy along its outside margin and curves towards the middle near the ends of the elytra. The yellow stripes do not reach the posterior elytral margins (Plate 8). It is easily distinguished from other flea beetle species by its black coloration and yellow stripes on elytra.

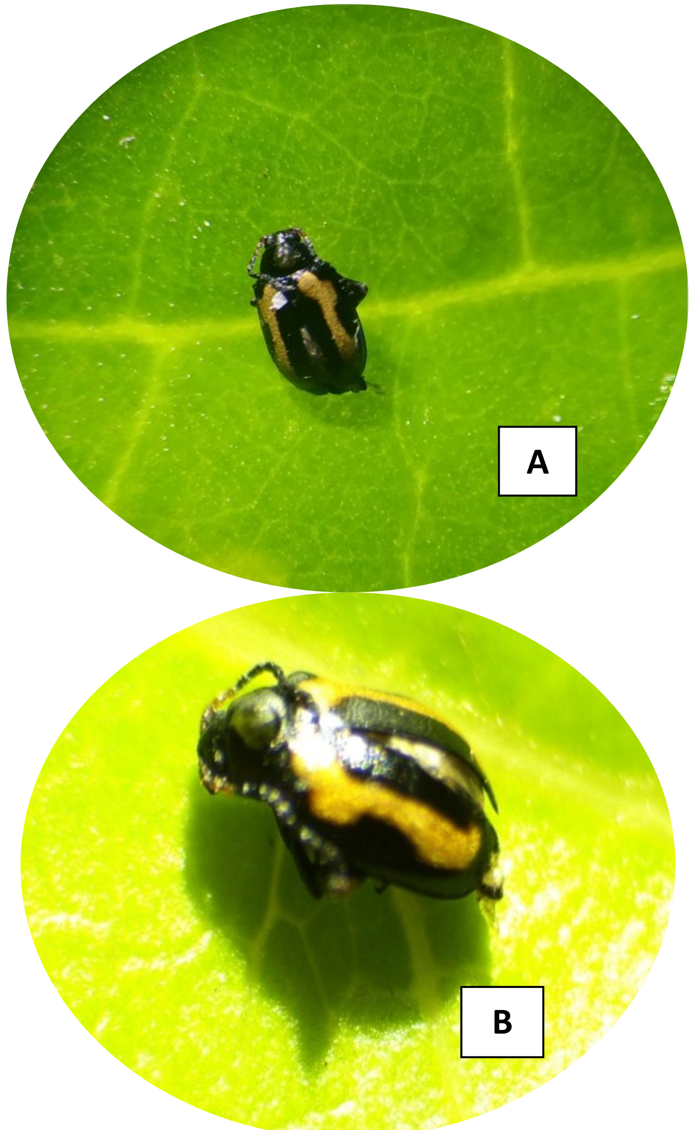

Plate 8. Stripped flea beetle (*Phyllotreta striolata* **)**

4.1.2 White-spotted flea beetle (*Monolepta signata*)

Monolepta signata belongs to Galerucinae subfamily of Chrysomelidae family. Monolepta is the largest genus of the subfamily Galerucinae, Maulik (1936) included 78 species from the Indian subregion. In the present study 1 species of *Monolepta* is recorded from SAU. Members of this genus are generally ovate, moderately convex, slightly narrowed in front and behind, dorsal surface smooth, shiny and finely punctured, segment 1 of hind tarsi markedly long and claws appenndiculate.

The single specimen studied here *M. signata* (oliver) having antennae short and pale yellowish, scutellum boarder than long with the apical margin broadly rounded, elytral puncturation fine and the sutural margin pale yellowish. No attempt is made here to establish this sole specimen as a new species. General appearance oblong, narrow, small (2.5mm) and pale yellowish. Antennae short and extending up to the middle of elytra. Prothorax broader than long, posterior angles rounded, surface is finely punctuates. Elytra pattern similar to signata but its suture being pale yellowish, punctration fine and confused (Plate 9).

Head is reddish brown. Antennae are extending almost to the apex of elytron and club shapped. The antennal segments are blackish except the three basal segments which are brown. Pronotum reddish brown and scutellum black. Elytra pale yellow with black pattern as follows: margins all around narrowly stained, a stripe along suture, humerous completely covered, a median transverse band extended considerably in a horizontal direction (sometimes occupying a large portion of the elytral surface). Markings on elytra black. Legs and abdominal segments are reddish brown. Posterior tarsus is very long (Plate 9).

Monolepta signata varies from small to medium-sized. According to wide geographical distribution, this species shows a high variety in coloration pattern. Characteristic are the brownish to black elytron with circular humeral and preapical yellow spots and most significantly *M. signata*, head and pronotum bear same coloration, usually pale brown to reddish brown.

Plate 9. White-spotted flea beetle (*Monolepta signata*)

4.2 Percent leaf infestation by number at different days after transplanting

The significant variations were observed among the different treatments used for the management practices in terms of percent leaf infestation by number due to attack of flea beetle at different days after transplanting (DAT).

At 15 DAT, the highest leaf infestation by number (18.63%) was recorded in T_9 (untreated control) which was statistically different from all other treatments followed by T_2 (11.67%) comprised of Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_7 (11.18%) comprised of Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval (Table 2). On the other hand, the lowest leaf infestation (2.26%) was observed in T_4 comprised of Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval which was statistically different from all other treatments followed by T_6 (5.17%) comprised of Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_8(6.10%) comprised of Bioneem plus 1 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3(8.88%) comprised of Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_1(10.54) comprised of Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval and T5(10.88%)

comprised of Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval. At 25 DAT, the highest leaf infestation (32.38%) was recorded in T_9 comprised of untreated control which was statistically different from all other treatments followed by T_7 (20.69%) and T_5 (19.66%) (Table1). On the other hand, the lowest leaf infestation was recorded in T_4 (4.217%) which was significantly different from all other treatments. More or less similar trends were also recorded at 35, 45 and 55 DAT in terms of percent leaf infestation by number (Table 2).

The highest leaf infestation by number was found in T_9 (untreated control) at 35, 45 and 55 DAT (44.74%, 47.65% and 43.88% respectively). Among the treated plots, the highest leaf infestation by number was found in T_7 (Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval) at 35, 45 and 55 DAT (21.19%, 18.90% and 16.13% respectively, where the lowest was found in T_4 (Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval) at 35, 45 and 55 DAT (8.467%, 7.01% and 6.867%, respectively).

In terms of mean infestation of leaf by number, the highest was found in T_9 (37.41%) comprised of untreated control which was significantly different from all other treatments followed by T_7 (17.02%), T_5 (15.75%) and T_2 (14.88%). On the other hand the lowest mean leaf infestation by number was found in T_4 (5.837%) which was followed by T_3 (11.78%) and significantly different from all other treatments (Table 2). In case of percent reduction over control, the highest reduction over control was achieved by T_4 (84.42%) where the lowest was found in T_7 (54.56%) (Table 2).

From the Table 2 it was observed that among the different treatments, T_4 performed best in reducing the leaf infestation of cabbage (84.42%) by number due to attack of flea beetle than the other treatments; whereas, T_7 showed the least performance results in reducing the leaf infestation of cabbage (54.56%) by number over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent leaf infestation of cabbage by number was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

Table 2. Leaf infestation of cabbage by number due to attack of flea beetle at different days after transplanting (DAT) in different treatments

Treatments	% Leaf infestation					Mean	% Reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	10.54 b	12.87 d	19.63 c	20.76 b	13.55 de	15.47 c	58.70
T_2	11.67 b	15.88 c	17.75 d	14.79 f	14.31 c	14.88 d	60.27
T_3	8.88 c	10.51 e	9.72 e	15.81 e	13.98 cd	11.78 f	68.55
T_4	2.62 e	4.22 f	8.47 f	7.01 g	6.87 g	5.84 g	84.42
T_5	10.88 b	19.66 b	18.01 d	17.67 c	12.53 e	15.75 c	57.95
T_6	5.17 d	16.83 c	19.82 c	16.33 d	15.68 b	14.76 d	60.58
T_7	11.18 b	20.69 b	21.19 b	18.90 b	16.13 b	17.02 b	54.56
T_8	6.10 d	9.59 e	19.15 c	16.68 d	10.78 f	12.46 e	66.73
T_9	18.63 a	32.38 a	44.74 a	47.65 a	43.88 a	37.41 a	--
$LSD_{(0.05)}$	1.07	1.04	1.01	0.48	0.94	0.46	--
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	
CV%	6.48	3.81	2.93	1.46	3.29	1.64	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.
T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.3 Number of holes/head of a plant at different days after transplanting (DAT)

The significant variations were observed among different treatments used for the management practices in terms of number of holes/infested head of a plant due to attack of flea beetle at different days after transplanting (DAT) (Table 3).

At 15 DAT, the highest number of holes/infested head of a plant (11) was recorded in T_9 which was significantly different from all other treatments followed by T_7 (7.33) and T_5 (6.67) and T1 (6.67) (Table 3). On the other hand, the lowest number of holes/leaf of a plant (4.67) was observed in T_4 which was statistically different from all other treatments followed by T_3 (5.67), T_2 (5.67) and T_8 (6.00).

At 25 DAT, the highest number of holes/head of a plant (14) was recorded in T_9, followed by T_7 (8.33) and T_5 (8.00) (Table 2). On the other hand, the lowest number of holes per leaf of a plant (5.00) was recorded in T_4 which was significantly different from all other treatments. More or less similar trends were also recorded in case of 35, 45 and 65 DAT in terms of percent leaf infestation and the number of holes per head of cabbage (Table 3).

At 35, 45 and 55 DAT, the highest number of holes/head of a plant was found in T_9 (16.67, 18.33 and 14.33 at 35, 45 and 55 DAT, respectively) but among the treated plots, the highest number of holes/head of a plant (12.00, 8.67 and 9.33 at 35, 45 and 88 DAT, respectively) was found in T_7 where the lowest number of holes/leaf of a plant (6.33, 7.67 and 7.00 at 35, 45 and 55 DAT, respectively) was observed in T_4.

Among the treated plots, T_4 showed the best performance and next to T_3, T_8 and at all management stages of flea beetles (Table 3). T_7 showed the lowest performance as management practices against flea beetle followed by T_5, T_1 and T_2.

In terms of mean infestation/head of cabbage, the highest infestation was found in T_9 (14.87) comprised of untreated control which was significantly different from all other treatments. Among the management practices, the highest infestation was found in T_7 (9.33) which is statistically similar with T_5 (8.93), T_1 (8.40) and T_2 (8.40) followed by T_6 (7.87) and T_8 (7.60). On the other hand, the lowest mean infestation was observed in T_4 (6.13) which was followed by T_3 (6.87) (Table 3).

In case of percent reduction over control, the highest reduction over control was achieved by T_4 (58.74%) where the lowest was found in T_7 (37.22%) which was very close to T_5 (39.99%) (Table 3).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the infestation intensity of leaf of cabbage by number of holes (58.74 %) due to attack of flea beetle than the other treatments; whereas, T_7 showed the least performance in reducing the infestation intensity of leaf of cabbage by number of holes (37.22%) over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent infestation intensity of leaf of cabbage by number of holes was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

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Table 3. Infestation intensity of leaf of cabbage by number of holes due to attack of Flea beetle at different days after transplanting (DAT) in different treatments

Treatments	No. of holes / plant					Mean	% reduction over control
	15 DAT	25 DAT	35 DAT	45 DAT	55 DAT		
T_1	6.67 b	7.67 bc	9.67 bc	10.00 cd	8.00 bcd	8.40 bc	43.49
T_2	5.67 bc	7.67 bc	9.67 bc	11.00 bc	8.00 bcd	8.40 bc	43.49
T_3	5.67 bc	6.00 cd	7.67 d	9.33 cde	6.67 b	6.87 de	52.46
T_4	4.67 c	5.00 d	6.33 e	7.67 e	7.00 cd	6.13 e	58.74
T_5	6.67 b	8.00 b	9.67 b	12.00 b	8.33 bc	8.93 b	39.91
T_6	6.00 bc	6.67 bc	8.33 cd	11.00 bc	7.33 bcd	7.87 c	47.08
T_7	7.33 b	8.33 b	10.33 b	12.00 b	8.67 b	9.33 b	37.22
T_8	6.00 bc	7.00 bc	8.67 cd	8.67 de	7.67 bcd	7.60 cd	48.87
T_9	11.00 a	14.00 a	16.67 a	18.33 a	14.33 a	14.87 a	--
LSD $_{(0.05)}$	1.59	1.57	1.32	1.79	1.37	0.92	--
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	--
CV%	13.85	11.65	7.90	9.31	9.36	6.05	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.
T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.4 Percent (%) head infestation by number at vegetative stage

Significant variations were observed among the different treatments used for the management practices in terms of % head infestation by number due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 4). At 25 DAT the highest % head infestation by number (36.80%) was recorded in T_9. But among the treated plots, the highest % head infestation by number was found in T_7 (27.09%) which was statistically different from all other treatments and closely followed by T_5 (27.35%). On the other hand, the lowest % head infestation by number was observed in T_4 (16.57%) which was significantly similar with T_3 (15.92) (Table 4).

More or less similar trend of % head infestation by number were recorded at 35, 45, 55 and 65 DAT. But the rate of % head infestation by number incidence was decreasing with the increase of the age of the cabbage plants within the treated plots. But opposite feature was found in T_9 i.e. gradually increased % head infestation by number was found with the increase of the age of the cabbage.

In case of mean infestation, more or less similar trend of % head infestation by number occurrence was also observed and the highest % head infestation (43.93%) was recorded in T_9 which was significantly different from all other treatments. But in case of treated plots, T_7 (26.83%) showed the highest % head infestation by number which was statistically similar with T_5 (26.39%) followed by T_1 (23.70%). On the other hand, the lowest % head infestation by number (18.04%) was held in T_4 which was statistically similar with T_3 (18.31) and closely followed by T_8 (19.21%).

In case of % reduction over control, the highest reduction over control was achieved by T_4 (58.93%) which was closely followed by T_3 (58.32%). Whereas the lowest reduction over control was found in T_7 (38.93%) which was very close to T_5 (39.94%) (Table 4).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in reducing the infestation of cabbage head

(58.93%) by number due to attack of flea beetle at Vegetative Stage than the other treatments; whereas, T_7 showed the least performance results in reducing the infestation of cabbage head (38.93%) by number due to attack of flea beetle at Vegetative Stage over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation of cabbage head by number due to attack of flea beetle at Vegetative Stage was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

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Table 4. Infestation of cabbage plant by number due to attack of flea beetle at different days after transplanting (DAT) in different treatments

Treatments	% infestation of head					Mean	% reduction over control
	25 DAT	35 DAT	45 DAT	55 DAT	65 DAT		
T_1	21.67 d	26.46 d	39.32 b	16.57 d	14.48 b	23.70 c	46.06
T_2	20.36 d	28.39 d	32.34 e	12.92 e	10.64 d	20.93 d	52.36
T_3	15.92 f	18.47 f	34.86 d	10.64 f	11.67 cd	18.31 fg	58.32
T_4	16.57 f	20.36 ef	32.34 e	12.49 e	8.46 e	18.04 g	58.93
T_5	27.35 c	31.50 c	39.32 b	21.28 b	12.49 c	26.39 b	39.94
T_6	18.78 e	22.00 e	31.50 e	18.78 c	8.26 e	19.86 e	54.79
T_7	29.05 b	34.86 b	36.80 c	20.36 b	13.08 bc	26.83 b	38.93
T_8	18.47 e	22.00 e	28.39 f	16.57 d	10.64 d	19.21 ef	56.27
T_9	36.80 a	55.13 a	56.39 a	31.50 a	39.85 a	43.93 a	--
$LSD_{(0.05)}$	1.52	3.06	1.71	1.34	1.54	0.96	--
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	--
CV%	3.83	6.14	2.69	4.31	6.16	2.29	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.
T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.5 Leaf infestation intensity at harvesting

Significant variations were observed among the different treatments used for the management practices in terms of leaf infestation intensity due to attack of flea beetle during harvesting period (Table 5).

The highest leaf infestation intensity (22.66%) was recorded in T_9 which was significantly different from all other treatments. But in the treated plots, the highest leaf infestation intensity was found in T_7 (14.61%) which was statistically similar with T_5 (13.96%) and T_1 (13.46%) followed by T_2 (10.96%). On the other hand, the lowest leaf infestation intensity was observed in T_4 (5.73%) which was significantly different from all other treatments followed by T_3 (8.98%) and T_8 (10.77%). The results obtained from other treatments showed intermediate level of leaf infestation intensity. So, it can be observed that the leaf infestation intensity among the treatments from highest to the lowest was shown as $T_9 > T_7 > T_5 > T_1 > T_2 > T_6 > T_8 > T_3 > T_4$.

In case of % reduction over control, the highest reduction over control on leaf infestation intensity was achieved by T_4 (74.69%) where the lowest was found in T_7 (35.53%) which was very close to T_5 (38.39%) (Table 5).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the infestation intensity of leaf (74.69%) of cabbage by flea beetle at harvesting than the other treatments; whereas, T_7 showed the least performance in reducing the infestation intensity of leaf (35.53%) of cabbage by flea beetle at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of leaf of cabbage by flea beetle at harvesting was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

Table 5. Infestation intensity of leaf of cabbage by flea beetle in different treatments in different treatments during harvesting

Treatments	% leaf infestation at harvest	% reduction over control
T_1	13.46 b	40.60
T_2	10.96 c	51.53
T_3	8.98 d	60.35
T_4	5.73 e	74.69
T_5	13.96 b	38.39
T_6	10.92 c	51.80
T_7	14.61 b	35.53
T_8	10.77 c	52.47
T_9	22.66 a	--
LSD $_{(0.05)}$	1.26	--
Level of significance	0.05	--
CV%	5.87	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.
T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.6 Infestation intensity of head of cabbage by number of holes during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of number of holes/infested head due to attack of flea beetle during harvesting period (Table 5). The highest number of holes/infested head (33.67) was recorded inT_9 which was significantly different from all other treatments. But among the treated plots, the highest number of holes/infested head was found in T_7 (24.67) which was statistically similar with T_5 (24.33), T_1 (24.00) and T_2 (23.33) followed by T_6 (21.67). On the other hand, the lowest number of holes/infested head was observed in T_4 (14.00) which was significantly different from all other treatments followed by T_3 (17.33) and T_8 (18.00). The result obtained from other treatments showed intermediate level of number of holes/infested head. So, it can be observed that the number of holes/infested head among the treatments from highest to the lowest was shown as $T_9 > T_7 > T_5 > T_1 > T_2 > T_6 > T_8 > T_3 > T_4$.

In case of % reduction over control, the highest on number of holes/infested head was achieved by T_4 (58.41%) where the lowest was found in T_7 (26.73%) which was very close to T_5 (27.74%) and T_1 (28.71) (Table 6).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the infestation intensity of head (58.41%) of cabbage by number of holes due to attack of flea beetle at harvesting than the other treatments; whereas, T_7 showed the least performance in reducing the infestation intensity of head (26.73%) of cabbage by number of holes due to attack of flea beetle at harvesting over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of head of cabbage by number of holes due to attack of flea beetle at harvesting was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

Table 6. Infestation intensity of head of cabbage by number of holes due to attack of flea beetle in different treatments at harvesting

Treatments	No. of holes/plant	% reduction over control
T_1	24.00 b	28.71
T_2	23.33 b	30.71
T_3	17.33 d	48.53
T_4	14.00 e	58.41
T_5	24.33 b	27.74
T_6	21.67 c	35.64
T_7	24.67 b	26.73
T_8	18.00 d	46.54
T_9	33.67 a	--
LSD $_{(0.05)}$	1.26	--
Level of significance	0.05	--
CV%	3.25	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.

T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.7 Percent (%) infestation of head by number during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of number of % infestation of head by number due to attack of flea beetle during harvesting period (Table 7).

The highest % infestation of head by number (37.60) was recorded in T_9 which was significantly different from all other treatments. But in the treated plots, the highest % infestation of head by number was found in T_7 (12.92) which was closely followed by T_5 (11.92%), T_1 (11.44%) and T_2 (10.64). On the other hand, the lowest % infestation of head by number was observed in T_4 (6.69) which was significantly similar with T_3 (7.50), T_8 (7.67) and T_6 (8.04) followed by T_2 (10.64).

The results obtained from other treatments gave intermediate level of % infestation of head by number. So, it can be observed that the % infestation of head by number among the treatments from highest to the lowest was shown as $T_9 > T_7 > T_5 > T_1 > T_2 > T_6 > T_8 > T_3 > T_4$.

In case of percent reduction over control, the highest reduction over control on percent infestation of head by number was achieved by T_4 (82.18%) where the lowest was found in T_7 (65.64%) which was very close to T_5 (68.30%) and T_1 (69.57%) (Table 7).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in reducing the infestation intensity of head by number by flea beetle (82.18%) at harvesting than the other treatments; whereas, T_7 showed the least performance results in reducing the infestation intensity of head by number by flea beetle (65.64%) at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of head by number by flea beetle at harvesting was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

Table 7. Incidence of cabbage flea beetle in the infested head due to attack of flea beetle in different treatments at harvesting

Treatments	% head infestation at harvest	% reduction over control
T_1	11.44 bc	69.57
T_2	10.64 c	71.70
T_3	7.50 d	80.05
T_4	6.69 d	82.18
T_5	11.92 bc	68.30
T_6	8.04 d	78.62
T_7	12.92 b	65.64
T_8	7.67 d	79.60
T_9	37.60 a	--
LSD $_{(0.05)}$	1.53	--
Level of significance	0.05	--
CV%	6.95	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.

T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.8.1 Height of head during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of height of head due to attack of flea beetle during harvesting period (Table 7). The highest height of head (13.77 cm) was recorded in T_4 which was statistically identical with T_3 (13.12 cm). On the other hand, the lowest head height (9.90 cm) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest head height (12.26 cm) was found in T_7 which was closely followed by T_5 (12.39 cm), T_1 (12.52 cm), T_2 (12.69 cm), T_6 (12.72 cm) and T_8 (12.87 cm). The gradually decreased trend was observed in case of height of head as $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

In terms of % increase over control, the highest increase over control on head height was observed with the treatment of T_4 (39.43%) which was very close to T_3 (32.48%) where the lowest was achieved from T_7 (23.80%) which was very close to T_5 (25.11%) (Table 8).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in percent increasing height of head (39.43%) at harvesting than the other treatments; whereas, T_7 showed the least performance results in percent increasing height of head (23.80%) at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of in percent increasing height of head at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$.

4.8.2 Diameter of head during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of diameter of head due to attack of flea beetle during harvesting period (Table 8). The highest diameter of head (20.62 cm) was recorded in T_4 which was statistically different from all other treatments followed by T_3 (20.05

cm) and T_8 (18.65 cm). On the other hand, the lowest head diameter (13.78 cm) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest head diameter (16.19 cm) was found in T_7 which was statistically identical with T_5 (16.21 cm) and closely followed by T_1 (16.96 cm) and T_2 (17.1 cm). The gradually decreased trend was observed in case of diameter of head as $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

In terms of % increase over control, the highest increase over control on head diameter was observed with the treatment of T_4 (49.64%) where the lowest was achieved from T_7 (17.49%) which was very close to T_5 (17.63%) (Table 8).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in percent increasing diameter of head (49.64%) at harvesting than the other treatments; whereas, T_7 showed the least performance results in percent increasing diameter of head (17.49%) at harvesting over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of in percent increasing diameter of head at harvesting was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

Table 8. Effect of different treatments on yield contributing characters of Cabbage

Treatments	Height (cm)	% increase over control	Diameter (cm)	% increase over control
T_1	12.52 bc	26.43	16.96 e	23.08
T_2	12.69 bc	28.14	17.10 e	24.09
T_3	13.12 ab	32.48	20.05 b	45.75
T_4	13.77 a	39.05	20.62 a	49.64
T_5	12.39 bc	25.11	16.21 f	17.63
T_6	12.72 bc	28.44	18.07 d	31.13
T_7	12.26 c	23.80	16.19 f	17.49
T_8	12.87 bc	29.96	18.65 c	35.34
T_9	9.90 d	--	13.78 g	--
LSD $_{(0.05)}$	0.66	--	0.47	--
Level of significance	0.05	--	0.05	--
CV%	3.06	--	1.55	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.

T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.9.1 Single head weight (kg) during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of single head weight due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 8). The highest single head weight (2.19 kg) was recorded in T_4 which was statistically different from all other treatments and followed by T_3 (1.947 kg) and T_8 (1.937 kg). On the other hand, the lowest single head weight (1.04 kg) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest single head weight (1.44 kg) was found in T_7 which was closely followed by T_5 (1.46 kg), T_1 (1.67 kg) and T_2 (1.70). The gradually decreased rank was observed in case of single head weight as $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$ (Table 9).

In terms of % increase over control, the highest increase over control on single head weight was observed with the treatment of T_4 (110.87%) where the lowest was achieved from T_7 (38.75%) which was very close to T_5 (40.38%) (Table 8). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of in percent increasing diameter of head at harvesting was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

4.9.2 Total yield (t ha^{-1})

Significant variations were observed among the different treatments used for the management practices in terms of total yield (t ha^{-1}) due to attack of flea beetle (Table 8). The highest total yield (75.76 t ha^{-1}) was recorded in T4 which was statistically different from all other treatments followed by T_3 (66.95 t ha^{-1}) and T_8 (66.76 t ha^{-1}). The lowest total yield (35.65 t ha^{-1}) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest total yield (49.67 t ha^{-1}) was found in T_7 which was closely followed by T_5 (50.52 t ha^{-1}), T_1 (58.40 t ha^{-1}) and

T_2 (58.74 t ha^{-1}). The gradually decreased trend was observed in case of total yield as $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$ (Table 9).

In terms of % increase over control, the highest increase over control on total yield (t/ha) was observed with the treatment of T_4 (112.51%) which followed by T_3 (87.79%) and T_8 (87.26%) whereas the lowest was achieved from T_7 (39.36%) which was very close to T_5 (41.71%) (Table 8). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of in percent increase of total yield (t ha^{-1}) at harvesting was $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$.

Table 9. Individual head wt. and total yield (ton ha^{-1}) of cabbage due to attack of flea beetle in different treatments during Harvesting

Treatments	Single head wt. (kg)	% increase over control	Total yield (ton ha^{-1})	% increase over control
T_1	1.67 c	61.25	58.40 d	63.82
T_2	1.70 c	63.75	58.74 d	64.77
T_3	1.95 b	87.21	66.95 b	87.79
T_4	2.19 a	110.87	75.76 a	112.51
T_5	1.46 d	40.38	50.52 e	41.71
T_6	1.83 bc	75.67	62.69 c	75.84
T_7	1.44 d	38.75	49.67 f	39.36
T_8	1.94 b	86.25	66.76 b	87.26
T_9	1.04 e	--	35.65 g	--
LSD $_{(0.05)}$	0.16	--	0.52	--
Level of Significance	0.05	--	0.05	--
CV%	5.70	--	5.51	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.

T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.10.1 Infested head weight (kg) plant^{-1} during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of infested head weight/plant due to attack of flea beetle during harvesting (Table 9). The highest infested head weight plant^{-1} (1.093 kg) was recorded in T_4 which was statistically similar with all other treatments followed by the untreated control T_9 (0.62kg). But in the treated plots, the lowest infested head weight plot^{-1} (0.98 kg) was found in T_5 which was closely followed by T_7 (0.993 kg). The gradually decreased trend was observed in case of healthy head weight plot^{-1} as $T_4 > T_3 > T_8 > T_2 > T_6 > T_1 > T_7 > T_5 > T_9$ (Table 10).

In terms of % increase over control, the highest increase over control on infested head weight plant^{-1} was observed with the treatment of T_4 (76.29%) followed by T_3 (75.32%) and T_8 (73.71%). Whereas the lowest was achieved from T_5 (58.06%) which was very close to T_7 (60.21%) (Table 10). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of in percent increase of total yield (t ha^{-1}) at harvesting was $T_4 > T_3 > T_8 > T_2 > T_6 > T_1 > T_7 > T_5 > T_9$.

4.10.2 Healthy head weight (kg) plant^{-1} during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of healthy head weight/plant due to attack of flea beetle during harvesting (Table 10). The highest healthy head weight plant^{-1} (2.24 kg) was recorded in T_4 which was statistically similar with T_3 (2.18 kg), T_8 (2.17 kg) and T_6 (2.117 kg). On the other hand, the lowest healthy head weight plant^{-1} (1.31 kg) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest healthy head weight/plant (1.90 kg) was found in T_7 which was closely followed by T_5 (1.94 kg). The results obtained from T_1 (1.94 kg), T_2

(2.10 kg) and T_3 (2.18 kg) gave intermediate results of healthy head weight plant^{-1}. The gradually decreased trend was observed in case of healthy head weight plot^{-1} as $T_4 > T_3 > T_8 > T_6 > T_2 > T_1 > T_5 > T_7 > T_9$ (Table 10).

In terms of % increase over control, the highest increase over control on healthy head weight plant^{-1} was observed with the treatment of T_4 (71.22%) followed by T_3 (66.64%) and T_8 (65.64%). Whereas the lowest was achieved from T_7 (45.27%) which was very close to T_5 (48.32%) (Table 9). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of in percent increase of total yield (t ha^{-1}) at harvesting was $T_4 > T_3 > T_8 > T_2 > T_6 > T_1 > T_7 > T_5 > T_9$.

Table 10. Infested head weight and healthy head weight of cabbage due to attack of flea beetle in different treatments during Harvesting

Treatments	Infested Head Weight (kg)	% Increase over control	Healthy Head Weight (kg)	% increase over control
T_1	0.99 a	60.75	1.94 b	48.32
T_2	1.07 a	73.06	2.10 a	60.30
T_3	1.08 a	75.32	2.18 a	66.64
T_4	1.09 a	76.29	2.24 a	71.22
T_5	0.98 a	58.06	1.94 b	48.32
T_6	1.01 a	63.39	2.12 a	61.60
T_7	0.99 a	60.21	1.90 b	45.27
T_8	1.07 a	73.71	2.17 a	65.64
T_9	0.62 b	--	1.31 c	--
LSD $_{(0.05)}$	0.16	--	0.14	--
Level of significance	0.05	--	0.05	--
CV%	9.61	--	3.74	--

In column, means containing same letter(s) indicate significantly similar under DMRT at 5% level of significance.
T_1 = Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval, T_2 =Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval, T_3 = Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval, T_4 = Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval, T_5 = Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval, T_6 = Tobacco leaf extract @ 3.0 g L^{-1} of water at 7 days interval, T_7 = Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval, T_8 = Bioneem plus 2 EC @ 1.0 ml L^{-1} of water at 7 days interval and T_9 = Untreated control

4.11 Relationship between leaf infestation intensity and head weight

The results revealed that there was strong negative correlation between leaf infestation intensity and single head weight, which suggested that with the increase of leaf infestation intensity there was a partially influenced on single head weight. A linear regression was fitted between single head weight and leaf infestation intensity (Fig.2). The correlation coefficient (r) was – 0.783 and the contribution of the regression (R^2) were 0.617. In the present study, it was observed that flea beetle infestation on leaf passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced single head weight.

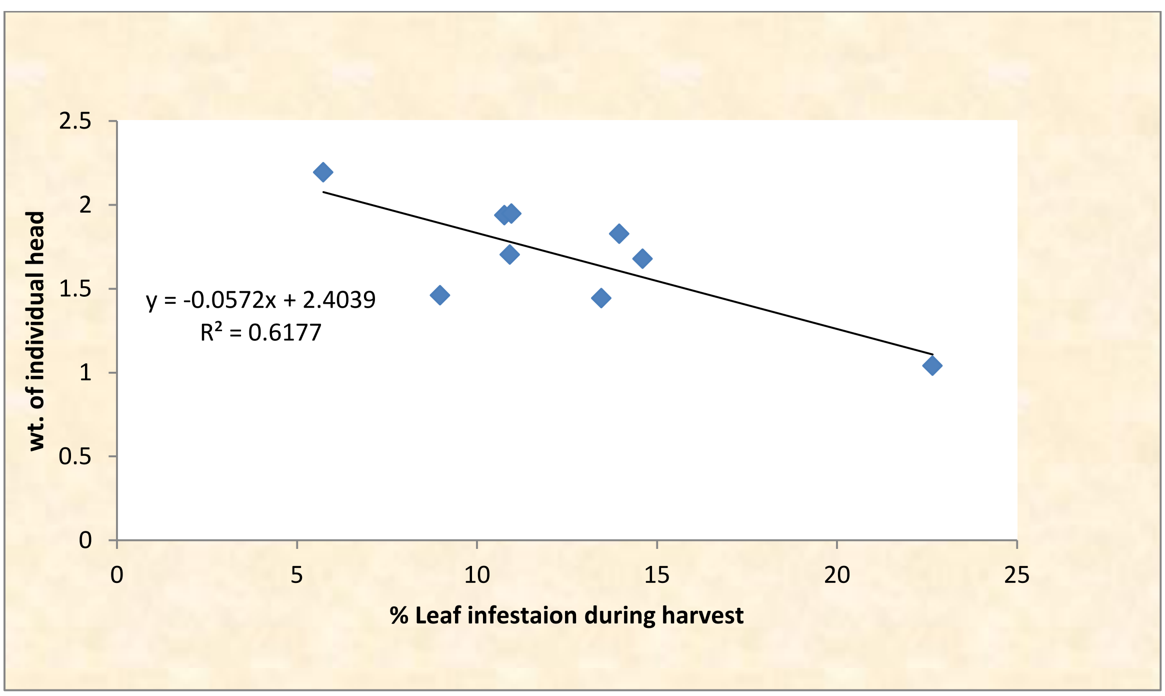

Figure 4. Relationship between percent leaf infestation during harvest and wt. of individual head among different treatments

4.12 Relationship between leaf infestation intensity and yield (t ha^{-1})

The results revealed that there was strong negative correlation between leaf infestation intensity and total yield/ha, which suggested that with the increase of leaf infestation intensity there was a significant influence on total yield/ha. A linear regression was fitted between total yield ha^{-1} weight and leaf infestation intensity (Fig.3). The correlation coefficient (r) was – 0.789 and the contribution of the regression (R^2) were 0.623. In the present study, it was observed that flea beetle infestation on leaf passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

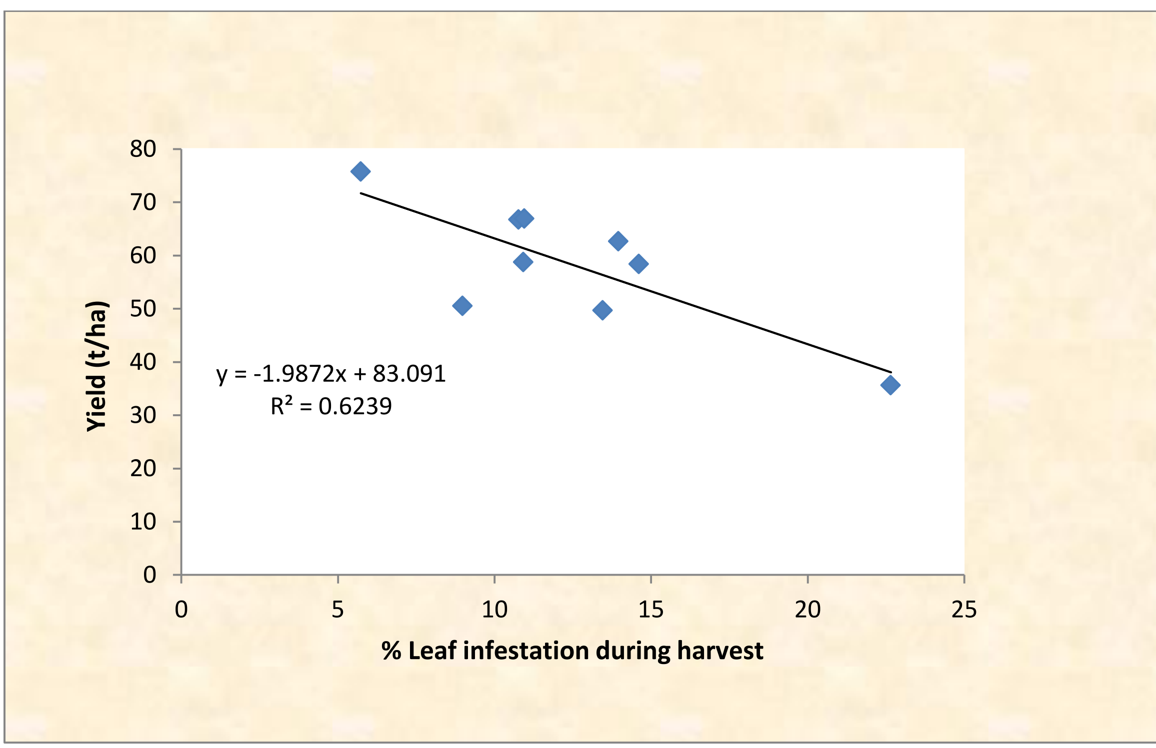

Figure 5. Relationship between leaf infestation intensity and yield (t ha^{-1}) among different treatments

4.13 Relationship between no. of holes during harvest and wt. of individual head

The results revealed that there was strong negative correlation between leaf infestation intensity and total yield/ha, which suggested that with the increase of number of holes in plant there was a significant influence on total yield/ha. A linear regression was fitted between total yield/ha weight and leaf infestation intensity (Fig.4). The correlation coefficient (r) was – 0.762 and the contribution of the regression (R^2) were 0.581. In the present study, it was observed that flea beetle infestation on leaf passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

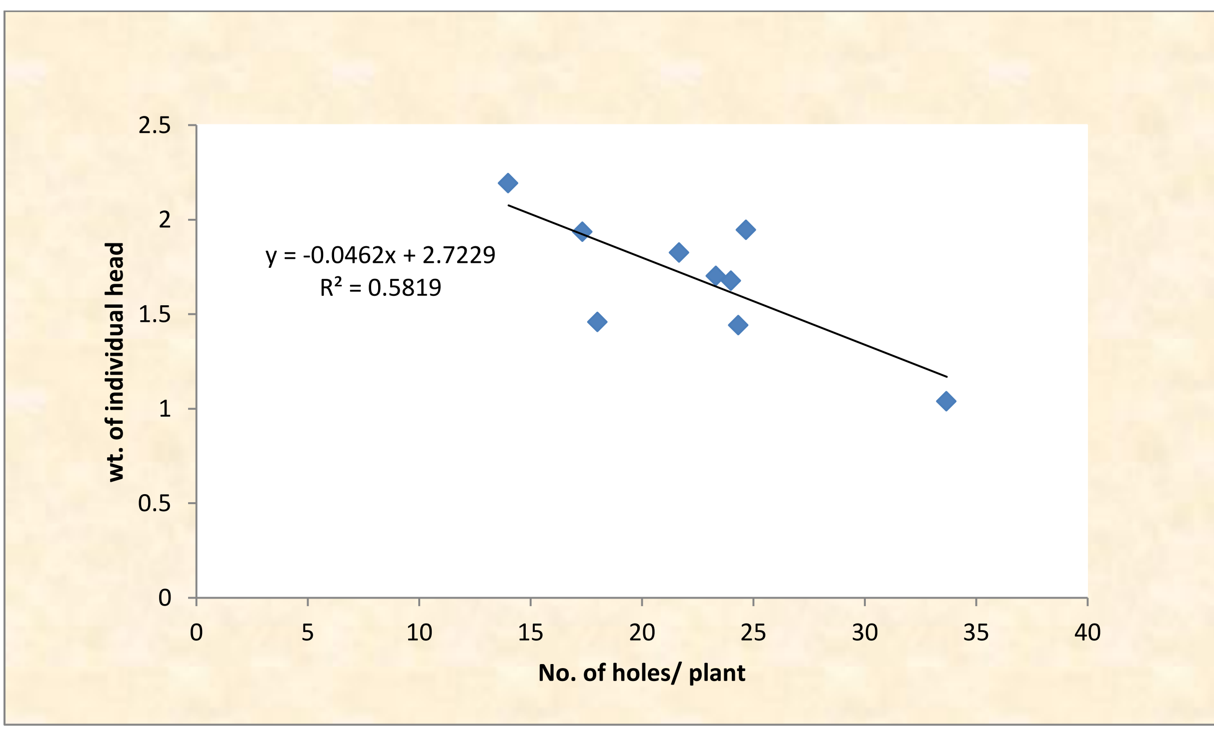

Figure 6. Relationship between no. of holes per plant during harvest and wt. of individual head among different treatments

4.14 Relationship between percent head infestation during harvest and wt. of individual head

The results revealed that there was strong negative correlation between leaf infestation intensity and total yield/ha, which suggested that with the increase of head infestation intensity there was a significant influence on total yield/ha. A linear regression was fitted between total yield ha^{-1} weight and head infestation intensity (Fig.5). The correlation coefficient (r) was – 0.642 and the contribution of the regression (R^2) were 0.413. In the present study, it was observed that flea beetle infestation on head passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

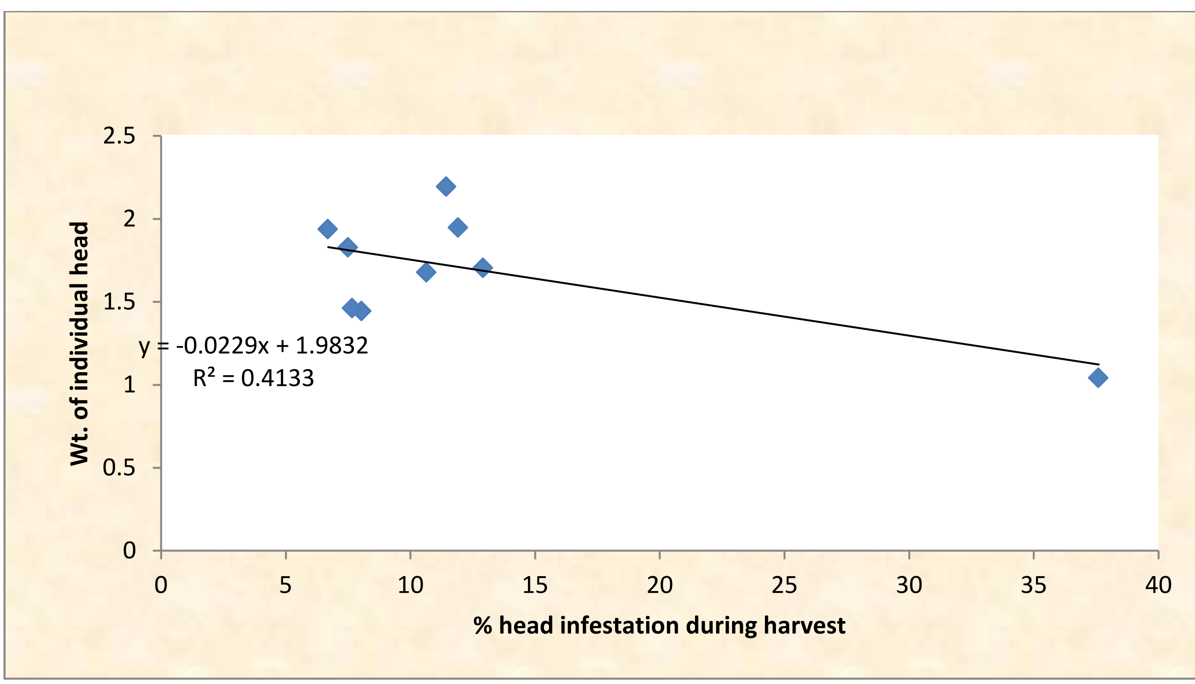

Figure 7. Relationship between percent head infestation during harvest and wt. of individual head among different treatments.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the central farm, Sher-e-Bangla Agricultural University during the period from October 2017 to March 2018 to evaluate the available flea beetle species and management of flea beetle attacking in the cabbage field.

Nine treatments viz. (i) T_1 (Sevin 85WP @ 2.0 g L^{-1} of water at 7 days interval), (ii) T_2 (Decis 2.5 EC @ 1.0 ml L^{-1} of water at 7 days interval), (ii) T_3 (Voliam flexi @ 0.5 ml L^{-1} of water at 7 days interval), (iv) T_4 (Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval), (v) T_5 (Dursban 20EC @ 1.0 ml L^{-1} of water at 7 days interval), (vi) T_6 (Tobacco leaf extract @ 3.0 g $^{L-1}$ of water at 7 days interval), (vii) T_7 (Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval), (viii) T_8 (Bioneem plus 1 EC @ 1.0 ml L^{-1} of water at 7 days interval) and (ix) T_9 (Untreated Control) were included in this study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Two species of flea beetle i.e. Stripped flea beetle (*Phyllotreta striolata*) and White-spotted flea beetle (*Monolepta signata*) were found in the research field during the experimental period.

Results showed that the significant variations were observed among different ages of the cabbage plant in terms of percent leaf infestation, number of holes head^{-1} and percent head infestation by number. From beginning of yield formation stage to at harvest, significant results was also observed in terms of leaf infestation intensity, number of holes / infested head, percent infestation of head by number, percent head infestation by weight, height of head, diameter of head, single head weight (kg), healthy head weight (kg plot^{-1}) and total yield (t ha^{-1}).

Results showed that the lowest percentage of leaf infestation (2.62, 4.22, 8.47, 7.01 and 6.87 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 5.84) was observed in

T_4 where the highest (18.63, 32.38, 44.74, 47.65 and 43.88 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 37.41) was obtained from T_9. But in the treated plots, the highest percentage of leaf infestation (11.18, 20.69, 21.19, 18.90 and 16.13 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 17.02) was achieved from T_7.

Again, it was found that the lowest number of holes /plant (4.67, 5.00, 6.33, 7.67 and 7.00 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 6.13) was observed in T_4 where the highest (11.00, 14.00, 16.67, 18.33 and 14.33 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 14.87) was obtained from T_9. But in the treated plots, the highest number of holes plant^{-1} (7.33, 8.33, 10.33, 12.00 and 8.67 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 9.33) was achieved from T_7.

Results showed that the lowest percentage of head infestation by number (16.57, 20.36, 32.34, 12.49 and 8.46 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 18.04) was observed in T_4 where the highest (36.80, 55.13, 56.39, 31.50 and 39.85 at 15, 25, 35, 45 and 55 DAT, respectively i.e. mean = 43.93%) was obtained from T_9. But in the treated plots, the highest percentage of head infestation by number (29.05, 34.86, 36.80, 20.36 and 13.08 at 25, 35, 45, 55 and 65 DAT, respectively i.e. mean = 26.83) was achieved from T_7.

Again, during harvesting period the lowest leaf infestation intensity (5.73%), number of holes per infested head (14.00), percent infestation of head by number (6.69), highest height of head (13.77 cm), diameter of head (20.62 cm), single head weight (2.19 kg), healthy head weight (2.24 kg plant^{-1}) and highest total yield (75.76 t ha^{-1}) were observed in T_4 where the highest leaf infestation intensity (22.66%), number of holes / infested head (33.67), percent infestation of head by number (37.60), lowest height of head (9.90 cm), diameter of head (13.78 cm), single head weight (1.04 kg), healthy head weight (1.31 kg plant^{-1}) and lowest total yield (35.65 t ha^{-1}) were obtained from T_9. But in the treated plots, the highest leaf infestation intensity (14.61%), number of holes / infested head (24.67), percent infestation of head by number (12.92), lowest height of head (12.26 cm), diameter of head (16.19 cm), single head weight (1.44 kg), healthy head weight (1.90 kg plant^{-1}) and lowest total yield (49.67 t ha^{-1}) were obtained from T_7.

In terms of percent reduction or increase over control the highest percent reduction of leaf infestation over control (84.42%), percent reduction of number of holes /plant over control (58.74%), percent reduction of head infestation by number over control (58.93%), percent reduction of leaf infestation at harvesting over control (74.69%), %percent reduction of number of holes/infested head at harvesting over control (58.41%), percent reduction of infestation of head during harvest by number (82.18%), percent increase of height of head over control (39.05%), percent increase of diameter of head over control (49.64%) and percent increase of Total yield over control (112.51%) were achieved by T_4 where the lowest percent reduction of leaf infestation over control (54.56%), percent reduction of number of holes /plant at harvesting over control 26.73%), percent reduction of head infestation by number over control (38.93%), percent reduction of leaf infestation at harvesting over control (35.53%), percent reduction of number of holes per infested head during harvest over control (26.73%), percent reduction of infestation of head during harvest by number (65.64%), percent increase of height of head over control (23.80%), percent increase of diameter of head over control (17.49%) and increase of total yield over control (39.36%) were achieved by T_7.

From the above discussion on summary, it can be concluded that, the treatment of T_4 comprised of Ripcord 10EC @ 1.0 ml L^{-1} of water at 7 days interval gave the highest performance compared to all other treatments used under the present study where the lowest performance was obtained by control treatment. On the other hand, the lowest performance among the treated plots was achieved by T_7 (Neem seed kernel extract @ 3.0 g L^{-1} of water at 7 days interval).

RECOMMENDATIONS

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

1. Diversity of flea beetle may be studied in several years all over Bangladesh to identify the number of flea beetle species.

2. Further trials with effective chemical insecticides and botanicals may be done at different AEZs of the country.

CHAPTER VI

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APPENDICES

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

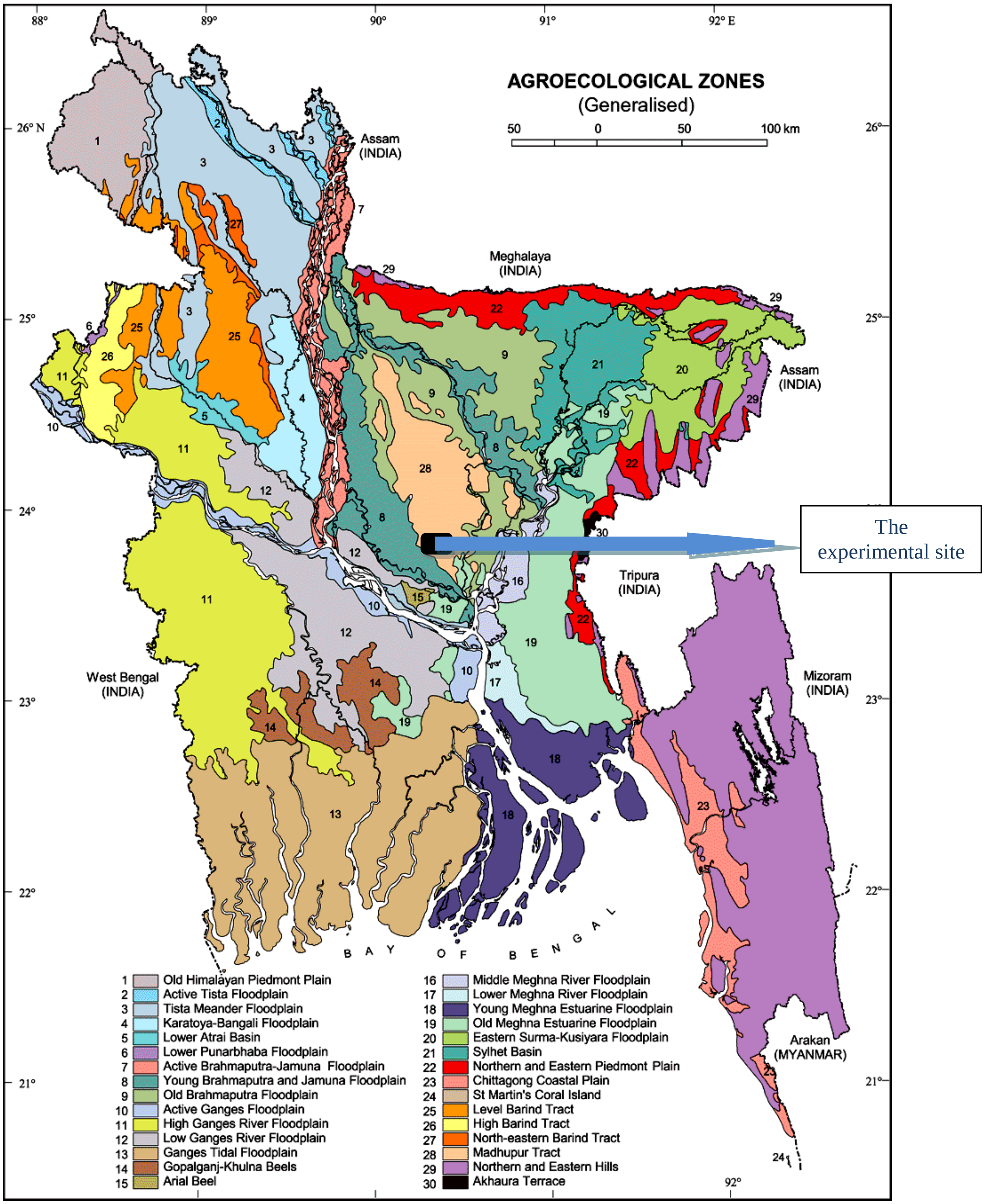

Figure: The map of Bangladesh showing experimental site.

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (October, 2017 to March, 2018) at Sher - e - Bangla Agricultural University campus

Month	Air temperature (ºc)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October,2017	79	25	32	175	6
November, 2017	65	21	30	35	8
December, 2017	74	15	29	15	9
January, 2018	68	13	24	7	9
February, 2018	57	18	30	25	8
March, 2018	57	20	33	65	7

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

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

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

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

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

Source of variance	Degrees of Freedom	Mean square of % leaf infestation					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	3.164	0.587	0.391	0.195	0.509	0.175
Treatment	8	64.398**	199.053**	323.068**	377.371**	342.694**	223.545**
Error	16	0.380	0.359	0.338	0.075	0.291	0.070

** Significant at 0.01 level of probability;

Appendix V. Analysis of variance of the data on the infestation intensity of leaf of cabbage by number of holes due to attack of Flea beetle as influenced by different treatments

Source of variance	Degrees of Freedom	Mean square of number of holes/leaf of a plant					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	0.259	0.704	0.333	0.778	0.863	0.058
Treatment	8	9.787**	19.426**	25.250**	28.500**	15.833**	18.943**
Error	16	0.843	0.829	0.583	1.069	0.625	0.278

** Significant at 0.01 level of probability;

Appendix VI. Analysis of variance of the data on the infestation of cabbage head by number due to attack of Flea beetle at Vegetative Stage as influenced by different treatments

Source of variance	Degrees of Freedom	Mean square of % head infestation					
		15 DAT	25 DAT	35 DAT	45 DAT	55 DAT	Mean infestation
Replication	2	0.000	3.853	0.269	0.877	0.748	0.510
Treatment	8	144.07**	380.044**	202.029**	117.575**	285.629**	198.100**
Error	16	0.763	3.131	0.979	0.594	0.787	0.306

** Significant at 0.01 level of probability;

Appendix VII. Analysis of variance of the data on leaf infestation intensity, number of holes / infested head, % head infestation by number of cabbage due to flea beetle at harvesting as influenced by different treatments

Source of variance	Degrees of Freedom	Mean square		
		Leaf infestation intensity	Number of holes / infested head	% head infestation by number
Replication	2	0.383	0.778	0.376
Treatment	8	66.305**	95.750**	276.171**
Error	16	0.534	0.528	0.780

** Significant at 0.01 level of probability;

Appendix VIII. Analysis of variance of the data on yield and yield contributing characters of Cabbage due to flea beetle at harvesting as influenced by different treatments

Source of variance	Degrees of Freedom	Mean square				
		Height of head	Diameter of head	Single head weight (kg)	Healthy head weight (kg/ plot)	Total yield (t/ha)
Replication	2	0.251	0.041	0.009	0.004	0.322
Treatment	8	3.378**	13.320**	0.351*	0.750**	419.467
Error	16	0.146	0.074	0.009	0.006	0.089

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