BIORATIONAL MANAGEMENT OF LEAF FEEDING INSECT PESTS OF CABBAGE

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DEDICATED TO MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled, **"BIORATIONAL MANAGEMENT OF LEAF FEEDING INSECT PESTS OF CABBAGE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **Asma Akter, Registration No. 19-10394** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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BIORATIONAL MANAGEMENT OF LEAF FEEDING INSECT PESTS OF CABBAGE

ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2020 to February, 2021 to evaluate the effectiveness of some biorationals against leaf feeding insect pests of cabbage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Six treatments, viz. T_1 (Spinomax 45SC @ 0.5 ml/L of water at 7 days interval); T_2 (Biomax 1.2EC @ 2 ml/L of water at 7 days interval); T_3 (Bioneem plus 1EC @ 3 ml/L of water at 7 days interval); T_4 (Antario @ 2 g/L of water at 7 days interval); T_5 (Fytomax @ 2 ml/L of water at 7 days interval) and T_6 (untreated control) were used. Among the management practices, the lowest percentage of leaf infestation of cabbage by tobacco caterpillar (9.58%) and jute hairy caterpillar (6.88%) was found in T_1 treated plot that reduced the highest leaf infestation over control (72.73% and 68.67%, respectively); whereas the highest percentage infestation by tobacco caterpillar (35.13%) and jute hairy caterpillar (21.96%) was found in untreated plot (T_6). The lowest mean incidence of tobacco caterpillar (5.74 larvae/6 plants) and jute hairy caterpillar (4.15 larvae/6 plants) was found in T_1 that reduced highest incidence over control (49.52% and 58.95%, respectively); whereas the highest values of all these parameters were achieved from untreated control treatment (T_6). The lowest cabbage head infestation (23.64%) was recorded in T_1, that gave the highest yield of cabbage (75.80 t ha^{-1}) that increased the highest yield over control (96.93%). From the above study, it was found that the treatment T_1 comprised of Spinomax 45SC @ 0.5 ml/L of water at 7 days interval gave the highest performance compared to those of all other treatments used in the present study. Spinomax 45SC may be used for the management of leaf feeding insect pests of cabbage.

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ABBREVIATIONS AND ACRONYMS

% = Percentage

AEZ = Agro-Ecological Zone

BBS = Bangladesh Bureau of Statistics

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

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

^0C = 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

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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 very low as compare to the actual requirements. In 2019-2020, the total winter vegetable production area was 575 acres with a total production of 2576 metric tons in which 384 metric tons of cabbage were produced on 55 acres of land (BBS 2020). In our country the consumption rate of vegetables is 33 kg/head/yr., but in developed countries it is 7-8 times higher (FAO 2015).

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 belongs to the Cruciferae family. It has been recognized as a very important commercial vegetable to the farmers in providing income and nutrition worldwide (FAOSTAT 2007, Kfir 2004, Lohr and Kfir 2004, Oruku and Ndungu 2001). Cabbage is an excellent source of calcium, potassium, and vitamin C. It is an important source of antioxidants since it is rich in certain substances with high antioxidant capacity such as vitamin C (ascorbic acid), carotenoids and polyphenols (Leja *et al*. 2007). The regular consumption of vegetables, specifically the dark green leafy vegetables is highly recommended because of their potential in reducing the risks of chronic diseases. These vegetables are important food crops because they provide adequate amounts of dietary vitamins and minerals for humans (Miller-Cebert *et al*. 2009).

Cabbage is consumed either raw or processed in different ways, e.g., boiled or, fermented or, used in salads. Due to its antioxidant, anti-inflammatory and antibacterial properties, cabbage has widespread use in traditional medicine, in alleviation of symptoms associated with gastrointestinal disorders (gastritis, peptic and duodenal ulcers, irritable bowel syndrome) as well as in treatment of minor cuts and wounds and mastitis. Fresh cabbage juice, prepared either separately or mixed with other vegetables such as carrot and celery, is often included in many commercial weight-loss diets (Samec *et al*. 2011).

The insect-pests attacking cabbage are diamondback moth (*Plutella xylostella* Linnaeus), cabbage butterfly (*Pieris brassicae* Linnaeus), tobacco caterpillar (*Spodoptera litura* Fabricius), cabbage semilooper (*Trichoplusia ni* Hubner), aphid (*Brevicoryne brassicae* Linnaeus), painted bug (*Bagrada cruciferarum* Kirkaldy), cabbage leaf webber (*Crocidolomia binotalis* Zeller), cabbage head borer (*Hellula undalis* Fabricius), cabbage flea beetle (*Phyllotreta cruciferae* Goeze) and jute/bihar hairy caterpillar (*Spilosoma obliqua* Walk) are observed commonly on cabbage in different seasons and cause considerable losses (Aiswarya *et al*. 2018).

Tobacco caterpillar (*Spodoptera litura* Fab.) is a polyphagous pest and cause considerable damage to vegetables (Srivastava *et al*. 2018). It is one of the important insect pests of agricultural crops in the Asian tropics and the pest was found to occur in cabbage growing areas (Reddy *et al*. 2017). The larvae of *S. litura* can cause 26–100% yield loss in field (Tuan *et al*. 2014). In Bangladesh, Ahmed (2008) reported that tobacco caterpillar causes damage 3.99% to 13.44% on leaves and 23.33% to 58.33% on plants depending on the varieties.

Jute/Bihar hairy caterpillar, *Spilarctia obliqua* (Walker) (Arctiidae: Lepidoptera), is a widely distributed, serious polyphagous pest (Gupta and Bhattacharya 2008). The pest causes loss in yield and quality of crops (Rahman and Khan 2010). *Spilarctia obliqua* (Walker) vernacularly known as jute hairy caterpillar, is a highly polyphagous and sporadic pest infesting approximately 126 plants species in 24 families (Singh and Varatharajan 1999).

The proper management of these two pests (*Spodoptera litura* and *Spilarctia obliqua*) is very much important for a successful production of cabbage through various methods. Mechanical, biological and chemical etc. control has been reported throughout the world. The farmers of Bangladesh are using chemical insecticides indiscriminately to combat these insect pests of cabbage. Chemical control become a matter of great concern of human health and environmental pollution (Rikabdar 2000). Farmers depend on intensive pesticides application to minimize the crop damage and chemical farming is resulting in environmental pollution toxicity and residual effects, at the same time pests become resistant to chemicals which are banned by the government. (Verma and Mishra 2010). Chemical toxicity causes several health hazards and leads to pollution to the environment and misbalance the ecology. It is reported that 1% of the chemical used in the pest control reached the target, remaining 99% causes hazards to the environment. We should not forget Rachel Carson "Silent spring" where she mentioned the ill effects of DDT (dichlorodiphenyltrichloroethane) and its impact on the environments (Debbarma *et al.* 2017). In the absence of effective alternative management options to tackle pests, small holder farmers rely extensively on indiscriminate application of synthetic pesticides. These synthetic pesticides are harmful to human health, detrimental to the environment and biodiversity, and lead to rapid build-up of resistance in the target pests while decimating natural enemies of pests, resulting in secondary pest outbreaks (Bailey *et al*. 2010).

Biorationals are inherently different from conventional pesticides and have lower risks associated with their use (Ware and Whitacre 2004). According to Environmental Protection Agency (EPA) the term "biorationals" is practically synonym to term "biopesticides" which have low risk, are derived from natural sources including plants, animals, bacteria and certain minerals and are divided into "microbials", plant-incorporated protectants (PIPs) and biochemical (Rosell *et al*. 2008). Biopesticides may offer an essential alternative to the indiscriminate use of synthetic pesticides. Biopesticides are generally less toxic than conventional pesticides and therefore considered safer for human health. Biopesticides often only affect the target pests and therefore do not pose negative effects on the environment. Also, their use does not lead to resistance build-up in target pests. Nzanza and Mashela (2012) confirmed that the biopesticides are natural and usual control of crop insect pests and these obviously occurring substances control pests through non-toxic mechanisms (Bardin *et al*. 2008). The global market for biopesticides is valued at 3.0 billion USD, accounting for 5% of the global pesticide market (Marrone 2014). With an annual compounded growth rate of more than 15%, it is anticipated that biopesticide market share will equal that of synthetic pesticides between 2040 and 2050 (Dalmas and Koutroubas 2018, Olson 2015).

Among the biopesticides viz. Spinosad, Abamectin, Azadirachtin, *Bacillus thuringiensis*, *Beauveria bassiana*, NPV etc. are widely used to control the insect pests of cabbage. These are safe for environment, human health and beneficial insects. But these biopesticides are used in vegetable cultivation without the optimum doses because of having no knowledge of optimum doses to the farmers.

It is necessary to apply such biorational approaches for cabbage insect pests, which will be much eco-friendly for profitable cabbage yield.

Keeping these considerations in view, the present study has been undertaken to fulfill the following objectives:

- To determine the extent of damage caused by two leaf feeding insect pests at different plant growth stages.
- To evaluate the effectiveness of some biorationals against major leaf feeding insect pests of cabbage.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop in Bangladesh which is generally grown in the Rabi season. Cabbage is infested by large numbers of insect pests in the field, which cause considerable yield damage in every year. Among them, tobacco caterpillar, *Spodoptera litura* (Fab.) is one of the most serious pests and jute hairy caterpillar, *Spilosoma obliqua* (Walker) on cabbage is a sporadic pest and widely distributed in the world. Farmers mainly control pests through the use of different chemicals. But the concept of management of pest employing bio-rational materials gained momentum as mankind become more conscious about the environment. Bio-rational based management is the recent and eco-friendly approaches for pest control. Information related to the management of tobacco caterpillar and jute hairy caterpillar using bio-rational based management is very scanty. Though, some of the important and informative works and research findings related to the control of leaf feeding insect pests through biorational based management so far been done at home and abroad have been reviewed in this chapter under following sub-headings:

2.1. General review of insect pests of cabbage

2.1.1 Tobacco caterpillar (*Spodoptera litura*)

The tobacco caterpillar, *Spodoptera litura* (Fab.) belongs to the order Lepidoptera of the family Noctuidae. Tobacco caterpillar also known as Prodenia caterpillar/ Cabbage caterpillar.

2.1.1.1 Systematic position

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Noctuidae

Genus: *Spodoptera*

Species: *Spodoptera litura*

2.1.1.2 Origin and distribution of tobacco caterpillar

Tobacco caterpillar (*Spodoptera litura*) sometimes called tobacco cutworm, is a serious polyphagous pest in Asia, Oceania and the Indian subcontinent that was first described by Johan Christian Fabricius in 1775 (Jin-Feng *et al*. 2014). The pest occurs in India, Pakistan, Bangladesh, Sri Lanka, South East Asia, China, Korea, Japan, Philippines, Indonesia, Australia, Pacific Islands, Hawaii and Fiji (Hill 1993).

2.1.1.3 Host range of tobacco caterpillar

Tobacco caterpillar (*Spodoptera litura*) infested all cruciferous vegetables including cabbage, cauliflower, broccoli, Chinese cabbage, mustard, radish, turnip etc. in Bangladesh and documented at least 128 countries or territories of the world and is believed to be the most universally distributed of all lepidopterous insect pests (Sarfraz *et al*. 2006). Shelton (2004) reported that currently, this insect pest is present all over the world wherever the crucifers exist.

2.1.1.4. Life cycle of tobacco caterpillar

Soni *et al*. (2001) evaluated the host preference of *S. litura* using castor, cabbage, and cauliflower as host plants. Results showed that the overall mean diameter of egg was 0.534 mm. The mean incubation period was significantly highest on cabbage (5.60 days) and the lowest on castor (3.40 days). The larval periods, pre-pupal periods were shortest on cauliflower (16.30 and 10.40 days, respectively). The average weight per larvae and pupae was the maximum on cauliflowers (1619.36 and 306.70 mg, respectively) and minimum on castor (1419.24 and 242.65 mg, respectively). Sizes of the full-grown larvae and pupae were the maximum on cauliflower (34.83 mm and 5.45 mm width) while, it was the lowest on castor (32.62 mm length and 5.05 mm width). Cauliflower recorded the highest wing span and body length of adult female (34.41 and 17.32 mm, respectively) and male (32.18 and 15.55 mm, respectively). The percentage of larval survival, pupation and adult emergence were also highest on cauliflower (94.00, 85.10 and

92.50%, respectively), whereas the longevity of female and male moth was recorded on cabbage (8.20 and 7.05 days, respectively), and minimum on castor (6.09 and 5.06 days, respectively). Similarly, the highest fecundity of female was recorded on cabbage and the lowest on cauliflower (557.06 and 397.63 eggs, respectively). The highest growth index value (5.22) was recorded on cauliflower and the lowest in castor (3.54).

2.1.1.5 Nature of damage of tobacco caterpillar

Tobacco caterpillar is the most destructive insect pest, sometimes cause complete failure of the crop. After hatching, the caterpillars start feeding on the under surface of the leaves. Leaves of heavily damaged plants have many feeding holes and sometimes the leaves take a 'sieve-like' appearance. It also destroys the leaves of cabbage by making holes in the head and greatly reduces its market value. As a result of feeding, the plants either fail to form compact cabbage heads or produce deformed heads (Uddin *et al*. 2007).

2.1.2 Jute hairy caterpillar (*Spilosoma obliqua*)

The jute hairy caterpillar, *Spilosoma obliqua* (Walker) belongs to the order Lepidoptera and the family Noctuidae. Jute hairy caterpillar is also known as Bihar hairy caterpillar.

2.1.2.1 Systematic position

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Arctiidae

Genus: *Spilosoma*

Species: *Spilosoma obliqua*

2.1.2.2 Origin and distribution of jute hairy caterpillar

Jute hairy caterpillar (*Spilosoma obliqua*) is widely distributed in India, China, Bangladesh, Myanmar, Nepal and Pakistan (CPC 2004). In India, it is a serious pest in West Bengal, Bihar, Madhya Pradesh, Uttar Pradesh, Punjab and Manipur (Bhosale *et al*. 2019).

2.1.2.3 Host range of jute hairy caterpillar

Jute hairy caterpillar (*Spilosoma obliqua*) is polyphagous and feeds on at least 126 species of plant including pulses, cereals, vegetables, oilseeds, mulberry, turmeric, fiber crops such as jute, roselle, ramie and sun hemp and non-cultivated plants and weeds. In India, the insect is a serious pest of fiber crops, sometimes occurring in epidemic outbreaks (Sivakumar *et al*. 2020).

2.1.2.4 Life cycle of tobacco caterpillar

Each female lays up to 1000 eggs on the undersides of leaves in several batches. When these hatch, the larvae at first scrape the under surface of the leaf, but as they grow they feed on the edges of the leaves, giving these a net-like appearance (Selvaraj *et al*. 2015).

The larvae are large, tuberculate and densely covered with tufts of hairs and feed on the leaves of a variety of plants. They are often extremely destructive. They are usually beautiful moths and can be easily recognized by the presence of a tymbal organ on the meta-episternum and a pre-spiracularcounter tympanal hood (Mani 1990).

Singh and Singh (1993) studied the comparative development and survival of caterpillar (*S. obliqua* Walker) at different temperature and varieties of sunflower. At 40°C there was no survival of larvae. The larval period, larval survival, pre-pupal and pupal period, pupal survival, pupal weight, fecundity, hatchability and incubation period decreased with the increase in temperature from 25°C to 35°C. Adult longevity was maximum at 30°C.

2.1.2.5 Nature of damage of jute hairy caterpillar

Jute hairy caterpillar eats all types of young and matured leaves. The female moth lays eggs on the dorsal surface of the leaves in batch. The young larvae, after hatching, remain on the dorsal leaf surface in groups up to 6- 7 days of hatching. Thereafter, they spread all over the plant. The larvae eat the green portions of leaves when they are in groups and the leaves look like white thin membranes, which are easily observed from the far. They eat the young twigs when the infestation is severe. The third and onward instar larvae cause serious damages and significant reduction in yield (Gupta and Bhattacharya 2008, Hath and Chakraborty 2004, Hussain and Begum 1995).

2.2 Bio-rational management with bio pesticides

Bio-rational or low risk pesticides are being used to replace the conventional ones. Bio-rational insecticides are synthetic or natural substances that are more effective to control insect pests with having low toxicity to non-target organisms and the environment (Hara 2000). There are many alternative control options to manage the insect pests by use of biocontrol agents, microbials, and botanicals (Bugg *et al*. 2008, Singh *et al*. 2007, Milner 1997, Lowery and Isman 1994). Biorational approaches by utilizing botanical preparations and natural products are gaining significance as possible alternative measures for the ecofriendly management of insect-pests (Joshi *et al*. 2020).

Many studies had evaluated the effect of biopesticides in controlling cabbage insect pests following their sole or individual applications (Yadav *et al*. 2017, Chatterjee and Mondal 2008). These corroborate with the observation that spinosad and emamectin benzoate are highly effective (Acharya *et al.* 2015, Mitch *et al.* 2014, Choudhari *et al*. 2001). Sole application of *B. thuringiensis* and buprofezin are moderately effective against lepidopteran caterpillars. The infestation level can be further decreased and yield can be increased significantly with alternating applications, which might be due to the different mode of action (Chandrayudu *et al*. 2015, Singh 2015, Ragaei and Sabry 2011). Frequent application of same/ similar insecticides lead to resistance (Thomas and Nauen 2015). Hence, alternate application is highly recommended, in particular spinosad or emamectin benzoate in alternate with *B. thuringiensis.*

Similarly, entomopathogens like *Bacillus thuringiensis* (Bt) are also ecofriendly alternatives. The most promising bacterial fermented derivatives like spinosad, emamectin benzoate and abamectin play pivotal role in controlling lepidopteran insect pests (Kumar and Venkat 2006). These have obvious advantages in term of effectiveness, specificity and safety to non-target organisms. Insecticide resistance mainly occurs due to the frequent application of chemical insecticides, and it can be overcome with insecticides having different mode of action (Ahmad *et al*. 2007).

Biopesticides namely buprofezin (Award 40 SC), emamectin benzoate (Suspend 5 SG), spinosad (Libsen 45 SC) and *B. thuringiensis* individually in their recommended doses is compared with their alternate application with *B. thuringiensis* against the "caterpillar complex" on cabbage. All the recommended package of practices was followed except plant protection measures. Buprofezin (Award 40 SC), emamectin benzoate (Suspend 5 SG), spinosad (Libsen 45 SC) and *B. thuringiensis* (Bt) @ 1.0 ml/L, 1.0 g/L, 0.50 ml/L and 3.0 g/L, respectively were used. Insecticidal spray was initiated when insect density rose above threshold level (Dutt and Das 2021).

Spinosad is the most effective treatment for the reduction of the pest population, *Spodoptera litura* than *Bacillus thuringiensis* and Indoxacarb. Latha (2012) has been reported the effectiveness of spinosad over *Spodoptera litura*. She observed that hundred per cent control was observed at seven and fifteen days after application of spinosad. Paliwal and Oommen (2005) also reported that spinosad was most effective against *S. litura* in cauliflower. Rajan and Muthukrishan (2009) also reported the superiority of spinosad in controlling *Spodoptera litura* on different crops. Gupta (2000) recorded significantly higher yield of cabbage heads for the treatment of spinosad.

There are a variety of plant derived products with insecticide activity. These natural compounds are part of the protective chemistry that serves to protect plants from insects, herbivores and pathogens by interfering in their physiological processes. As they are naturally occurring compounds, the use of such materials can be useful for the production of environmentally sound pesticides (Isman and Akhtar 2007). One such compound is Azadirachtin, which is the main bioactive chemical in the neem base foundation it's an effective natural product that works on insects. Better performance exhibited by neem product may be due to repellency of the larvae of different instars on the leaves from the treated plants and secondly due to antifeedant effect on the larvae (Rajput *et al*. 2003).

Botanical pesticides are also special because they can be produced easily by farmers for sustainable agriculture and small industries (Roy *et al.* 2005). Sharma *et al*. (1999) conducted experiment for the effect of host plants like castor (*Ricimus* c*ommunis*), cabbage, cauliflower, tomatoes and wild cabbage and also the effect of neem oil on food utilization indices of *S. litura*. They stated that, cauliflower was the most preferred host. Neem oil markedly decreased feeding by *S. litura* larva on these plants.

Bacillus thuringiensis, Bt, is used as a biopesticide. It produces spores with a crystalline protein called endotoxin. This protein formed by the bacteria called as Cry toxin has insecticidal properties and must be consumed by the target insect pest and is not dangerous to mammals or the ecosystem (BARI 2014). The insecticidal bacterium, *Bacillus thuringiensis* (Bt) is a widely occurring gram-positive, spore-forming soil bacterium that produces parasporal, proteinaceous, crystal inclusion bodies during sporulation. Bt has been the most successful commercial microbial insecticide, and also has been the subject of the overwhelming majority of genetic engineering studies to improve efficacy (Mehlhorn 2011, Federici 2010, Lacey and Kaya 2007).

Potassium salts of fatty acids are insecticidal soaps. Insecticidal soaps are very effective on soft-bodied pests such as aphids, adelgids, lacebugs, leafhoppers, mealybugs, thrips, sawfly larvae (pear and rose slugs), scale insects (especially scale crawlers), plant bugs, caterpillars, spider mites and whiteflies. Soaps have low mammalian toxicity. However, they can be mildly irritating to the skin or eyes. Insecticidal soaps are biodegradable, do not persist in the environment. Many formulations of insecticidal soap can be used on various food crops up to the day of harvest.

CHAPTER III

MATERIALS AND METHODS

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, 2020 to February, 2021. It was conducted to evaluate the effectiveness of some biorationals against leaf feeding insect pests of cabbage. 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 performed in the Central Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh and which is situated in 23º74´´N latitude and 90º35´´E longitude and an elevation of 8.2 m from sea level (Anon. 1989) that has been presented in Appendix I.

3.2 Climate of the experimental field

Subtropical, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*. 1979). The average maximum and minimum temperature were 29.19º C and 18.36º C respectively, during the experimental period. In our country Rabi season is characterized by plenty of sunshine and cool. Meteorological data which are related to the temperature, relative humidity and rainfall during the study period were collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix II.

3.3 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al*. 1991). The land of the selected experimental plot is medium high under the

Tejgaon series (FAO 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Dhaka and has been represented in Appendix III.

3.4 Materials used for the experiment

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 Lal Teer Seed Limited, Tejgaon, Dhaka.

3.5 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications in the central farm. The field with good tilth was divided into 4 blocks. The layout of the experiment was prepared to evaluate the treatments. Each experiment consists of total 24 plots of size 2.5 m × 1.6 m. The layout of the experiment is shown in Figure 1.

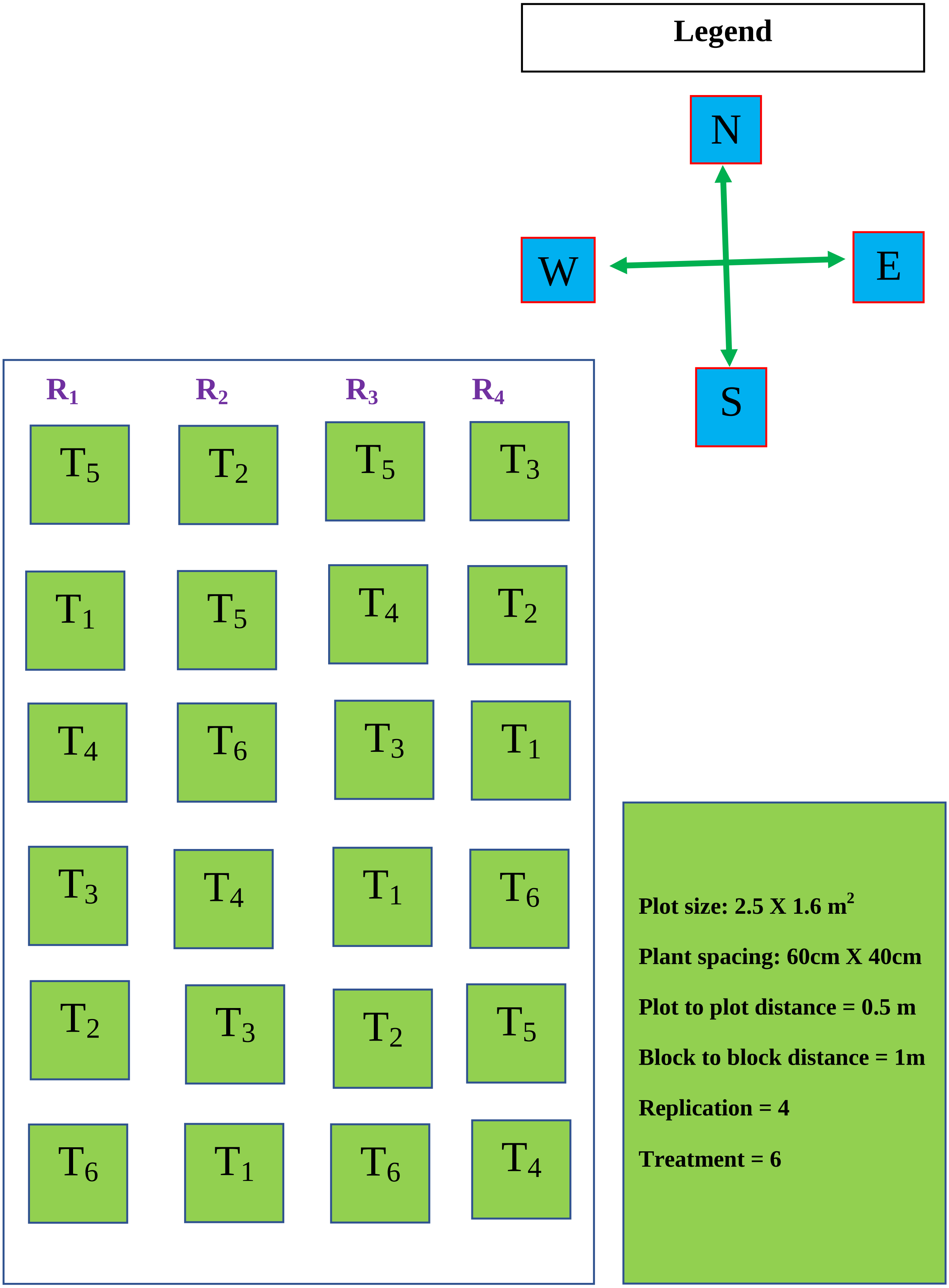

Figure 1. Layout of the experimental plot.

3.6 Land preparation

The selected plot of the experiment was opened in the last week of November 2020 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 15 cm from the soil surface keeping the drain around the plots.

3.7 Manuring and fertilization

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers were applied according to the recommended fertilizer doses for cabbage production per hectare by Rashid *et al.* (2006) (Table 1).

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

Fertilizers and Manures	Dose ha^{-1}
Cowdung	10 ton
Urea	150 kg
TSP	100 kg
MoP	125 kg

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 days after transplanting (DAT) as ring method under moist soil condition and mixed thoroughly with the soil as soon as possible for better utilization.

3.8 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. Ten (10) grams of seeds were sown in seedbed on October 24, 2020. 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 polythene sheet 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 1).

Plate 1. Cabbage seedlings in the seedbed.

3.9 Transplanting

Healthy and uniform seedlings of 30 days old were transplanting in the experimental plots on 26 November, 2020. 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 (Plate 2).

Plate 2. Transplanted cabbage seedlings in the experimental plot.

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 as described below:

3.10.1 Gap filling

In the experimental plot, the transplanted seedlings 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 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 35, 55 and 75 days of transplanting. Weeding was done by uprooting and using with mechanical weed control method.

3.10.3 Irrigation

After transplanting light irrigation was done to each plot by a watering can at every morning and afternoon. It was continued for a week for rapid growth and well establishment of the transplanted seedlings. Supplementary irrigation was given at 5 days interval. Stagnant water was drained out successfully at the time of excess irrigation (Plate 3).

Plate 3. The experimental plot during irrigation.

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 (Plate 4).

Plate 4. The experimental plot during earthing up.

3.11 Treatments used for management

The experiment was evaluated to determine the effectiveness of some biorationals against leaf feeding insect pests of cabbage. The biorational based treatments as well as their doses used in the study are given in Table 2.

Table 2. Biorational based treatments including control treatment (untreated) and their application doses

Treatments	Trade name	Chemical name	Doses
T_1	Spinomax 45SC	Spinosad	0.5 ml/L of water
T_2	Biomax 1.2EC	Abamectin	2.0 ml/L of water
T_3	Bioneem plus 1EC	Azadirachtin	3.0 ml/L of water
T_4	Antario	Bt. and Abamectin	2.0 g/L of water
T_5	Fytomax	Potassium salts of fatty acid	2.0 ml/L of water
T_6	Untreated control	Water	Water

3.12 Treatments application

T_1: Spinomax 45SC @ 0.5 ml/L of water was sprayed at 7 days interval. Under this treatment, Spinomax 45SC was applied @ 2.5 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 43 DAT.

T_2: Biomax 1.2EC @ 2 ml/L of water of water was sprayed at 7 days intervals. Under this treatment, Biomax 1.2EC was applied @ 10 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 43 DAT.

T_3: Bioneem plus 1EC @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, Bioneem plus 1EC was applied @ 15 ml /5L of water mixed with 1 pinch of soap powder to make the oil easily soluble in water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 43 DAT.

T_4: Antario @ 2 g/L of water was sprayed at 7 days interval. Under this treatment, Antario was applied @ 10 g /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 43 DAT.

T_5: Fytomax @ 2 ml/L of water was sprayed at 7 days interval. Under this treatment, Fytomax was applied @ 10 ml /5L of water. After proper shaking, the prepared spray was applied with knap-sack sprayer at 7 days intervals commencing from 43 DAT.

T_6: Untreated control. No pest control measure was applied in the cabbage field.

3.13 Data collection

Six plants per plot were randomly selected and tagged for data collection. The cabbage plants were closely examined at regular intervals commencing from 43 days after transplanting (DAT) to harvesting of cabbage head. Tobacco caterpillar infestation were recorded at 43, 50, 57, 64, 71 and 78 DAT and jute hairy caterpillars which were sporadic pests came from nearby land recorded at 57,64,71,78 and 86 DAT (Plate 5). The following parameters were considered during data collection:

Plate 5. Experimental field of cabbage during the study period.

3.13.1 Counting of insect pests of cabbage and infested leaves

Data were collected on the number of tobacco caterpillar and jute hairy caterpillar larvae and number of infested leaves caused by tobacco caterpillar and jute hairy caterpillar larvae from randomly earlier selected 6 tagged plants per plot and counted individually for each treatment (Plate 9 and 10).

3.13.2 Number, weight of healthy and infested cabbage head

Data were collected on the number of healthy and infested cabbage head per plot which was harvested at fully mature head (upto 24th February) stage of cabbage and weighted individually for each treatment. Data on the yield contributing characters of cabbage like diameter of head, height/thickness of head, weight of head and yield t ha^{-1} was also recorded after harvesting.

3.14 Level of infestation

The number of uninfested and infested leaves and plants of cabbage caused by the tobacco caterpillar and sporadic pests i.e. jute hairy caterpillars were counted. The observations were recorded at the first observation of damage leaves and plants and were continued up to harvesting stage of the cabbage at 7 days of interval. The data on the yield was also recorded (Plate 6 and 7). The level of leaf and plant infestations per plant and plot respectively was then calculated using the following formula:

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

3.15 Percent insect infestation on head

The infested heads were calculated at vegetative and harvesting stages using the following formula:

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

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

3.16 Harvesting

Harvesting of the cabbage was not possible on a particular date because the initiation of head as well as attaining the head at marketable size in different plants were not uniform. Only the compact marketable heads were harvested by using sharp knife. Compactness of the head was tested by pressing with thumbs, before harvesting of the cabbage head (Plate 8).

3.17 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

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

3.18 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 6. A healthy cabbage.

Plate 7. A damaged cabbage.

Plate 8. After harvesting healthy marketable cabbage from the experimental field.

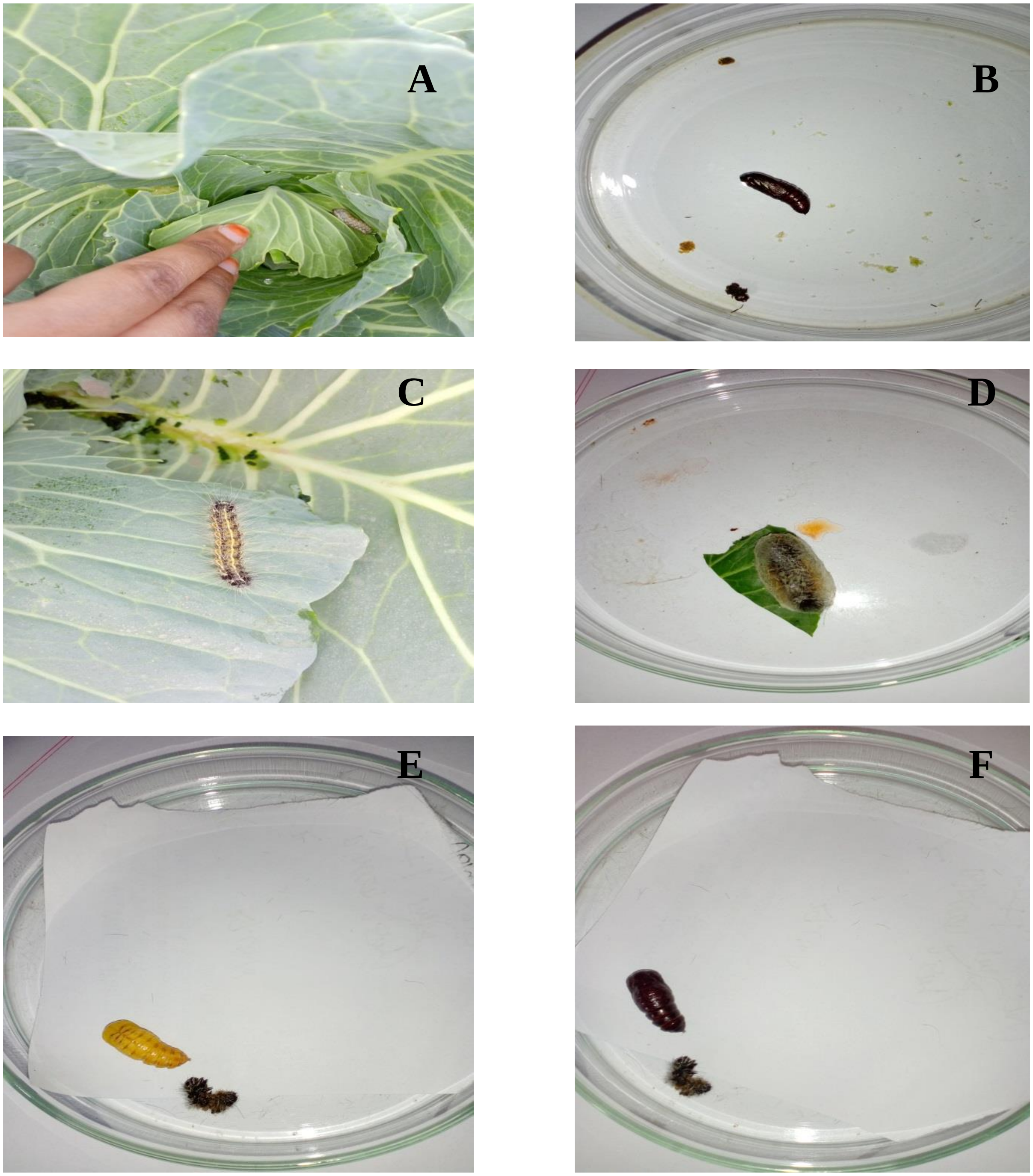

Plate 9. (A) Tobacco caterpillar larva, (B) Pupa of tobacco caterpillar, (C) Jute hairy caterpillar larva, (D) Cocoon of jute hairy caterpillar, (E) Pre pupa of jute hairy caterpillar, (F) Pupa of jute hairy caterpillar.

(A)

(B)

(C)

(D)

Plate 10. (A) Tobacco caterpillar moth (B) Jute hairy caterpillar moth (C) Damage caused by tobacco caterpillar both leaves and head, (D) Damage caused by jute hairy caterpillar only leaves.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSIONS

The study was conducted to evaluate some biorationals against leaf feeding insect pests of cabbage in the field at the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2020 to February, 2021. The findings of the study have been interpreted and discussed under the following sub-headings:

4.1 Percent leaf infestation by number at different days after transplanting

4.1.1 Percent leaf infestation by tobacco caterpillar

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 tobacco caterpillar at different days after transplanting (DAT).

At 43 DAT, the highest leaf infestation by number (28.68%) was recorded in T_6 (untreated control) which was statistically different from all other treatments followed by T_5 (24.55%), T_3 (21.38%) and T_4 (17.64%) (Table 3). On the other hand, the lowest leaf infestation (10.54%) was observed in T_1 which was statistically different from all other treatments followed by T_2 (14.19%). At 50 DAT, the highest leaf infestation (32.78%) was recorded in T_6 comprised of untreated control which was statistically different from all other treatments and followed by T_5 (26.73%), T_3 (23.54%) and T_4 (19.19%) (Table 3). On the other hand, the lowest leaf infestation was recorded in T_1 (12.91%) which was significantly different from all other treatments and followed by T_2 (17.49%). More or less similar trends were also recorded at 57, 64 and 71 DAT in terms of percent leaf infestation by number (Table 3).

The highest leaf infestation by number was found in T_6 (untreated control) at 57, 64 and 71 DAT (36.82%, 39.23% and 38.15%, respectively). Among the treated plots, the highest leaf infestation by number was found in T_5 at 57, 64 and 71 DAT (21.21%, 18.05% and 17.89%, respectively, where the lowest was found in T_1 at 57, 64 and 71 DAT (9.63%, 7.49% and 7.32%, respectively). In terms of mean infestation of leaf by number, the highest was found in T_6 (35.13%) comprised of untreated control which was significantly different from all other treatments and followed by T_5 (21.69%), T_3 (18.62%) and T_4 (15.20%). On the other hand, the lowest mean leaf infestation by number was found in T_1 (9.58%) which was followed by T_2 (12.35%) and significantly different from all other treatments (Table 3). In case of percent reduction over control, the highest reduction over control was achieved by T_1 (72.73%) where the lowest was found in T_5 (38.26%) (Table 3).

From the Table 3 it was observed that among the different treatments, T_1 performed best in reducing the leaf infestation of cabbage (72.73%) by number due to attack of tobacco caterpillar than the other treatments; whereas, T_5 showed the least performance results in reducing the leaf infestation of cabbage (38.26%) 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 $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Many studies had evaluated the effect of biopesticides in controlling cabbage insect pests following their sole or individual applications (Yadav *et al*. 2017, Chatterjee and Mondal 2008). These corroborate with the observation that spinosad and emamectin benzoate are highly effective (Acharya *et al.* 2015, Mitch *et al.* 2014, Choudhari *et al*. 2001).

Table 3. Infestation of cabbage by number due to attack of tobacco caterpillar at different days after transplanting

Treatments	Percent leaf infestation					Mean	Percent reduction over control
	43 DAT	50 DAT	57 DAT	64 DAT	71 DAT		
T_1	10.54 f	12.91 f	9.63 f	7.49 f	7.32 f	9.58 f	72.73
T_2	14.19 e	17.49 e	11.19 e	9.57 e	9.29 e	12.35 e	64.84
T_3	21.38 c	23.54 c	18.25 c	15.46 c	14.48 c	18.62 c	46.99
T_4	17.64 d	19.19 d	15.04 d	12.36 d	11.78 d	15.20 d	56.73
T_5	24.55 b	26.73 b	21.21 b	18.05 b	17.89 b	21.69 b	38.26
T_6	28.68 a	32.78 a	36.82 a	39.23 a	38.15 a	35.13 a	--
LSD $_{(0.05)}$	**1.27**	**1.24**	**1.42**	**1.75**	**1.59**	**0.30**	**--**
CV%	**4.44**	**3.84**	**5.19**	**7.04**	**6.58**	**1.10**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.

[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]

DAT = Days after transplanting.

4.1.2 Percent leaf infestation by jute hairy caterpillar

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 jute hairy caterpillar at different days after transplanting (DAT).

At 50 DAT, the highest leaf infestation by number (19.14%) was recorded in T_6 (untreated control) which was statistically different from all other treatments and followed by T_5 (17.39%) and T_3 (16.46%) (Table 4). On the other hand, the lowest leaf infestation (8.37%) was observed in T_1 which was statistically different from all other treatments and followed by T_2 (11.33%) and T_4 (14.39). At 57 DAT, the highest leaf infestation (21.42%) was recorded in T_6 comprised of untreated control which was statistically different from all other treatments followed by T_5 (14.49%), T_3 (12.67%) and T_4 (10.50%) (Table 4). On the other hand, the lowest leaf infestation was recorded in T_1 (7.11%) which was significantly different from all other treatments followed by T_2 (8.28%). More or less similar trends were also recorded at 64, 71 and 78 DAT in terms of percent leaf infestation by number (Table 4).

The highest leaf infestation by number was found in T_6 (untreated control) at 64, 71 and 78 DAT (22.39%, 23.47% and 23.36% respectively). Among the treated plots, the highest leaf infestation by number was found in T_5 at 64, 71 and 78 DAT (12.42%, 12.36% and 11.35% respectively, where the lowest was found in T_1 at 64, 71 and 78 DAT (6.54%, 6.32% and 6.07%, respectively). In terms of mean infestation of leaf by number, the highest was found in T_6 (21.96%) comprised of untreated control which was significantly different from all other treatments followed by T_5 (13.60%), T_3 (11.85%) and T_4 (10.04%). On the other hand, the lowest mean leaf infestation by number was found in T_1 (6.88%) which was followed by T_2 (8.18%) and significantly different from all other treatments (Table 4). In case of percent reduction over control, the highest reduction over control was achieved by T_1 (68.67%) where the lowest was found in T_5 (38.07%) (Table 4).

From the Table 4 it was observed that among the different treatments, T_1 performed the best in reducing the leaf infestation of cabbage (68.67%) by number due to the attack of jute hairy caterpillar than the other treatments; whereas, T_5 showed the least performance results in reducing the leaf infestation of cabbage (38.07%) 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 $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

The most promising bacterial fermented derivatives like spinosad, emamectin benzoate and abamectin play pivotal role in controlling lepidopteran insect pests (Kumar and Venkat 2006).

Table 4. Infestation of cabbage by number due to attack of jute hairy caterpillar at different days after transplanting

Treatments	Percent leaf infestation					Mean	Percent reduction over control
	50 DAT	**57 DAT**	**64 DAT**	**71 DAT**	**78 DAT**		
T_1	8.37 e	7.11 f	6.54 e	6.32 e	6.07 f	6.88 f	68.67
T_2	11.33 d	8.28 e	7.04 e	7.13 e	7.13 e	8.18 e	62.75
T_3	16.46 b	12.67 c	10.34 c	10.29 c	9.48 c	11.85 c	46.04
T_4	14.39 c	10.50 d	8.54 d	8.36 d	8.42 d	10.04 d	54.28
T_5	17.39 b	14.49 b	12.42 b	12.36 b	11.35 b	13.60 b	38.07
T_6	19.14 a	21.42 a	22.39 a	23.47 a	23.36 a	21.96 a	--
LSD $_{(0.05)}$	**1.30**	**1.02**	**0.82**	**0.88**	**0.83**	**0.40**	**--**
CV%	**6.13**	**5.59**	**4.98**	**5.39**	**5.16**	**2.26**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.2 Incidence of insect pest population

4.2.1 Incidence of tobacco caterpillar

The significant variations were observed among the different treatments used for the management practices in terms of number of tobacco caterpillar at different days after transplanting (DAT).

At 43 DAT, the highest number of tobacco caterpillar (10.35 larvae/6 plants) was recorded in T_6 (untreated control) which was statistically different from all other treatments followed by T_5 (8.48 larvae/6 plants) and T_3 (8.26 larvae/6 plants) and T_4 (7.43 larvae/6 plants) (Table 5). On the other hand, the lowest leaf infestation (6.05 larvae/6 plants) was observed in T_1 which was statistically similar with T_2 (6.61 larvae/6 plants). At 50 DAT, the highest number of tobacco caterpillar (11.58 larvae/6 plants) was recorded in T_6 comprised of untreated control which was statistically different from all other treatments followed by T_5 (9.13 larvae/6 plants) and T_3 (8.56 larvae/6 plants), T_4 (7.57 larvae/6 plants) and T_2 (7.42 larvae/6 plants) (Table 5). On the other hand, the lowest number of tobacco caterpillar was recorded in T_1 (6.25 larvae/6 plants) which was significantly different from all other treatments. More or less similar trends were also recorded at 57, 64 and 71 DAT in terms of number of tobacco caterpillar (Table 5).

The highest number of tobacco caterpillar was found in T_6 (untreated control) at 57, 64 and 71 DAT (11.89, 11.37 and 11.67 larvae/6 plants, respectively). Among the treated plots, the highest number of tobacco caterpillar was found in T_5 at 57, 64 and 71 DAT (8.46, 7.99 and 7.45 larvae/6 plants, respectively, where the lowest was found in T_1 at 57, 64 and 71 DAT (5.69, 5.38 and 5.31, respectively). In terms of mean number of tobacco caterpillar, the highest was found in T_6 (11.37 larvae/6 plants) comprised of untreated control which was significantly different from all other treatments followed by T_5 (8.30 larvae/6 plants), T_3 (7.85 larvae/6 plants) and T_4 (7.11 larvae/6 plants). On the other hand, the lowest mean number of tobacco caterpillar was found in T_1 (5.74 larvae/6 plants) which was followed by T_2 (6.47 larvae/6 plants) and significantly different from all other treatments (Table 5). In case of percent reduction over control, the highest reduction over control was achieved by T_1 (49.52%) where the lowest was found in T_5 (27.00%) (Table 5).

From the Table 5 it was observed that among the different treatments, T_1 performed the best in reducing the number of tobacco caterpillar on cabbage (49.52%) than the other treatments; whereas, T_5 showed the least performance results in reducing the number of tobacco caterpillar on cabbage (27.00%) by number over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of number of tobacco caterpillar on cabbage was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Latha (2012) has been reported the effectiveness of spinosad over *Spodoptera litura*. She observed that hundred per cent control was observed at seven and fifteen days after application of spinosad.

Table 5. Effect of treatments on incidence of tobacco caterpillar per six plants at different days after transplanting

Treatments	**Number of tobacco caterpillar per six plants**					**Mean**	**Percent reduction over control**
	43 DAT	**50 DAT**	**57 DAT**	**64 DAT**	**71 DAT**		
T_1	6.05 d	6.25 d	5.69 f	5.38 d	5.31 d	5.74 f	49.52
T_2	6.61 cd	7.42 c	6.32 e	6.26 cd	5.75 d	6.47 e	43.09
T_3	8.26 b	8.56 b	7.79 c	7.58 b	7.04 b	7.85 c	30.96
T_4	7.43 bc	7.57 c	7.10 d	7.01 bc	6.43 c	7.11 d	37.47
T_5	8.48 b	9.13 b	8.46 b	7.99 b	7.45 b	8.30 b	27.00
T_6	10.35 a	11.58 a	11.89 a	11.37 a	11.67 a	11.37 a	--
LSD $_{(0.05)}$	**1.06**	**0.89**	**0.58**	**0.98**	**0.58**	**0.38**	**--**
CV%	**9.24**	**7.20**	**5.02**	**8.80**	**5.46**	**3.32**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.2.2 Incidence of jute hairy caterpillar

The significant variations were observed among the different treatments used for the management practices in terms of number of jute hairy caterpillar at different days after transplanting (DAT).

At 50 DAT, the highest number of jute hairy caterpillar (8.24 larvae/6 plants) was recorded in T_6 (untreated control) which was statistically different from all other treatments followed by T_5 (7.34 larvae/6 plants), T_3 (7.14 larvae/6 plants) and T_4 (6.47 larvae/6 plants) (Table 6). On the other hand, the lowest leaf infestation (5.01 larvae/6 plants) was observed in T_1 which was statistically similar with T_2 (5.49 larvae/6 plants). At 57 DAT, the highest number of jute hairy caterpillar (9.31 larvae/6 plants) was recorded in T_6 comprised of untreated control which was statistically different from all other treatments followed by T_5 (7.08 larvae/6 plants) and T_3 (6.60 larvae/6 plants), T_4 (5.73 larvae/6 plants) and T_2 (5.05 larvae/6 plants) (Table 6). On the other hand, the lowest number of jute hairy caterpillar was recorded in T_1 (4.19 larvae/6 plants) which was significantly different from all other treatments. More or less similar trends were also recorded at 64, 71 and 78 DAT in terms of number of jute hairy caterpillar (Table 6).

The highest number of jute hairy caterpillar was found in T_6 (untreated control) at 64, 71 and 78 DAT (10.25, 11.22 and 11.53 larvae/6 plants, respectively). Among the treated plots, the highest number of jute hairy caterpillar was found in T_5 at 64, 71 and 78 DAT (6.74, 6.23 and 6.18 larvae/6 plants, respectively, where the lowest was found in T_1 at 64, 71 and 78 DAT (4.07, 3.97 and 3.51 larvae/6 plants, respectively). In terms of mean number of jute hairy caterpillar, the highest was found in T_6 (10.11 larvae/6 plants) comprised of untreated control which was significantly different from all other treatments followed by T_5 (6.71 larvae/6 plants), T_3 (6.14 larvae/6 plants) and T_4 (5.48 larvae/6 plants). On the other hand, the lowest mean number of jute hairy caterpillar was found in T_1 (4.15 larvae/6 plants) which was followed by T_2 (4.84 larvae/6 plants) and significantly different from all other treatments (Table 6). In case of percent reduction over control, the highest reduction over control was achieved by T_1 (58.95%) where the lowest was found in T_5 (33.63%) (Table 6).

From the Table 6 it was observed that among the different treatments, T_1 performed best in reducing the number of jute hairy caterpillar on cabbage (58.95%) than the other treatments;

whereas, T_5 showed the least performance results in reducing the number of jute hairy caterpillar on cabbage (33.63%) by number over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of number of jute hairy caterpillar on cabbage was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Sole application of *B. thuringiensis* and buprofezin are moderately effective against lepidopteran caterpillars. The infestation level can be further decreased and yield can be increased significantly with alternating applications, which might be due to the different mode of action (Chandrayudu *et al*. 2015, Singh 2015, Ragaei and Sabry 2011).

Table 6. Effect of treatments on incidence of jute hairy caterpillar per six plants at different days after transplanting

Treatments	Number of jute hairy caterpillar per six plants					Mean	Percent reduction over control
	50 DAT	57 DAT	64 DAT	71 DAT	78 DAT		
T_1	5.01 d	4.19 e	4.07 e	3.97 e	3.51 e	4.15 f	58.95
T_2	5.49 d	5.05 d	4.96 d	4.58 d	4.14 d	4.84 e	52.13
T_3	7.14 b	6.60 b	6.07 c	5.59 c	5.31 c	6.14 c	39.27
T_4	6.47 c	5.73 c	5.53 cd	5.10 c	4.56 d	5.48 d	45.80
T_5	7.34 b	7.08 b	6.74 b	6.23 b	6.18 b	6.71 b	33.63
T_6	8.24 a	9.31 a	10.25 a	11.22 a	11.53 a	10.11 a	--
LSD $_{(0.05)}$	**0.56**	**0.48**	**0.61**	**0.49**	**0.55**	**0.43**	**--**
CV%	**5.84**	**5.28**	**6.70**	**5.51**	**6.37**	**4.67**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.

[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]

DAT = Days after transplanting.

4.3 Percent head infestation by tobacco caterpillar

Significant variations were observed among the different treatments used for the management practices in terms of % head infestation by number due to attack of tobacco caterpillar at different days after transplanting (DAT) (Table 7).

At 43 DAT, the highest % head infestation by number (49.50%) was recorded in T_6 (untreated control) which was statistically different from all other treatments followed by T_5 (41.00%), T_3 (37.10%) and T_4 (33.85%) (Table 7). On the other hand, the lowest % head infestation (25.28%) was observed in T_1 which was statistically different from all other treatments followed by T_2 (28.89%). At 50 DAT, the highest % head infestation (54.56%) was recorded in T_6 comprised of untreated control which was statistically different from all other treatments followed by T_5 (45.64%), and T_3 (40.98%) was statistically similar with T_4 (42.01%) (Table 7). On the other hand, the lowest % head infestation was recorded in T_1 (31.81%) which was significantly different from all other treatments followed by T_2 (33.52%). More or less similar trends were also recorded at 57, 64 and 71 DAT in terms of percent leaf infestation by number (Table 7).

In case of mean infestation, more or less similar trend of % head infestation by number was also observed and the highest % head infestation (56.32%) was recorded in T_6 which was significantly different from all other treatments. But in case of treated plots, T_5 (39.74%) showed the highest % head infestation by number which was statistically different from all other treatments followed by T_3 (35.57%), T_4 (32.76%) and T_2 (27.51%). On the other hand, the lowest % head infestation by number (23.64%) was held in T_1.

In case of % reduction over control, the highest reduction over control was achieved by T_1 (58.02%). Whereas the lowest reduction over control was found in T_5 (29.44 %) (Table 7).

From the above mentioned findings it was revealed that among the different treatments, T_1 performed best results in reducing the infestation of cabbage head (58.02%) by number due to attack of tobacco caterpillar than the other treatments; whereas, T_5 showed the least performance results in reducing the infestation of cabbage head (29.44%) by number due to attack of tobacco caterpillar 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 tobacco caterpillar was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Rajan and Muthukrishan (2009) reported the superiority of spinosad in controlling *Spodoptera litura* on different crops.

Table 7. Effect of biorational management practices on cabbage head infestation by tobacco caterpillar at different days after transplanting

Treatments	Percent infestation of head					Mean	Percent reduction over control
	43 DAT	50 DAT	57 DAT	64 DAT	71 DAT		
T_1	25.28 f	31.81 e	24.86 f	20.50 f	15.76 f	23.64 f	58.02
T_2	28.89 e	33.52 d	28.87 e	25.46 e	20.83 e	27.51 e	51.15
T_3	37.10 c	40.98 c	37.47 c	32.74 c	29.57 c	35.57 c	36.84
T_4	33.85 d	42.01 c	32.88 d	29.69 d	25.35 d	32.76 d	41.83
T_5	41.00 b	45.64 b	41.42 b	37.26 b	33.36 b	39.74 b	29.44
T_6	49.50 a	54.56 a	58.10 a	62.22 a	57.24 a	56.32 a	--
LSD $_{(0.05)}$	**1.89**	**1.67**	**1.35**	**1.81**	**1.72**	**0.49**	**--**
CV%	**3.60**	**2.75**	**2.47**	**3.56**	**3.88**	**0.93**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.4 Leaf infestation intensity at harvesting

4.4.1 Leaf infestation intensity by tobacco caterpillar during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of leaf infestation intensity due to the attack of tobacco caterpillar during the harvesting period (Table 8).

The highest leaf infestation intensity (31.66%) was recorded in $T_{6,}$ which was significantly different from all other treatments. But in the treated plots, the highest leaf infestation intensity was found in T_5 (20.55%) which was statistically dissimilar and followed by T_3 (16.61%) and T_4 (13.57%). On the other hand, the lowest leaf infestation intensity was observed in T_1 (8.79%) which was significantly different and followed by T_2 (10.70%). So, it can be observed that the leaf infestation intensity among the treatments from the highest to the lowest was shown as $T_6 > T_5 > T_3 > T_4 > T_2 > T_1$.

In case of % reduction over control, the highest reduction over control on leaf infestation intensity was achieved by T_1 (72.24%) where the lowest was found in T_5 (35.09%) (Table 8).

From the above mentioned findings it was revealed that among the different treatments, T_1 performed the best in reducing the infestation intensity of leaf (72.24%) of cabbage by tobacco caterpillar at harvesting than the other treatments; whereas, T_5 showed the least performance in reducing the infestation intensity of leaf (35.09%) of cabbage by tobacco caterpillar 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 tobacco caterpillar at harvesting was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Paliwal and Oommen (2005) reported that spinosad was most effective against *S. litura* in cauliflower.

Table 8. Percent leaf infestation intensity of cabbage by tobacco caterpillar in different treatments during harvesting

Treatments	Percent leaf infestation by tobacco caterpillar at harvest	Percent reduction over control
T_1	8.79 f	72.24
T_2	10.70 e	66.20
T_3	16.61 c	47.54
T_4	13.57 d	57.14
T_5	20.55 b	35.09
T_6	31.66 a	--
LSD $_{(0.05)}$	**1.70**	**--**
CV%	**6.85**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.4.2 Leaf infestation intensity by jute hairy caterpillar during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of leaf infestation intensity due to the attack of jute hairy caterpillar during the harvesting period (Table 9).

The highest leaf infestation intensity (19.61%) was recorded in T_6 which was significantly different from all other treatments. But in the treated plots, the highest leaf infestation intensity was found in T_5 (13.57%) which was statistically dissimilar with T_3 (10.816%), T_4 (8.87%) and T_2 (8.01%). On the other hand, the lowest leaf infestation intensity was observed in T1 (6.29%) which was significantly different from all other treatments. So, it can be observed that the leaf infestation intensity among the treatments from the highest to the lowest was shown as $T_6 > T_5 > T_3 > T_4 > T_2 > T_1$.

In case of % reduction over control, the highest reduction over control on leaf infestation intensity was achieved by T_1 (67.92%) where the lowest was found in T_5 (30.80%) (Table 9).

From the above mentioned findings it was revealed that among the different treatments, T_1 performed the best in reducing the infestation intensity of leaf (67.92%) of cabbage by the jute hairy caterpillar at harvest than the other treatments; whereas, T_5 showed the least performance in reducing the infestation intensity of leaf (30.80%) of cabbage by tobacco caterpillar 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 jute hairy caterpillar at harvesting was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Biopesticides namely buprofezin (Award 40SC), emamectin benzoate (Suspend 5SG), spinosad (Libsen 45SC) and *B. thuringiensis* individually in their recommended doses is compared with their alternate application with *B. thuringiensis* against the “caterpillar complex” on cabbage. All the recommended package of practices was followed except plant protection measures. Buprofezin (Award 40SC), emamectin benzoate (Suspend 5SG), spinosad (Libsen 45SC) and *B. thuringiensis* (Bt) @ 1.0 ml/L, 1.0 g/L, 0.50 ml/L and 3.0 g/L, respectively were used. Insecticidal spray was initiated when insect density rose above threshold level (Dutt and Das 2021).

Table 9. Percent leaf infestation intensity of cabbage by jute hairy caterpillar in different treatments during harvesting

Treatments	Percent leaf infestation by jute hairy caterpillar at harvest	Percent reduction over control
T_1	6.29 e	67.92
T_2	8.01 d	59.15
T_3	10.81 c	44.87
T_4	8.87 d	54.77
T_5	13.57 b	30.80
T_6	19.61 a	--
LSD $_{(0.05)}$	**1.07**	**--**
CV%	**6.49**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.5 Percent infestation of head by number due to attack of tobacco caterpillar during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of percent infestation of head by number due to attack of tobacco caterpillar during harvesting period (Table 10).

The highest % infestation of head by number (45.52%) was recorded in T_6 which was significantly different from all other treatments. In the treated plots, the highest % infestation of head by number was found in T_5 (33.47%) which was statistically dissimilar with T_3 (29.30%) and T_4 (25.33%). On the other hand, the lowest % infestation of head by number was observed in T_1 (12.55%) which was significantly different from all other treatments and followed by T_2 (16.62%). So, it can be observed that the leaf infestation intensity among the treatments from highest to the lowest was shown as $T_6 > T_5 > T_3 > T_4 > T_2 > T_1$.

In case of percent reduction over control, the highest reduction over control on percent infestation of head by number was achieved by T_1 (72.43%) where the lowest was found in T_5 (26.47%) (Table 10).

From the above mentioned findings it was revealed that among the different treatments, T_1 performed the best results in reducing the infestation intensity of head by number due to attack of tobacco caterpillar (72.43%) at harvest than the other treatments. Whereas, T_5 showed the least performance results in reducing the infestation intensity of head by number by tobacco caterpillar (26.47%) at harvest 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 tobacco caterpillar at harvest was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Table 10. Percent head infestation of cabbage by tobacco caterpillar in the infested head in different treatments at harvest

Treatments	Percent head infestation by tobacco caterpillar at harvest	Percent reduction over control
T_1	12.55 f	72.43
T_2	16.62 e	63.49
T_3	29.30 c	35.63
T_4	25.33 d	44.35
T_5	33.47 b	26.47
T_6	45.52 a	--
LSD $_{(0.05)}$	**2.65**	**--**
CV%	**6.70**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.6.1 Height of head during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of height of head during harvesting period (Table 11). The highest height of head (12.13 cm) was recorded in T_1 which was statistically identical with T_2 (12.11 cm) and T_4 (11.47 cm). On the other hand, the lowest head height (8.58 cm) was found in T_6 which was significantly different from all other treatments. But in the treated plots, the lowest head height (10.75 cm) was found in T_5 which was statistically identical with T_3 (11.18 cm). The gradually decreased trend was observed in case of height of head as $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

In terms of % increase over control, the highest increase over control on head height was observed in the treatment T_1 (41.37%) which was very close to T_2 (41.14%), where the lowest was achieved from T_5 (25.29%) (Table 11).

From the above mentioned findings it was revealed that among the different treatments, T_1 performed the best results in percent increasing height of head (41.37%) at harvest than the other treatments; whereas, T_5 showed the least performance results in percent increasing height of head (25.29%) at harvest over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of percent increasing height of head at harvesting was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

4.6.2 Diameter of head during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of diameter of head during harvesting period (Table 11). The highest diameter of head (22.75 cm) was recorded in T_1 which was statistically identical with T_2 (22.11 cm) and T4 (22.03 cm). On the other hand, the lowest head diameter (15.37 cm) was found in T_6 which was significantly different from all other treatments. But in the treated plots, the lowest head diameter (20.26 cm) was found in T_5 which was statistically identical with T_3 (21.25 cm). The gradually decreased trend was observed in case of diameter of head as $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

In terms of % increase over control, the highest increase over control on head diameter was observed with the treatment of T_1 (48.01%) where the lowest was achieved from T_5 (31.81%) (Table 11).

From the above mentioned findings it was revealed that among the different treatments, T_1 performed the best results in percent increasing diameter of head (48.01%) at harvest than the other treatments; whereas, T_5 showed the least performance results in percent increasing diameter of head (31.81%) at harvest 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 harvest was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Table 11. Effect of different treatments on yield contributing characters of cabbage

Treatments	Height (cm)	Percent increase over control	Diameter (cm)	Percent increase over control
T_1	12.13 a	41.37	22.75 a	48.01
T_2	12.11 a	41.14	22.11 ab	43.85
T_3	11.18 b	30.30	21.25 bc	38.26
T_4	11.47 ab	33.68	22.03 ab	43.33
T_5	10.75 b	25.29	20.26 c	31.81
T_6	8.58 c	--	15.37 d	--
LSD $_{(0.05)}$	**0.73**	**--**	**0.99**	**--**
CV%	**4.54**	**--**	**3.31**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.

[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]

DAT = Days after transplanting.

4.7.1 Single head weight during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of single head weight during harvesting (Table 12). The highest single head weight (1.93 kg) was recorded in T_1 which was statistically different from all other treatments and followed by T_2 (1.76 kg) and T_4 (1.59 kg). On the other hand, the lowest single head weight (0.97 kg) was found in T_6 which was significantly different from all other treatments. But in the treated plots, the lowest single head weight (1.31 kg) was found in T_5 which was close to T_3 (1.39 kg). The gradually decreased rank was observed in case of single head weight as $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

In terms of % increase over control, the highest increase over control on single head weight was observed with the treatment of T_1 (98.97%) where the lowest was achieved from T_5 (35.05%) (Table 12). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of single head weight at harvest was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

4.7.2 Total yield

Significant variations were observed among the different treatments used for the management practices in terms of total yield (t ha^{-1}) of cabbage (Table 12). The highest total yield (75.80 t ha^{-1}) was recorded in T_1 which was statistically different from all other treatments and followed by T_2 (69.04 t ha^{-1}) and T_4 (61.64 t ha^{-1}). The lowest total yield (38.49 t ha^{-1}) was found in T_6 which was significantly different from all other treatments. But in the treated plots, the lowest total yield (50.59 t ha^{-1}) was found in T_5 which was followed by T_3 (53.99 t ha^{-1}). The gradually decreased trend was observed in case of total yield as $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$ (Table 12).

In terms of % increase over control, the highest increase over control on total yield was observed with the treatment of T_1 (96.93%) which was followed by T_2 (79.37%) and T_4 (60.14%), whereas the lowest was achieved from T_5 (31.44%) and followed by T_3 (40.27%) (Table 12). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent increase of total yield (t ha-[1]) at harvest was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Gupta (2000) recorded significantly higher yield of cabbage heads for the treatment of spinosad.

Table 12. Individual head weight and total yield of cabbage in different treatments during harvesting

Treatments	Single head wt. (kg)	Percent increase over control	Total yield (ton/ha)	Percent increase over control
T_1	1.93 a	98.97	75.80 a	96.93
T_2	1.76 b	81.44	69.04 b	79.37
T_3	1.39 d	43.30	53.99 d	40.27
T_4	1.59 c	63.92	61.64 c	60.14
T_5	1.31 d	35.05	50.59 e	31.44
T_6	0.97 e	--	38.49 f	--
LSD $_{(0.05)}$	**0.15**	**--**	**2.64**	**--**
CV%	**6.75**	**--**	**3.07**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

4.8.1 Infested head weight during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of infested head weight during harvesting (Table 13). The highest infested head weight (1.19 kg) was recorded in T_1 which was statistically similar with T_2 (1.16 kg) and followed by T_4 ((1.10 kg). On the other hand, the lowest infested head weight (0.72 kg) was found in T_6 which was significantly different from all other treatments. But in the treated plots, the lowest infested head weight (1.01 kg) was found in T_5 which was statistically similar to T_3 (1.05 kg). The gradually decreased trend was observed in case of infested head weight as $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$ (Table 13).

In terms of % increase over control, the highest increase over control on infested head weight was observed with the treatment of T_1 (65.28%) followed by T_2 (61.11%) and T_4 (52.78%). Whereas the lowest was achieved from T_5 (40.28%) which was very close to T_3 (45.83%) (Table 13). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent increase of infested head weight during harvesting was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

4.8.2 Healthy head weight during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of healthy head weight during harvesting (Table 13). The highest healthy head weight (2.20 kg) was recorded in T_1 which was statistically similar with T_2 (2.16 kg), and T_4 (2.05 kg). On the other hand, the lowest healthy head weight (1.38 kg) was found in T_6 which was significantly different from all other treatments. But in the treated plots, the lowest healthy head weight (1.82 kg) was found in T_5 which was closely followed by T_3 (1.91 kg). The gradually decreased trend was observed in case of healthy head weight as $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$. (Table 13).

In terms of % increase over control, the highest increase over control on healthy head weight was observed with the treatment of T_1 (59.42%) followed by T_2 (56.52%) and T_4 (48.55%). Whereas the lowest was achieved from T_5 (31.88%) which was close to T_3 (38.40%) (Table 13). As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent increase of healthy head weight at harvesting was $T_1 > T_2 > T_4 > T_3 > T_5 > T_6$.

Table 13. Infested head weight and healthy head weight of cabbage in different treatments during harvesting

Treatments	Infested head weight (kg)	Percent increase over control	Healthy head weight (kg)	Percent increase over control
T_1	1.19 a	65.28	2.20 a	59.42
T_2	1.16 ab	61.11	2.16 a	56.52
T_3	1.05 cd	45.83	1.91 bc	38.40
T_4	1.10 bc	52.78	2.05 ab	48.55
T_5	1.01 d	40.28	1.82 c	31.88
T_6	0.72 e	--	1.38 d	--
LSD $_{(0.05)}$	**0.08**	**--**	**0.17**	**--**
CV%	**5.20**	**--**	**6.20**	**--**

In column, means containing same letter(s) are not significantly different by DMRT at 5% level of significance.
[T_1= Spinomax 45SC @ 0.5 ml/L of water at 7 days interval, T_2= Biomax 1.2EC @ 2 ml/L of water at 7 days interval, T_3= Bioneem plus 1EC @ 3 ml/L of water at 7 days interval, T_4= Antario @ 2 g/L of water at 7 days interval, T_5= Fytomax @ 2 ml/L of water at 7 days interval and T_6= Untreated control]
DAT = Days after transplanting.

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

Significant relationship was found between leaf infestation by tobacco caterpillar and yield of cabbage when correlation was fitted between these two parameters. There was a very strong (R^2 = 0.9222) and negative (slope = -1.4174) correlation found between leaf infestation by tobacco caterpillar and yield of cabbage, i.e. yield of cabbage decreased with the increasing of cabbage leaf infestation by caterpillar (Figure 2). Tobacco caterpillar infestation on leaf indirectly prevented plants to produce and supply nutrient and water. The plants growth and development became stunted with a reduced yield.

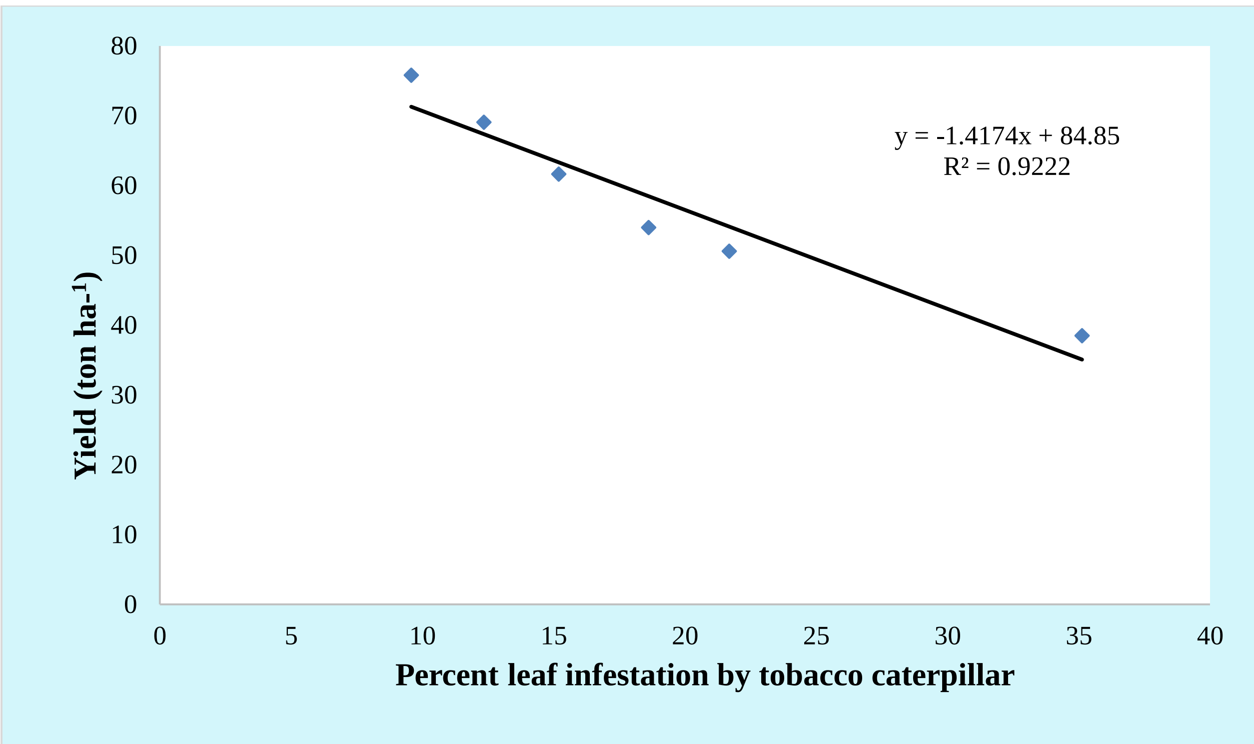

Figure 2. Relationship between leaf infestation by tobacco caterpillar and yield of cabbage.

4.10 Relationship between leaf infestation by jute hairy caterpillar and yield of cabbage

Significant relationship was observed when correlation was made between leaf infestation by jute hairy caterpillar and yield of cabbage. The highly significant ($p<0.05$), very strong ($R^2 = 0.9062$) and negative (slope = -2.3646) correlation was found between these two parameters, i.e. yield of cabbage decreased with the increasing of leaf infestation by jute hairy caterpillar (Figure 3). From the present study, it was revealed that leaf infestation by jute hairy caterpillar indirectly prevented plants to produce and supply nutrient and water. The plants growth and development became stunted with a reduced yield.

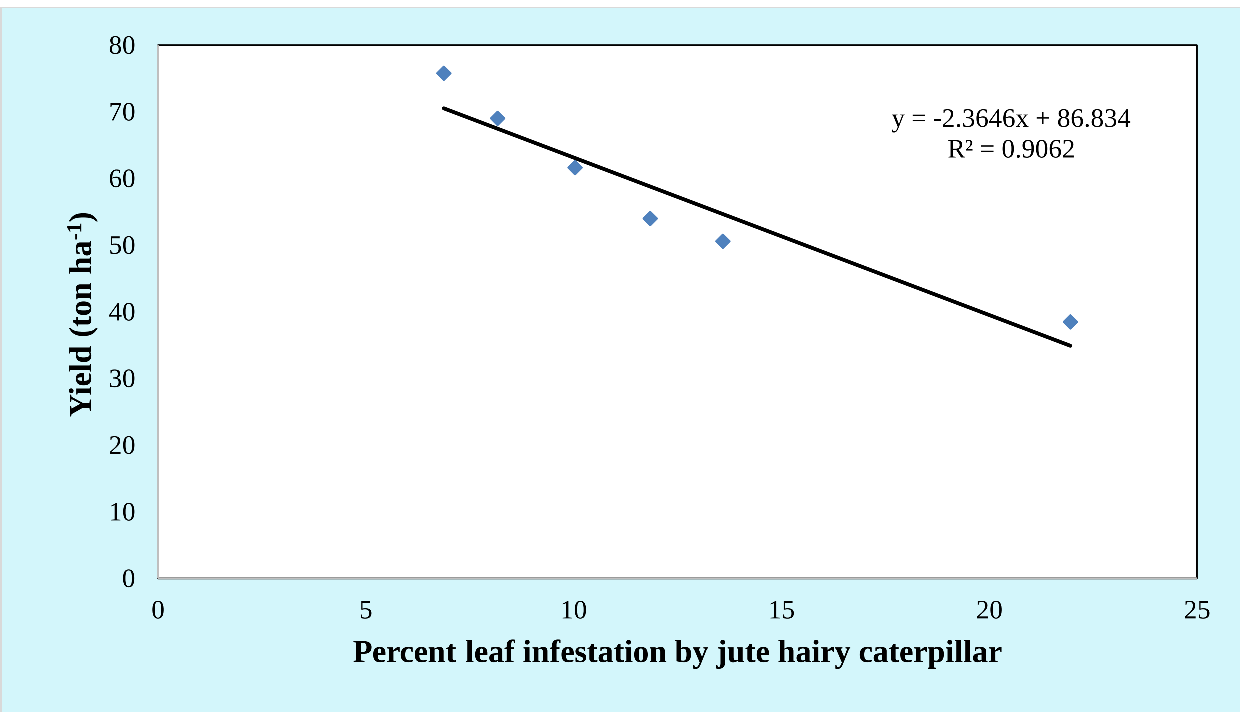

Figure 3. Relationship between leaf infestation by jute hairy caterpillar and yield of cabbage.

4.11 Relationship between incidence of tobacco caterpillar and yield of cabbage

When a linear regression was fitted between these two parameters, a highly significant ($p<0.05$), very strong ($R^2 = 0.9227$) and negative (slope = -6.5396) correlation was found between incidence of tobacco caterpillar and yield of cabbage, i.e. yield of cabbage decreased with the increasing incidence of tobacco caterpillar (Figure 4). From the present study, it may be revealed that higher number of tobacco caterpillar increased the leaf infestation of cabbage which indirectly prevented plants to produce and supply nutrient and water. The plants growth and development became stunted with a reduced yield.

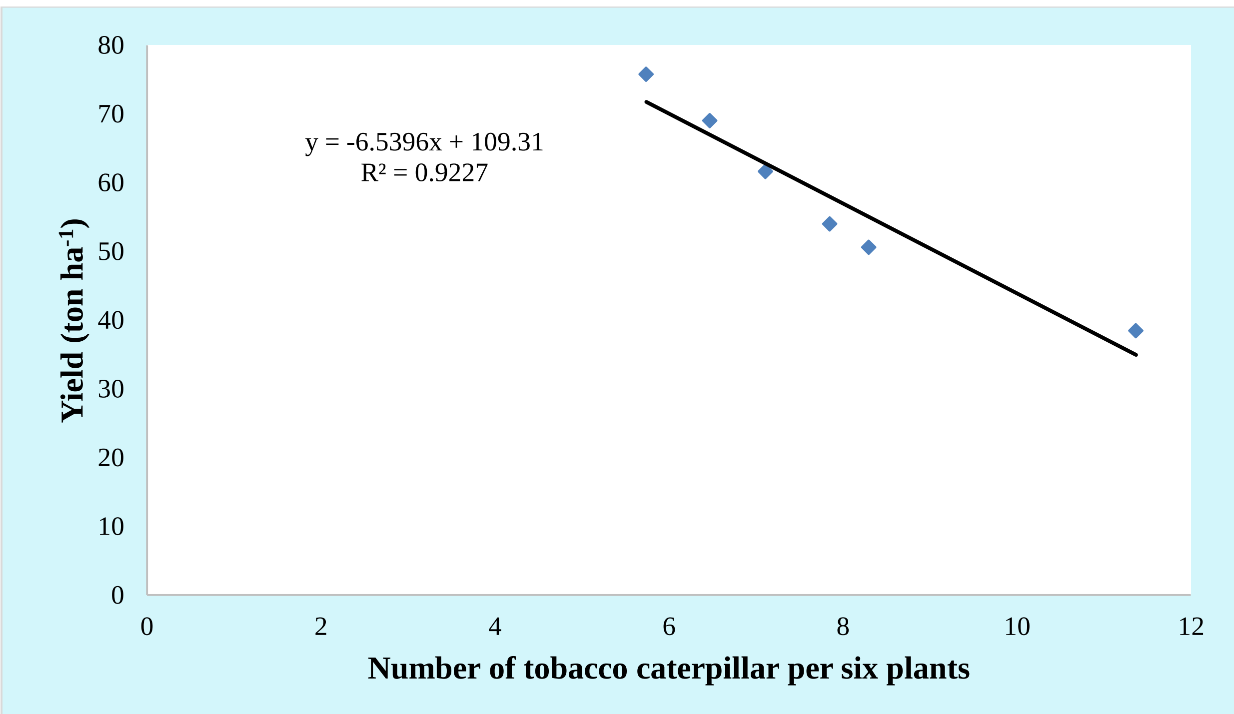

Figure 4. Relationship between incidence of tobacco caterpillar and yield of cabbage.

4.12 Relationship between incidence of jute hairy caterpillar and yield of cabbage

A linear regression was fitted between the incidence of jute hairy caterpillar and yield of cabbage (t ha^{-1}). A highly significant ($p<0.05$), very strong ($R^2 = 0.8991$) and negative (slope = -6.06) correlation was found between these two parameters, i.e. yield of cabbage decreased with the increasing number jute hairy caterpillar (Figure 5). In this study, it was revealed that the higher number of jute hairy caterpillar led to the higher leaf infestation of cabbage.

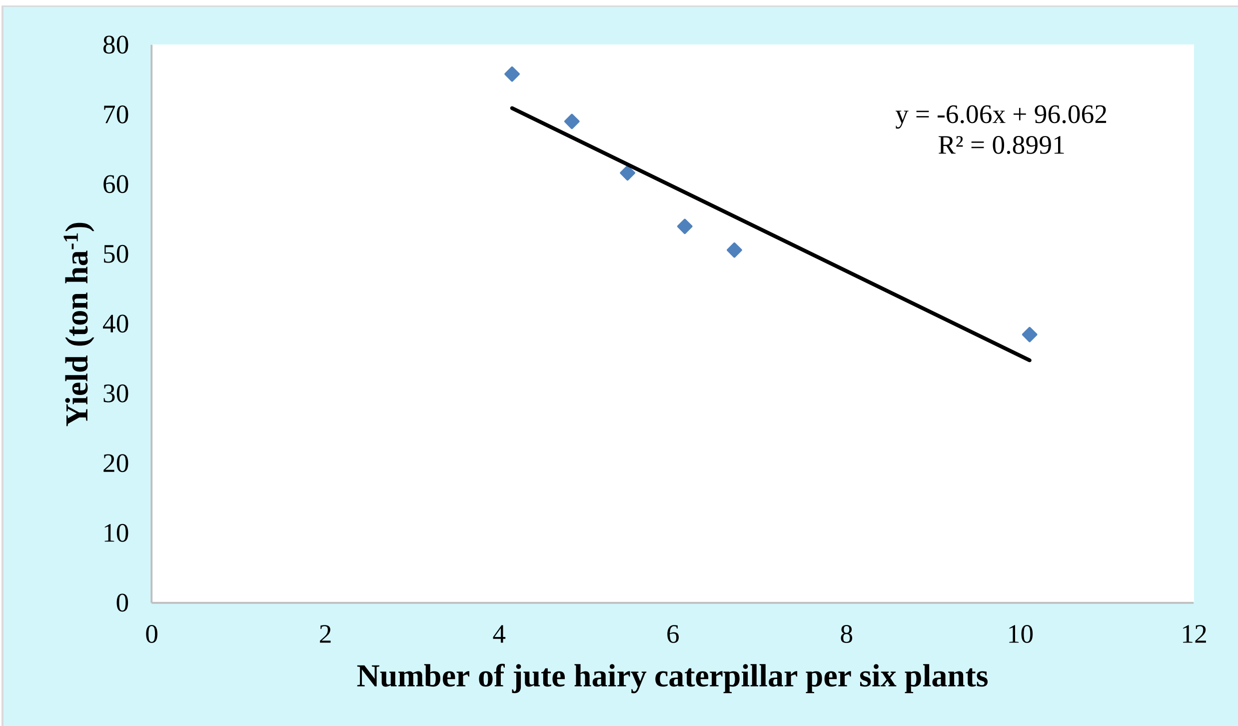

Figure 5. Relationship between incidence of jute hairy caterpillar and yield of cabbage.

4.13 Relationship between percent head infestation during harvest and weight of individual head

The results revealed that there was strong negative correlation between head infestation intensity and weight of individual head (kg), which suggested that with the increase of head infestation intensity there was a decrease on single head weight (kg). A linear regression was fitted between weight of individual head and head infestation intensity at harvest (Figure 6). A highly significant ($p<0.05$), very strong ($R^2 = 0.9911$) and negative (slope = -0.0287) correlation was found between these two parameters. In the present study, it was observed that infestation on head passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced single head weight.

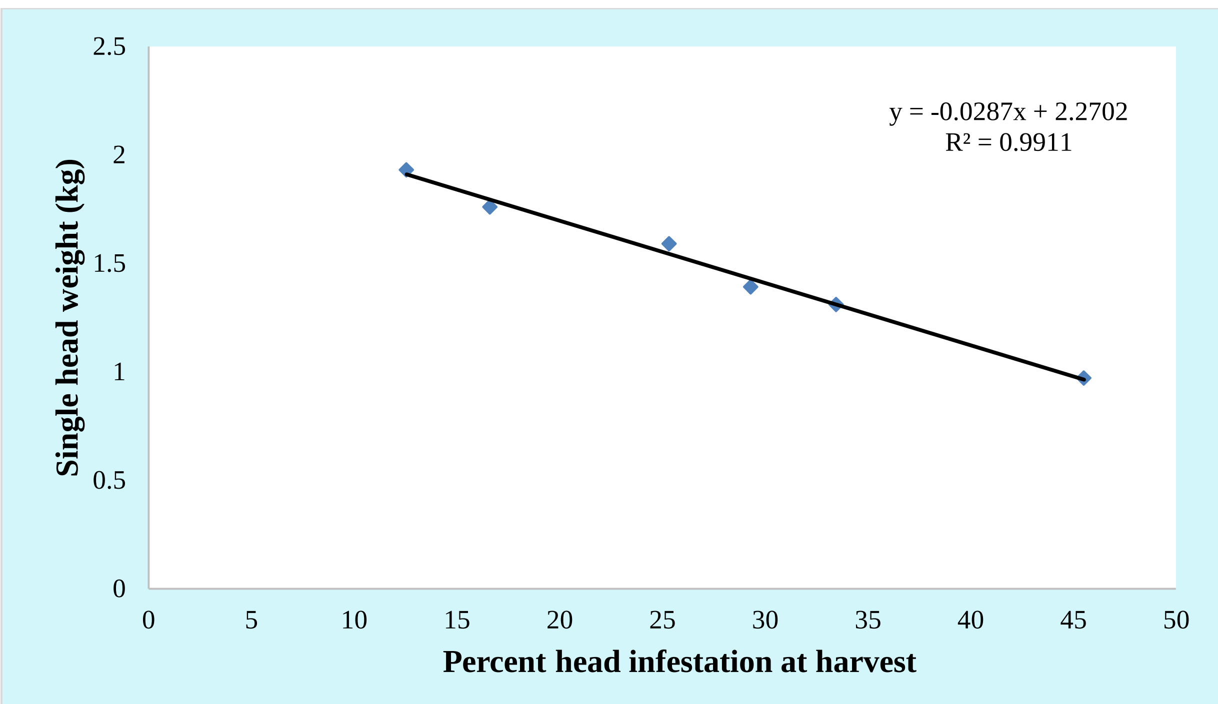

Figure 6. Relationship between percent head infestation during harvest and weight of individual head.

4.14 Relationship between percent head infestation during harvest and total yield of cabbage

A linear regression was fitted between total yield of cabbage (t ha^{-1}) and percent head infestation at harvest (Figure 7). The results revealed that there was strong negative correlation between head infestation intensity and total yield (t ha^{-1}), which suggested that with the increase of head infestation intensity, there was a significant decrease on total yield of cabbage. A highly significant ($p<0.05$), very strong (R^2 = 0.9904) and negative (slope = -1.1229) correlation was found between these two parameters. In the present study, it was observed that infestation on head passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

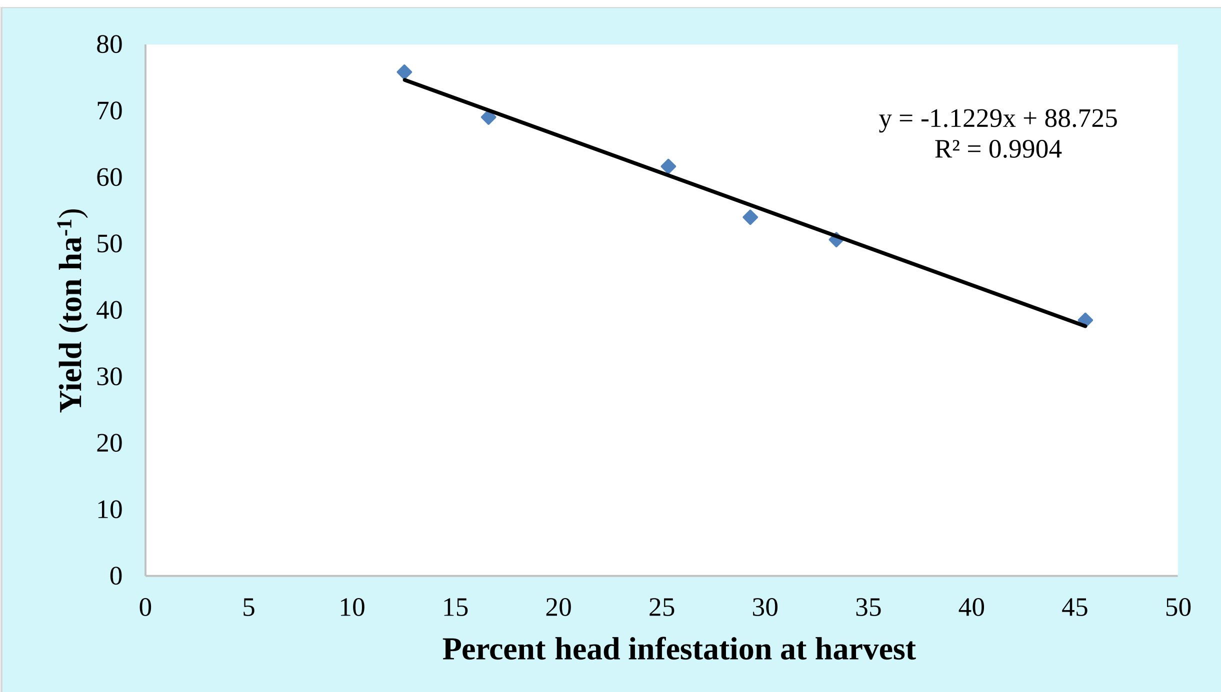

Figure 7. Relationship between percent head infestation during harvest and total yield of cabbage.

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the central farm, Sher-e-Bangla Agricultural University during the period from October 2020 to February 2021 to evaluate some biorationals against leaf feeding insect pests in the cabbage field.

Six treatments, viz. T_1 (Spinomax 45SC @ 0.5 ml/L of water at 7 days interval); T_2 (Biomax 1.2EC @ 2 ml/L of water at 7 days interval); T_3 (Bioneem plus 1EC @ 3 ml/L of water at 7 days interval); T_4 (Antario @ 2 g/L of water at 7 days interval); T_5 (Fytomax @ 2 ml/L of water at 7 days interval); and T_6 (untreated control) were included in this study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications.

Two leaf feeding insect pests i.e. tobacco caterpillar (*Spodoptera litura*) and jute hairy caterpillar (*Spilosoma obliqua*) 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, and percent head infestation by number. From the beginning of head formation stage to the harvest, significant results was also observed in terms of leaf infestation intensity, 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 by tobacco caterpillar (10.54, 12.91, 9.63, 7.49 and 7.32 at 43, 50, 57, 64 and 71 DAT, respectively and the average percent of leaf infestation 9.58 was observed in $T_{1,}$ where the highest (28.68, 32.78, 36.82, 39.23 and 38.15 at 43, 50, 57, 64 and 71 DAT, respectively and the average percent of leaf infestation 35.13 was obtained from T_6. But in the treated plots, the highest percentage of leaf infestation (24.55, 26.73, 21.21, 18.05 and 17.89 at 43, 50, 57, 64 and 71 DAT, respectively and the average percent of leaf infestation 21.69 was achieved from T_5.

In case of jute hairy caterpillar, the lowest percentage of leaf infestation (8.37, 7.11, 6.54, 6.32 and 6.07 at 50, 57, 64, 71 and 78 DAT, respectively and the average percent of leaf infestation 6.88 was observed in T_1 where the highest (19.14, 21.42, 22.39, 23.47 and 23.36 at 50, 57, 64 , 71 and 78 DAT, respectively and the average percent of leaf infestation 21.96 was obtained from T_6. But in the treated plots, the highest percentage of leaf infestation (17.39, 14.49, 12.42, 12.36 and 11.35 at 50, 57, 64, 71 and 78 DAT, respectively and the average percent of leaf infestation 13.60 was achieved from T_5.

In case of incidence of two insects, the lowest mean number of two insect larvae per six plants was found in T_1 (5.74 and 4.15 for tobacco caterpillar and jute hairy caterpillar respectively). On the other hand, the highest mean number of tobacco caterpillar and jute hairy caterpillar larvae per six plants was found in T_6 (11.37 and 10.11, respectively). But in the treated plots, the highest mean number of tobacco caterpillar and jute hairy caterpillar larvae per six plants was found in T_5 (8.30 and 6.71, respectively).

Results showed that the lowest percentage of head infestation by number (25.28, 31.81, 24.86, 20.50 and 15.76 at 43, 50, 57, 64 and 71 DAT, respectively and the average percent of head infestation 23.64 was observed in T_1 where the highest (49.50, 54.56, 58.10, 62.22 and 57.24 at 43, 50, 57, 64 and 71 DAT, respectively and the average percent of head infestation 56.32 was obtained from T_6 . But in the treated plots, the highest percentage of head infestation by number (41.00, 45.64, 41.42, 37.26 and 33.36 at 43, 50, 57, 64 and 71 DAT, respectively and the average percent of head infestation 39.74 was achieved from T_5.

Again, during harvesting period the lowest leaf infestation intensity of tobacco caterpillar and jute hairy caterpillar (8.79% and 6.29%, respectively), percent infestation of head by number (12.55%), the highest height of head (12.13 cm), diameter of head (22.75 cm), single head weight (1.93 kg), healthy head weight (2.20 kg) and the highest total yield (75.80 t ha^{-1}) were observed in $T_{1.}$ In contrast, the highest leaf infestation intensity of tobacco caterpillar and jute hairy caterpillar (31.66% and 19.61% respectively), percent infestation of head by number (45.52%), the lowest height of head (8.58 cm), diameter of head (15.37 cm), single head weight (0.97 kg), healthy head weight (1.38 kg) and the lowest total yield (38.49 t ha^{-1}) were obtained from T_6. But in the treated plots, the highest leaf infestation intensity tobacco caterpillar and jute hairy caterpillar (20.55% and 13.57% respectively), percent infestation of head by number

(33.47%), the lowest height of head (10.75 cm), diameter of head (20.26 cm), single head weight (1.31 kg), healthy head weight (1.82 kg) and lowest total yield (50.59 t ha^{-1}) were obtained from T_5.

In terms of percent reduction or increase over control, the highest percent reduction of leaf infestation by tobacco caterpillar and jute hairy caterpillar over control (72.73% and 68.67%, respectively), incidence of tobacco caterpillar and jute hairy caterpillar over control (49.52% and 58.95%, respectively), percent reduction of head infestation by number over control (58.02%), percent reduction of leaf infestation of tobacco caterpillar and jute hairy caterpillar at harvest over control (72.24% and 67.92%, respectively), percent reduction of infestation of head during harvest by number (72.43%), percent increase of height of head over control (41.37%), percent increase of diameter of head over control (48.01%) and percent increase of total yield over control (96.93%) were achieved by $T_{1.}$ On the other hand, the lowest percent reduction of leaf infestation of tobacco caterpillar and jute hairy caterpillar over control (38.26% and 38.07%, respectively), incidence of tobacco caterpillar and jute hairy caterpillar over control (27.00% and 33.63%, respectively), percent reduction of head infestation by number over control (29.44%), percent reduction of leaf infestation of tobacco caterpillar and jute hairy caterpillar at harvest over control (35.09% and 30.80%, respectively), percent reduction of infestation of head during harvest by number (26.47%), percent increase of height of head over control (25.29%), percent increase of diameter of head over control (31.81%) and increase of total yield over control (31.44%) were achieved by T_5 .

From the above discussion on summary, it can be concluded that, the treatment of T_1 comprised of Spinomax 45SC @ 0.5 ml/L of water at 7 days interval gave the best performance compared to all other treatments used under the present study, where the lowest performance was obtained by untreated control. On the other hand, the lowest performance among the treated plots was achieved by T_5 (Fytomax @ 2 ml/L of water at 7 days interval).

RECOMMENDATIONS

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

1. Spinomax 45SC may be used for the management of leaf feeding insect pests of cabbage.

2. Other biorationals may be included for the management of leaf feeding insect pests of cabbage.

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

CHAPTER VI

REFERENCES

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CHAPTER VII

APPENDICES

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APPENDICES

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

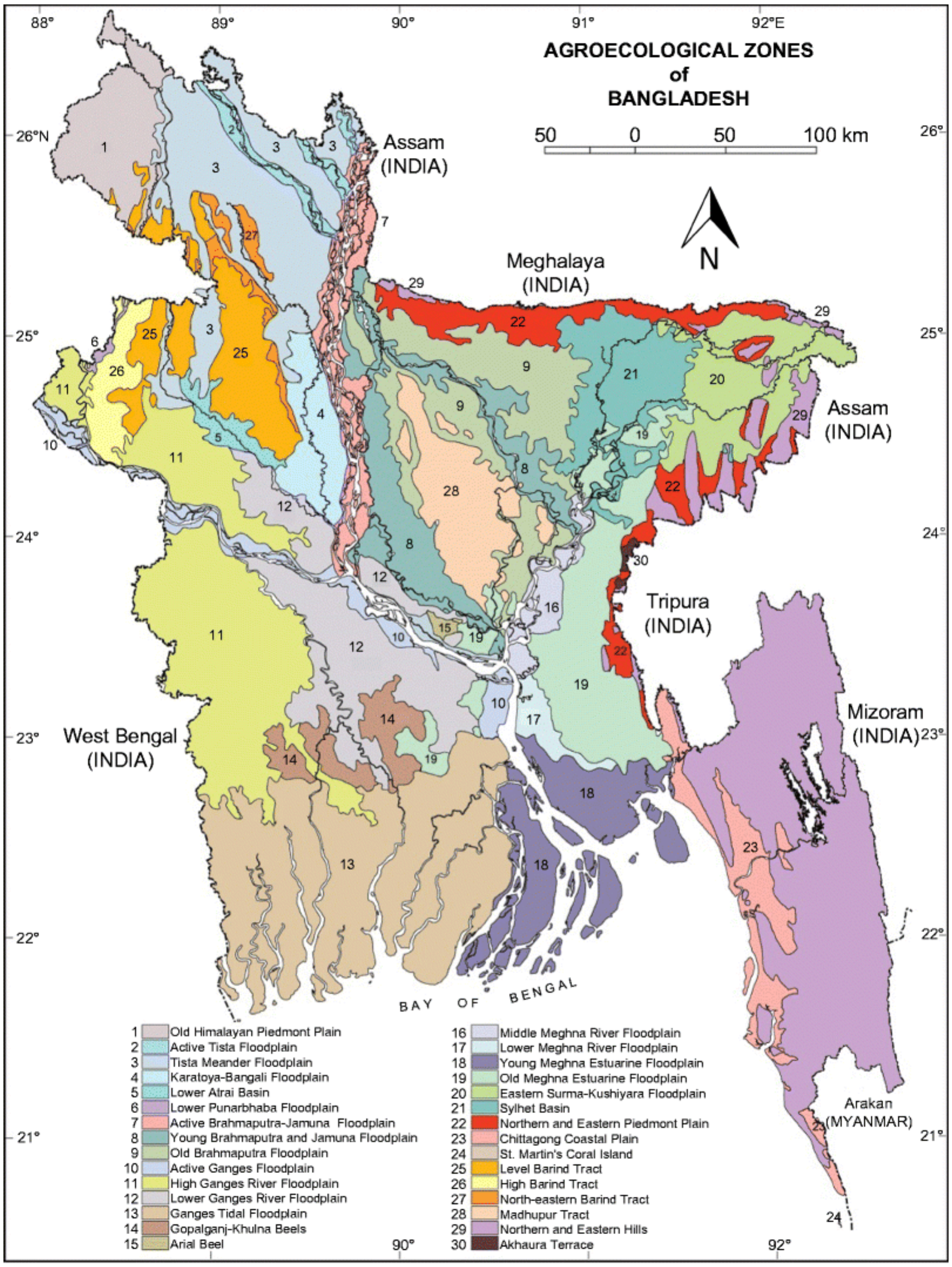

Figure: The map of Bangladesh showing experimental site.

Appendix II. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (October, 2020 to February, 2021) at Sher- e - Bangla Agricultural University campus

Month	Air temperature (^0C)		Relative humidity (%)	Rainfall (mm) (Total)	Sunshine (hr.)
	Maximum	Minimum			
October,2020	32	25.31	74	163	7
November,2020	30	19.80	66	26	8
December,2020	29.40	15.50	79	13	9
January,2021	24.36	13.25	67	8	7
February,2021	30.2	17.92	54	27	6

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

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

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

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