DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT PESTS OF BROCCOLI

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CERTIFICATE

*This is to certify that thesis entitled **"DAMAGE ASSESSMENT AND MANAGEMENT OF INSECT PESTS OF BROCCOLI"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **MAHFUZUR RAHMAN, Registration no. 13-05499** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2020
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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September, 2018 to May, 2019 to evaluate the damage assessment and management of insect and other arthropod pests of broccoli. The experiment was laid out in Randomized Complete Block Design (2 factor) replicated with three times. For this study, factor A- V_1: Local variety (Anika), V_2: BARI broccoli 1 and V_3: Exotic variety and factor B- T_1: Contact (Malathion 57EC @ 2ml/L of water); T_2: Systemic (Actara 25WG @ 0.12gm/L of water); T_3: Stomach (Sevin 85WP @ 1gm/L of water), T_4: Antifedent (Neem oil @ 3ml/L of water) and T_0: Control. The cutworm infestation on broccoli seedlings was highest in $V_{1.}$ The infestation was initiated in the broccoli field at 4 DAT and become maximum at 10 DAT. The infestation was declined gradually and no infestation was recorded at 18 DAT. The incidence of insect pests like aphid, diamond back moth, cabbage semi-looper, Jassid and mole cricket, insect pest infestation (i.e. leaves and plants) were lowest and highest in yield attributing characteristics (i.e. plant height, number of leaves, length of leaves, breadth of leaves, curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha) for exotic variety.The incidence of aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket, the number of infested leaves and plants caused by insect pests were low and high in case of plant height, number of leaves, length of leaves, breadth of leaves, curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha for spraying neem oil @ 3ml/L of water. Again, Exotic variety along with spraying neem oil @ 3ml/L of water showed the best performance in reducing the number of insect incidence, insect infestation (i.e. leaves and plants) and yield attributing characteristics. The order of rank was $V_3T_4 < V_2T_4 < V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 < V_1T_{0.}$

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
CV	Coefficient of variation
°C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
CRSP	Collaborative Research Support Project
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wettable Powder

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CHAPTER I

INTRODUCTION

The broccoli is a member of 'Cole Crop group' closely related to cabbage, cauliflower, kale and mustard. It is botanical classified as a variety of *Brassica oleracea* species, grown during cool-season for its green flowering head. The word broccoli comes from Italian word *broccolo*, which means 'flowering crest of a cabbage". Broccoli has large flower heads, usually green in color, arranged in a tree-like structure on branches sprouting from a thick, edible stalk. There are three classes of broccoli, i.e. green, white and purple, among them green type broccoli is the most popular (Shoemaker 1962). India is the second largest producer of broccoli after China, while the US ranks third. It is also used as a vegetable in many other countries such as Spain, Mexico, Italy, France, United States, etc. (Kumar *et al.* 2014). It is a minor vegetable in Bangladesh and commercial cultivation of broccoli has increased especially in the area of Dhaka and Gazipur districts.

Broccoli is a high-quality vegetable for fresh use and is one of the most popular frozen vegetables. It is highly nutritious crop containing high amount of vitamins (A and C) and minerals (K, P, Ca and Fe) (Nonnecke 1989). Moreover, it also contains ascorbic acid, thiamine, riboflavin and niacin. Broccoli is the richest source of protein among cole crops (Lincolin 1987 and Thompson and Kelly 1957). A high intake of broccoli has been found to reduce the risk of cancer (as it contains glucoraphanin compound) and also prevents heart disease (Allen and Allen 2007). Therefore, it can be met up some degree of vitamin A and vitamin C requirement and can contribute to solve malnutrition problem in Bangladesh. The per capita production of vegetable in Bangladesh is very low as compared to that of other countries. Due to low production of vegetables, the percent per capita consumption is only about 30g but it is 70g with potato and sweet potato. It is an alarming situation for vegetable consumption in Bangladesh. So, a large-scale production of broccoli can help to increase vegetable consumption.

Broccoli is environmentally better adapted than cauliflower and is reported to withstand comparatively at higher temperature than cauliflower (Rashid 1976). Broccoli can be grown on a wide range of soil types, ranging from light sand to heavy loam ar even clay that are well supplied with organic matter (Katayal 1994). Successful production of broccoli depends on various factors.

Pest problem is one of the major constraints for achieving higher production. Broccoli suffers extensively from insect pests and it is attacked by more than 25 insect species (Bhoopathi and Pathak 2012). Major insects of broccoli are diamondback moth (*Plutella xylostella* L.), leaf webber (*Crocidolomia binotalis* Zeller), cabbage butterfly (*Pieris brassicae* L.), mustard sawfly (*Athalia lugens proxima* Klug), aphid (*Brevicoryne brassicae* L.), painted bug (*Bagrada cruciferarum* Kirkaldy), cabbage webworm (*Hellula undalis* Feb.), termite (*Microtermes obesi* Holmgren), cutworm (*Agrotis ipsilon* Hufnagel), leaf eating weevil (*Tanymecus circumdatus* Wiedemann), cabage semilooper (*Trichoplusia ni* Hubner), leaf miner (*Chromatomyia horticola* Goureau), whitefly (*Bemisia tabaci* Gennadius), red spider mite (*Tetranychus urticae* Koch), crucifer flea beetle (*Phyllotreta cruciferae* Goeze), thrips (*Frankliniella occidentalis* Pergande) etc. Diamondback moth is the most destructive insect for broccoli (Satyagopal *et al.* 2015). The high levels of incidence of these pests affect crop production. Most vegetable crops are subjected to pest damage and seeds, roots, stems, leaves and fruit are all susceptible. Insect damage ranges from reduced plant vigor to plant death and heavy crop losses occur. Insect injury plants by chewing foliages, sucking juices, laying eggs and transmitting diseases.

Managing and controlling insect pests is one of the keys to successful vegetable farming and their identification is an essential first step. Farmers use chemical insecticides as an indiscreaminate rate for insect pest management in broccoli field. As a result, it become hazardous for human health, environment and other animals (Grainge and Ahmed 1988). Botanical pesticides are also special because they can be prodced easily by farmers for sustainable agriculture and small industries (Roy *et al.* 2005). About 413 different species/sub-species of insect pest have been listed by (Schmutterer, 1995) found to be susceptible to neem products. The listed species/sub-species belongs to different insect orders most of them were Lepidoptera (136) and Coleopteran (79). In Bangladesh, no works found on the efficacy of botanical insecticides in broccoli field. For this reason, this study was taken to evaluate insect incidence and management practices of broccoli.

Objectives

For fulfill of the study some objectives are sorted out. They are given in follows:

i. To find out the incidence of major insect pest of broccoli in field condition;

ii. To evaluate the damage cause by insect pest of broccoli; and

iii. To find out tolerant variety of broccoli.

CHAPTER II

REVIEW OF LITERATURE

Broccoli is a minor but become an important vegetable crop in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests, diamondback moth, leaf webber, cabbage butterfly, mustard sawfly, aphid, painted bug, cabbage webworm, termite, cutworm, leaf eating weevil, cabage semilooper, leaf miner, whitefly, red spider mite, crucifer flea beetle, thrips etc. are the major pests of broccoli. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings:

2.1. General review of insect pest of broccoli

2.1.1. Diamondback moth

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

Nature of damage

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

The larval stage of the diamondback moth (DBM) makes numerous small holes in the leaves, and sometimes leaves fine webbing in the center of the plant. Foliar injury lowers the quality of the crop, and weakens the plant. The larvae themselves can be a contaminant of the final product. Of the three lepidopteron pests of cabbage, DBM is by far the most difficult to control in New York (Moyer 1999). It usually devours only a small portion of leaf. Larvae work on the underside and eat many small holes. Frequently they leave only the upper epidermis, which has an isinglass-like effect (Janmaat 2003).

2.1.2. Cabbage semi looper

The cabbage semi-looper (*Trichoplusia ni*) is a member of the moth family Noctuidae belongs to the order of Lepidoptera. It is found throughout the southern palaearctic ecozone, all of North America, part of Africa and most of the Oriental and Indo-Australian region.

Nature of damage

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

2.1.3. Cutworm

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

Nature of damage

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

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

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

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

2.1.4. Aphid

Nature of damage

The black bean aphid is a major pest of sugar beet, bean, and celery crops, with large numbers of aphids cause stunting of the plants. Beans suffer damage to flowers and pods which may not develop properly. Early-sown crops may avoid significant damage if they have already flowered before the number of aphids builds up in the spring (RIR 2013). Celery can be heavily infested. The plants are stunted by the removal of sap, the stems are distorted, harmful viruses are transmitted, and aphid residues may contaminate the crop (Godfrey and Trumble 2009). As a result of infestation by this aphid, leaves of sugar beet become swollen, roll, and cease developing. The roots grow poorly and the sugar content is reduced. In some other plants, the leaves do not become distorted, but growth is affected and flowers abort due to the action of the toxic saliva injected by the aphid to improve the flow of sap (HYPP 2013).

To obtain enough protein, aphids need to suck large volumes of sap. The excess sugary fluid, honeydew, is secreted by the aphids. It adheres to plants, where it promotes growth of sooty molds. These are unsightly, reduce the surface area of the plant available for photosynthesis and may reduce the value of the crop. These aphids are also the vectors of about 30 plant viruses, mostly of the non-persistent variety. The aphids may not be the original source of infection, but are instrumental in spreading the virus through the crop (RIR 2013). Various chemical treatments are available to kill the aphids and organic growers can use a solution of soft soap (Godfrey and Trumble 2009).

2.1.5. Mole cricket

Mole crickets are members of the insect family Gryllotalpidae, in the order Orthoptera (grasshoppers, locusts, and crickets).

Nature of damage

Some species are known to be pests of turf, especially in golf courses. One exotic species the Changa mole cricket *Scapteriscus didactylus* has been accidentally introduced to areas around Newcastle, NSW, but the impacts of this introduction are not yet clear (American Museum 2019).

Mole crickets damage turf grasses and other plants by tunneling just under the soil surface, disrupting plants and damaging roots. The most destructive types also feed on plant roots and shoots. Their protective tunnels push up grass and soil, looking much like mole tunnels through gardens and turf. In southern lawns, most damage occurs during summer when turf grasses peak in growth. By late summer and fall, damaged grasses turn brown and die (Garden Tech 2018).

The crickets usually damage seedlings, feeding aboveground on foliage or stem tissue, and belowground on roots and tubers. Girdling of the stems of seedling plants at the soil surface is a common form of injury, though young plants are sometimes severed and pulled belowground to be consumed. Additional injury to small plants is caused by soil surface tunneling, which may dislodge seedlings or cause them to desiccate. Southern mole cricket does much more tunneling injury than tawny mole cricket (Capinera and Leppla 2018).

Grasses differ in susceptibility to injury. Bahiagrass and bermudagrass are especially injured by mole crickets, whether grown as turf grass or as forage, though it is not clear if it is more attractive to crickets or more easily damaged. St. Augustinegrass seem to tolerate injury because of its dense growth habit, but it, too, is injured at times. Centipedegrass and zoysiagrass are infrequently injured (Capinera and Leppla 2018).

2.1.6. Jassid

Amrasca biguttula, commonly known as the cotton jassid (CABI, 2019), is a subspecies of leafhopper belonging to the subfamily Typhlocybinae of family Cicadellidae.

Nature of damage

Nakamura *et al*. (1967) estimated the population density of the green rice leafhopper *Nephotettix cincticeps* Uhler in spring field by the capture-recapture method. *N. cineticeps* is an important pest of rice in Japan which injures the crop not only in direct way but also in carrying the rice dwarf virus.

Butani and Jotwani (1984) reported that nymphs and adults suck the cell sap from the underside of leaves and inject their saliva into the tissues causing toxaemia. The affected leaves first become pale green, then yellow, reddish and finally brick red or brown in colour. This change is accompanied by curling and crinkling and leaves gradually dry away. The plants become stunted in growth and bear less number of buds and flowers, thereby, the yield is adversely affected.

Nordin and Ibrahim (1995) reported that, jassid suck cell sap and falling down flowering and fruiting bodies.

Indian garden jassid *A. biguttula biguttula* is serious pest of many agricultural crops in India and Australia. It attacks crops such as soybean, sunflower, cotton, tomato, maize, pigeon pea, mung bean and several others (Kamble *et al.* 2014, Sathe *et al.* 2014).

Since jassid suck the cell sap and cause sooty moulds over crop plants, affect pathosynthesis, growth and yield of the crops and transmit various viral diseases to crops (Kamble and Sathe 2015).

Heavy infestations on cotton, okra, and sunflower make the leaves turn yellow, curl up and fall off. The insects also secrete honeydew, and sooty mould often grows on this, restricting the amount of light reaching the plant's photosynthetic surfaces and reducing the yield (Singh *et al.* 2018).

2.2. Management practices of insect pests of broccoli

2.2.1. Cultural control

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

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

Dempster (1969) studied the effects of weed control in brussels sprouts on *P. rapae* and found that weeds provide a habitat for predators of the caterpillar. However, yield reduction due to weed competition outweighed the advantageous effects of insect control obtained in the weedy plots. Buranday and Rarest (1975) compared the abundance of adults and oviposition of *P. xylostella* in a cabbage field and in a field with cabbage and tomato intercropped. Both factors were lower in the intercropped field and it was suggested that volatile compounds emitted by the tomatoes repelled the adult moths. The recommended planting pattern is two cabbage rows between two rows of tomato. The pest control benefits' with respect to reduction in larval feeding damage were not assessed as plots were sprayed regularly with *B. thuringiensis*, masking of tomato and larvae. In another study,: numbers of *P. xylostella* larvae and pupae were reduced by intercropping cabbage with tomato, barley, dill, garlic, oats or safflower (Talekar *et al*. 1986).

Kenny and Chapman (1988) assessed an intercrop of cabbage and dill (*Anethum graveolens* L.). The number of cabbage aphids on cabbages planted near dill was lower than those planted without dill. Results for numbers of *P. rapae* and *Plutella xylostella* and damage measurement were inconsistent due to low pest populations. Competition from dill was found to reduce yield, but a different planting arrangement could overcome this problem.

Remove weeds and plant resi-due to help reduce egg-laying sites and seedling weeds that nourish small cutworms. Tilling land before planting, which helps expose and kill overwintering larvae. Tilling also removes plant residue, which helps to discourage egg laying. Avoid using green manure as this may encourage egg laying, instead use com-post. Tilling land in the fall; this helps destroy or expose overwintering larvae or pupae (Hahn and Burkness 2015).

Clean cultivation and destruction of alternate host plant are practiced for controlling cotton jassid (Hussain 2017).

On cotton, it has been found that growing a cultivar with hairs on the undersides of the leaves reduces infestation, and that long hairs are better at deterring the insect from laying than are short hairs; this seems to be due to the hairs preventing the insect from getting close enough to the leaf surface to deposit its eggs (Khan and Agarwal 1984). Most injury to vegetable transplants occurs on small plants, so placement of larger plants is suggested as a strategy to avoid injury (Schuster and Price 1992). Crickets can quickly invade crop land that has been fumigated or otherwise cleared of crickets, so isolation from sources of crickets, or planting in large blocks of land with proportionally little edge, is desirable (Poe 1976). The best cultural practice for mole cricket management on turf grass is to maintain the turf in the healthiest condition possible, allowing the grass to recover from injury by mole crickets. This entails proper use of irrigation and fertilization, and also proper mowing height.

2.2.2. Mechanical control

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

Talekar *et al.* (1986) found that sprinkler irrigation applied to cabbage for five minutes at dusk throughout the life of the crop physically disrupted diamondback moth flying activity and oviposition and drowned larvae and adults. Such a modification of a cultural practice could be a valuable component of a pest management system.

The use of lightweight netting row covers, as a barrier to oviposition, is another effective non-chemical insect control technique. Row covers are mainly used to extend the growing season and by protecting against frosts provide early vegetables by decreasing time to maturity (Mansour 1989) and they are also effective as barriers against *P. rapae* and *P. xylostella.*

Cutworms can control by placing aluminum foil or cardboard collars around transplants. This creates a barrier that physically prevents cutworm larvae from feeding on plants. When placing these collars around plants, make sure one end is pushed a few inches into the soil, and the other end extends several inches above ground. This should prevent most species of cutworms from getting to plants (Hahn and Burkness 2015).

2.2.3. Chemical control

In controlling moths still mostly are used organic phosphorus esters. In this group classified active compounds are chlorine pirifos-methil, phenitrotion and acephate (Pelosini 1999). Sufficient efficacy in this relation can attain also with pyrethroids (cypermethrin, deltamethrin, lambda-cyhalothrin, betacyfluthrin and tefluthrin). In Slovenia registered products for controlling cabbage moth are from a group of pyrethroids, a product on the basis of pyrethrin, a product which corresponds to oxadiazine and one from the group of insect development inhibitors (IRI). Pyrethroids which are registered in Slovenia are Fastac 10 % SC (alfa-cypermethrin) and Karate

Zeon 5 CS (lambda-cyhalothrin). Two products are also used when controlling cabbage moth, namely pyrethrin (Spruzit powder) and indoxacarb (Steward). Active ingredient indoxacarb refers to the group of oxadiazines which is also advanced one. Insecticides from the oxadiazines group block Na-channels in nerve fibers. Target insects stop feeding, stay paralyzed and die soon. Product Steward is suitable for integrated production. Chitinase inhibitors display minor danger for human being and are suitable especially for controling eggs and young larvae (Corvi and Nardi 1998). Among inhibitors of insect development active ingredients are teflubenzuron, esaflumuron and lufenuron (Pelosini 1999). The last one is registered in Slovenia and represents an active ingredient of product Match 050 EC.

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

Fenos® (Flubendiamide) and Prevathon® (Chlorantraniliprole) are novel diamide products thus providing growers excellent rotation partners to manage insecticide resistance development in vegetables. These products quickly became very popular among growers since they were very effective against diamondback moth and other lepidopteran larvae (Edralin, *et al.* 2011).

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

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

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

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

In 1998, 800 g a.i. profenofos/ha is better for controlling okra jassid in India (Kaur 2002).

Acetamiprid SP 125 ml/acre is good for controlling cotton jasssid (Hussain 2017).

Subramanian *et al.* (1978) evaluated various combination of organic insecticides and Dipel 8 L against *Amrasca biguttula biguttula* Ishida. It was found that a spray containing carybaryl and Dipel was effective in reducing the incidence of jassid while sprays containing endosulfan and mixture of quinalphos with Dipel reduced the incidence of little leaf disease. The treatment also caused a decline in the population of *A. devastans* and *H. phycitis*.

Liquid and granular formulations of insecticides are commonly applied to the soil to suppress mole crickets. In some cases, insecticide application should be followed by irrigation because the insecticide must enter the root zone of the plants to be most effective, but this is an insecticide-specific requirement so the insecticide label should be read carefully for application directions. Bait formulations are also useful. Various baits have proven effective, but most contain wheat bran, cottonseed meal, or some other grain product plus 2-5% toxicant. Addition of 5 to 15% water and 2 to 5% molasses to the grain-toxicant mixture are sometimes recommended (Thomas 1928, Walker 1982). Mole crickets feed at night so baits should be applied in the early evening. Baits are incompatible with irrigation and rainfall.

2.2.4. Biological control

Biological control includes use of natural enemies/biological control agents to regulate cabbage butterflies. Three well known biological control agents including *Bacillus thuringiensis* (Bt), entomopathogenic nematodes and wasps have a potential to manage cabbage butterfly population in the vegetable gardens and fields.

Chemical pest control agents are extensively used in all countries of the world but they are regarded as ecologically unacceptable. Therefore, there is an increased social pressure to replace them gradually with biopesticides which are safe to humans and non-target organisms. The harmful environmental implications of the synthetic chemicals have compelled to search for some alternative methods. This leads to increased development of compounds based on the models of naturally occurring toxins of biological origin, having various biological activities. Biopesticides include a broad array of microbial pesticides, biochemicals derived from micro-organisms and other natural sources, and processes involving the genetic modification of plants to express genes encoding insecticidal toxins. This review outlines the current state of knowledge on the potential use of biopesticides in global control of pests.

In order to develop sustainable pest management programs for *Brassica* crops, an effective biological control program for *P. xylostella* must be integrated with effective control measures for *C. pavonana* (e.g. selective insecticides, manipulation of endemic predator complexes, trap crops and other means of host plant manipulation). Biological control can form the foundation for IPM strategies for the management of *P. xylostella* and other crucifer pests (Furlong *et al.* 2008a) but in order to take this approach, a detailed understanding of pest and natural enemy ecology is required (Furlong *et al.* 2008b ; Furlong and Zalucki 2007).

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

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

2.2.4.1. *Bacillus thuringiensis kurstaki* (Bt)

This bacterium is recognized as a bacterial insecticide but it is not harmful to the humans, animals or the environment. This is a very effective biopesticide on young larval stages as compared to the mature larval stages of cabbage lepidopterous insect pests.

This microbial biocontrol agent is commercially available and can be applied using traditional sprayers. For the effective control of cabbage lepidopterous insect pests, *Bacillus thuringiensis kurstaki* should be applied at every seven day interval after noticing the first incidence of pest.

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

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

2.2.4.2. Entomopathogenic nematodes

Currently, entomopathogenic nematodes are used as effective biological control agents against many different kinds of soil-dwelling insect pests of many economically important crops and turfgrasses. These nematodes are commercially available and are not harmful to humans, animals and even beneficial insects like honeybees. Canadian researchers have demonstrated that the entomopathogenic nematodes including

Steinernema carpocapsae, *S. feltiae* and *S. riobrave* can cause 76 to 100% mortality of cabbage butterflys *Artogeia rapae* if applied at temperatures ranging from 25 to 30°C and their LC50 values were ranged from 4 to 18 infective juveniles (Bélair *et al*. 2003). Mahar *et al.* (2005) also reported that in addition to the above stated species of entomopathogenic nematodes, *Heterorhabditis bacteriophora* and *H. indica* nematodes can infect and kill both larvae and pupae of cabbage butterflies. Recently, another insect-parasitic nematode, *Rhabditis blumi* also been shown to be effective against cabbage butterfly (Park *et al*. 2012).

The South American nematode *Steinernema scapterisci* kills *Neocapteriscus* mole crickets by introducing bacteria into their bodies, causing an overwhelming infection (Nguyen and Smart 1992a). *Steinernema neocurtillae* is native to Florida and attacks native *Neocurtilla hexadactyla* mole crickets (Nguyen and Smart 1992b).

An entomopathogenic nematode, *Steinernema scapterisci* Nguyen & Smart, was introduced from Uruguay in 1985 (Nguyen and Smart 1992). It is specific to mole crickets, persists readily under Florida's environmental conditions, and is dispersed by crickets. Field collections consistently show infection levels of 10% or greater (Parkman *et al*. 1993 a&b, Parkman and Smart 1996), and infected crickets die within 12 days.

2.2.4.3. Parasitoid

Trichogramma is a potential biological control agent against lepidopterous insect pest. It is an egg parasitoid that kills the pest before it can cause any damage to the plant. *Trichogramma* are among the smallest insects, having a wingspread of about 1/50th of an inch. Despite its size, this parasitic wasp is an efficient destroyer of the eggs of more than 200 species of moths and butterflies which are leaf eaters in the larval stage. *Trichogramma* wasps seek out eggs, but do not feed on or harm vegetation. It is a particularly effective control agent because it kills its host before a plant can be damaged.

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

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

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

A various species of parasitic wasps can serves as effective biological control agents against lepidopterous insect pests of cabbage. The egg parasitic wasp, *Trichogramma spp.* is the most effective egg parasitoid against lepidopterous insect pests of cabbage. Seven species of parasitoid wasps (five larval and two pupal parasitoids) and two species of hyperparasitoid wasps were determined. The parasitoids were included the braconids *Cotesia plutellae* (Kurdjumov), *Bracon hebetor* Say and *Apanteles* sp., the ichneumonid *Diadegma semiclausum* (Hellen), and the eulophid *Oomyzus sokolowskii* (Kurdjumov) as larval parasitoids, and the ichneumonids *Diadromus collaris*

(Gravenhorst) and *Diadromus subtilicornis* (Gravenhorst) as pupal parasitoids. In addition, the pteromalids *Mokrzeckia obscura* Graham and *Pteromalus* sp. were identified as the hyperparasitoids (Afiunizadeh, *et. al.* 2011).

Microsporidium is a pathogenic parasite for many insects including lepidopteran pests. It is an obligatory in nature which has a wide distribution around the world. It has a big potential as a microbial pesticide or biopesticide agent for controlling insect populations (Sajap 2004).

Zainal- Abidin *et al.* (2004) named microsporidia isolated from Malaysia's *P. xylostella* as *Nosema bombycis* based on the morphological characters. Experimental studies have shown that this parasite can cause high mortality rates in DBM in particular the larval stages.

Anagrus atomus, Aphelopus maculiceps and *Aphelopus wittei* are the parasite of cotton jassid. Among them *Anagrus atomus* is the egg parasite (CABI 2020).

Parasitoid wasps of the genus *Larra* (Hymenoptera: Crabronidae) attack mole crickets, the female laying an egg on the external surface of the mole cricket, and the larva developing externally on the mole cricket host. *Ormia depleta* (Diptera: Tachinidae) is a specialized parasitoid of mole crickets in the genus *Neoscapteriscus*; the fly's larvae hatch from eggs inside her abdomen; she is attracted by the call of the male mole cricket and deposits a larva or more on any mole cricket individual (just as many females as males) with which she comes in contact (UF 2015).

The only biological control program against *N. didactylus* was in Puerto Rico, and it succeeded in establishing the parasitoid wasp *Larra bicolor* from Amazonian Brazil (Wolcott 1941).

One introduced parasitoid is *Larra bicolor* Fabricius (Hymenoptera: Crabronidae), which was imported from Bolivia in 1981 and established in both southern and northern

Florida, but seems to be constrained by availability of suitable adult food sources (nectar from flowers) in Florida (Frank *et al*. 1995).

Another parasitoid *Ormia depleta* (Wiedemann) (Diptera: Tachinidae), which was imported from Brazil in 1988, is attracted to the calls of male mole crickets. Its release has resulted in reduced mole cricket injury in southern Florida (Frank *et al*. 1996).

2.2.4.4. Botanical control

A botanical pesticide can be employed as an alternative source to control pests with biodegradable concern, reductive contamination in environment and human health hazards (Devlin and Zettel 1999; Grainge and Ahmed 1988). Ahmed (2008) enlisted 2121 plant species, possessing pest control property which include neem, sweetflag, cashew, custard apple, sugar apple, derris, lantana, tayanin, indian privet, agave, crow plant etc. 1005 species of plants having biological properties against insect pests including 384 species as antifeedants, 297 as repellents, 97 as attractants and 31 as growth inhibitors.

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

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

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

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

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

Azadirachtin is the most potent growth regulator and antifeedant (Warthen *et al.* 1978; Butterworth and Morgan 1968).The triterpenoid azadirachtin was first isolated from the seeds of the tropical neem tree by Butterworth and Morgan (1968). Its definite structural formula, which resembles somewhat that of ecdysone, was finally explained in 1985 by Kraus *et al.*and Bilton *et al.* (Figure 1).

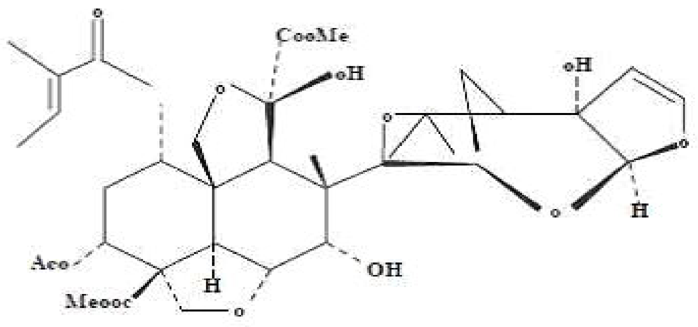

Figure 1. Structural formula of azadirachtin (Butterworth and Morgan 1968)

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

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

The females of some lepidopterous insects are repelled by neem products on treated plant parts or other substrates and will not lay eggs on them under laboratory conditions.

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

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

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

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

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

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

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

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

For controlling cotton jassid Neem oil is used as a biopesticide (Koul *et al.* 2014).

2.2.6. IPM management

For controlling Jassid in India, IPM package (5 g/kg imidacloprid/ha + foliar spray with 500 g a.i. monocrotophos/ha + 30 g a.i. cypermethrin/ha) showed best performance in 1999 and 2000. This package also reduce the population of Jassid and leaf injury also (Kaur 2002).

Naik *et al.* (2009) indicated that thiamethoxam @ 0.05% and combination treatments of thiamethoxam @ 0.0025% + novaluron @ 0.05% and thiamethoxam @ 0.0025% + azadirachtin @ 0.15% were highly effective in reducing population of *A. bigutulla bigutulla* besides recording higher fruit yield of brinjal.

Kadam *et al*. (2015) reported that mixture of Trichoderma ST 5% + imidacloprid 0.004% + NSKE 5% + Trichoderma chilonis @ 50,000 ha^{-1} controlled jassids best at 14 days.

CHAPTER III

MATERIALS AND METHODS

The present study regarding incidence and management practices of insect pests of broccoli particularly diamond back moth (*Plutella xylostella*), cabbage semi-looper (*Trichoplusia ni*), cutworm (*Agrotis ipsilon*), aphid (*Aphis fabae*), mole cricket (*Gryllotalpa brachyptera*) and jassid (*Amrasca biguttula*) has been conducted during September 2018 to May 2019 in the experimental fields of Sher-e-Bangla Agricultural University (SAU), Dhaka. Laboratory studies were also done in the laboratory under the Department of Entomology, SAU. Required materials and methodology are described below under the following sub-headings:

3.1. Location

The experiments were conducted in the experimental farm of SAU, Dhaka situated at latitude 23.46 N and longitude 90.23E with an elevation of 8.45 meter the sea level. Laboratory studies were done in the laboratory of Entomology department, SAU.

3.2. Climate

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

3.3. Soil

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

3.4. Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The target land was divided into 27 equal plots (2.5m×1.5m) with plot to plot distance of 0.50 m and block to block distance is 0.75 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment were followed immediately after land preparation.

3.5. Manure and fertilizer

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

3.6. Design of experiment and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) two factors with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 15 unit plots. The size of the unit plot was 3 m×1.2 m. The block to block and plot-to-plot distance was .75m and 0.5m, respectively.

3.7. Collection of seed, seedling raising

The seeds of selected broccoli varieties i.e. BARI broccoli 1, exotic variety, local variety (Anika) were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Siddik Bazar, Gulistan, Dhaka. Before sowing, the germination test of seeds was done and on an average, 90% germination was found for these varieties. Seeds were then sown on the 17th October, 2018 in seedbed containing a mixture of equal proportion well decomposed cow dung and loam soil. After sowing seeds, the seedbeds were irrigated regularly. After germination, the seedlings were sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

Plate 1: Local variety (Anika) Plate 2: BARI broccoli 1 Plate 3: Exotic variety

3.8. Seedling transplanting

The 30 days old healthy and uniform sized seedlings of broccoli varieties were transplanted on November 16th, 2018 in the main field. Each plot contains 10 seedlings of broccoli with 2 rows followed by 50cm x 50cm (row to row and plant to plant distance, respectively).

Plate 4: Seedlings transplanting in the experimental field

3.9. Cultural practices

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

3.10. Treatments

The experiment was evaluated to determine the incidence and damage assessment of insect and other arthropod pests of broccoli particularly diamond back moth, cabbage semi-looper, cutworm, aphid, mole cricket and jassid. The treatments were used in this study are given bellow:-

Factor A:

Different broccoli cultivar

V_1= Local variety (Anika)

V_2= BARI broccoli 1

V_3= Exotic variety

Factor B:

Different insecticides

T_0= No treatment/ control

T_1= Contact (Malathion 57EC @ 2ml/L of water)

T_2= Systemic (Actara 25WG @ 0.12gm/L of water)

T_3= Stomach (Sevin 85WP @ 1gm/L of water)

T_4= Antifedent (Neem oil @ 3ml/L of water)

3.11. Preparation of neem oil as treament

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. For neem oil application, 15 ml neem oil (@ 3.0 ml/L of water was used. The mixture was sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant.

3.12. Treatment application

T_1: Malathion 57EC @ 2.00 ml/L of water was sprayed at 7 days interval. For this treatment 10.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_2: Actara 25WG @ 0.12 gm/L of water was sprayed at 7 days interval. For this treatment 0.60 gm of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_3: Sevin 85WP @ 2.00 gm/L of water was sprayed at 7 days interval. For this treatment 5.0 gm of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 15 DAT.

T_4: Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 15 ml /5L of water mixed with detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_0: Untreated control treatment. There was no any control measure was applied in broccoli field.

3.13. Data collection

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

3.13.1. Number of insect pests of broccoli and number of infested leaves caused by different insect pests

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

3.13.2. Number of infested plants by cutworm

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

Plate 5: Mole cricket in the experimental field

3.13.3. Number and weight of the healthy and infested broccoli head

Data were collected on the number of healthy and infested broccoli head per plot which was harvested at fully mature head stage of broccoli and weighted separately for each treatment.

3.14. Calculation

3.14.1. Percent of infested leaves by insect pests of broccoli

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

Plate 6: Measuring weight of broccoli by digital weight machine

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

3.14.2. Percent Cutworm infested plant

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

Plate 7: Infested plant by cutworm

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

3.14.3. Percent head infestation by number

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

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

3.14.4. Percent broccoli head infestation by weight

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

Plate 8: Infested plant by mole cricket

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

3.14.5. Percent reduction of broccoli head infestation over control

The number and weight of infested broccoli head and total broccoli head for each treated plot and untreated control plot were recorded and the percent reduction of broccoli head infestation in number and weight was calculated using the following formula:

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

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.14.6. Percent yield loss

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

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

3.14.7. Statistical analysis

Data statistically analyzed by 2 factor randomized complete block design through MSTAT-C software and LSD range tests was used to determine the incidence and damage assessment of insect pest of broccoli.

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate damage assessment and management of insect and other arthropod pests of broccoli in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from September, 2018 to May, 2019. The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.1. Cutworm infestation

The level of infestation of broccoli seedlings caused by cutworm at different days after transplanting (DAT) was evaluated in this study. From the study it was observed that there was a numerical variation found at different DAT in terms of number of cutworm infested broccoli seedlings per plot, but there was no statistical variation found in number of infested seedlings per plot at different DAT of cabbage seedlings (Figure 2). At the initial stage of seedling transplanting (2 DAT), no cutworm infestation (0.0) was recorded in the field, but the number of cutworm infested cabbage seedlings was increased with increase of time. And it was reached in highest infestation at 10 DAT depending on the varieties (2.0 to 3.0 infested seedlings/plot). Afterward the cutworm infestation was decreased gradually and declined in no infestation (0.0) at 16 DAT and subsequently 18 DAT.

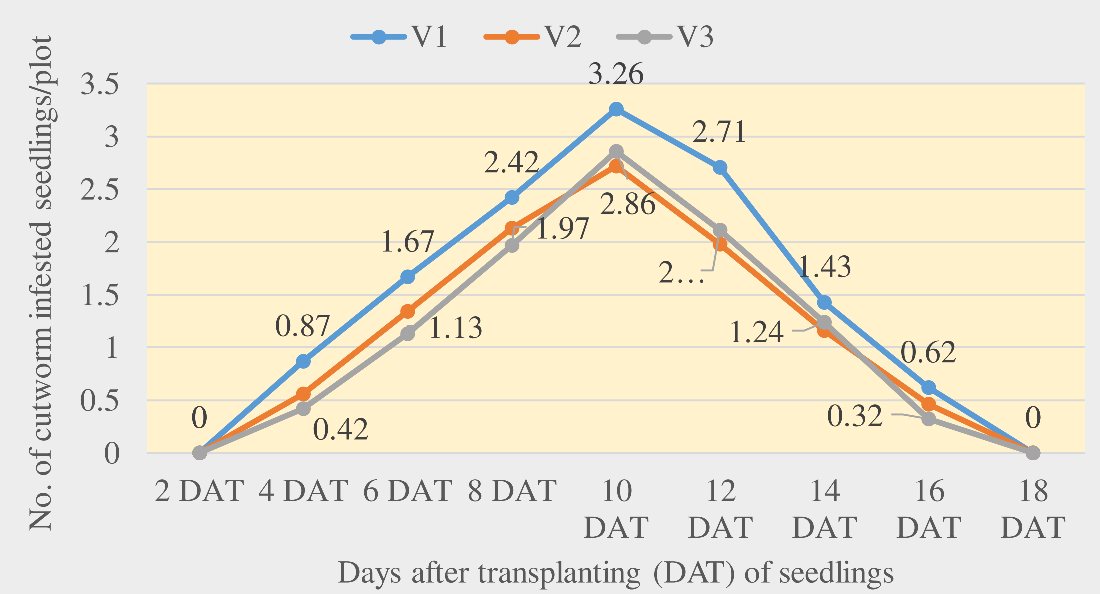

Figure 2: Tends of cutworm infested seedlings at different DAT of broccoli in the field

In case varietal variation, the total number of cutworm infested seedlings per plot was ranged from 3.82 to 5.67 infested seedlings/plot. The highest total number of cutworm infested seedlings per plot was recorded in V_1 (5.67), which was 56.70% seedling infestation out of 10 seedlings per plot. On the other hand, the lowest total number of cutworm infested seedlings per plot was recorded in V_3 (3.82 infested seedlings/plot), which was 38.20% seedling infestation out of 10 seedlings per plot and V_2 (5.12 infested seedlings/plot), which was 51.20% seedling infestation out of 10 seedlings per plot. But it observed that there was numerical variation was found among the varieties in terms of total number of cutworm infested seedlings per plot, but no statistical variation was found among the terms of seedling infestation (Figure 3).

From the findings it was revealed that the cutworm infestation on broccoli seedlings was ranged from 3.82 to 5.67 in the field, where the lowest infestation was recorded

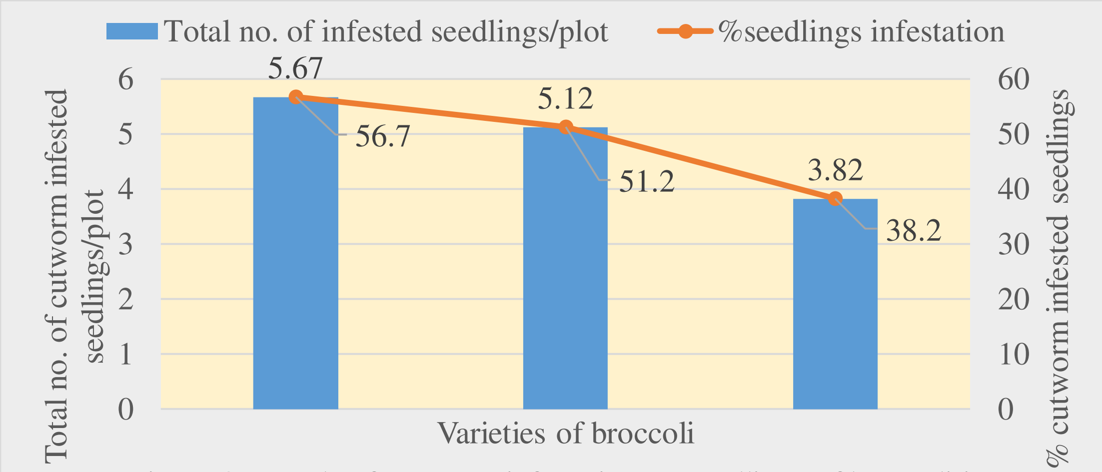

Figure 3: Trends of cutworm infestation on seedlings of broccoli in the field

3.82 in V_3, which was statistically similar with all other treatments. On the other hand, the highest cutworm infestation 5.67 was recorded in V_1. It was also observed that the no cutworm infestation (0.0) was recorded at 2 DAT in the broccoli field. But the cutworm infestation was initiated in the broccoli field at 4 DAT and the maximum infestation (2.0 to 3.0 infested seedling/plot) was recorded at 10 DAT, whereas the infestation was declined gradually with the increase of time and no infestation was recorded at 18 DAT. Therefore, it was concluded that management practice particularly for cutworm should be applied between 3 to 16 DAT of broccoli seedlings in the field.

4.2. Varietal performance of broccoli against different insect pest

4.2.1. In case of aphid

The average number of aphids per five tagged plants was ranged from 1.54 to 2.88. The highest average number of aphids per five tagged plants was recorded in V_1 (2.88 aphids). On the other hand, the lowest average number of aphids per five tagged plants was recorded in V_3 (1.54 aphids). But it observed that there was statistical variation among the varieties in terms of average number of aphids per five tagged plants (Figure 4).

The average number of infested leaves caused by aphids per five tagged plants was ranged from 0.83 to 1.81. The highest average number of infested leaves caused by aphids per five tagged plants was recorded in V_1 (1.81 leaves). On the other hand, the lowest average number of infested leaves caused by aphids per five tagged plants was recorded in V_3 (0.83 leaves). But it observed that there was statistical variation among the varieties in terms of average number of infested leaves caused by aphids per five tagged plants (Figure 4).

The average number of infested plants caused by aphids per plot was ranged from 1.15 to 2.56. The highest average number of infested plants caused by aphids per plot was recorded in V_1 (2.56 plants). On the other hand, the lowest average number of infested plants caused by aphids per plot was recorded in V_3 (1.15 plants). But it observed that there was statistical variation among the varieties in terms of average number of infested plants caused by aphids per plots (Figure 4).

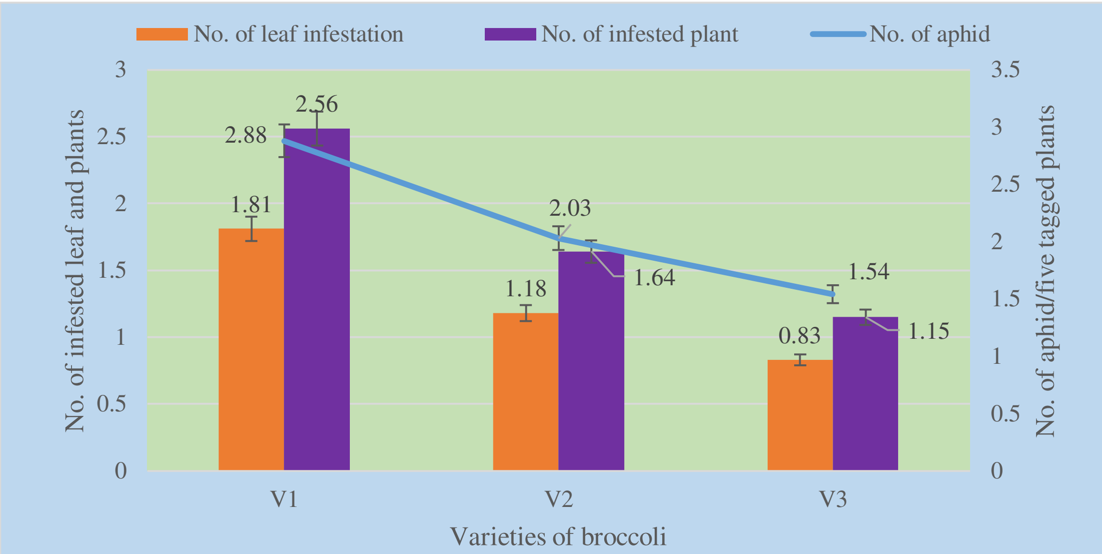

Figure 4: Effect of aphid infestation on different broccoli varieties

From the findings it was revealed that the incidence of aphid on broccoli was ranged from 1.54 to 2.88 in the field, where the lowest infestation was recorded 1.54 in V_3, which was statistically different from other varieties. In case of the number of infested leaf caused by aphid, the lowest number of infested leaves per five tagged plants was recorded in V_3 (0.83 leaves). Again, V_3 showed the lowest performance (1.15 plants) in terms of number of plants per plot.

4.2.2. In case of diamond back moth

The average number of diamond back moth per five tagged plants was ranged from 5.03 to 10.21. The highest average number of diamond back moth per five tagged plants was recorded in V_1 (10.21 Diamond back moth). On the other hand, the lowest average number of diamond back moth per five tagged plants was recorded in V_3 (5.03 Diamond back moth). But it observed that there was statistical variation among the varieties in terms of average number of diamond back moth per five tagged plants (Figure 5).

The average number of infested leaves caused by diamond back moth per five tagged plants was ranged from 2.63 to 4.56. The highest average number of infested leaves caused by diamond back moth per five tagged plants was recorded in V_1 (4.56 leaves). On the other hand, the lowest average number of infested leaves caused by diamond back moth per five tagged plants was recorded in V_3 (2.63 leaves). But it observed that there was statistical variation among the varieties in terms of average number of infested leaves caused by diamond back moth per five tagged plants (Figure 5).

The average number of infested plants caused by diamond back moth per plot was ranged from 1.36 to 3.02. The highest average number of infested plants caused by diamond back moth per plot was recorded in V_1 (3.02 plants). On the other hand, the lowest average number of infested plants caused by diamond back moth per plot was recorded in V_3 (1.36 plants). But it observed that there was statistical variation among the varieties in terms of average number of infested plants caused by diamond back moth per plots (Figure 5).

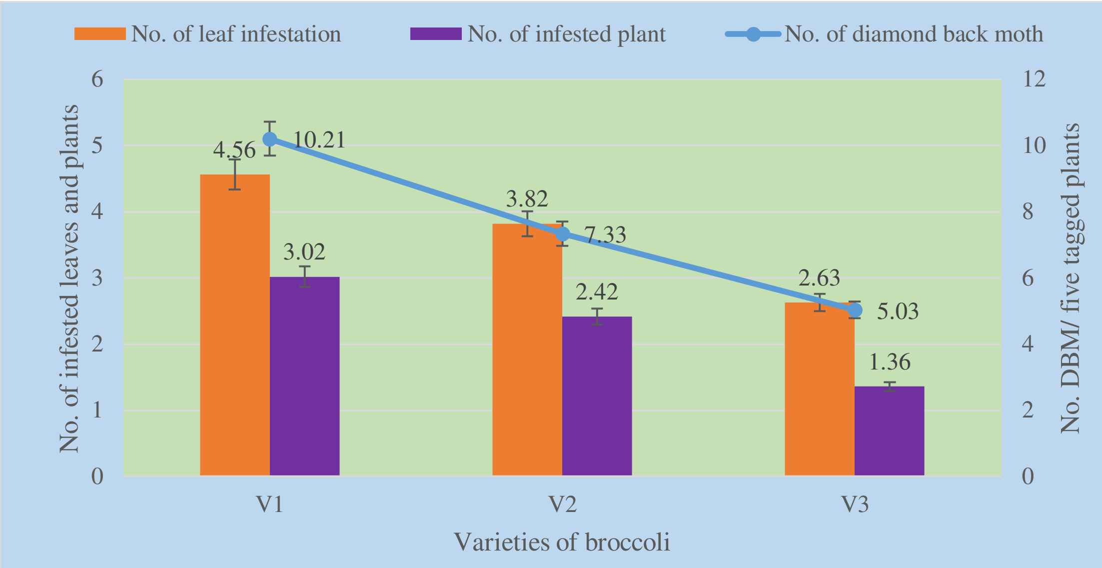

Figure 5: Effect of diamond back moth infestation on different broccoli varieties

From the findings it was revealed that the incidence of diamond back moth on broccoli was ranged from 5.03 to 10.21 in the field, where the lowest infestation was recorded 5.03 in V_3, which was statistically different from other varieties. In case of the number of infested leaves caused by diamond back moth, the lowest number of infested leaves per five tagged plants was recorded in V_3 (2.63 leaves). Again, V_3 showed the lowest performance (1.36 plants) in terms of number of plants per plot.

4.2.3. In case of cabbage semi-looper

The average number of cabbage semi-looper per five tagged plants was ranged from 4.82 to 7.21. The highest average number of cabbage semi-looper per five tagged plants was recorded in V_1 (7.21 cabbage semi-looper). On the other hand, the lowest average number of cabbage semi-looper per five tagged plants was recorded in V_3 (4.82 cabbage semi-looper). But it observed that there was statistical variation among the varieties in terms of average number of cabbage semi-looper per five tagged plants (Figure 6).

The average number of infested leaves caused by cabbage semi-looper per five tagged plants was ranged from 1.78 to 3.03. The highest average number of infested leaves caused by cabbage semi-looper per five tagged plants was recorded in V_1 (3.03 leaves). On the other hand, the lowest average number of infested leaves caused by cabbage semi-looper per five tagged plants was recorded in V_3 (1.78 leaves). But it observed that there was statistical variation among the varieties in terms of average number of infested leaves caused by cabbage semi-looper per five tagged plants (Figure 6).

The average number of infested plants caused by cabbage semi-looper per plot was ranged from 1.05 to 2.71. The highest average number of infested plants caused by cabbage semi-looper per plot was recorded in V_1 (2.71 plants). On the other hand, the lowest average number of infested plants caused by cabbage semi-looper per plot was recorded in V_3 (1.05 plants). But it observed that there was statistical variation among the varieties in terms of average number of infested plants caused by cabbage semi-looper per plots (Figure 6).

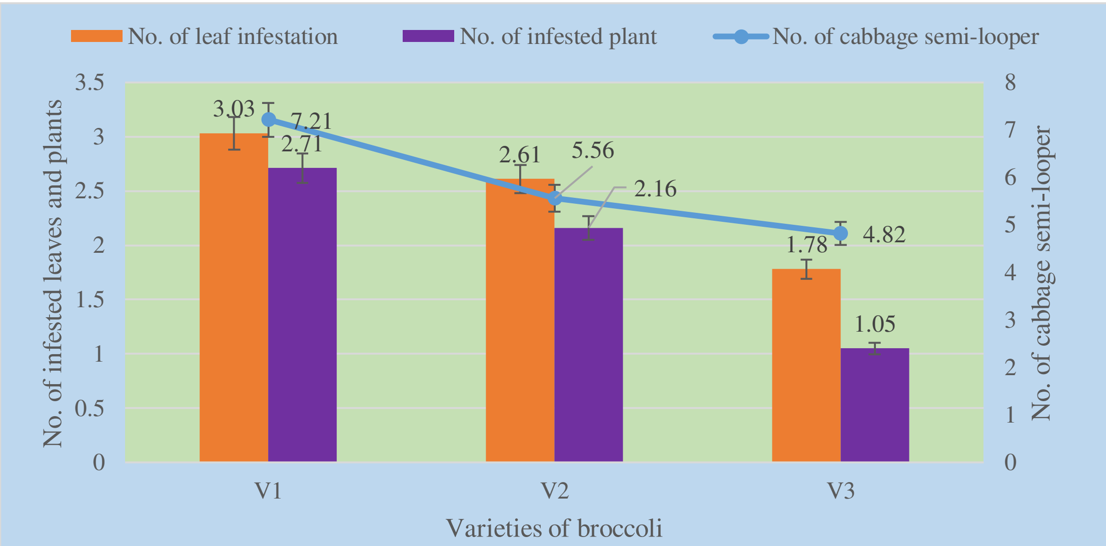

Figure 6: Effect of cabbage semi-looper infestation on different broccoli varieties

From the findings it was revealed that the incidence of cabbage semi-looper on broccoli was ranged from 4.82 to 7.21 in the field, where the lowest infestation was recorded

4.82 in V_3, which was statistically different from other varieties. In case of the number of infested leaves caused by cabbage semi-looper, the lowest number of infested leaves per five tagged plants was recorded in V_3 (1.78 leaves). Again, V_3 showed the lowest performance (2.71 plants) in terms of number of plants per plot.

4.2.4. In case of jassid

The average number of jassid per five tagged plants was ranged from 7.76 to 12.24. The highest average number of jassid per five tagged plants was recorded in V_1 (12.24 jassid). On the other hand, the lowest average number of jassid per five tagged plants was recorded in V_3 (7.76 jassid). But it observed that there was statistical variation among the varieties in terms of average number of jassid per five tagged plants (Figure 7).

The average number of infested leaves caused by jassid per five tagged plants was ranged from 3.56 to 5.67. The highest average number of infested leaves caused by jassid per five tagged plants was recorded in V_1 (5.67 leaves). On the other hand, the lowest average number of infested leaves caused by jassid per five tagged plants was recorded in V_3 (3.56 leaves). But it observed that there was statistical variation among the varieties in terms of average number of infested leaves caused by jassid per five tagged plants (Figure 7).

The average number of infested plants caused by jassid per plot was ranged from 2.82 to 5.72. The highest average number of infested plants caused by jassid per plot was recorded in V_1 (5.72 plants). On the other hand, the lowest average number of infested plants caused by jassid per plot was recorded in V_3 (2.82 plants). But it observed that there was statistical variation among the varieties in terms of average number of infested plants caused by jassid per plots (Figure 7).

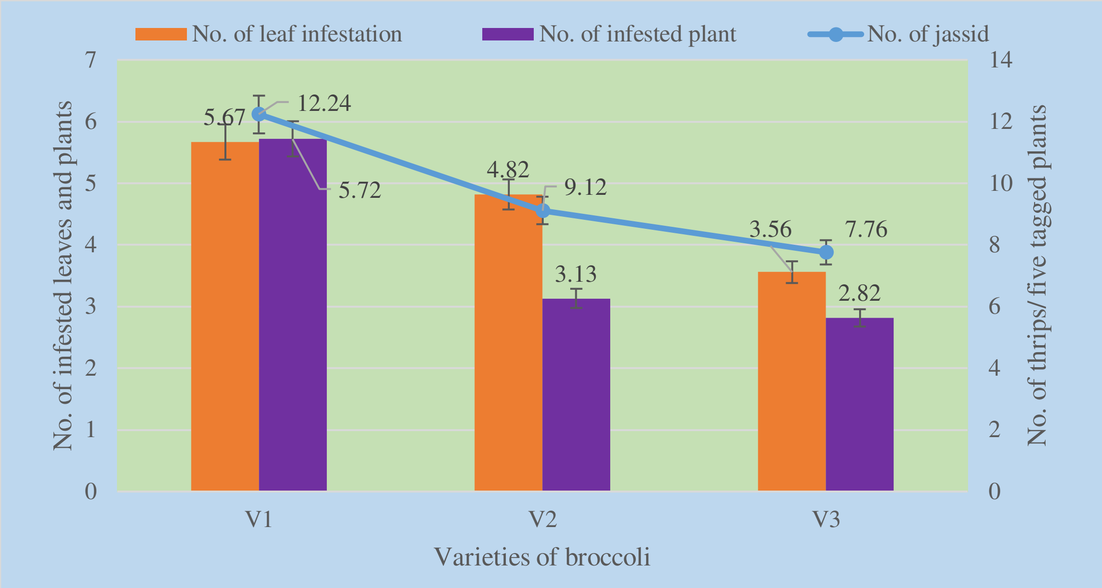

Figure 7: Effect of jassid infestation on different broccoli varieties

From the findings it was revealed that the incidence of jassid on broccoli was ranged from 7.76 to 12.24 in the field, where the lowest infestation was recorded 7.76 in V_3, which was statistically different from other varieties. In case of the number of infested leaves caused by jassid, the lowest number of infested leaves per five tagged plants was recorded in V_3 (3.56 leaves). Again, V_3 showed the lowest performance (2.82 plants) in terms of number of plants per plot.

4.2.5. In case of mole cricket

The average number of mole cricket per plot was ranged from 0.83 to 2.23. The highest average number of mole cricket per plot was recorded in V_1 (2.23 mole cricket). On the other hand, the lowest average number of mole cricket per plot was recorded in V_3 (0.83 mole cricket). But it observed that there was statistical variation among the varieties in terms of average number of mole cricket per plot (Figure 8).

The average number of infested plants caused by mole cricket per plot was ranged from 1.47 to 3.62. The highest average number of infested plants caused by mole cricket per plot was recorded in V_1 (3.62 plants). On the other hand, the lowest average number of infested plants caused by mole cricket per plot was recorded in V_3 (1.47 plants). But it observed that there was statistical variation among the varieties in terms of average number of infested plants caused by mole cricket per plot (Figure 8).

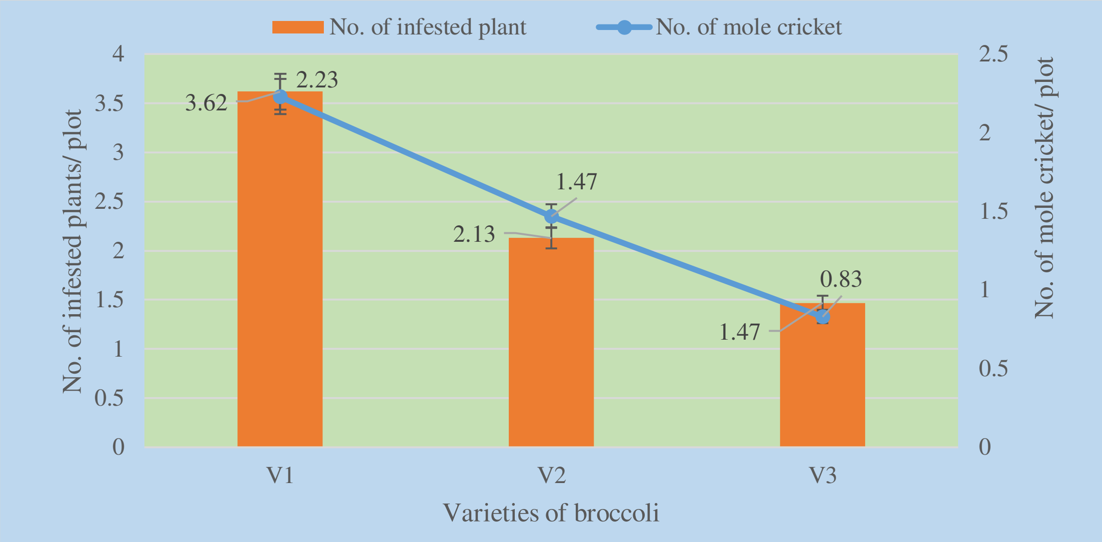

Figure 8: Effect of mole cricket infestation on different broccoli varieties

From the findings it was revealed that the incidence of mole cricket on broccoli was ranged from 0.83 to 2.23 in the field, where the lowest infestation was recorded 0.83 in V_3, which was statistically different from other varieties. In case of the number of infested plants caused by mole cricket, the lowest number of infested plants per plot was recorded in V_3 (1.47 plants).

4.3. Performance of different treatments against different insect pest of broccoli

4.3.1. In case of insect incidence of broccoli

The average number of aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants was ranged from 1.09 to 3.96, 1.54 to 4.12, 1.63 to 3.79, 3.23 to 6.21 and 0.47 to 2.13, respectively. The highest average number of aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants were recorded in T_0 (3.96, 4.12, 3.79, 6.21 and 2.13, respectively). On the other hand, the lowest average number of aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants were recorded in T_4 (1.09, 1.69, 1.63, 3.23, and 0.47, respectively). But it observed that there was statistical variation among the different treatments of broccoli in terms of average number of aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants (Figure 9).

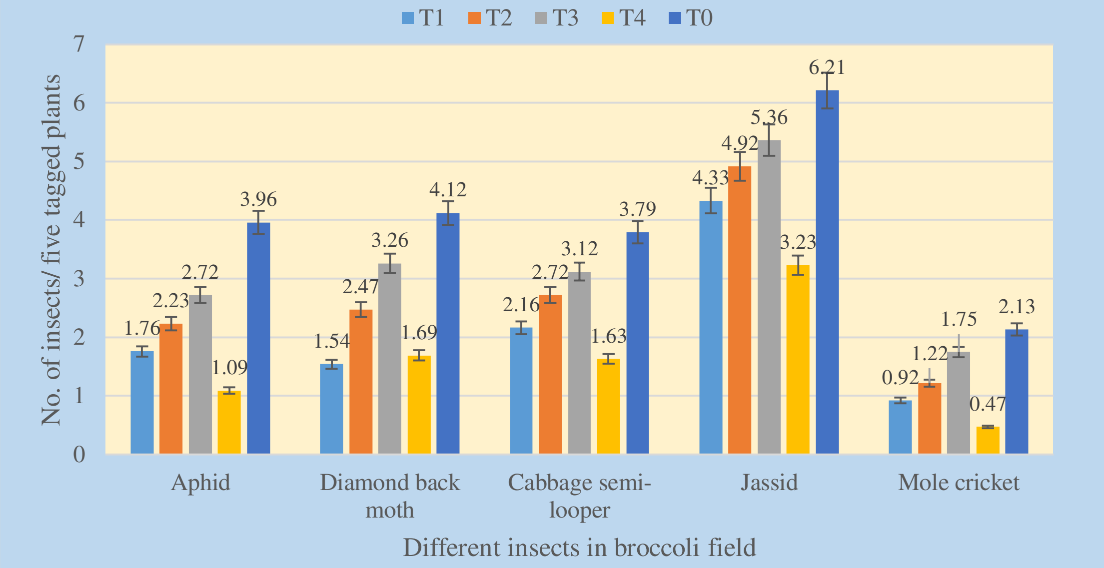

Figure 9: Effect of different insects incidence on different treatments of broccoli

From the findings it was revealed that the incidence of aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket on broccoli were low in T_4 (1.09, 1.69, 1.63, 3.23, and 0.47, respectively) comprised of spraying antifedent (Neem oil @) 3ml/Lof water at 7 days interval), which was statistically different from other treatments of broccoli and high in T_0 (3.96, 4.12, 3.79, 6.21 and 2.13, respectively). Again, T_4 showed the best performance in case of incidence of different insects of broccoli per five tagged plants.

4.3.2. In case of the number of infested leaves of broccoli

The average number of infested leaves caused by aphids, diamond back moth, cabbage semi-looper and jassid per five tagged plants was ranged from 2.67 to 6.33, 2.33 to 4.89, 1.31 to 3.07 and 2.07 to 3.98, respectively. The highest average number of infested leaves caused by aphids, diamond back moth, cabbage semi-looper and jassid per five tagged plants were recorded in T_0 (6.33, 4.89, 3.07 and 3.98, respectively). On the other hand, the lowest average number of infested leaves caused by aphids, diamond back moth, cabbage semi-looper and jassid per five tagged plants were recorded in T_4 (2.67, 2.33, 1.31 and 2.07, respectively). But it was observed that there was statistical variation among the different treatments of broccoli in terms of average number of infested leaves caused by aphids, diamond back moth, cabbage semi-looper and jassid per five tagged plants (Figure 10).

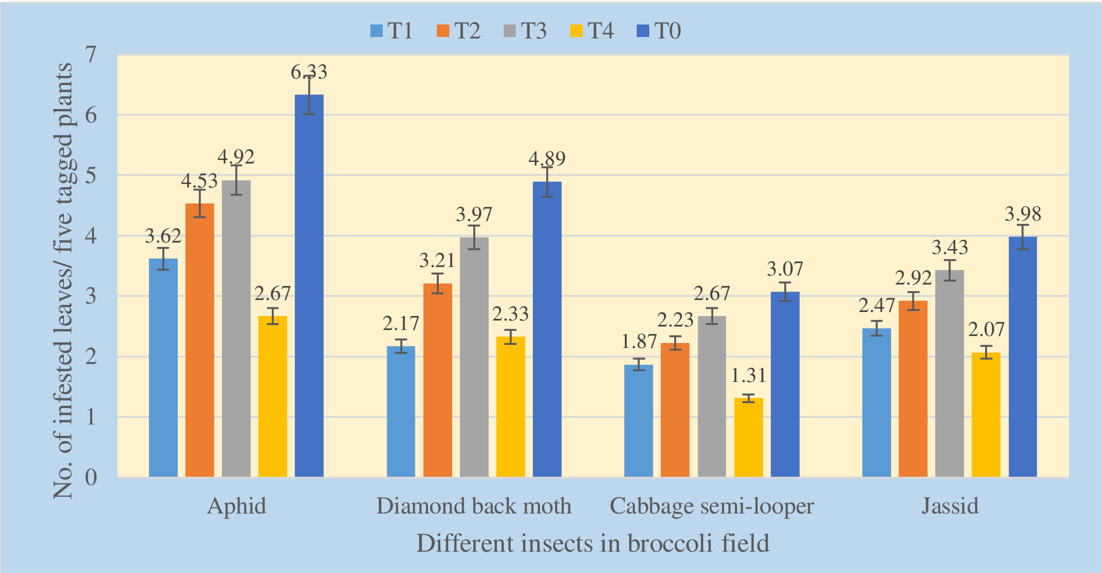

Figure 10: Effect of leaf infestation caused by different insects at different treatments of broccoli

From the findings it was revealed that the number of infested leaves caused by aphid, diamond back moth, cabbage semi-looper and jassid on broccoli were low in T_4 (2.67, 2.33, 1.31 and 2.07, respectively) comprised of spraying antifedent (Neem oil @) 3ml/Lof water at 7 days interval), which was statistically different from other treatments of broccoli and high in T_0 (6.33, 4.89, 3.07 and 3.98, respectively). Again, T_4 showed the best performance in case of the number of infested leaves caused by different insects of broccoli per five tagged plants.

4.3.3. In case of the number of infested plants of broccoli

The average number of infested plants caused by aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot were ranged from 1.51 to 7.13, 1.43 to 3.92, 0.98 to 3.13, 1.87 to 3.18 and 0.56 to 2.16, respectively. The highest average number of infested plants caused by aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot were recorded in T_0 (7.13, 3.92, 3.13, 3.18 and 2.16, respectively). On the other hand, the lowest average number of infested plants caused by aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot were recorded in T_4 (1.51, 1.43, 0.98, 1.87 and 0.56, respectively). But it was observed that there was statistical variation among the different treatments of broccoli in terms of average number of infested plants caused by aphids, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot (Figure 11).

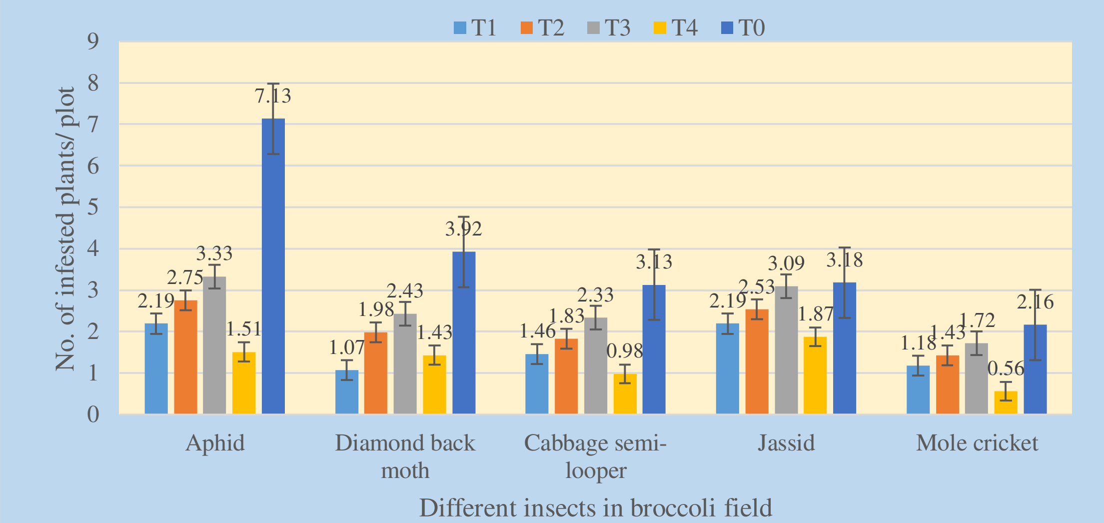

Figure 11: Effect of plant infestation caused by different insects at different treatments of broccoli

From the findings it was revealed that the number of infested plant caused by aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket on broccoli were low in T_4 (1.51, 1.43, 0.98, 1.87 and 0.56, respectively) comprised of spraying antifedent (Neem oil @) 3ml/Lof water at 7 days interval), which was statistically different from other treatments of broccoli and high in T_0 (7.13, 3.92, 3.13, 3.18 and 2.16, respectively). Again, T_4 showed the best performance in case of the number of infested plants caused by different insects of broccoli per plot.

4.4. Performance of different combinatons of varieties and treatments against different insect pest of broccoli

4.4.1. Number of insect pests

The significant variations were observed among the combination of varieties and treatments in terms of the number of insect pests like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket present per five tagged plants of broccoli. In case of aphid, the lowest number was recorded in V_3T_4 (1.10 aphids/five tagged plants), which was statistically different from others and followed by V_2T_4 (1.38), V_3T_1 (1.85), V_2T_1 (2.32), V_1T_4 (2.57), V_3T_2 (2.90), V_1T_1 (3.13), V_2T_2 (3.53), V_1T_2 (3.60) and V_3T_3 (3.89). On the other hand, the highest number was recorded in V_1T_0 (5.81 aphid/five tagged plants), which was significantly different from others and followed by V_2T_0 (5.36), V_3T_0 (5.04), V_1T_3 (4.38) and V_2T_3 (4.25 aphid/five tagged plants) (Table 1).

In case of diamond back moth, the lowest number was recorded in V_3T_4 (5.54 diamond back moth/five tagged plants), which was statistically different from others and followed by V_2T_4 (6.31), V_3T_1 (6.48), V_2T_1 (6.73), V_1T_4 (6.95), V_3T_2 (7.28), V_1T_1 (7.44), V_2T_2 (7.68), V_1T_2 (7.87) and V_3T_3 (8.21). On the other hand, the highest number was recorded in V_1T_0 (9.64 diamond back moth/five tagged plants), which was significantly different from others and followed by V_2T_0 (9.17), V_3T_0 (8.96), V_1T_3 (8.52) and V_2T_3 (8.31 diamond back moth/five tagged plants) (Table 1).

In case of cabbage semi-looper, the lowest number was recorded in V_3T_4 (1.34 cabbage semi-looper/five tagged plants), which was statistically different from others and followed by V_2T_4 (1.82), V_3T_1 (2.01), V_2T_1 (2.17), V_1T_4 (2.32), V_3T_2 (2.45), V_1T_1 (2.53), V_2T_2 (2.89), V_1T_2 (3.21) and V_3T_3 (3.33). On the other hand, the highest number was recorded in V_1T_0 (4.05 cabbage semi-looper/five tagged plants), which was significantly similar with V_2T_0 (3.92) and followed by V_3T_0 (3.83), V_1T_3 (3.54) and V_2T_3 (3.49 cabbage semi-looper/five tagged plants) (Table 1).

In case of jassid, the lowest number was recorded in V_3T_4 (2.97 jassid/five tagged plants), which was statistically similar with V_2T_4 (3.34) and followed by V_3T_1 (3.48), V_2T_1 (3.59), V_1T_4 (3.77), V_3T_2 (3.98), V_1T_1 (4.09), V_2T_2 (4.24), V_1T_2 (4.65) and V_3T_3 (4.92). On the other hand, the highest number was recorded in V_1T_0 (5.57 jassid/five tagged plants), which was significantly similar with V_2T_0 (5.44) and followed by V_3T_0 (5.28), V_1T_3 (5.18) and V_2T_3 (5.06 jassid/five tagged plants) (Table 1).

In case of mole cricket, the lowest number was recorded in V_3T_4 (0.64 mole cricket/five tagged plants), which was statistically similar with V_2T_4 (0.73), V_3T_1 (0.84) and followed by V_2T_1 (0.93), V_1T_4 (0.99), V_3T_2 (1.08), V_1T_1 (1.22), V_2T_2 (1.30), V_1T_2 (1.37) and V_3T_3 (1.45). On the other hand, the highest number was recorded in V_1T_0 (1.93 mole cricket/five tagged plants), which was significantly similar with V_2T_0 (1.84) and followed by V_3T_0 (1.73), V_1T_3 (1.62) and V_2T_3 (1.53 mole cricket/five tagged plants) (Table 1).

Table 1: Effect of different combination of varieties and treatments on the number of insect pests per five tagged plants of broccoli

Combination	Number of insect pests per five tagged plants per plot				
	Aphids	Diamond back moth	Cabbage semi-looper	Jassid	Mole cricket
V_1T_1	3.13 g	7.44 h	2.53 f	4.09 e	1.22 d
V_1T_2	3.60 f	7.87 fg	3.21 cd	4.65 cd	1.37 c
V_1T_3	4.38 d	8.52 d	3.54 c	5.18 b	1.62 b
V_1T_4	2.57 h	6.95 ij	2.32 fg	3.77 f	0.99 e
V_1T_0	5.81 a	9.64 a	4.05 a	5.57 a	1.93 a
V_2T_1	2.32 i	6.73 j	2.17 g	3.59 f	0.93 e
V_2T_2	3.53 f	7.68 g	2.89 e	4.24 de	1.30 d
V_2T_3	4.25 d	8.31 e	3.49 c	5.06 bc	1.53 c
V_2T_4	1.38 k	6.31 l	1.82 h	3.34 gh	0.73 f
V_2T_0	5.36 b	9.17 b	3.92 ab	5.44 a	1.84 a
V_3T_1	1.85 j	6.48 k	2.01 g	3.48 fg	0.84 f
V_3T_2	2.90 h	7.28 hi	2.45 f	3.98 e	1.08 de
V_3T_3	3.89 e	8.21 e	3.33 c	4.92 c	1.45 c
V_3T_4	1.10 l	5.54 m	1.34 i	2.97 h	0.64 f
V_3T_0	5.04 c	8.96 c	3.83 b	5.28 b	1.73 b
LSD (0.05)	0.21	0.28	0.31	0.41	0.22
CV (%)	11.27	4.63	4.63	6.39	8.36

[V_1T_1: Local variety (Anika) + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_1T_2: Local variety (Anika) + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_1T_3: Local variety (Anika) + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_1T_4: Local variety (Anika) + Spraying antifedent (Neem oil @ 3ml/L of water); V_1T_0: Local variety (Anika) + Control; V_2T_1: BARI broccoli 1 + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_2T_2: BARI broccoli 1 + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_2T_3: BARI broccoli 1 + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_2T_4: BARI broccoli 1 + Spraying antifedent (Neem oil @ 3ml/L of water); V_2T_0: BARI broccoli 1 + Control; V_3T_1: Exotic variety + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_3T_2: Exotic variety + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_3T_3: Exotic variety + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_3T_4: Exotic variety + Spraying antifedent (Neem oil @ 3ml/L of water); V_3T_0: Exotic variety + Control.]

From these above findings it was revealed that, among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety + Spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in reducing the number of insect pests like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against incidence of insect pests in terms of reducing the number of aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants was $V_3T_4 < V_2T_4 <$

$V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 <$ V_1T_0. More or less similar research was also conducted by several researchers. Ahmed (2008) and Karim *et al.* (2007) evaluated the similar performance of aqueous neem extract against the pests.

4.4.2. Number of leaf infestation caused by insect pests

The significant variations were observed among the combination of varieties and treatments in terms of the number of infested leaves caused by insect pests like aphid, diamond back moth, cabbage semi-looper and jassid per five tagged plants of broccoli. In case of aphid, the lowest number of infested leaves was recorded in V_3T_4 (1.43 leaves/five tagged plants), which was statistically similar with V_2T_4 (1.93) and followed by V_3T_1 (2.23), V_2T_1 (2.37), V_1T_4 (2.52), V_3T_2 (2.90), V_1T_1 (3.24), V_2T_2 (3.58), V_1T_2 (3.89) and V_3T_3 (3.99). On the other hand, the highest number of infested leaves was recorded in V_1T_0 (5.45 leaves/five tagged plants), which was significantly different from others and followed by V_2T_0 (4.89), V_3T_0 (4.70), V_1T_3 (4.46) and V_2T_3 (4.18 leaves/five tagged plants) (Table 2).

In case of diamond back moth, the lowest number of infested leaves was recorded in V_3T_4 (2.94 leaves/five tagged plants), which was statistically different from others and followed by V_2T_4 (3.37), V_3T_1 (3.55), V_2T_1 (3.89), V_1T_4 (4.17), V_3T_2 (4.27), V_1T_1 (4.41), V_2T_2 (4.57), V_1T_2 (4.77) and V_3T_3 (4.99). On the other hand, the highest number of infested leaves was recorded in V_1T_0 (6.00 leaves/five tagged plants), which was significantly different from others and followed by V_2T_0 (5.87), V_3T_0 (5.62), V_1T_3 (5.40) and V_2T_3 (5.24 leaves/five tagged plants) (Table 2).

In case of cabbage semi-looper, the lowest number of infested leaves was recorded in V_3T_4 (1.11 leaves/five tagged plants), which was statistically similar with V_2T_4 (1.32) and V_3T_1 (1.42) and followed by V_2T_1 (1.75), V_1T_4 (1.81), V_3T_2 (2.04), V_1T_1 (2.19), V_2T_2 (2.46), V_1T_2 (2.52) and V_3T_3 (2.58). On the other hand, the highest number of infested leaves was recorded in V_1T_0 (3.05 leaves/five tagged plants), which was significantly similar with V_2T_0 (2.96) and V_3T_0 (2.91) and followed by V_1T_3 (2.82) and V_2T_3 (2.64 leaves/five tagged plants) (Table 2).

In case of jassid, the lowest number of infested leaves was recorded in V_3T_4 (2.10 leaves/five tagged plants), which was statistically similar with V_2T_4 (2.18), V_3T_1 (2.31), V_2T_1 (2.39) and V_1T_4 (2.47) and followed by V_3T_2 (2.54), V_1T_1 (2.62), V_2T_2 (2.77), V_1T_2 (2.94) and V_3T_3 (3.14). On the other hand, the highest number of infested leaves was recorded in V_1T_0 (4.00 leaves/five tagged plants), which was significantly different from others and followed by V_2T_0 (3.73), V_3T_0 (3.60), V_1T_3 (3.40) and V_2T_3 (3.25 leaves/five tagged plants) (Table 2).

Table 2: Effect of different combination of varieties and treatments on number of infested leaves caused by insect pests per five tagged plants of broccoli

Combination	**No. of infested leaves caused by insect pests per 5 tagged plants per plot**			
	Aphid	**Diamond back moth**	**Cabbage semi-looper**	**Jassid**
V_1T_1	3.24 e	4.41 f	2.19 d	2.62 e
V_1T_2	3.89 d	4.77 e	2.52 c	2.94 d
V_1T_3	4.46 c	5.40 c	2.82 b	3.40 c
V_1T_4	2.52 fg	4.17 g	1.81 e	2.47 ef
V_1T_0	5.45 a	6.00 a	3.05 a	4.00 a
V_2T_1	2.37 g	3.89 h	1.75 ef	2.39 f
V_2T_2	3.58 de	4.57 e	2.46 c	2.77 de
V_2T_3	4.18 c	5.24 d	2.64 bc	3.25 c
V_2T_4	1.93 gh	3.37 i	1.32 g	2.18 f
V_2T_0	4.89 b	5.87 b	2.96 a	3.73 b
V_3T_1	2.23 g	3.55 i	1.42 fg	2.31 f
V_3T_2	2.90 f	4.27 fg	2.04 de	2.54 e
V_3T_3	3.99 d	4.99 de	2.58 c	3.14 c
V_3T_4	1.43 h	2.94 j	1.11 g	2.10 f
V_3T_0	4.70 b	5.62 bc	2.91 ab	3.60 b
LSD (0.05)	0.52	0.33	0.29	0.33
CV (%)	7.21	6.21	5.21	5.29

[V_1T_1: Local variety (Anika) + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_1T_2: Local variety (Anika) + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_1T_3: Local variety (Anika) + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_1T_4: Local variety (Anika) + Spraying antifedent (Neem oil @ 3ml/L of water); V_1T_0: Local variety (Anika) + Control; V_2T_1: BARI broccoli 1 + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_2T_2: BARI broccoli 1 + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_2T_3: BARI broccoli 1 + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_2T_4: BARI broccoli 1 + Spraying antifedent (Neem oil @ 3ml/L of water); V_2T_0: BARI broccoli 1 + Control; V_3T_1: Exotic variety + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_3T_2: Exotic variety + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_3T_3: Exotic variety + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_3T_4: Exotic variety + Spraying antifedent (Neem oil @ 3ml/L of water); V_3T_0: Exotic variety + Control.]

From these above findings it was revealed that, among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety + Spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in reducing the number of infested leaves caused by insect pests like aphid, diamond back moth, cabbage semi-looper and jassid per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests in terms of reducing the number of infested leaves caused by insect pests like aphid, diamond back moth, cabbage semi-looper and jassid per five tagged plants was $V_3T_4 < V_2T_4 < V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 < V_1T_0$. More or less similar research was also conducted by several researchers. Ahmed (2008) and Karim *et al.* (2007) evaluated the similar performance of aqueous neem extract against the pests.

4.4.3. Number of infested plant caused by insect pests

The significant variations were observed among different combination of varieties and treatments in terms of the number of infested plants caused by insect pests like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot of broccoli. In case of aphid, the lowest number of infested plants was recorded in V_3T_4 (1.41 plants/plot), which was statistically similar with V_2T_4 (1.57) and V_3T_1 (1.94) and followed by V_2T_1 (2.07), V_1T_4 (2.20), V_3T_2 (2.41), V_1T_1 (2.57), V_2T_2 (2.92), V_1T_2 (3.12) and V_3T_3 (3.33). On the other hand, the highest number was recorded in V_1T_0

(4.52 plants/plot), which was significantly different from others and followed by V_2T_0 (4.18), V_3T_0 (4.02), V_1T_3 (3.74) and V_2T_3 (3.54 plants/plot) (Table 3).

In case of diamond back moth, the lowest number was recorded in V_3T_4 (1.40 plants/plot), which was statistically similar with V_2T_4 (1.55) and V_3T_1 (1.77) and followed by V_2T_1 (2.08), V_1T_4 (2.25), V_3T_2 (2.45), V_1T_1 (2.54), V_2T_2 (2.77), V_1T_2 (3.03) and V_3T_3 (3.18). On the other hand, the highest number was recorded in V_1T_0 (3.90 plants/plot), which was significantly different from others and followed by V_2T_0 (3.74), V_3T_0 (3.59), V_1T_3 (3.46) and V_2T_3 (3.32 plants/plot) (Table 3).

In case of cabbage semi-looper, the lowest number was recorded in V_3T_4 (0.85 plants/plot), which was statistically different from others and followed by V_2T_4 (1.20), V_3T_1 (1.29), V_2T_1 (1.34), V_1T_4 (1.40), V_3T_2 (1.51), V_1T_1 (1.57), V_2T_2 (1.61), V_1T_2 (1.68) and V_3T_3 (1.80). On the other hand, the highest number was recorded in V_1T_0 (2.53 plants/plot), which was significantly similar with V_2T_0 (2.41) and followed by V_3T_0 (2.24), V_1T_3 (2.00) and V_2T_3 (1.89 plants/plot) (Table 3).

In case of jassid, the lowest number was recorded in V_3T_4 (1.50 plants/plot), which was statistically similar with V_2T_4 (1.57) and V_3T_1 (1.72) and followed by V_2T_1 (1.93), V_1T_4 (2.05), V_3T_2 (2.14), V_1T_1 (2.30), V_2T_2 (2.47), V_1T_2 (2.60) and V_3T_3 (2.75). On the other hand, the highest number was recorded in V_1T_0 (3.40 plants/plot), which was significantly similar with V_2T_0 (3.27) and followed by V_3T_0 (3.09), V_1T_3 (2.99) and V_2T_3 (2.89 plants/plot) (Table 3).

In case of mole cricket, the lowest number was recorded in V_3T_4 (0.49 plants/plot), which was statistically similar with V_2T_4 (0.55), V_3T_1 (0.64) and V_2T_1 (0.73) and followed by V_1T_4 (0.83), V_3T_2 (0.89), V_1T_1 (1.00), V_2T_2 (1.07), V_1T_2 (1.17), and V_3T_3 (1.27). On the other hand, the highest number was recorded in V_1T_0 (1.78 plants/plot), which was significantly similar with V_2T_0 (1.69) and V_3T_0 (1.62) and followed by V_1T_3 (1.50) and V_2T_3 (1.37 plants/plot) (Table 3).

Table 3: Effect of different combination of varieties and treatments against the number of infested plants caused by insect pests per plot of broccoli

Combination	Number of infested plants caused by insect pests per plot				
	Aphid	Diamond back moth	Cabbage semi-looper	Jassid	Mole cricket
V_1T_1	2.57 e	2.54 d	1.57 d	2.30 e	1.00 d
V_1T_2	3.12 d	3.03 c	1.68 cd	2.60 d	1.17 c
V_1T_3	3.74 c	3.46 b	2.00 bc	2.99 b	1.50 b
V_1T_4	2.20 f	2.25 e	1.40 e	2.05 ef	0.83 d
V_1T_0	4.52 a	3.90 a	2.53 a	3.40 a	1.78 a
V_2T_1	2.07 f	2.08 e	1.34 e	1.93 f	0.73 ef
V_2T_2	2.92 d	2.77 d	1.61 d	2.47 d	1.07 c
V_2T_3	3.54 c	3.32 c	1.89 c	2.89 c	1.37 b
V_2T_4	1.57 g	1.55 f	1.20 e	1.57 g	0.55 e
V_2T_0	4.18 b	3.74 b	2.41 a	3.27 ab	1.69 a
V_3T_1	1.94 fg	1.77 f	1.29 e	1.72 g	0.64 e
V_3T_2	2.41 ef	2.45 d	1.51 d	2.14 e	0.89 d
V_3T_3	3.33 cd	3.18 c	1.80 c	2.75 c	1.27 c
V_3T_4	1.41 g	1.40 f	0.85 f	1.50 g	0.49 e
V_3T_0	4.02 b	3.59 b	2.24 b	3.09 b	1.62 ab
LSD (0.05)	0.48	0.48	0.28	0.28	0.27
CV (%)	7.21	4.21	4.21	4.92	7.12

[V_1T_1: Local variety (Anika) + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_1T_2: Local variety (Anika) + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_1T_3: Local variety (Anika) + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_1T_4: Local variety (Anika) + Spraying antifedent (Neem oil @ 3ml/L of water); V_1T_0: Local variety (Anika) + Control; V_2T_1: BARI broccoli 1 + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_2T_2: BARI broccoli 1 + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_2T_3: BARI broccoli 1 + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_2T_4: BARI broccoli 1 + Spraying antifedent (Neem oil @ 3ml/L of water); V_2T_0: BARI broccoli 1 + Control; V_3T_1: Exotic variety + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_3T_2: Exotic variety + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_3T_3: Exotic variety + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_3T_4: Exotic variety + Spraying antifedent (Neem oil @ 3ml/L of water); V_3T_0: Exotic variety + Control.]

From these above findings it was revealed that among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety + Spraying antifedent (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in reducing the number of infested plants caused by insect pests like aphid, diamond back moth, cabbage sami-looper, jassid and mole cricket per plot than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against aphid in terms of reducing the number of infested plants caused by insect pests like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot was $V_3T_4 < V_2T_4 < V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 < V_1T_0$. More or less similar research was also conducted by several researchers. Ahmed (2008) and Karim *et al.* (2007) evaluated the similar performance of aqueous neem extract against the pests.

4.5. Yield attribute characteristic

4.5.1. In case of varietal performance

Plant height: The significant variation was observed in plant height of broccoli, whereas, the maximum average plant height was found in V_3 (39.33 cm) which was significantly different from other varieties and followed by V_2 (37.56 cm). On the other hand, the minimum average number plant height was found in V_1 (36.12 cm) which was significantly different from other varieties (Table 4).

Number of leaf: The significant variation was observed in the number of leaves of broccoli, whereas, the maximum average number of leaves was found in V_3 (17.62 leaves) which was significantly different from other varieties and followed by V_2 (14.13 leaves). On the other hand, the minimum average number of leaves was found in V_1 (10.87 leaves) which was significantly different from other varieties (Table 4).

Length of leaf: The significant variation was observed in length of leaves of broccoli, whereas, the maximum average length of leaves was found in V_3 (40.31 cm) which was significantly different from other varieties and followed by V_2 (38.67 cm). On the other hand, the minimum average length of leaves was found in V_1 (35.89 cm) which was significantly different from other varieties (Table 4).

Breadth of leaf: The significant variation was observed in breadth of leaves of broccoli, whereas, the maximum average breadth of leaves was found in V_3 (12.87 cm) which was significantly different from other varieties and followed by V_2 (10.46 cm). On the other hand, the minimum average length of leaves was found in V_1 (9.21 cm) which was significantly different from other varieties (Table 4).

Table 4: Effect of different varieties on plant height, number of leaf, leaf length and breadth of broccoli

Varieties	Plant height (cm)	Number of leaf per plant	Leaf length (cm)	Leaf breadth (cm)
V_1	36.12 c	10.87 c	35.89 c	9.21 c
V_2	37.56 b	14.13 b	38.67 b	10.46 b
V_3	39.33 a	17.62 a	40.31 a	12.87 a
LSD (0.05)	0.83	1.35	1.29	0.71
CV (%)	7.56	6.29	10.33	8.21

[V_1: Local variety (Anika); V_2: BARI broccoli 1; V_3: Exotic variety.]

From these above findings it was revealed that among the different Varieties, V_3 comprised with exotic variety showed the best performance in case of plant height, number of leaves, length and breadth of leaves than the others. As a result, the order of rank of varieties of broccoli in terms of plant height, number of leaves, length breadth of leaves was V_3> V_2> V_3. More or less similar research was also conducted by several researchers. Sanchez *et al.* (2016) evaluated the performance of exotic variety of broccoli was higher than the other varieties.

Curd height: The significant variation was observed in curd height of broccoli, whereas, the maximum average curd height was found in V_3 (21.26 cm) which was significantly different from other varieties. On the other hand, the minimum average curd height was found in V_1 (15.33 cm) which was significantly different from other varieties and followed by V_2 (18.72 cm) (Table 5).

Curd diameter: The significant variation was observed in the average diameter of curd of broccoli. Maximum average curd diameter was found in V_3 (20.46cm) which was significantly different from other varieties and followed by V_2 (19.43 cm). On the other hand, the minimum average curd height was found in V_1 (16.89 cm) (Table 5).

Perimeter of curd: The significant variation was observed in the perimeter of curd of broccoli. Maximum perimeter of curd of broccoli was found in V_3 (39.67 cm) which was significantly different from other varieties and followed by V_2 (32.78 cm). On the other hand, the minimum perimeter of curd was found in V_1 (29.12 cm) (Table 5).

Total curd weight per plot: The significant variation was observed in total curd weight of broccoli per plot, whereas, the maximum average weight of curd was found in V_3 (5.14 kg) which was significantly different from other varieties and followed by V_2 (4.38 kg). On the other hand, the minimum average weight of curd was found in V_1 (2.43 kg) (Table 5).

Yield per hectare: The significant variation was observed in the total yield of broccoli per hectare, whereas, the minimum average weight was found in V_1 (6.48 ton) which was significantly different from other varieties and followed by V_2 (11.68 ton). On the other hand, the maximum average weight was found in V_3 (13.71 ton) (Table 5).

Table 5: Effect of varieties on curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha of broccoli

Varieties	Curd height (cm)	Curd diameter (cm)	Perimeter of curd (cm)	Curd weight/ plot (kg)	Yield/ha (ton)
V_1	15.33 c	16.89 c	29.12 c	2.43 c	6.48 c
V_2	18.72 b	19.43 b	32.78 b	4.38 b	11.68 b
V_3	21.26 a	20.46 a	39.67 a	5.14 a	13.71 a
LSD (0.05)	2.14	0.78	2.33	0.62	1.25
CV (%)	1.46	5.19	6.23	5.72	10.76

[V_1: Local variety (Anika); V_2: BARI broccoli 1; V_3: Exotic variety.]

From these above findings it was revealed that among the different Varieties, V_3 comprised with exotic variety showed the best performance in case of curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha than the others. As a result, the order of rank of varieties of broccoli in terms of curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha was V_3> V_2> V_1. More or less similar research was also conducted by several researchers. Sanchez *et al*. (2016) evaluated the performance of exotic variety of broccoli was higher than the other varieties.

4.5.2. In case of effect of different treatments

Plant height: The significant variation was observed in plant height of broccoli, whereas, the maximum average plant height was found in T_4 (38.12 cm) which was significantly different from other treatments and followed by T_1 (36.87 cm) and T_2 (36.23 cm). On the other hand, the minimum average plant height was found in T_0 (34.36 cm) which was significantly different from other treatments and followed by T_3 (34.56 cm) (Table 6).

Number of leaf: The significant variation was observed in the number of leaves of broccoli, whereas, the maximum average number of leaves was found in T_4 (16.47 leaves) which was significantly different from other treatments and followed by T_1 (14.36 leaves) and T_2 (13.12 leaves). On the other hand, the minimum average number of leaves was found in T_0 (9.82 leaves) which was significantly different from other treatments and followed by T_3 (12.53 leaves) (Table 6).

Length of leaf: The significant variation was observed in length of leaves of broccoli, whereas, the maximum average length of leaves was found in T_4 (38.98 cm) which was significantly different from other treatments and followed by T_1 (36.33 cm) and T_2 (35.12 cm). On the other hand, the minimum average length of leaves was found in T_0

(34.21 cm) which was significantly different from other treatments and followed by T_3 (35.97 cm) (Table 6).

Breadth of leaf: The significant variation was observed in breadth of leaves of broccoli, whereas, the maximum average breadth of leaves was found in T_4 (12.46 cm) which was significantly different from other treatments and followed by T_1 (11.29 cm) and T_2 (10.31 cm). On the other hand, the minimum average length of leaves was found in T_0 (8.21 cm) which was significantly different from other treatments and followed by T_3 (9.67 cm) (Table 6).

Table 6: Effect of different varieties on plant height, number of leaf, leaf length and breadth of broccoli

Treatments	Plant height (cm)	Number of leaf per plant	Leaf length (cm)	Leaf breadth (cm)
T_1	36.87 b	14.36 b	36.33 b	11.29 b
T_2	36.23 bc	13.12 c	35.12 c	10.31 c
T_3	34.56 d	12.53 d	35.97 d	9.67 d
T_4	38.12 a	16.47 a	38.98 a	12.46 a
T_0	34.36 e	9.82 e	34.21 e	8.21 e
LSD (0.05)	0.76	0.82	0.49	0.51
CV (%)	6.13	8.15	6.78	6.72

[T_1: Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); T_2: Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); T_3: Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); T_4: Spraying antifedent (Neem oil @ 3ml/L of water); T_0: Control.]

From these above findings it was revealed that among the different treatments, T_4 comprised with spraying antifedent (Neem oil @ 3ml/L of water) showed the best performance in case of plant height, number of leaves, length and breadth of leaves than the others. As a result, the order of rank of treatments of broccoli in terms of plant height, number of leaves, length and breadth of leaves was $T_4 > T_1 > T_2 > T_3 > T_0$. More or less similar research was also conducted by several researchers. Ahmed (2008) evaluated the similar performance of aqueous neem extract against the pests and increasing yield attributing characteristics.

Curd height: The significant variation was observed in curd height of broccoli, whereas, the maximum average curd height was found in T_4 (20.45 cm) which was significantly different from other treatments and followed by T_1 (19.67 cm) and T_2 (19.21 cm). On the other hand, the minimum average curd height was found in T_0 (17.79 cm) which was significantly different from other treatments and followed by T_3 (18.82 cm) (Table 7).

Curd diameter: The significant variation was observed in the average diameter of curd of broccoli, whereas, the maximum average curd diameter was found in T_4 (21.13 cm) which was significantly different from other treatments and followed by T_1 (20.56 cm) and T_2 (18.72 cm). On the other hand, the minimum average curd diameter was found in T_0 (15.33 cm) which was significantly different from other treatments and followed by T_3 (17.17 cm) (Table 7).

Perimeter of curd: The significant variation was observed in the perimeter of curd of broccoli, whereas, the maximum perimeter of curd of broccoli was found in T_4 (39.47 cm) which was significantly different from other treatments and followed by T_1 (37.87 cm) and T_2 (36.12 cm). On the other hand, the minimum perimeter of curd was found in T_0 (28.82 cm) which was significantly different from other treatments and followed by T_3 (34.67 cm) (Table 7).

Total curd weight per plot: The significant variation was observed in total curd weight of broccoli per plot, whereas, the maximum average weight of curd was found in T_4 (4.92 kg) which was significantly different from other treatments and followed by T_1 (4.53 kg) and T_2 (4.16 kg). On the other hand, the minimum average weight of curd was found in T_0 (3.12 kg) which was significantly different from other treatments and followed by T_3 (3.98 kg) (Table 7).

Yield per hectare: The significant variation was observed in the total yield of broccoli per hectare, whereas, the minimum average weight was found in T_0 (8.32 ton) which was significantly different from other treatments and followed by T_3 (10.61 ton) and T_2 (11.09 ton). On the other hand, the maximum average weight was found in T_4 (13.12 ton) which was significantly different from other treatments and followed by T_1 (12.08 ton) (Table 7).

Table 7: Effect of different treatments on curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha of broccoli

Treatments	Curd height (cm)	Curd diameter (cm)	Perimeter of curd (cm)	Curd weight/plot (kg)	Yield/ha (ton)
T_1	19.67 b	20.56 b	37.87 b	4.53 b	12.08 b
T_2	19.21 c	18.72 c	36.12 c	4.16 c	11.09 c
T_3	18.82 d	17.17 d	34.67 d	3.98 c	10.61 c
T_4	20.45 a	21.13 a	39.47 a	4.92 a	13.12 a
T_0	17.79 e	15.33 e	28.82 e	3.12 d	8.32 d
LSD (0.05)	0.34	0.51	1.23	0.32	0.72
CV (%)	7.24	9.71	7.36	8.17	10.76

[T_1: Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); T_2: Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); T_3: Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); T_4: Spraying antifedent (Neem oil @ 3ml/L of water); T_0: Control.]

From these above findings it was revealed that among the different treatments, T_4 comprised with spraying antifedent (Neem oil @ 3ml/L of water) showed the best performance in case of curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha than the others. As a result, the order of rank of different treatments of broccoli in terms of curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha was $T_4 > T_1 > T_2 > T_3 > T_0$. More or less similar research was also conducted by several researchers. Ahmed (2008) evaluated the similar performance of aqueous neem extract against the pests and increasing yield attributing characteristics.

4.5.3. In case of effect of combinations of treatments and varieties

Plant height: The significant variation was observed in plant height of broccoli, whereas, the maximum average plant height was found in V_3T_4 (40.33 cm), which was statistically similar with V_2T_4 (39.54) and followed by V_3T_1 (39.12), V_2T_1 (38.76), V_1T_4 (38.49), V_3T_2 (38.17), V_1T_1 (37.92), V_2T_2 (37.63), V_1T_2 (37.33) and V_3T_3 (37.03 cm). On the other hand, the miniimum average plant height was found in V_1T_0 (34.78 cm), which was statistically similar with V_2T_0 (35.18), V_3T_0 (35.43) and V_1T_3 (36.11) and followed by V_2T_3 (36.57 cm) (Table 8).

Number of leaf: The significant variation was observed in the number of leaves of broccoli, whereas, the maximum average number of leaves was found in V_3T_4 (17.87 leaves), which was statistically similar with V_2T_4 (17.34) and followed by V_3T_1 (17.09), V_2T_1 (16.56), V_1T_4 (16.43), V_3T_2 (16.16), V_1T_1 (15.87), V_2T_2 (15.72), V_1T_2 (15.32) and V_3T_3 (15.11 cm). On the other hand, the miniimum average number of leaves was found in V_1T_0 (10.33 leaves), which was significantly different from others and followed by V_2T_0 (11.67), V_3T_0 (12.87), V_1T_3 (13.76), V_2T_3 (14.33 leaves) (Table 8).

Length of leaf: The significant variation was observed in leaf length of broccoli, whereas, the maximum average length of leaves was found in V_3T_4 (39.82 cm), which was statistically similar with V_2T_4 (39.21) and followed by V_3T_1 (38.72), V_2T_1 (38.11), V_1T_4 (37.63), V_3T_2 (36.34), V_1T_1 (35.98), V_2T_2 (35.33), V_1T_2 (34.76) and V_3T_3 (33.56 cm). On the other hand, the miniimum average length of leaves was found in V_1T_0 (29.17 cm), which was statistically similar with V_2T_0 (29.92), V_3T_0 (30.11) and V_1T_3 (30.87) and followed by and V_2T_3 (32.62 cm). (Table 8).

Breadth of leaf: The significant variation was observed in breadth of leaf of broccoli, whereas, the maximum average leaf breadth was found in V_3T_4 (14.21 cm), which was significantly different from others and followed by V_2T_4 (13.54), V_3T_1 (13.03), V_2T_1 (12.78), V_1T_4 (12.33), V_3T_2 (11.87), V_1T_1 (11.41), V_2T_2 (11.12), V_1T_2 (10.67) and V_3T_3 (10.32 cm). On the other hand, the miniimum average leaf breadth was found in V_1T_0 (8.67 cm), which was statistically similar with V_2T_0 (8.92) and V_3T_0 (9.29) and followed by V_1T_3 (9.56) and V_2T_3 (9.98 cm). (Table 8).

Table 8: Effect of different combinations of varieties and treatments on plant height, number of leaf, leaf length and breadth of broccoli

Combinations	Plant height (cm)	Number of leaf per plant	Leaf length (cm)	Leaf breadth (cm)
V_1T_1	37.92 c	15.87 c	35.98 c	11.41 e
V_1T_2	37.33 c	15.32 c	34.76 d	10.67 f
V_1T_3	36.11 d	13.76 de	30.87 f	9.56 g
V_1T_4	38.49 b	16.43 b	37.63 b	12.33 cd
V_1T_0	34.78 d	10.33 g	29.17 f	8.67 h
V_2T_1	38.76 b	16.56 b	38.11 b	12.78 c
V_2T_2	37.63 c	15.72 c	35.33 c	11.12 e
V_2T_3	36.57 c	14.33 d	32.62 e	9.98 g
V_2T_4	39.54 ab	17.34 a	39.21 a	13.54 b
V_2T_0	35.18 d	11.67 f	29.92 f	8.92 h
V_3T_1	39.12 b	17.09 b	38.72 b	13.03 b
V_3T_2	38.17 b	16.16 b	36.34 c	11.87 d
V_3T_3	37.03 c	15.11 c	33.56 d	10.32 f
V_3T_4	40.33 a	17.87 a	39.82 a	14.21 a
V_3T_0	35.43 d	12.87 e	30.11 f	9.29 h
LSD (0.05)	1.63	1.13	1.98	0.71
CV (%)	9.63	8.92	10.45	9.11

[V_1T_1: Local variety (Anika) + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_1T_2: Local variety (Anika) + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_1T_3: Local variety (Anika) + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_1T_4: Local variety (Anika) + Spraying antifedent (Neem oil @ 3ml/L of water); V_1T_0: Local variety (Anika) + Control; V_2T_1: BARI broccoli 1 + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_2T_2: BARI broccoli 1 + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_2T_3: BARI broccoli 1 + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_2T_4: BARI broccoli 1 + Spraying antifedent (Neem oil @ 3ml/L of water); V_2T_0: BARI broccoli 1 + Control; V_3T_1: Exotic variety + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_3T_2: Exotic variety + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_3T_3: Exotic variety + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_3T_4: Exotic variety + Spraying antifedent (Neem oil @ 3ml/L of water); V_3T_0: Exotic variety + Control.]

From these above findings it was revealed that among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety + Spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in increasing plant height, number of leaves, leaf length and breadth (40.33 cm, 17.87

leaves, 39.82 cm and 14.21 cm, respectively) than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied in increasing plant height, number of leaves, leaf length and breadth was V_3T_4> V_2T_4> V_3T_1> V_2T_1> V_1T_4> V_3T_2> V_1T_1> V_2T_2> V_1T_2> V_3T_3> V_2T_3> V_1T_3> V_3T_0> V_2T_0> V_1T_0. More or less similar research was also conducted by several researchers. Ahmed (2008) and Karim *et al.* (2007) evaluated the similar performance of aqueous neem extract against the pests and increasing the yield attributing characeristics.

Curd height: The significant variation was observed in the height of curd of broccoli, whereas, the maximum average curd height was found in V_3T_4 (22.13 cm), which was statistically similar with V_2T_4 (21.92) and followed by V_3T_1 (21.67), V_2T_1 (21.23), V_1T_4 (20.89), V_3T_2 (20.56), V_1T_1 (20.17), V_2T_2 (19.45), V_1T_2 (18.89) and V_3T_3 (17.78 cm). On the other hand, the minimum average curd height was found in V_1T_0 (15.62 cm), which was statistically similar with V_2T_0 (15.89) and followed by V_3T_0 (16.23), V_1T_3 (16.76) and V_2T_3 (17.11 cm) (Table 9).

Curd diameter: The significant variation was observed in diameter of curd of broccoli, whereas, the maximum average curd diameter was found in V_3T_4 (20.33 cm), which was statistically similar with V_2T_4 (20.12) and V_3T_1 (19.97) and followed by V_2T_1 (19.63), V_1T_4 (19.32), V_3T_2 (19.07), V_1T_1 (18.67), V_2T_2 (18.36), V_1T_2 (17.89) and V_3T_3 (17.53 cm). On the other hand, the minimum average curd diameter was found in V_1T_0 (16.13 cm), which was statistically similar with V_2T_0 (16.33) and V_3T_0 (16.69) and followed by V_1T_3 (16.92) and V_2T_3 (17.21 cm) (Table 9).

Perimeter of curd: The significant variation was observed in the perimeter of curd of broccoli, whereas, the maximum average curd perimeter was found in V_3T_4 (38.78 cm), which was significantly different from others and followed by V_2T_4 (38.46), V_3T_1

(38.21), V_2T_1 (37.96), V_1T_4 (37.57), V_3T_2 (36.33), V_1T_1 (35.72), V_2T_2 (35.29), V_1T_2 (34.36) and V_3T_3 (33.56 cm). On the other hand, the minimum average curd perimeter was found in V_1T_0 (29.33 cm), which was statistically similar with V_2T_0 (29.76) and V_3T_0 (30.59) and followed by V_1T_3 (31.67) and V_2T_3 (32.47 cm) (Table 9).

Total curd weight per plot: The significant variation was observed in the weight of curd per plot of broccoli, whereas, the maximum average curd weight per plot was found in V_3T_4 (5.22 kg), which was statistically similar with V_3T_1 (5.18) and followed by V_3T_2 (5.03), V_3T_3 (4.67), V_2T_4 (4.53), V_2T_1 (4.29), V_3T_0 (4.11), V_2T_2 (3.82), V_2T_3 (3.76) and V_2T_0 (3.46 kg). On the other hand, the minimum average curd weight per plot was found in V_1T_0 (2.72 kg), which was statistically similar with V_1T_3 (2.97), V_1T_2 (3.07), V_1T_1 (3.19) and V_1T_4 (3.33 kg) (Table 9).

Yield per hectare: The significant variation was observed in the yield of curd per hectare of broccoli, whereas, the maximum average curd yield per hectare was found in V_3T_4 (13.92 ton), which was statistically similar with V_3T_1 (13.81) and followed by V_3T_2 (13.41), V_3T_3 (12.45), V_2T_4 (12.01), V_2T_1 (11.44), V_3T_0 (10.96), V_2T_2 (10.19), V_2T_3 (10.03) and V_2T_0 (9.23 ton). On the other hand, the minimum average curd yield per hectare was found in V_1T_0 (7.25 ton), which was statistically similar with V_1T_3 (7.92), V_1T_2 (8.19), V_1T_1 (8.51) and V_1T_4 (8.88 ton) (Table 9).

Table 9: Effect of different combinations of varieties and treatments on curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha of broccoli

Combinations	Curd height (cm)	Curd diameter (cm)	Curd perimete (cm)	Weight of curd/plot (kg)	Yield/ha (ton)
V_1T_1	20.17 c	18.67 c	35.72 c	3.19 ef	8.51 ij
V_1T_2	18.89 d	17.89 d	34.36 d	3.07 f	8.19 j
V_1T_3	16.76 f	16.92 ef	31. 67 e	2.97 f	7.92 jk
V_1T_4	20.89 b	19.32 b	37.57 b	3.33 e	8.88 i
V_1T_0	15.62 g	16.13 f	29.33 f	2.72 f	7.25 k
V_2T_1	21.23 b	19.63 b	37.96 b	4.29 c	11.44 e
V_2T_2	19.45 cd	18.36 c	35.29 c	3.82 d	10.19 g
V_2T_3	17.11 e	17.21 e	32.47 e	3.76 de	10.03 g
V_2T_4	21.92 a	20.12 a	38.46 b	4.53 c	12.01 d
V_2T_0	15.89 g	16.33 f	29.76 f	3.46 e	9.23 h
V_3T_1	21.67 b	19.97 ab	38.21 b	5.18 ab	13.81 a
V_3T_2	20.56 bc	19.07 c	36.33 c	5.03 b	13.41 b
V_3T_3	17.78 e	17.53 d	33.56 d	4.67 bc	12.45 c
V_3T_4	22.13 a	20.33 a	38.78 a	5.22 a	13.92 a
V_3T_0	16.23 f	16.69 f	30.59 f	4.11 d	10.96 f
LSD (0.05)	1.19	0.76	1.83	0.48	0.62
CV (%)	7.54	9.93	8.24	8.89	9.47

[V_1T_1: Local variety (Anika) + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_1T_2: Local variety (Anika) + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_1T_3: Local variety (Anika) + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_1T_4: Local variety (Anika) + Spraying antifedent (Neem oil @ 3ml/L of water); V_1T_0: Local variety (Anika) + Control; V_2T_1: BARI broccoli 1 + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_2T_2: BARI broccoli 1 + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_2T_3: BARI broccoli 1 + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_2T_4: BARI broccoli 1 + Spraying antifedent (Neem oil @ 3ml/L of water); V_2T_0: BARI broccoli 1 + Control; V_3T_1: Exotic variety + Spraying contact insecticide (Malathion 5 EC @ 2ml/L of water); V_3T_2: Exotic variety + Spraying systemic insecticide (Actara 25 WG @ 0.2gm/L of water); V_3T_3: Exotic variety + Spraying stomac insecticide (Sevin 85 WP @ 1gm/L of water); V_3T_4: Exotic variety + Spraying antifedent (Neem oil @ 3ml/L of water); V_3T_0: Exotic variety + Control.]

From these above findings it was revealed that among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety + Spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in increasing curd height, curd diameter, curd perimeter, total weight of curd/plot and yield/ha (22.13 cm, 20.33 cm, 38.78 cm, 5.22 kg and 13.92 ton, respectively) than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied in increasing curd height, curd diameter, curd perimeter, total weight of curd/plot and yield/ha was V_3T_4> V_2T_4> V_3T_1> V_2T_1> V_1T_4> V_3T_2> V_1T_1> V_2T_2>

$V_1T_2 > V_3T_3 > V_2T_3 > V_1T_3 > V_3T_0 > V_2T_0 > V_1T_0$. More or less similar research was also conducted by several researchers. Ahmed (2008) and Karim *et al.* (2007) evaluated the similar performance of aqueous neem extract against the pests and increasing the yield attributing characteristics.

4.6. Relationship between the number of insect pests and yield of broccoli

4.6.1. In case of aphid

Significant relationship was found between the number of aphid and yield of broccoli at different combination of varieties and treatments when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong ($R^2=0.4197$) and negative (slope =-1.0146) correlation was found between the number of aphid and yield of broccoli, i.e. yield of broccoli decreased with the increase of the number of aphid.

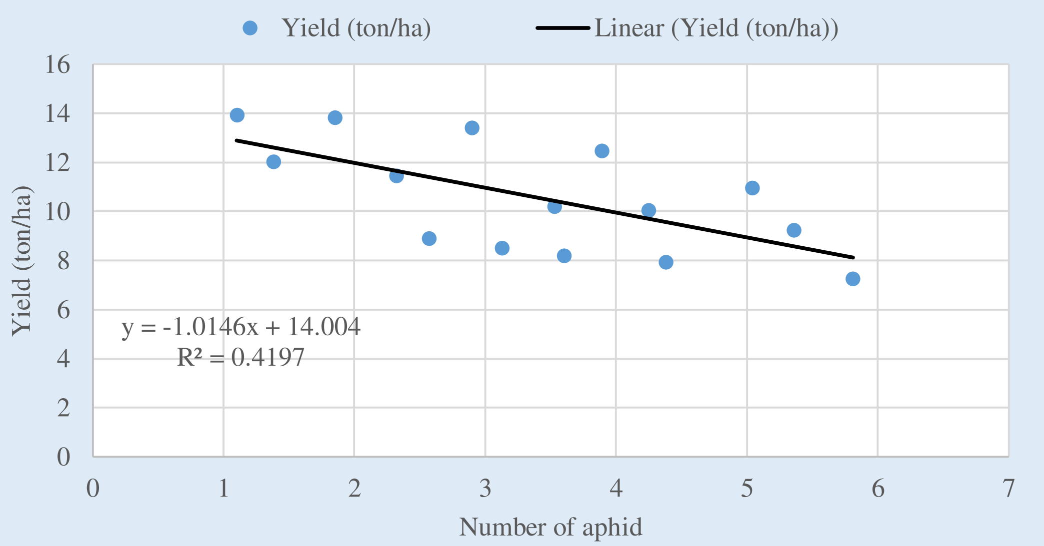

Figure 12: Relationship between the number of aphid and yield of broccoli at different combinations of varieties and treatments

4.6.2. In case of diamond back moth

Significant relationship was found between the number of diamond back moth and yield of broccoli at different combination of varieties and treatments when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong

(R^2=0.4192) and negative (slope =-1.2478) correlation was found between the number of diamond back moth and yield of broccoli, i.e. yield of broccoli decreased with the increase of the number of diamond back moth.

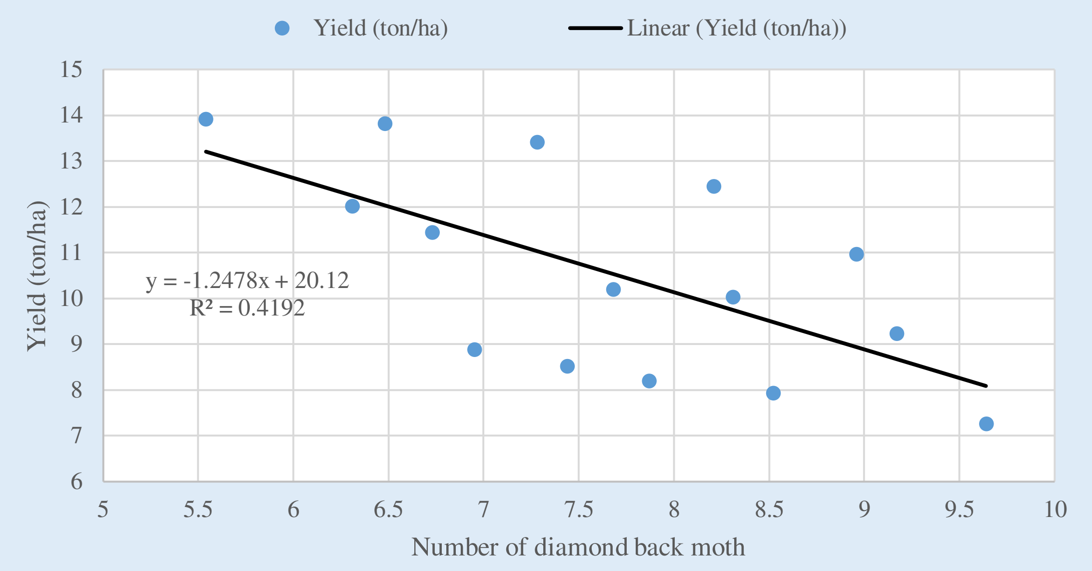

Figure 13: Relationship between the number of diamond back moth and yield of broccoli at different combinations of varieties and treatments

4.6.3. In case of cabbage semi-looper

Significant relationship was found between the number of cabbage semi-looper and yield of broccoli at different combination of varieties and treatments when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.4043) and negative (slope =-1.6876) correlation was found between the number of cabbage semi-looper and yield of broccoli, i.e. yield of broccoli decreased with the increase of the number of cabbage semi-looper.

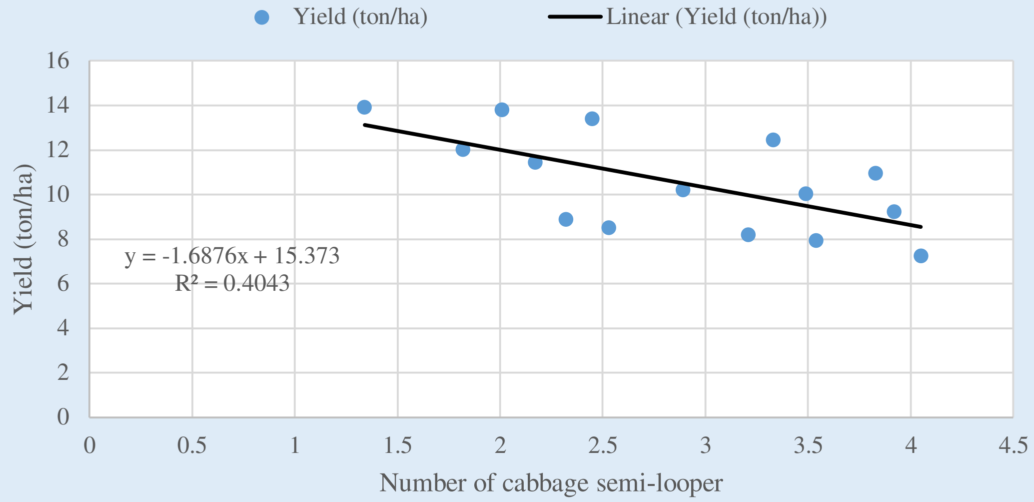

Figure 14: Relationship between the number of cabbage semi-looper and yield of broccoli at different combinations of varieties and treatments

4.6.4. In case of jassid

Significant relationship was found between the number of jassid and yield of broccoli at different combination of varieties and treatments when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.3905) and negative (slope =-1.6491) correlation was found between the number of jassid and yield of broccoli, i.e. yield of broccoli decreased with the increase of the number of jassid.

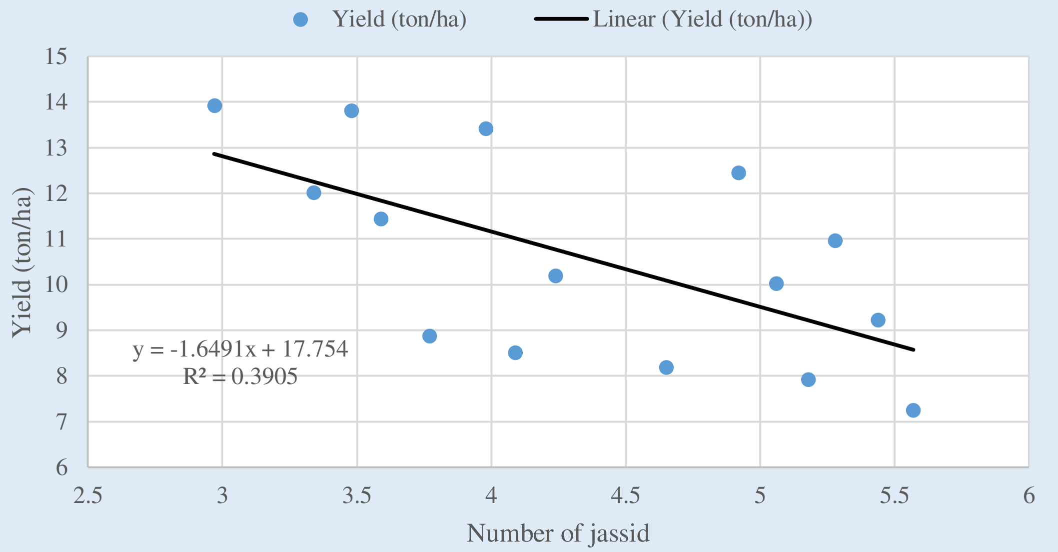

Figure 15: Relationship between the number of jassid and yield of broccoli at different combinations of varieties and treatments

4.6.5. In case of mole cricket

Significant relationship was found between the number of mole cricket and yield of broccoli at different combination of varieties and treatments when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.4292) and negative (slope =-3.5894) correlation was found between the number of mole cricket and yield of broccoli, i.e. yield of broccoli decreased with the increase of the number of mole cricket.

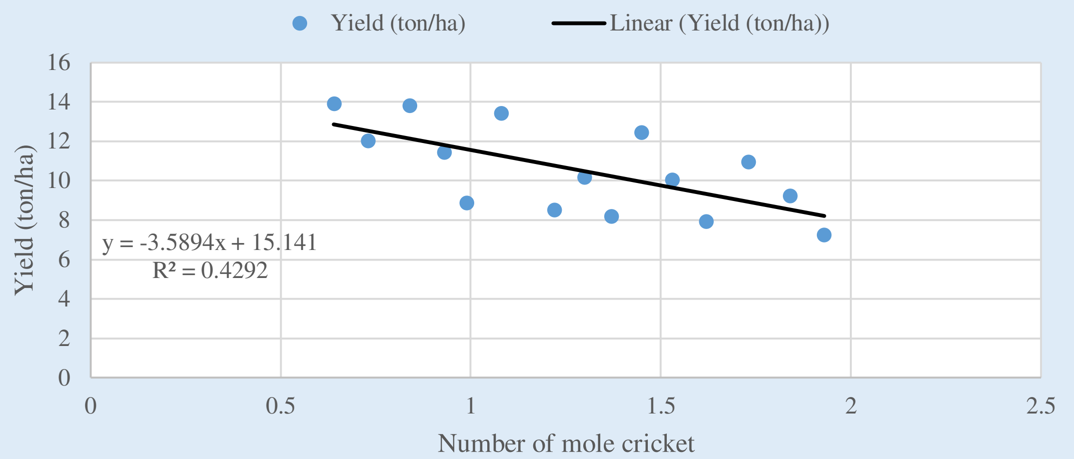

Figure 16: Relationship between the number of mole cricket and yield of broccoli at different combinations of varieties and treatments

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September, 2018 to May, 2019 to evaluate the incidence and damage assessment of insect and other arthropod pests of broccoli.

5.1. Summary

5.1.1. Cutworm infestation

The cutworm infestation on broccoli seedlings was ranged from 38.20 to 56.70% in the field, where the highest infestation (56.70%) was recorded in V_1, which was significantly different from others. On the other hand, the lowest cutworm infestation (38.20%) was recorded in V_3. It was also observed that the no cutworm infestation (0.0) was recorded at 2 DAT in the broccoli field. But the cutworm infestation was initiated in the broccoli field at 4 DAT and the maximum infestation (2.0 to 3.0 infested seedling/plot) was recorded at 10 DAT, whereas the infestation was declined gradually with the increase of time and no infestation was recorded at 18 DAT. Therefore, it was concluded that management practice particularly for cutworm should be applied between 3 to 16 DAT of broccoli seedlings in the field.

5.1.2. In case of varieties

The incidence of aphid on broccoli was ranged from 1.54 to 2.88 in the field, where the lowest infestation was recorded 1.54 in V_3, which was statistically different from other varieties. In case of the number of infested leaf caused by aphid, the lowest number of infested leaves per five tagged plants was recorded in V_3 (0.83 leaves). Again, V_3 showed the lowest performance (1.15 plants) in terms of number of plants per plot.

The incidence of diamond back moth on broccoli was ranged from 5.03 to 10.21 in the field, where the lowest infestation was recorded 5.03 in V_3, which was statistically different from other varieties. In case of the number of infested leaves caused by diamond back moth, the lowest number of infested leaves per five tagged plants was recorded in V_3 (2.63 leaves). Again, V_3 showed the lowest performance (1.36 plants) in terms of number of plants per plot.

The incidence of cabbage semi-looper on broccoli was ranged from 4.82 to 7.21 in the field, where the lowest infestation was recorded 4.82 in V_3, which was statistically different from other varieties. In case of the number of infested leaves caused by cabbage semi-looper, the lowest number of infested leaves per five tagged plants was recorded in V_3 (1.78 leaves). Again, V_3 showed the lowest performance (2.71 plants) in terms of number of plants per plot.

The incidence of jassid on broccoli was ranged from 7.76 to 12.24 in the field, where the lowest infestation was recorded 7.76 in V_3, which was statistically different from other varieties. In case of the number of infested leaves caused by jassid, the lowest number of infested leaves per five tagged plants was recorded in V_3 (3.56 leaves). Again, V_3 showed the lowest performance (2.82 plants) in terms of number of plants per plot.

The incidence of mole cricket on broccoli was ranged from 0.83 to 2.23 in the field, where the lowest infestation was recorded 0.83 in V_3, which was statistically different from other varieties. In case of the number of infested plants caused by mole cricket, the lowest number of infested plants per plot was recorded in V_3 (1.47 plants).

Among the different Varieties, V_3 comprised with exotic variety showed the best performance in case of plant height, number of leaves, length of leaves, breadth of leaves, curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha (39.33 cm, 17.62 leaves, 40.31 cm, 12.87 cm, 21.26 cm, 20.46 cm, 39.67 cm, 5.14 kg/plot and 13.71 ton/ha, respectively) than the others. As a result, the order of rank of varieties of broccoli in terms of plant height, number of leaves, length of leaves, breadth of leaves, curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha was V_3> V_2> V_3.

5.1.3. In case of different treatments

The incidence of aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket on broccoli were low in T_4 (1.09, 1.69, 1.63, 3.23, and 0.47, respectively) comprised of spraying antifedent (Neem oil @) 3ml/Lof water at 7 days interval), which was statistically different from other treatments of broccoli and high in T_0 (3.96, 4.12, 3.79, 6.21 and 2.13, respectively). Again, T_4 showed the best performance in case of incidence of different insects of broccoli per five tagged plants.

The number of infested leaves caused by aphid, diamond back moth, cabbage semi-looper and jassid on broccoli were low in T_4 (2.67, 2.33, 1.31 and 2.07, respectively) comprised of spraying antifedent (Neem oil @) 3ml/Lof water at 7 days interval), which was statistically different from other treatments of broccoli and high in T_0 (6.33, 4.89, 3.07 and 3.98, respectively). Again, T_4 showed the best performance in case of the number of infested leaves caused by different insects of broccoli per five tagged plants.

The number of infested plant caused by aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket on broccoli were low in T_4 (1.51, 1.43, 0.98, 1.87 and 0.56, respectively) comprised of spraying antifedent (Neem oil @) 3ml/Lof water at 7 days interval), which was statistically different from other treatments of broccoli and high in T_0 (7.13, 3.92, 3.13, 3.18 and 2.16, respectively). Again, T_4 showed the best performance in case of the number of infested plants caused by different insects of broccoli per plot.

Among the different treatments, T_4 comprised with spraying antifedent (Neem oil @ 3ml/L of water) showed the best performance in case of plant height, number of leaves, length of leaves, breadth of leaves, curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha (38.12 cm, 16.47 leaves, 38.98 cm, 12.46 cm, 20.45 cm, 21.13 cm, 39.47 cm, 4.92 kg/plot and 13.12 ton/ha, respectively) than the others. As a result, the order of rank of treatments of broccoli in terms of plant height, number of leaves, length of leaves, breadth of leaves, curd height, curd diameter, perimeter of curd, curd weight/plot and yield/ha was $T_4 > T_1 > T_2 > T_3 > T_0$.

5.1.4. In case of combination of varieties and treatments

Among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety along with spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in reducing the number of insect pests like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against incidence of insect pests in terms of reducing the number of aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per five tagged plants was $V_3T_4 < V_2T_4 < V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 < V_1T_0$.

Among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety along with spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in reducing the number of infested leaves caused by insect pests like aphid, diamond back moth, cabbage semi-looper and jassid per five tagged plants than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against insect pests in terms of reducing the number of infested leaves caused by insect pests like aphid, diamond back moth, cabbage semi-looper and jassid per five tagged plants was $V_3T_4 < V_2T_4 < V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 < V_1T_0$.

Among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety along with spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in reducing the number of infested plants caused by insect pests like aphid, diamond back moth, cabbage sami-looper, jassid and mole cricket per plot than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied against aphid in terms of reducing the number of infested plants caused by insect pests like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket per plot was $V_3T_4 < V_2T_4 < V_3T_1 < V_2T_1 < V_1T_4 < V_3T_2 < V_1T_1 < V_2T_2 < V_1T_2 < V_3T_3 < V_2T_3 < V_1T_3 < V_3T_0 < V_2T_0 < V_1T_0$.

Among the different combination of varieties and treatments, V_3T_4 comprised with exotic variety along with spraying antifedent insecticide (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance in increasing plant height, number of leaves, leaf length, leaf breadth, curd height, curd diameter, curd perimeter, total weight of curd/plot and yield/ha (40.33 cm, 17.87 leaves, 39.82 cm, 14.21 cm, 22.13 cm, 20.33 cm, 38.78 cm, 5.22 kg and 13.92 ton, respectively) than the others. As a result, the order of rank of efficacy of the combination of varieties and treatments applied in increasing plant height, number of leaves, leaf length and leaf breadth, curd height, curd diameter, curd perimeter, total weight of curd/plot and yield/ha was $V_3T_4 > V_2T_4 > V_3T_1 > V_2T_1 > V_1T_4 > V_3T_2 > V_1T_1 > V_2T_2 > V_1T_2 > V_3T_3 > V_2T_3 > V_1T_3 > V_3T_0 > V_2T_0 > V_1T_0$.

5.2. Conclusion

From the present study, it may be concluded that the exotic variety of broccoli was the best variety among the other varieties in case of insect (like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket), insect infestation of leaves and plants along with the other yield attributing characteristics and yield. Whereas, the antifedent comprised with Neem oil @ 3ml/L of water at 7 days interval was the best treatment among the other treatments. In case of the combination of varieties and treatments, exotic variety along with antifedent (Neem oil @ 3ml/L of water at 7 days interval) showed the best performance for insect (like aphid, diamond back moth, cabbage semi-looper, jassid and mole cricket), insect infestation of leaves and plants along with the other yield attributing characteristics and yield than the other combinations.

Considering the findings of the study the following recommendations can be drawn:

1. Though exotic variety of broccoli was exotic variety for Bangladesh, so it should need more experiments.
2. Botanical insecticides as antifedent should be more used to control the sucking insect pest in the broccoli field.
3. Further study should be needed in different locations of Bangladesh for accuracy of the result obtained from the present experiment.

CHAPTER VI

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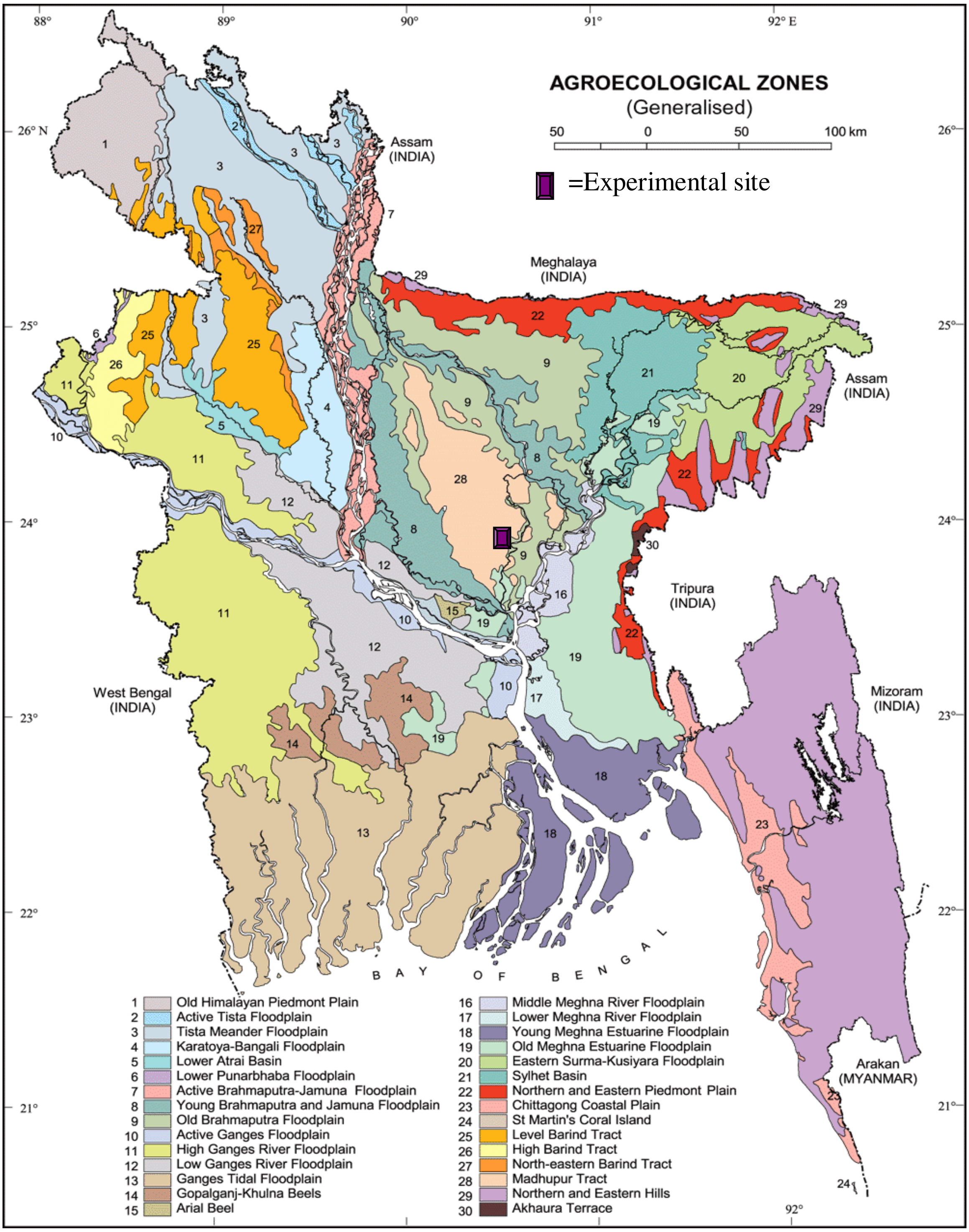
CHAPTER VII

APPENDICES

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



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

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

Chemical composition:

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

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