ECO-FRIENDLY MANAGEMENT OF INSECT PESTS OF BROCCOLI

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ECO-FRIENDLY MANAGEMENT OF INSECT PESTS OF BROCCOLI

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CERTIFICATE

This is to certify that the thesis entitled, 'Eco-Friendly Management of Insect Pests of Broccoli' submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of bona fide research work carried out by **Keshab Das,** Registration number: **13-05411** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:June,2020
Dhaka, Bangladesh

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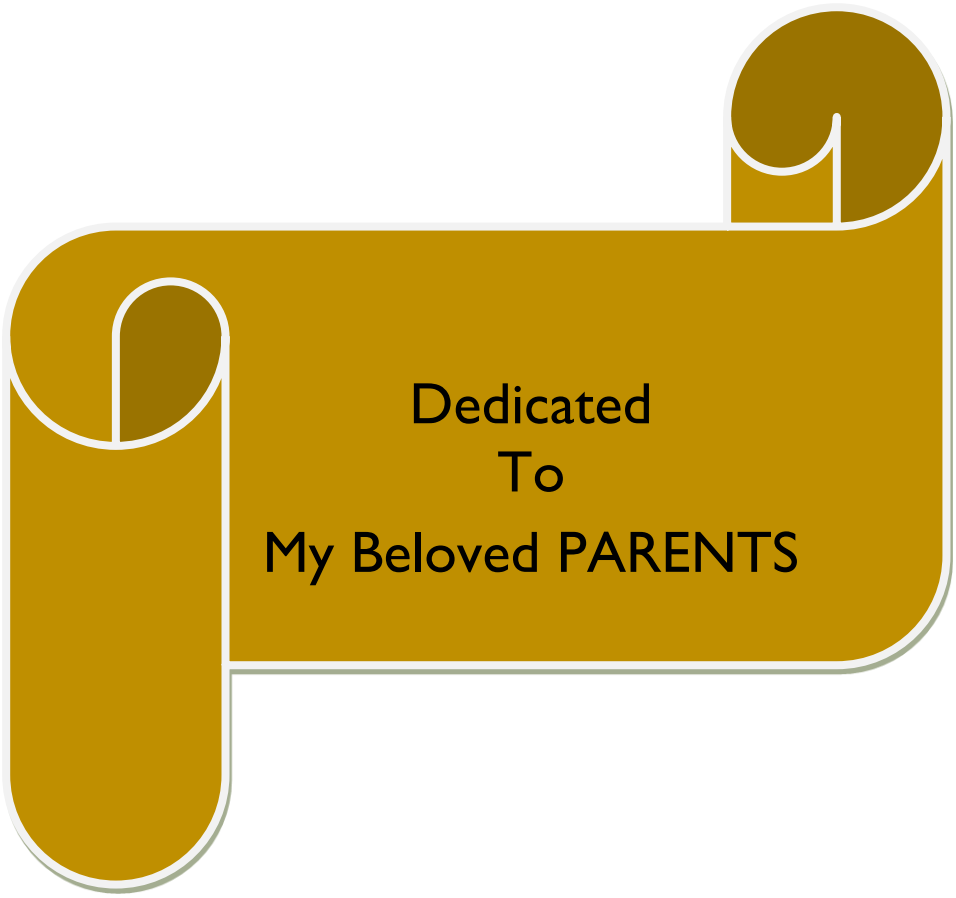
Dedicated
To
My Beloved PARENTS

ABBREVIATIONS

Elaborated Form		Abbreviated Form
And others (Co-workers)	=	*et al.*
Centimeter	=	cm
Coefficient of Variation	=	CV
Degree centigrade	=	^{o}C
Degree of freedom	=	Df
Example	=	viz.
Million tons	=	Mt
Non-significant	=	NS
Per Hectare	=	ha^{-1}
Percentage	=	%
Phosphorus	=	P
Potassium	=	K
Randomized Complete Block Design	=	RCBD
Standard Week	=	SW
Sher-e-Bangla Agricultural University	=	SAU
Standard Error	=	SE
that is	=	i.e.
Tons	=	T
ANOVA	=	Analysis of Variance

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The Author

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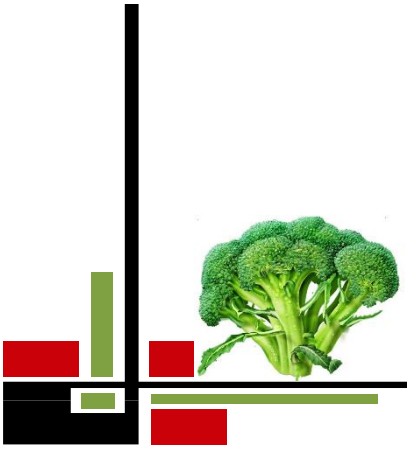
ABSTRACT

Present work was carried out in the experimental field of Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh in order to assess the population abundance and eco-friendly management of insect pests of broccoli. The experiment was conducted in randomized complete block design (RCBD) with three replications. The treatments used in the experiment are Emamectin benzoate, Spinosad, Buprofezin, Imidacloprid, neem seed kernel extract, Lambda cyahlothrin and control (no pesticide). Four insect pests were found majorly in the broccoli field such as cabbage caterpillar, diamond back moth, cabbage aphid and flea beetle. Their peak population was recorded 1.98, 0.50, 238.62 and 2.98 per 5 plant at 51st, 6th, 7th and 3rd Standard week respectively. Among seven treatments, Emamectin benzoate observed the least number of population density the broccoli field. Population density of cabbage caterpillar, diamond back moth, cabbage aphid and flea beetle was 0.54, 0.16, 18.33 and 0.96 per plant whereas in all cases the highest population was recorded from the control treatment. Highest yield (23.14 ton/ha) of broccoli obtained from Emamectin benzoate So, Emamectin benzoate can be used as an eco-friendly agent in controlling insect pests of broccoli.



Chapter I
Introduction

CHAPTER I

INTRODUCTION

Vegetables form integral part of human diet and are regarded as an important source of carbohydrates, proteins, vitamins, minerals and fibers for human being. Plant-based foods contain significant amounts of bioactive compounds, which provide desirable health benefits beyond basic nutrition.

In the last decades, special attention has been paid towards edible plants, especially those that are rich in secondary metabolites (frequently called phytochemicals) and nowadays, there is an increasing interest in the antioxidant activity of such phytochemicals present in diet. Recent reports suggest that cruciferous vegetables act as a good source of natural antioxidants due to the high levels of carotenoids, tocopherols and ascorbic acid, and strong epidemiological evidence shows that these compounds may help to protect the human body against damage by reactive oxygen species. In addition to carotenoids, tocopherols, and ascorbic acid, most of the anti-oxidative effect related to plant food intake is mainly due to the presence of phenolic compounds, which have been associated with flavor and color characteristics of fruits and vegetables. In this aspect, the popularity and consumption of vegetable Brassica species is increasing because of their nutritional value. Brassica crops have been related to the reduction of the risk of chronic diseases including cardiovascular diseases and cancer. Brassica foods are very nutritive, providing nutrients and health-promoting phytochemicals such as vitamins, carotenoids, fiber, soluble sugars, minerals, glucosinolates and phenolic compounds (Podsedek 2007, Jahangir *et al.* 2009).

The family Brassicaceae (=Cruciferae) consists of 350 genera and about 3,500 species, and includes several genera like Camelina, Crambe, Sinapis, Thlaspi and Brassica. The genus *Brassica* is the most important one within the tribe Brassiceae, which includes some crops and species of great worldwide economic importance such as *Brassica oleracea* L., *Brassica napus* L. and *Brassica rapa* L. The same

species can be utilized for several uses according to different forms or types. The genus is categorized into oilseed, forage, condiment, and vegetable crops by using their buds, inflorescences, leaves, roots, seeds, and stems. Brassicaceae vegetables represent an important part of the human diet worldwide, are consumed by people all over the world and are considered important food crops in China, Japan, India, and European countries. The main vegetable species is *B. oleracea*, which includes vegetable and forage forms, such as kale, cabbage, broccoli, Brussels sprouts, cauliflower and others; *B. rapa* includes vegetable forms, such as turnip, Chinese cabbage and pakchoi, along with forage and oilseed types; *B. napus* crops are mainly used like oilseed (rapeseed), although forage and vegetable types like leaf rape and nabicol are also included; finally, the mustard group which is formed by three species, *B. carinata*, *B. nigra* and *B. juncea*, is mainly used as a condiment although leaves of *B. juncea*are also consumed as vegetables and they are widely used for both fresh and processed markets in Asian countries (Moreno *et al*. 2010, Price *et al.* 1998).

Broccoli (scientific name: *Brassica oleracea* var *botrytis*) is a member of the Brassicaceae plant family, also known as the mustard family. Other familiar plants in the species *Brassica oleracea* include Brussels sprouts, cabbage, cauliflower, kale, and kohlrabi. Broccoli is a derivative of cabbage, and was selected for its edible, immature flower heads. The flower buds are green or purple, are picked before they open, and are eaten raw or cooked. Broccoli sprouts are also edible, consumed raw, and are a popular health food in the U.S.

Broccoli originated in the Mediterranean region where it has been cultivated since Roman times, but is a relatively new crop to the U.S. The first commercial broccoli crop grown in the U.S. was started in California in 1923, but broccoli did not become a significant commercial crop in the U.S. until after World War II (Annon 2020).

Broccoli is grown in winter season in Bangladesh as an annual crop. It is environmentally better adapted and can withstand comparatively high temperature than cauliflower (Rashid *et al.* 1976). Its wider environmental adaptability, higher

nutritive value, good taste and less risk to crop failure due to various biotic and abiotic factors indicate that there is enough scope for its promotional efforts. Its popularity to the consumers of urban area is increasing day by day in our country. But its cultivation has not spread much beyond the farms of different agricultural organizations. This is mainly due to the lack of awareness among the people about its importance and lack of available information production technology about it. Cultivation of broccoli in our country are confined into a very limited area with a minimum production and its average yield is only about 10.5 metric tons per hectare which is very low compared to other broccoli growing countries like 24 t/ha in Italy, 20 t/ha in Japan and 18 t/ha in Turkey (Ahmed *et al.*2004).

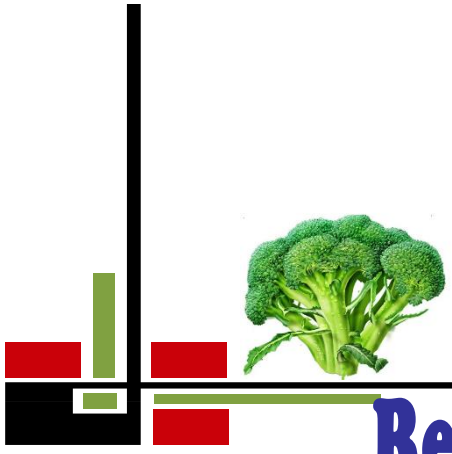
Broccoli suffers extensively from insect pests and it is attacked by more than 25 insect species. While there are some common pests across the globe, others are region specific and some of them are active vectors of deadly diseases besides causing direct damage to crops. Aphids, mites, etc. in particular, had the devastating effects on the broccoli. Pests like cabbage butterfly, diamond back moth and aphids cause havoc in North Eastern region of India and Bangladesh. Pest succession studies are useful in devising economically feasible and ecologically sound integrated pest management.

In vegetable production, the use of insecticides has become very common and no market vegetable is supposed to be free from pesticide residue. The indiscriminate use of insecticides over past four decades has created not only the serious problems of contaminating the different components of the environment excessively and pervasively but also resulted in long term persistence, pest outbreak, development of resistance, ill-effect on non-target organism, resurgence and replacement of pests, and health hazards to man and animals due to presence of toxic residues in vegetables. Keeping in view the consequences of major reliance on pesticides and growing public preference for “Ecomark vegetables” it has become indispensable today to opt for such practices which holds the promise of providing solution to pest

problems in a eco-friendly and sustainable manner. The produce of proposed farming under the situation would be a balance between higher production and use of bio-rational insecticide. It is high time that eco-friendly pesticides are exploited to combat these insect pests.

The present investigations were, therefore, undertaken with a view to fulfilling the following objectives:

1. To assess the population abundance of major insect pests of broccoli in the rabi season.
2. To study the efficacy of different eco-friendly pesticides for the management of major insect pest of broccoli.



Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Broccoli originated in the Mediterranean region where it has been cultivated since Roman times, but is a relatively new crop to the U.S. The first commercial broccoli crop grown in the U.S. was started in California in 1923, but broccoli did not become a significant commercial crop in the U.S. until after World War II (Annon 2020). Broccoli is a derivative of cabbage, and was selected for its edible, immature flower heads. The flower buds are green or purple, are picked before they open, and are eaten raw or cooked. Broccoli sprouts are also edible, consumed raw, and are a popular health food in the U.S.

2.1. Biology and Botany of Broccoli

The cultivated Cole crops have a common origin in the wild forms of the *Brassica oleracea* group. The many varieties show considerable diversity in form, with different parts of the plant being consumed as vegetables. Most varieties have been in cultivation for such a long time that little detail remains of how they originated.

It is necessary to define broccoli, as there is considerable confusion in both scientific and lay nomenclature. Broccoli is an Italian word from the Latin *brachium*, meaning an arm or branch (Boswell, 1949). In Italy the term broccoli is used for the young edible floral shoots on brassica plants, including cabbages and turnips, and was originally applied to sprouting forms but now includes heading forms, which develop a large, single, terminal inflorescence. The white-heading forms are also commonly referred to as cauliflowers, derived from the Latin *caulis* (stem) and *floris* (flower). Broccoli is often used to describe certain types of cauliflower, notably in Britain where the term heading or winter broccoli is traditionally reserved for biennial types. The term broccoli without qualification is also generally applied in America to the annual green-sprouting form known in Britain and Italy as *calabrese*.

The term sprouting as used in sprouting broccoli refers to the branching habit of this type, the young edible inflorescences often being referred to as sprouts. The term

Cape frequently used in conjunction with broccoli or as a noun is traditionally reserved for certain color-heading forms of *italic.*

At harvest the surface of the cauliflower head (the curd) is a dome of tissue made up of a mass of proliferated floral meristems (Sadik, 1962), of which about 10% actually develop into flower buds, with the rest aborting. In broccoli the head or sprouts (in sprouting types) are a mass of fully differentiated flower buds, relatively few of which abort prior to flowering. The marketable cauliflower is onto genetically younger than the marketable broccoli, and the cauliflower stage in broccoli is represented by relatively small buttons of tissue. Classified on this basis the broccolis would be synonymous with var. *italic* and the cauliflowers with var. *botrytis.*

2.2. History and evolution of broccoli

The sprouting broccolis are thought to have originated from the eastern Mediterranean though it is not known when they first appeared. The earliest description of sprouting broccoli is probably that by Dale champ in the 16th century (Nieuwhof 1969). Miller's *Gardeners' Dictionary* of 1724 refers to "sprout cauliflower" or "Italian asparagus" (Sturtevant, 1919). In both instances the sprouting nature of the plant is indicated in their descriptions.

From the eastern Mediterranean, broccolis were introduced into Italy where considerable diversification must have taken place. For example, Giles (1941) recorded and classified a wide range of both sprouting and colored heading broccolis; these apparently occurred wherever there was cultivation of land in central and southern Italy and Sicily. Of the colored heading types, many cultivars were seen by him growing around Naples, Rome, Florence, Pisa, and Genoa in the Italian Riviera and in Calabria (Giles 1941).

Giles noted that the Italian sprouting broccolis were quite distinct in appearance from sprouting broccolis grown in Britain and that no white-sprouting forms of the types known in Britain were found. He recognized 3 morphological groups varying

in the degree of branching and in the length of the floral shoots. The most compact forms resembled heading types and were known as calabrese (Giles, 1944), a derivation from Calabria in southern Italy (Nieuwhof, 1969).

Broccolis were long ago introduced into Britain but their popularity has never been great (Giles, 1941) and relatively few cultivars are grown today. According to Miller's Gardeners' Dictionary of 1724, introduction of "sprout cauliflower" or "Italian asparagus" into this country took place in the early part of the 18th century. In 1729, a London gardener, Switzer, was said to have been cultivating several types from a mixed batch of seed. One type had small "whitish-yellow flowers" resembling a cauliflower; others resembled "common sprouts" and "flowers of a colewort" and a third type had purple flowers (Sturtevant, 1919).

2.3. Health benefits of broccoli

Broccoli (*Brassica oleracea*) is a cruciferous vegetable related to cabbage, kale, cauliflower, and Brussels sprouts. These vegetables are known for their beneficial health effects. Broccoli is high in many nutrients, including fiber, vitamin C, vitamin K, iron, and potassium. It also boasts more protein than most other vegetables. This green veggie can be enjoyed both raw and cooked, but recent research shows that gentle steaming provides the most health benefits (Yuan *et al.* 2009).

Raw broccoli contains almost 90% water, 7% carbs, 3% protein, and almost no fat. Broccoli is very low in calories, providing only 31 calories per cup (91 grams). The nutrition facts for 1 cup (91 grams) of raw broccoli are: calories: 31, water: 89%, protein: 2.5 grams, carbs: 6 grams, sugar: 1.5 grams, fiber: 2.4 grams and fat: 0.4 grams (USDA 2019). Broccoli's carbs mainly consist of fiber and sugars. The sugars are fructose, glucose, and sucrose, with small amounts of lactose and maltose (USDA 2019). However, the total carb content is very low, with only 3.5 grams of digestible carbs per cup (91 grams). Fiber is an important part of a healthy diet. It can promote gut health, help prevent various diseases, and aid weight loss (Slavin 2013).

Proteins are the building blocks of your body, necessary for both growth and maintenance. Broccoli is relatively high in protein, which makes up 29% of its dry weight, compared to most vegetables. However, because of its high water content, 1 cup (91 grams) of broccoli only provides 3 grams of protein.

Broccoli contains a variety of vitamins and minerals, including (Fekete 2017, Shaik-Dasthagiri saheb *et al.* 2013, Bügel 2003) vitamin C which is an antioxidant, this vitamin is important for immune function and skin health. A 1/2-cup (45-gram) serving of raw broccoli provides almost 70% of the DV. Vitamin K1 in Broccoli contains high amounts of vitamin K1, which is important for blood clotting and may promote bone health. Folate (vitamin B9) is particularly important for pregnant women, folate is needed for normal tissue growth and cell function. Potassium is an essential mineral, potassium is beneficial for blood pressure control and heart disease prevention. Manganese which is a trace element is found in high amounts in whole grains, legumes, fruits, and vegetables.

Observational studies suggest that the consumption of cruciferous vegetables, including broccoli, is linked to a reduced risk of many cancers, including lung, colorectal, breast, prostate, pancreatic, and gastric cancers (Béliveau and Gingras 2007). The main isothiocyanate in broccoli, sulforaphane acts against the formation of cancer at the molecular level by reducing oxidative stress. (James *et al.* 2012). Sulforaphane occurs at 20–100 times higher amounts in young broccoli sprouts than in full-grown heads of this vegetable.

Broccoli is one of the world's most popular vegetables. It is easy to prepare and edible both raw and cooked. It is high in many nutrients, including a family of plant compounds called isothiocyanates, which may have numerous health benefits. It is also a decent source of fiber and higher in protein than most other vegetables.

2.4. Global production scenario of Broccoli

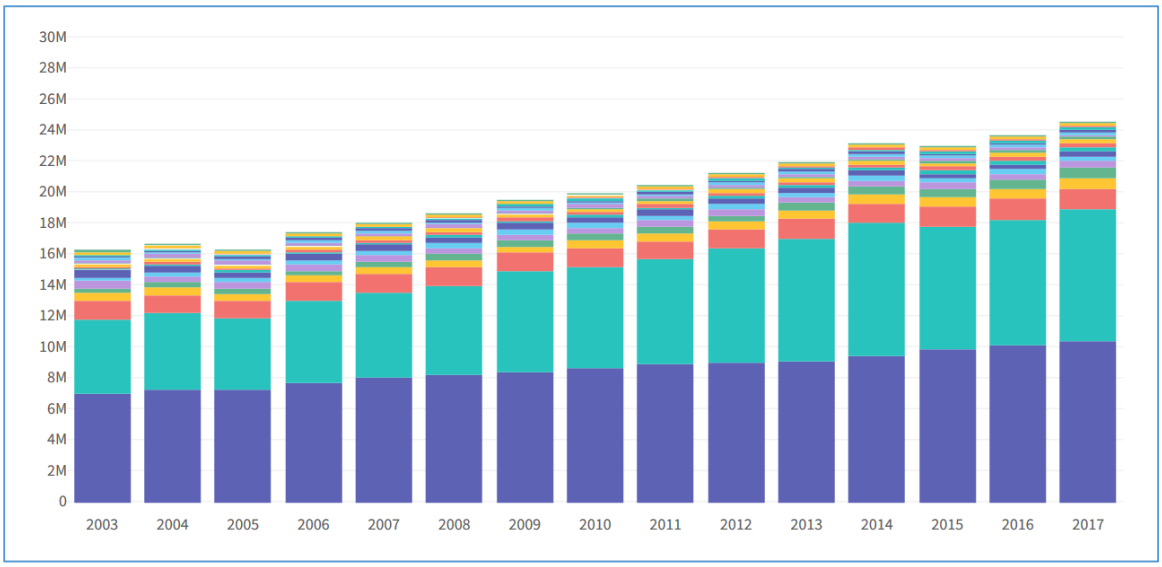
Broccoli is a vegetable under cole crops. There are other vegetables in this group such as kale, cabbage, cauliflower etc. Worldwide, broccoli production is counted and estimated with the production of cauliflower. In 2017 global broccoli and cauliflower production was 25.96 m MT, where in 2016, 2015, 2014 and 2013 the production was 25.03 m MT, 24.37 m MT, 24.49 m MT and 23.36 m MT respectively. China holds the first position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in China was 10.36 m MT, where in 2016, 2015, 2014 and 2013 the production was 10.11 m MT, 9.86 m MT, 9.43 m MT and 9.1m MT respectively.

India holds the second position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in India was 8.56 m MT, where in 2016, 2015, 2014 and 2013 the production was 8.09 m MT, 7.93 m MT, 8.57 m MT and 7.89 m MT respectively.

The USA holds the third position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in USA was 1.31 m MT, where in 2016, 2015, 2014 and 2013 the production was 1.34 m MT, 1.29 m MT, 1.22 m MT and 1.27 m MT respectively. Spain holds the fourth position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in Spain was 688.78 k MT, where in 2016, 2015, 2014 and 2013 the production was 640.08 k MT, 607.19 k MT, 596.97 k MT and 540.90 k MT respectively. Mexico holds the fifth position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in Mexico was 685.46 k MT, where in 2016, 2015, 2014 and 2013 the production was 583.28 k MT, 518.02 k MT, 503.97 k MT and 481.07 k MT respectively. Italy holds the sixth position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in Italy was 371.57 k MT, where in 2016, 2015, 2014 and 2013 the production was 388.28 k MT, 385.97 k MT, 405.05 k MT and 381.63 k MT respectively. Poland holds the seventh position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in

Poland was 317.02 k MT, where in 2016, 201590, 2014 and 2013 the production was 314.74 k MT, 352.87 k MT, 320.56 k MT and 276.03 k MT respectively. France holds the eighth position in broccoli and cauliflower production. In 2017, broccoli and cauliflower production in France was 315 k MT, where in 2016, 2015, 2014 and 2013 the production was 308.49 k MT, 309.6 k MT, 326.36 k MT and 361.20 k MT respectively.

China shares 39.9% of total global production, whereas India and USA shares 33.0% and 5.0% of total broccoli and cauliflower production respectively. In this regard, Spain, Mexico, Italy, Poland and France shares 2.7%, 2.6%, 1.4%, 1.2%, 1.2% of total global production respectively.



Source: Tridge market intelligence 2020

Figure 1. Year wise Global broccoli and cauliflower production.

2.5. Broccoli production in Bangladesh

Table 1. Year wise broccoli and cauliflower production in Bangladesh

Year	Production (MT)
2017	277.50 K
2016	268.48 K
2015	268.48 K
2014	183.00 K
2013	166.00 K
2012	166.20 K
2011	168.24 K

Source: Tridge Intelligence 2020

It is evident that the production of broccoli and cauliflower in Bangladesh has been increased gradually. The production has been increased by 64% from 2011 to 2017. In 2011, the annual production was 168.24 k MT where in 2017, it has been increased to 277.50 k MT. However, in 2016 and 2015 Bangladesh produced similar quantity (268.48 k MT). The country experienced a boom in 2014 and produced 183 k MT broccoli and cauliflower which was 166 k MT in the previous year. Bangladesh has 1.1% of market share in broccoli and cauliflower production globally.

2.6. Insect pests of broccoli, their biology, life cycle and nature of damage

2.6.1. Diamondback moth (DBM), *Plutella xylostella* (L.)

The most damaging pest of cruciferous family plants is diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) because of its greater dispersal ability, per-year larger number of generation and development of resistance to most commonly used insecticides. *P. xylostella* is a serious pest of cauliflower, cabbage, lily, broccoli, sprouts and Chinese cabbage (Huang 2003).

2.6.1.1. Distribution of DBM

Plutella xylostella was for the first time recorded in Europe but later found throughout America, Australia, Southeast Asia and New Zealand. For the first time, it was observed in North America in 1854, in Illinois, and then spread to Florida and the Rocky Mountains in 1883 and in 1905, diamondback moth was reported in British Columbia.

Diamondback moth is a serious pest of cruciferous plants worldwide and about 1 billion dollars of losses occur annually due to its larval damage (Talekar and Shelton 1993). It is reported that 90% of losses occur due to this pest and also reported that 60% loss occurs in production and 2 billion dollars of losses occur when controlling this pest (Verkerk and Wright 1996). It is estimated that 16 million dollars of losses occur on the basis of 2.5% damage on protective crops per annum by this pest. The larvae of DBM caused damage to all cruciferous family crops especially cabbage in Southeast Asia (Walden 2002).

2.6.1.2. Biology and life cycle of DBM

DBM is a tiny brownish color moth having triangular markings on their forewing. Eggs are laid singly on the underside of leaves. The female of diamondback moth lays 300 eggs in her reproductive period. The female of DBM lays eggs on the lower and upper side of the leaf surface and the ratio is 3:2, and very little amount of eggs are laid on the stems of the leaf (AVRDC 1987). An Egg hatching period is 2–4 days. As new tiny larvae emerge, they start feeding on the lower side of leaves. Larval duration is 10–15 days but it largely depends on the temperature and other environmental conditions. Color of young larvae is from whitish yellow to pale green. The life of an adult is 10–15 days. Larvae cause large defoliation of leaves (Gujar 1999). Diamondback moth adult is a weak flier and the length of adult moth is about 5 mm and width is 2 mm (Danthanarayana 1986).

After the emergence, the first instar makes mines in the spongy tissue and the second instar starts feeding on the lower side of the leaf and consumes all the tissue

expect the waxy layer. When fourth instar feeding is complete, it converts into a cocoon-like structure that is called the pupal stage, and at this stage feeding stops (Sakanoshita and Yanagita 1985). The duration of this stage depends upon the temperature and mostly it is 4–10 days, but it can decrease in warm areas and increase in cold areas; after adults emerge who feed on water or dew drops, their adult life is short (Pivnick *et al.* 1990).

In subtropical and tropical regions, where the cabbage and cauliflower or any other crops belonging to the Cruciferous family are grown throughout the year, all the stages of diamondback moth are present at any time. In the temperate region, where the crucifers crop are not grown throughout the year, and in winter season, both pupal and adult stages of diamondback moth hibernate in plant debris (Sears and Shelton 1985). A study was done in the New York state for the presence of diamondback moth during winter season using different pheromone traps and it found that no diamondback moths were caught (Harcourt 1954).

Diamondback moths have great abilities to disperse and migrate over long distances. Mass migration of DBM occurs in Britain, and the adult of diamondback moth migrates from Baltic to Southern Finland and covers about 3000 km, and this study indicates that the adult of DBM remains in flight continuously for several days.

2.6.1.3. Nature of damage by DBM

The larvae of diamondback moth *Plutella xylostella* feed on the foliage at their different larval stages and reduce the yield and also decrease the quality of vegetables (Endersby *et al.* 2003). Larvae of DBM damage the cabbage and cauliflower leaves by making small holes on the surface of leaves, often leaving the epidermis of leaves that is called Feeding Window; also, inside broccoli florets and cauliflower curds, contamination occurs due to this insect.

2.6.1.4. Chemical control of diamondback moth

There are many specific insecticides used for the control of DBM while certain chemicals are more effective against other pests as compared to DBM, so it is important to select appropriate chemicals according to insect pests. Some chemicals having longer residual action on later growth stages like prothiophos, cartap and fenvalerate mixtures are suitable for management of diamondback moth (Nakagome and Kato 1981). Organophosphates (OPs) have been considered as the most important group of compounds for the control of DBM. In OP groups, enough variations in chemical structures have contributed to the wide spectrum of efficacy and varied levels of resistance observed in DBM (Liu *et al.* 1982).

2.6.1.4.1. Pyrethroids

Many synthetic pyrethroids (permethrin constituting 0.01%, decamethrin of 0.004%, fenvalerate of 0.01% and cypermethrin of 0.005%) have no good results for controlling after 48 h of the treatment on adult diamondback moth while quinalphos constituting 0.05%, phosalone of 0.05%, endosulfan of 0.05%, monocrotophos of 0.05% and dichlovos of 0.05% have greater toxic effects on both adult and larval stages; after 6 h dichlovos and quinalphos recorded 100% mortality, endosulfan 93% and monocrotophos 63% (Mani and Krishnamoorthy 1984). Spinosad and permethrins caused 100% mortalities to diamondback moth adults and larvae in leaf dip and residual bioassays method after 72 h of treatment (Travis and Foster 2000).

2.6.1.4.2. Organophosphates

Spinosad and fenvalerate provide good results for the control of diamondback moth larvae at various development stages. Novalurin at 6–12 oz./acre is effective for the control of DBM as compared to non-treated plants, and spinosad is superior to all other insecticides for controlling DBM (Dakshina 2003). Emamectin benzoate with trademark PROCLAIMR is extensively used in the USA and has

great degradation on leaf surface and provides good control of DBM larvae and other pest species (Jansson and Lecrone 1988). Benzoyl phenyl urea and chitin synthesis inhibitors also show good results for controlling resistance-developed population of diamondback moth.

2.6.1.4.3. Neem-based insecticides

Neem-based insecticides are most effectively used for the management of P. xylostella and other insect pests of Crucifer crops (Leskovar and Boales 1996). This type of insecticide, that is, Align TM (3% formerly agri dyne, Salt Lake City, axadirachtin, Utah), was applied on Lepidopterous pests, mainly *P. xylostella* and other Crucifers crop pests in Texas. They get results that this insecticide significantly decreases the attack of P. xylostella and other insect pests of cabbages and Crucifer crops. Three plant extracts, *Annona muricata* seeds, *Annona saquamosa* seeds and *Stemona collinsae* roots, are also used at 20 mg/ml concentration and showed high toxic effects, that is, 100% mortality of larvae (Perera *et al.* 2005). The ethyl acetate extracted from *Phytolacca americama* root and extract of *Pseudolarix kaempferi*, that is, petroleum, is used for the control of DBM larvae; acetate shows stronger insecticidal effects on the second and third instar larvae of *P. xylostella* having LC50 values of 225 and 335 ppm (Neungpanich *et al.* 1991).

2.6.2. Cabbage aphid, *Brevicoryne brassicae* (Linn.)

The cabbage aphid, *Brevicoryne brassicae* (Linn.) (Homoptera: Aphididae) was reported as early as 1734 by Frisch in Germany (Essig 1948). In India, Lefroy and Howlett (1909) reported the species for the first time on brassica crops. There exists a considerable proportion of literature that deals with mainly geographical distribution, host plants, economic injury to the brassica crops, bionomics and studies of its chemical control. It is a destructive aphid native to Europe that is now found in many other areas of the world.

2.6.2.1. Distribution of cabbage aphid

B.brassicae is a cosmopolitan species and well distributed throughout the temperate and warm temperate parts of the world (Raychaudhuri 1980, Blackman and Eastop 2000, Carvalho *et al*. 2002) and is spread in Europe, Anterior and Middle Asia, North America, North Africa, Australia, and New Zealand. The species occurs widely throughout the territory of the former USSR, except for the Far North. In India it has been reported from Himachal Pradesh, Meghalaya, Manipur and Uttar Pradesh, Himachal Pradesh, Uttarakhand, Punjab, West Bengal, Karnataka, Andhra Pradesh, Tamil Nadu, Maharshtra, Gujarat, Jammu and Kashmir, Manipur, Tripura and other states where cabbage is grown (Ghosh *et al*. 1980). *B. brassicae* prefers for cooler climate than other brassica aphid, e.g., *Lipaphis erysimi*(Kalt.)(Ghosh *et al.* 1980).

2.6.2.2. Biology and life cycle of cabbage aphid

The cabbage aphid, *B. brassicae* are grayish-green with a waxy covering that gives them a grayish-white appearance. They have short siphunculus. Adults are present in both wingless and winged form. However, wingless females producing live young (nymphs), are the most common. It is one of the most serious sucking pest of brassica plants. It is a cosmopolitan species available in different agro-climatic conditions of the world where brassica crops are grown, particularly cabbage. It attacks all the parts of the brassica plants like fruits, inflorescence, leaves and shoots but mainly underside of the leaves as well as inner leaves of the head in cabbage and inter-spaces in the curd in cauliflower. Heavy infestation caused reduction in seed yield and subsequently death of the young plants (Batra 1960, Bahana and Karuhize 1986). It has been reported that *B. brassicae* is a vector of at least 23 viral diseases within the family Brassicaceae (Hill 1975).

Because of their rapid development time (8-12 days from first instar nymph to adult), asexual reproduction (males not needed), and extended reproductive life-span (30+ days at 4-6 nymphs per day), cabbage aphid complete up to 15

generations (often overlapping) during the growing season.

Debaraj *et al.* (1995) studied the biology of *B. brassicae* on six food plants in the laboratory at average room temperature, 16.3 ± 0.2 °C and average RH 50.2 ± 1.4% R.H. They could not observe any significant difference in the total nymphal development period on all the tested food plants. However, the reported that the nymphs of *B. brassicae* survived for slightly shorter period of 12.91 and 13.23 days on knoll-khol and cabbage-II (local variety) than the other food plants. Moreover, they found that the aphid was more fecund on knoll-khol (30.4 nymphs/female) and cabbage-II (28.6 nymphs/female) than others (mustard, cauliflower, radish and cabbage-I) and also survived longer on the above food plants.

The type of life cycle of *B. brassicae* depends on the climatic conditions during winter. In colder regions it is holocyclic (sexual forms - winged males and apterous oviparous females appear in autumn; females release a sex pheromone, nepetalactone, and after mating they lay overwintering eggs). Where the winter is mild, they are an holocyclic (aphids reproduce parthenogenetically throughout the year). Parthenogenetic females are viviparous (they give birth to nymphs). Depending on the temperature and humidity conditions, one cabbage aphid generation develops in 7-10 days (Markkula 1953, Hafez 1961).

2.6.2.3. Nature of damage by cabbage aphid

It feeds on both leaves and flowers of seed plants. Infested plants retard growing and flowers fall down, not forming fruits. Yellow spots are observed on leaves of food cabbage; these leaves twist and dry up. Plants produce small heads much later. Sticky faecal masses (honeydew) pollute the leaves. At high insect numbers, the yield may decrease by 34-62%.

B. brassicae attacks different parts of plant, but mainly underside of the interspaces in the curd in cauliflower. In flowering plants including radish and turnip, the main shoots are attacked turning pale and sucking quickly, even the mature seed

obtained were shriveled and unfit for sowing. Moreover, in oilseed rape, heavy infestation caused reduction in seed yield and subsequently death of the young plants (Batra 1960, Bahana and Karuhize, 1986). *B. brassicae* transfer dangerous viral diseases. It has been reported that it transmits at least 23 viral diseases within the family Brassicaceae (*Hill 1975*). Cioni *et al.* (2001) reported that *B. brassicae* transmits yellows closterovirus (BYV) and beet mild yellow virus [beet western yellows luteovirus] (BMYV) in Italy.

B. brassicae virus (BrBV), has been identified in the cabbage aphid by Ryabov (2007) which was similar to those of *flaviruses* identified for the first time in aphids. In Manipur, it attacks about eight species of brassica plants including indigenous varieties of cabbage causing great economic damage.

2.6.3. Cabbage caterpillar, *Pieris rapae*

Vegetable crops like cabbage, cauliflower, broccoli, Brussels sprouts, collards, mustard, radish, turnip and watercress attacked by cabbage butterfly.

2.6.3.1. Distribution of cabbage caterpillar

Pieris rapae L. is the most common and the most abundant of all the *Pieris* species and generally predominates in Europe and Asia. In India it has been recorded from U. P., Bengal, Bihar, Assam, Himachal Pradesh and Punjab, where it is found practically in all the district growing cruciferous crops (Singh 1959). In Bangladesh it is found in almost every district.

2.6.3.2. Biology and life cycle of cabbage caterpillar

The eggs are laid in clusters both on the upper and lower surfaces of the leaf, each cluster containing 50–80 eggs. The eggs hatch in 3.2±0.02 to 17.6±0.16 days in different months. The young caterpillar on hatching first feeds on its own egg shell and then starts feeding on the leaf. Caterpillar's stage occupies 15.6±0.03 to 40.7±0.89 days in different months, during which period it moults four times. The

caterpillars usually remain gregarious except when forced to disperse due to scarcity of food. Under normal conditions, they disperse towards the end of the fifth instar for finding suitable places for pupation and travel 70–80 yards. Pupa was pale green or greyish white and dotted with black and yellow markings. The ventral surface is flattened. Pupation takes place on the leaves and stems of trees, dark corners of verandah etc. and rarely on the host plants. The pupal stage is completed in 7.3±0.03 to 28.8±0.2 days depending upon the season. Mating takes place end to end and lasts for 60–95 minutes. The female starts laying eggs in clusters at the rate of 4–5 eggs per minute the next day after copulation (Singh 1959).

The butterflies are pale white and had a smoky shade on the dorsal side of the body. The wings are white with black tips on the forewings in case of both males and females which is augmented in the females (which has a larger black tip) by a pair of post-deiseal black spots with a black smear along the inner margin below the lower spot. The undersides of both sets of wings are pale yellow, dusted with grey except for the center and base of the forewings which are white. In female, the black dots of the forewings also appeared on the undersides (Madhumita and Gupta 2017). The adults live for 2.6±0.03 to 12.3±0.76 days in different months.

2.6.3.3. Nature of damage by cabbage caterpillar

It is a pest of cabbage and occasionally causes serious damage to the crop. They also feed upon broccoli, radish, turnip, cauliflower, tori and other crucifers. Damage is caused by caterpillars. Newly hatched caterpillars lacerate the leave surface of the host plants and skeletonize them. The grown up caterpillars voraciously feed on the leaves of host plant and sometimes eat away the whole plant.

2.6.4. Flea beetle, *Phyllotreta cruciferae*

Flea beetles (Coleoptera: Chrysomelidae, Subfamily: Galerucinae, Tribe: Alticini) are voracious pests that attack a wide variety of vegetables throughout the world,

particularly brassicaceous (cruciferous) plants. *Phyllotreta* spp. flea beetles are specialized to feed on Brassica plants throughout the United States and Canada (Capinera 2001). These beetles include the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze), the striped flea beetle, *Phyllotreta striolata* Fabr., and Zimmermann's flea beetle, *Phyllotreta zimmermanni* (Crotch) (Capinera 2001)

2.6.4.1. Biology and life cycle of flea beetle, *Phyllotreta cruciferae*

P. cruciferae has one to two generations per year depending on environmental conditions, and they can complete development from egg to adult in 6-8 weeks (Burgess 1977). Eggs are laid at the base of host plants and larvae emerge between 11-13 days (Feeny *et al. 1970*). After emerging, larvae burrow into the soil and proceed to feed on the roots of the same host plants the adults are feeding on (Feeny *et al.* 1970). There are three larval instars during which the insect feeds for 25-30 days before creating a pupal chamber in the soil and entering a pre-pupal period lasting 3-6 days, then pupate from 7-9 days. The adult is about 2.2mm long, metallic blue-black, and has enlarged hind femora specialized for jumping (Feeny et al. 1970, Burgess 1977). Beetles are capable of jumping and flying to disperse and travel from plant to plant. *P. cruciferae* over winters as an adult in soil, leaf litter, and other potential shelter materials, before emerging in spring (Feeny *et al.* 1970, Kinoshita *et al.* 1979). Beetles then disperse, mate, and lay their eggs leading to peak populations in late June then again in late July (Kinoshita et al. 1979).

2.6.4.2. Nature of damage by flea beetle

Flea beetle feed on plants by chewing small holes in the foliage, however, they do not chew through the entire leaf, leaving the lower epidermis intact (Burgess 1977, Soroka and Pritchard 1987). The lower epidermis then dries out falling from the plant, leaving the characteristic flea beetle feeding injury (Burgess 1977). When this defoliation occurs at a high rate, it can dry surrounding leaf tissues near the feeding holes which can kill young seedlings (Feeny *et al.* 1970, Burgess 1977).

Capinera (2001) indicates that this effect and seedling mortality can be more dramatic in spring when the weather is hot and dry. Little is known about the yield effects of surviving seedlings for a majority of crops, however, on broccoli it is shown that surviving plants may experience reduced growth, and direct feeding on florets greatly reduces yield (Soroka and Pritchard 1987). In canola, rape, and yellow mustard, *Phyllotreta* spp. feeding during the first few weeks after emergence, caused high seedling mortality, stunted plant growth, and reduced yield (Lamb 1984). In the same experiment flea beetle feeding had less of an impact on a later planting of the same crops (Lamb 1984). Larval feeding is typically less of a concern, the larvae usually feed on root hairs of the host plants in the case of *P. cruciferae* and *P. striolata*and this feeding injury can reduce the marketability of root crops (Kinoshita *et al.* 1978). *P. zimmermanni* larvae feed on the plant foliage of weeds surrounding crops unlike their adults.

2.7. Emamectin benzoate

Emamectin benzoate is the 4'-deoxy-4'-epi-methyl-amino benzoate salt of avermectin B1 (abamectin), which is similar structurally to natural fermentation products of Streptomyces avermitilis. Emamectin benzoate is being developed as a newer broad-spectrum insecticide for vegetables and has a very low application rate. The mechanism of action involves stimulation of high-affinity GABA receptors and a consequent increase in membrane chloride ion permeability. Animal studies indicate a wide margin of safety because mammalian species are much less sensitive due to lower GABA receptor affinities and relative impermeability of the blood-brain barrier.(Yang 2012)

Emamectin benzoate is a new insecticide of Syngenta Crop Protection, with a new mechanism of action and a strong activity against Lepidoptera as well as with and a high selectivity on useful organisms. This molecule acts if swallowed and has some contact action. It penetrates leaf tissues (translaminar activity) and forms a reservoir within the leaf. The mechanism of action is unique in the panorama of

insecticides. In facts, it inhibits muscle contraction, causing a continuous flow of chlorine ions in the GABA and H-Glutamate receptor sites.(Gunn *et al*. 1994).

2.8. Spinosad

Spinosad is an insecticide based on chemical compounds found in the bacterial species *Saccharopolyspora spinosa*. The genus *Saccharopolyspora* was discovered in 1985 in isolates from crushed sugarcane. The bacteria produce yellowish-pink aerial hyphae, with bead-like chains of spores enclosed in a characteristic hairy sheath. This genus is defined as aerobic, Gram-positive, nonacid-fast actinomycetes with fragmenting substrate mycelium. *S. spinosa* was isolated from soil collected inside a nonoperational sugar mill rum still in the Virgin Islands. Spinosad is a mixture of chemical compounds in the spinosyn family that has a generalized structure consisting of a unique tetracyclic ring system attached to an amino sugar (D-forosamine) and a neutral sugar (tri-O-methyl-L-rhamnose).(Hargreaves 2000). Spinosad is relatively nonpolar and not easily dissolved in water.Spinosad is a novel mode-of-action insecticide derived from a family of natural products obtained by fermentation of *S. spinosa*. Spinosyns occur in over 20 natural forms, and over 200 synthetic forms (spinosoids) have been produced in the lab. Spinosad contains a mix of two spinosoids, spinosyn A, the major component, and spinosyn D (the minor component), in a roughly 17:3 ratio.

2.9. Buprofezin

Insect growth regulators (IGRs) are selective insecticides interfering with normal growth and development.Buprofezin, 2-*tert*-butylimino-3-isopropyl-5-Phenyl perhydro-1,3,5-thiadiazin-4-one, developed by Nihon Nohyaku in 1981, is one of the first IGRs mainly acting against sucking insects such as whiteflies and scale insects.(Wang 2012). As a chitin synthesis inhibitor, it expresses its action at the time of moulting; the affected insects are not able to shed their cuticle and die

during this process. These symptoms resemble those induced by the benzoylphenylureas, although the chemical structure of buprofezin is not analogous to that of the benzoylphenylureas. (Guedes *et al*. 2016)

2.10. Lambda cyhalothrin

Lambda cyhalothrin is a synthetic pyrethroid insecticide and acaricide used to control a wide range of pests in a variety of applications. Pests controlled include aphids, Colorado beetles and butterfly larvae. Crops on which it may be applied include cotton, cereals, hops, ornamentals, potatoes, vegetables or others. It may also be used for structural pest management or in public health applications to control insects such as cockroaches, mosquitoes, ticks and flies which may act as disease vectors. (Naumann 1990).

Lambda cyhalothrin is available as an emulsifiable concentrate, wettable powder or ULV liquid, and is commonly mixed with buprofezin, pirimicarb, dimethoate or tetramethrin. It is compatible with most other insecticides and fungicides.

2.11. Imidacloprid

Imidacloprid is the most well-known and widely used representative of the neonicotinoid insecticides. It is a broad-spectrum neonicotinoid insecticide, with excellent systemic and contact activity that supports its use on many food crops, turf, and ornamentals and for termite and flea control. They are designed to act on nicotinic receptors to control insect pests and, at the same time, to express low toxicity to vertebrate species. This chapter explores the toxic kinetics, chemistry, and neurotoxicity. By oral administration, imidacloprid is rapidly absorbed, metabolized in the liver, and excreted, primarily via the urine. There are two major routes of metabolism in mammals. The first involves oxidative cleavage to imidazolidine and 6-chloronicotinic acid, with the imidazolidine moiety excreted via the urine. The second substantive route in the biotransformation of imidacloprid involves the hydroxylation of the intact molecule in the imidazolidine

ring, followed by the elimination of water and the formation of an unsaturated metabolite. Imidacloprid is absorbed and widely distributed to organs within 1 h following oral administration to rats. Imidacloprid was determined to produce minimal evidence of toxicity by acute dermal and inhalation routes of exposure and moderate acute toxicity by acute oral administration. Imidacloprid is not an irritant and does not produce evidence of dermal sensitization. Acute toxicity is characterized by nicotinic signs at relatively high levels of exposure. Due to its high insecticidal potency and relatively low mammalian toxicity, imidacloprid has a very high margin of safety. Imidacloprid is not mutagenic or carcinogenic, it is not a primary embryo toxicant, is not teratogenic, and has no effect on reproduction or development. (Untung 1991).

Chapter III

Materials and Method

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out in the research field of department of entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during November 2018 to March 2019 i.e. in the rabi season. Details of the experimental methodology is given below-

3.1. Description of experimental site

3.1.1. Geographical location and climate

The location of the site is 23074/N latitude and 900035/E longitude with an elevation of 8.2 meter from sea level. The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by heavy scanty rainfall during the rabi season. The soil belonged to "The Modhupur Tract", AEZ-28. The experimental area was flat having available irrigation and drainage system and above flood level.

3.2. Planting materials

An exotic variety of broccoli was used as the test crop in this experiment. Seeds were collected from BARI (Bangladesh Agricultural Research Institute), Gazipur, Bangladesh.

3.3. Treatments of the experiment

Present study comprised of seven treatments.

Table 2. Treatments of the experiment

Treatment No.	Name of the Treatment	Dose	Spray Interval
T_1	Spinosad	0.5 ml/L	15 Days
T_2	Emamectin benzoate	1 ml/L	
T_3	Buprofezin	0.2 g/L	
T_4	Lamda cyahalothrin	1ml/L	
T_5	Neem Seed kernel extract	5g/L	
T_6	Imidacloprid	0.5ml/L	
T_7	Control		

3.4. Experimental design and layout

The experiment was laid out in a single factor randomized complete block design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil hetero-genetic effects. Each block was divided into seven-unit plots as treatments demarked with raised bunds. Thus, the total numbers of plots were 7X3=21. The unit plot size was 3.6 m × 1.6 m. The distance maintained between two blocks and two plots were 0.5 m and 0.5 m, respectively.

3.5. Land preparation and intercultural operation

The broccoli variety seeds were sown in seedbed on October 2018. The plot selected for conducting the experiment was opened in the first week of November 2018 with assistance of farm division, and left exposed to the sun for a week. The soil was harrowed, ploughed and cross-ploughed several times after one week, followed by laddering in order to ensure good tilth condition.

Plate 01: Experimental field of Broccoli during the study period

Plate 02: Healthy Broccoli plant with card in the Experimental field

Organic and inorganic manures were incorporated with the soil of each unit site, shown below. Seedlings were transplanted on third week of November, 2018. Irrigation and drainage were provided when required. Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development.

3.6. Manuring and fertilizer application

As suggested by the Bangladesh Agricultural Research Institute, fertilizers N, P, K in the form of Urea, TSP, MoP and S, Zn, and B in the form of gypsum, zinc sulphate and borax were supplied (Mondal *et al.* 2011).

Table 3. Fertilizer and manure used in the experiment

Name of Fertilizer and manure	Total Amount (Kg/ha)	Last plough (Kg/ha)	Before transplanting (Kg/ha)	15 DAT	35 DAT
Cowdung/ FYM	10,000	5,000	5,000		
Urea	150			75	75
TSP	150	75	75		
MoP	120			60	60
Gypsum	100	100	100		
Boric Acid	3	3			
Molybdenum	1	1			

Source: Mondal *et al.* 2011

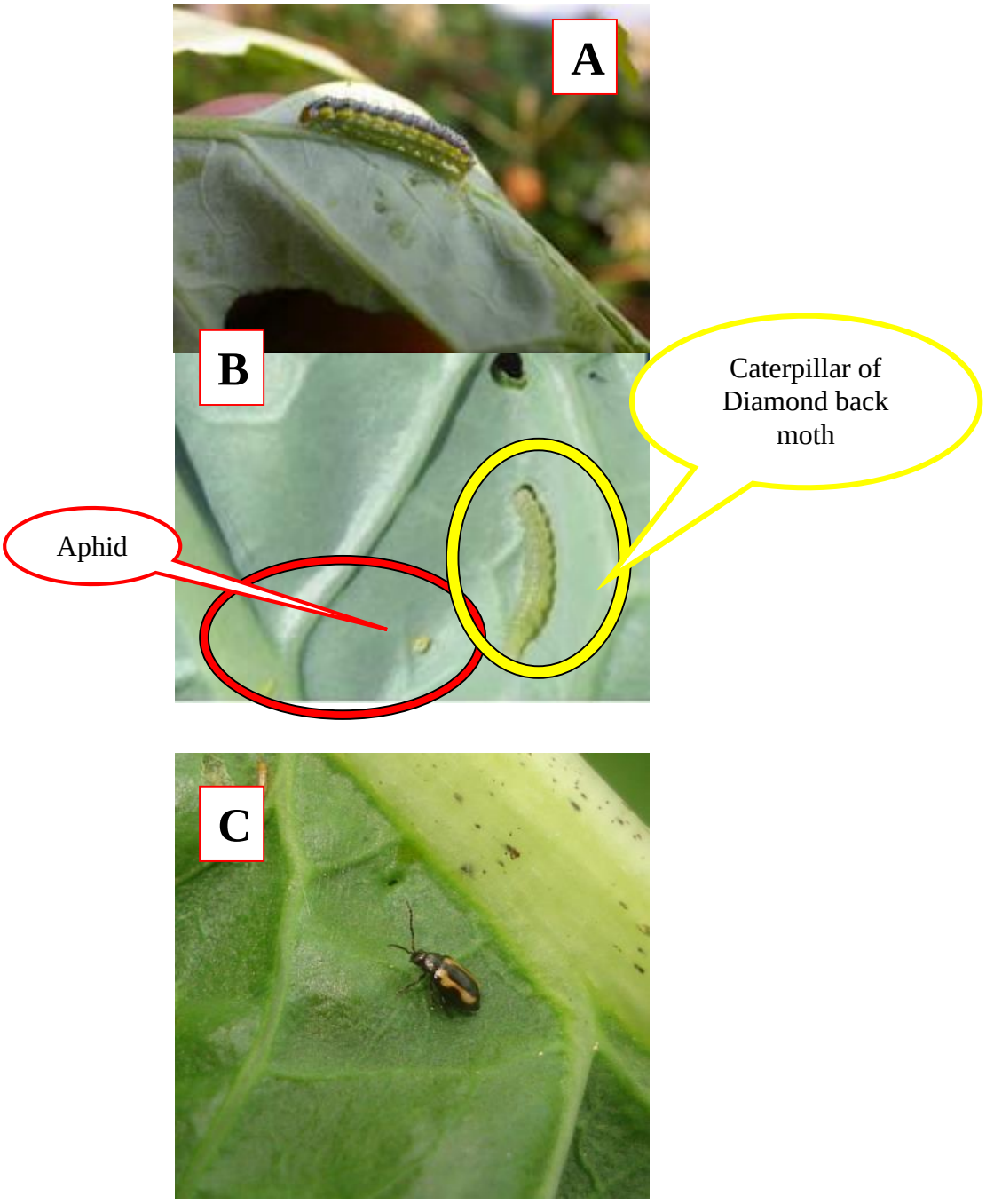


Plate 03: Photo of insect pests from the experimental field;
A shows caterpillar of *Pieris* sp,
B shows nymph of Aphid, *Brevicoryne brassicae* and caterpillar of Diamond back moth, and
C shows adult flea beetle

Plate 04: Healthy Broccoli after harvesting

3.7. Data recording

3.7.1. Data recording on population abundance of insect pests of broccoli

The control plots where there was no chemical applied were selected for the study of seasonal abundance. Data were collected soon after the seedling transplantation in main field. Data was collected from 18.11.2018 (48^{th} SW) to 02.03.2019 (9^{th} SW). In order to ease of the study, whole growing period was considered for data collection.

3.7.1.1. Data recording on the population abundance of *Pieris* sp

The population density of cabbage butterfly was recorded on the basis of number of caterpillar per plant. All the open leaves and heads of the selected plant were observed thoroughly and the number of larvae found was recorded.

3.7.1.2. Data recording on the population abundance of *P. xylostella*

Five infested plants were randomly selected from each replication and were thoroughly inspected weekly and the number of *P. xylostella* larvae and pupae were counted but not removed. The experiment was continued until harvest in both years. Population of *P. xylostella* was determined as the mean number of larvae and pupae per 5 broccoli plants.

3.7.1.3. Data recording on the population abundance of aphid *Brevicoryne brassicae*

Aphids were found feeding on the cell sap from the leaves of the plants. Actual number of nymph and adult aphids was counted on both sides of the leaves.

3.7.1.4. Data recording on the population abundance of *P. cruciferae*

Observations on the incidence of insect pests were recorded at weekly interval starting from initial appearance to crop harvest. Observations on the incidence of flea beetle, *Phyllotreta cruciferae* Goezewere recorded from 5 randomly selected plants from each plot by counting number of beetles per plant and then mean number per 5 plants was assessed. Insect numbers were assessed from three replications.

3.7.2. Data recording on the effect of treatments against the insect pests of broccoli

Pesticides were applied at 30 DAT, 45 DAT, 60 DAT and 75 DAT and in 15 days interval. Insecticides were applied as per recommended dose mentioned in Table 2 and at sunny day time. Insect counting was done after 7 days after spraying as well as 14 days after spraying. Then the mean number was calculated from data obtained from three replications.

3.7.2.1. Data recording on the effect of treatment against *Pieris* sp

The insect abundance of cabbage butterfly was recorded based on number of insects per plant. All the open leaves and heads of the sampled plants were watched completely and the number of pests found was recorded.

3.7.2.2. Data recording on the effect of treatment against *P. xylostella*

Population of *P. xylostella* was counted and the mean number of larvae and pupae per 5 broccoli plants were recorded.

3.7.2.3. Data recording on the effect of treatment against *Brevicoryne brassicae*

Actual number of nymph and adult aphids was counted on both sides of the leaves.

3.7.2.4. Data recording on the effect of treatment against *P. cruciferae*

Observations on the incidence of flea beetle, *Phyllotreta cruciferae* Goeze were recorded from 5 randomly selected plants from each plot by counting number of beetles per plant and then mean number per plot was assessed.

3.8. Statistical analysis

Recorded data were put and compiled on MS excel spreadsheet. Later on, data were analyzed by using STATISTICS 10 software for analysis of variance. ANOVA was made by F variance test and the mean value comparisons were performed.

Chapter IV

Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

4.1. Population abundance of insect pests in broccoli field during rabi season 2018-2019

4.1.1. Population abundance of *Pieris* sp in broccoli field during rabi season 2018-2019

Table 4. Population abundance of *Pieris* sp in broccoli field during rabi season 2018-2019

Date of count	Standard week	Week after transplant	No. of *Pieris* sp. (Mean no./5 Plants)
18.11.2018	48	1	0.40
25.11.2018	49	2	0.78
04.12.2018	50	3	1.24
12.12.2018	51	4	1.98
20.12.2018	52	5	1.42
28.12.2018	01	6	1.84
05.01.2019	02	7	1.84
13.01.2019	03	8	1.44
21.01.2019	04	9	1.24
29.01.2019	05	10	0.60
07.02.2019	06	11	0.42
15.02.2019	07	12	0.28
23.02.2019	08	13	0.24
02.03.2019	09	14	0.22

It is evident that (Table 4) caterpillar of cabbage butterfly (*Pieris* sp.) occupied the broccoli field from the very beginning of the cultivation. This pest appeared up to the crop maturity stage. *Pieris* sp. was abundant from 48th standard week to 9th standard week of the next year i.e. throughout the growing period. *Pieris* sp.

population was found 0.40 per 5 plants at the first week of transplanting (third week of November i.e. 48th SW) which was followed by 49th and 50th SW (0.78 and 1.24 caterpillar per 5 plants). The peak population (1.98 per 5 plants) of *Pieris* sp. was found 51st SW (4th week of transplanting). However, the population was decreased to 1.42 per 5 plants in the next week (1st SW) and then increased to 1.84 per 5 plants which remained same up to 7th week of transplanting (2nd SW). Then there was a gradual reduction in pest population up to the 14th week of transplanting. The population of *Pieris* sp. was found 1.44, 1.24, 0.60, 0.42, 0.28 and 0.24 per 5 plants on the 3rd, 4th, 5th, 6th, 7th and 8th standard week respectively. However, the lowest population (0.22 per 5 plants) was found in the last week (9th SW) of growing period. This result is in conformity with the findings of Pathak (2004) who reported that *P. brassicae* was more abundant during December and January. Similarly, experiments conducted on the seasonal incidence of *Pieris brassicae* L. during 2014-2015 and 2015-2016 at the University Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu revealed that *P. brassicae* were first observed in the 43rd standard week (1.33 larvae per plants) and lowest population of 0.12 caterpillar per plant during the 15th standard week. The *P. brassicae* population was maximum (5.74 caterpillar per plants) in 7th standard week respectively (Sharma *et al.* 2017). However, Sharmila e*t al.,* (2015) found that the larvae first appeared on cauliflower in the first week of November, and the population peaked during the fourth week of January 2005, and remained active up to April. Seasonal weather and other abiotic as well as biotic factors might influence the population dynamics of *Pieris* sp. population.

4.1.2. Population abundance of *P. xylostella* in broccoli field during rabi season 2018-2019

Table 5. Population abundance of *P. xylostella* in broccoli field during rabi season 2018-2019

Date of count	Standard week	Week after transplant	No. of *P. xylostella* (Mean no./ 5 Plants)
18.11.2018	48	1	0.00
25.11.2018	49	2	0.00
04.12.2018	50	3	0.00
12.12.2018	51	4	0.00
20.12.2018	52	5	0.00
28.12.2018	01	6	0.00
05.01.2019	02	7	0.00
13.01.2019	03	8	0.02
21.01.2019	04	9	0.04
29.01.2019	05	10	0.16
07.02.2019	06	11	0.50
15.02.2019	07	12	0.18
23.02.2019	08	13	0.20
02.03.2019	09	14	0.16

From this Table (5) it has clearly seen that *P. xylostella* occupied the broccoli field from middle to last of the cultivation period. In the very early stage this pest was not found but it was available from 3rd standard week to 9th standard week of the following year. In this table it clearly noticeable that *P. xylostella* was not observed from 48th standard week to 2nd standard week. *P. xylostella* population was observed 0.02 per 5 plants at the 8th week of transplanting (second week of January i.e.3rd SW) which was followed by 4th and 5th SW (0.04 and 0.16 per 5 plants respectively).The peak population (0.50 per 5 plants) of *P. xylostella* was observed

6th SW (11th week of transplanting).The lowest population (0.02 per 5 plants) was observed in the 3rd standard week. The *P. xylostella* population was found 0.18, 0.20, and 0.16 per 5 plants according to the 7th, 8th and 9th standard week respectively.

Activity of *P. xylostella* is lower in broccoli field compared to other pests. *P. xylostella* was more abundant (0.50 per 5 plants) during February. Choudhury and Pal (2006) also reported that *P. xylostella* was more abundant during February and March on developing pods of mustard.However, Dalve *et al.*(2009) reported that the pest population of *Plutella xylostella* (Linnaeus) on cabbage appeared from third week December which gradually increased and attained a peak of 8.9 larvae per 5 plants during the fourth week of January.The pest was more active during the month of January.According to the study of Ahmad and Ansari (2010),from September onwards during study,density of *P. xylostella* decreased down slowly up to harvesting of third crop of cauliflower in the month of April 2005 and 2006.

Climatic conditions, including higher temperatures and decreased rainfall were cited as major factors which regulate the population dynamics of *P. xylostella* while hot and dry conditions are known to be conducive for *P. xylostella* (Shelton 2001).Talekar and Shelton (1993) suggested that inversed temperatures can lead to the production of more generations per season.

4.1.3. Population abundance of *Brevicoryne brassicae* in broccoli field during rabi season 2018-2019

Table 6. Population abundance of *Brevicoryne brassicae* in broccoli field during rabi season 2018-2019

Date of count	Standard week	Week after transplant	No. of *Brevicoryne brassicae* (Mean no./ 5 Plants)
18.11.2018	48	1	0.00
25.11.2018	49	2	0.04
04.12.2018	50	3	0.36
12.12.2018	51	4	2.02
20.12.2018	52	5	1.24
28.12.2018	01	6	1.80
05.01.2019	02	7	3.20
13.01.2019	03	8	22.60
21.01.2019	04	9	19.72
29.01.2019	05	10	4.90
07.02.2019	06	11	22.16
15.02.2019	07	12	238.62
23.02.2019	08	13	178.34
02.03.2019	09	14	132.52

It has visible that (Table 6) caterpillar of *Brevicoryne brassicae* played a dynamic role of broccoli field from the second week of transplant. This pest becomes visible up to the crop maturity stage. *L.erysimi* was ample from 49th standard week to 9th standard week of the next year i.e. throughout the growing period. *L.erysimi* population was identified 0.04 per 5 plants at the second week of transplanting (4th week of November i.e. 49th SW) which was followed by 50th and 51st SW (0.36 and

2.02 per 5 plants respectively).There wasn't seen any pest population in the 48th standard week. The highest population (238.62 per 5 plants) of *Brevicoryne brassicae* was identified 7th SW (12th week of transplanting) followed by 8th and 9th SW (178 and 132 insects per 5 plants).The lowest population (0.04 per 5 plants) was discovered in the 49th SW. From the table it is clearly notified that increasing and decreasing rate of pest population was fluctuating during the growing season of broccoli field.

Present findings showed conformity with the study of Patel and Godhani (2016). Aphid, *Brevicoryne brassicae* (Kalt.) population was observed in cauliflower during 49th standard meteorological week (SMW) (2nd week of December) to 9th SMW (1st week of March).The maximum (91.46 aphids/25 cm^2 per leaf) aphid population was observed in 7th SMW (2nd week of February),whereas it was minimum in 49th SMW (2nd week of December).According to the study of Saranya *et al*. (2017),the infestation of aphids initiated in the 3rd week of December (50th SMW, 2015) and then gradually increased reaching a peak mean population of 207.53 aphids/3 leaves/ plant during the 1st week of March (10th SMW, 2016).

Badjena and Mandal (2005) have also reported the incidence of three species of aphids viz., *M. persicae* (major one) followed by *B. brassicae* and *Brevicoryne brassicae* and in the cauliflower fields starting from the second week of November reaching their peak of 216.3 aphids/ 3 leaves in their study. According to the findings of Chaudhari *et al*. (2001), the aphid, *B. brassicae* commenced its activity from mid-December and lingered on the crop till harvest during March end, similar to the present findings.

4.1.4. Population abundance of *P. cruciferae* in broccoli field during rabi season 2018-2019

Table 7. Population abundance of *P. cruciferae* in broccoli field during rabi season 2018-2019

Date of count	Standard week	Week after transplant	No. of *P. cruciferae* (Mean no./5 Plants)
18.11.2018	48	1	0.00
25.11.2018	49	2	0.00
04.12.2018	50	3	0.00
12.12.2018	51	4	0.00
20.12.2018	52	5	0.00
28.12.2018	01	6	0.00
05.01.2019	02	7	0.00
13.01.2019	03	8	2.98
21.01.2019	04	9	2.16
29.01.2019	05	10	1.32
07.02.2019	06	11	1.34
15.02.2019	07	12	0.68
23.02.2019	08	13	0.42
02.03.2019	09	14	0.24

It is apparent that (Table 7) from middle to last stage of broccoli cultivation the *P. cruciferae* was activated from the very beginning stage. There was not any pest population of *P. cruciferae* up to 6th week of transplanting. But population presence was recorded from 3rd standard week to 9th standard week of the next year. From the table it has clearly seen that *P. cruciferae* was not noticed from 48th standard week to 2nd standard week. *P. cruciferae* population was noticed (2.98 per 5 plants) at the 8th week of transplanting (2nd week of January i.e.3rd SW) which was followed by 4th and 5th SW (2.16 and 1.32 per 5 plants respectively). The peak population (2.98

per 5 plants) of *P. cruciferae* was found 3rd SW (8th week of transplanting) whereas, the lowest population (0.24 per 5 plants) was noticed in the last week (9th SW) of growing period. The *P. cruciferae* population was emerged 1.34, 0.68 and 0.42 per 5 plants respectively according to the 6th, 7th and 8th standard week.

The observation on seasonal incidence of flea beetle are in conformity with the findings of Nath and Saikia (2002) who reported that maximum infestation of flea beetle was observed during February in Assam, India. Our observations on flea beetle indicate a little delayed incidence on cabbage as compared to some of the earlier reports, while other reports are similar to our findings. The incidence of insect pests on cauliflower cultivars in Terai regions; maximum population of flea beetles, *Phyllotreta cruciferae* (0.78 beetles/ plant) were found during the last week and 3rd week of December (Ghosh *et al.,* 2000). Conversely, according to the study of Sharma (2004), flea beetle appeared in mid-September and reached its peak in first and second week of October.

4.2. Effect of treatments against insect pests in broccoli field

4.2.1. Effect of treatments against *Pieris* sp. during rabi season 2018-19

Table 8. Effect of treatments against *Pieris* sp. during rabi season 2018-19

Treatment No.	Name of the Treatment	No. of Insect per 5 plants
T_1	Spinosad @0.5 ml/L	1.37 cd
T_2	Emamectin benzoate @1ml/L	0.54 f
T_3	Buprofezin @0.2 g/L	0.96 e
T_4	Lamdacyahalothrin @1ml/L	1.16 de
T_5	Neem Seed kernel extract @5g/L	1.47 c
T_6	Imidacloprid @0.5ml/L	1.88 b
T_7	Control	2.14 a
S.E.	**0.11**	
CV (%)	**9.71**	

It is evident that (Table 8) treatments of present experiment had significantly influenced the population dynamics of *Pieris* sp. There was statistical variation among the different treatments used in the experiment. The lowest *Pieris* population (0.54 per 5 plants) was obtained from Emamectin benzoate (T_2) which was statistically different from any other treatments. The population then followed by Buprofezin (T_3) and Lamdacyahalothrin (T_4) and the number was 0.96 and 1.16 insect per 5 plants respectively. Though numerically differed but there was no statistical variation between $T_3$and T_4. Further, Spinosad (T_1) which observed 1.37 insects per 5 plants showed no statistical difference between T_4. Similarly, *Pieris* population was 1.47 per 5 plants in Neem Seed kernel extract (T_5) and though numerically differed but was statistically similar with that of T_1. Furthermore, T_6 (Imidacloprid) observed 1.88 *Pieris* sp. per 5 plants and it was significantly different from any other treatment. However, the highest population (2.14 per 5 plants) of *Pieris* sp. was found from control treatment (T_7).

Muthukumar *et al.* (2007) suggested to apply emamectin benzoate to control insects of cauliflower. Singh *et al.* (2010) also reported similar results. Emamectin is widely used in controlling lepidopterous pests (order of insects that as larvae are caterpillars and as adults have four broad wings including butterflies, moths, and skippers) in agricultural products in the US, Japan, Canada, and recently Taiwan. The low-application rate of the active ingredient needed (~6 g/acre) and broad-spectrum applicability as an insecticide has gained emamectin significant popularity among farmers (Yen and Lin 2004). Emamectin works as a chloride channel activator by binding gamma aminobutyric acid (GABA) receptor and glutamate-gated chloride channels disrupting nerve signals within arthropods. The compound stimulates the release of GABA from the synapses between nerve cells and while additionally increasing GABA's affinity for its receptor on the post-junction membrane of muscle cells in insects and arthropods (Rodríguez *et al.* 2007).

4.2.2. Effect of treatments against *P. xylostella* during rabi season 2018-19

Table 9. Effect of treatments against *P. xylostella* during rabi season 2018-19

Treatment No.	Name of the Treatment	No. of Insect per 5 plants
T_1	Spinosad @0.5 ml/L	0.51 d
T_2	Emamectin benzoate @1ml/L	0.16 f
T_3	Buprofezin @0.2 g/L	0.34 e
T_4	Lamdacyahalothrin @1ml/L	0.41 de
T_5	Neem Seed kernel extract @5g/L	0.61 c
T_6	Imidacloprid @0.5ml/L	0.77 b
T_7	Control	0.94 a
S.E.	**0.14**	
CV (%)	**11.08**	

It is clearly seen that (Table 9) treatments of present experiment had significantly affected the population dynamics of *P. xylostella.* There was statistical and numerical variation among the different treatments used in the experiment. The lowest *P. xylostella population* (0.16 per 5 plants) was obtained from Emamectin benzoate (T_2) which was statistically different from any other treatments. The population then followed by Buprofezin (T_3) and Lamdacyahalothrin (T_4) and the number was 0.34 and 0.41 insects per 5 plants respectively. Though numerically differed but there was no statistical variation between $T_3$and T_4. Further, Spinosad (T_1) which observed 0.51 insect per 5 plants showed no statistical difference between T_4. Similarly,*P. xylostellas* population was 0.61 per 5 plants in Neem Seed kernel extract (T_5) and though numerically differed but was statistically difference with that of T_1. Furthermore, T_6 (Imidacloprid) observed 0.77 *P. xylostella* per 5 plants and it was significantly different from any other treatment. However, the

highest population (0.94 per 5 plants) of *P. xylostella* was found from control treatment (T_7).

According to Shivalinga swamy *et al.* (2008), on the basis of post treatment larval population and damage, emamectin benzoate was found to be most effective against all the test insects. In all the three test dosages of emamectin benzoate, no significant difference was noted in the level of infestation or damage caused by the insects. Emamectin benzoate was effective against all the three insects even at the lowest dose.

4.2.3. Effect of treatments against *Brevicoryne brassicae* during rabi season 2018-19

Table 10. Effect of treatments against *Brevicoryne brassicae* during rabi season 2018-19

Treatment No.	Name of the Treatment	No. of Insect per 5 plants
T_1	Spinosad @0.5 ml/L	61.42 cd
T_2	Emamectin benzoate @1ml/L	18.33 e
T_3	Buprofezin @0.2 g/L	37.33 de
T_4	Lamdacyahalothrin @1ml/L	47.67 d
T_5	Neem Seed kernel extract @5g/L	83.66 c
T_6	Imidacloprid @0.5ml/L	125.63 b
T_7	Control	172.54 a
S.E.	**12.64**	
CV (%)	**19.91**	

It is apparent that (Table 10) treatments of present experiment had significantly influenced the population dynamics of *Brevicoryne brassicae* .There was statistical variation among the different treatments used in the experiment. The lowest *Brevicoryne brassicae* population (18.33 per 5 plants) was obtained from

Emamectin benzoate (T_2) which was statistically similar with that of (T_3). The population then followed by Buprofezin (T_3) and Lamdacyahalothrin (T_4) and the number was 37.33 and 47.67insect per 5 plants respectively. Though numerically differed but there was no statistical variation between $T_3$and T_4. Further, Spinosad (T_1) which observed 61.42 insect per 5 plants showed no statistical difference between T_4. Similarly, *Brevicoryne brassicae* population was 83.66 per 5 plants in Neem Seed kernel extract (T_5) and though numerically differed but was statistically similar with that of T_1. Furthermore, T_6 (Imidacloprid) observed 125.63 *Brevicoryne brassicae* plant and it was significantly different from any other treatment. However, the highest population (172.54 per 5 plants) of *Brevicoryne brassicae* was found from control treatment (T_7).

Several reports found pesticide resistance of aphid. Aphids are a group of insects that have become global pests in agriculture and frequently exhibit insecticide resistance.The cabbage aphid, *Brevicoryne brassicae* has developed resistance to at least seventy different synthetic compounds, and different insecticide resistance mechanisms have been reported worldwide (Silva *et al.* 2012).

4.2.4. Effect of treatments against *P. cruciferae* during rabi season 2018-19

Table 11. Effect of treatments against *P. cruciferae* during rabi season 2018-19

Treatment No.	Name of the Treatment	No. of Insect per 5 plants
T_1	Spinosad @0.5ml/L	2.05 d
T_2	Emamectin benzoate @1ml/L	0.96 f
T_3	Buprofezin @0.2g/L	1.34 e
T_4	Lamdacyahalothrin @1ml/L	1.88 d
T_5	Neem Seed kernel extract @5g/L	2.33 c
T_6	Imidacloprid @0.5ml/L	2.71 b
T_7	Control	3.04 a
S.E.	**1.08**	
CV (%)	**4.86**	

It is noticeable that treatments of present experiment had significantly affected the population dynamics of *P. cruciferae.* There was statistical and numerical variation among the different treatments used in the experiment. The lowest *P. cruciferae* population (0.96 per 5 plants) was obtained from Emamectin benzoate (T_2) which was statistically different from any other treatments. The population then followed by Buprofezin (T_3) and Lamdacyahalothrin (T_4) and the number was 1.34 and 1.88 insect per 5 plants respectively. There was significantly variation between T_3 and T_4. Further, Spinosad (T_1) which observed 2.05 insect per 5 plants showed no statistical difference between T_4. Similarly, *P. cruciferae* population was 2.33 per 5 plants in Neem Seed kernel extract (T_5) and not only numerically differed but also was statistically difference with that of T_1. Furthermore, T_6 (Imidacloprid) observed 2.71 *P. cruciferae* per 5 plants and it was significantly different from any other treatment. However, the highest population (3.04 per 5 plants) of *P. cruciferae* was found from control treatment (T_7).

4.3. Yield of broccoli influenced by different treatments

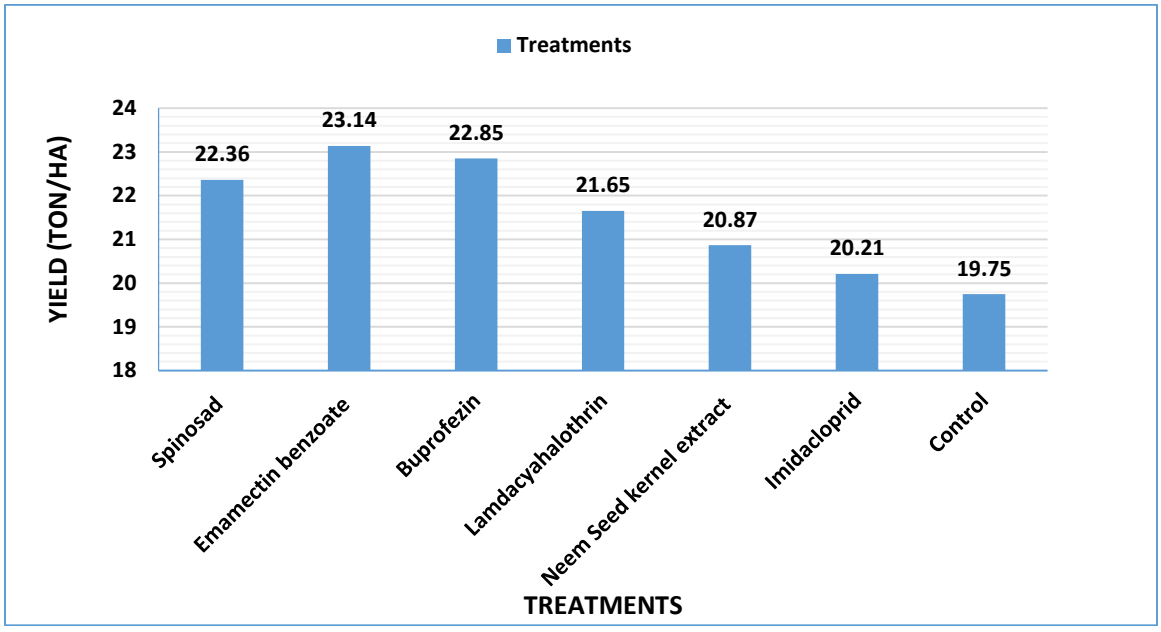


Figure 2. Yield (ton/ha) of broccoli.

From this graph it is clearly seen that yield of broccoli influenced by different treatments. There are mainly seven types of treatment such as Spinosad, Emamectin benzoate, Buprofezin, Lamdacyahalothrin, Neem Seed kemel extract, Imidacloprid and Control. These treatments played a significant role in the yield of broccoli field. The highest yield (23.14 ton/ha) of broccoli was obtained from Emamectin benzoate. It was followed by Buprofezin (22.85 ton/ha) and Spinosad (22.36 ton/ha). Furthermore, in the next treatment (Lamda cyahalothrin), yield of broccoli was 21.65 ton/ha that was higher than Neem seed kernel extract (20.87 ton/ha) and Imidacloprid (20.21 ton/ha). However, the lowest yield of broccoli was 19.75 ton/ha which came from Control treatment.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The study was undertaken to assess the population abundance of insect pests dwelling broccoli as well as to find the eco-friendly i.e. bio rational control measures against insect pests in broccoli field. The study was conducted in the Entomology field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Randomized complete block design (RCBD) was used for setting the experiment. Spinosad, Emamectin benzoate, Buprofezin, Lambda cyahalothrin, Imidacloprid, Neem seed kernel extract, and untreated control were used as different treatments in the experiment.

Cabbage butterfly (*Pieris* sp.) occupied the broccoli field from the very beginning of the cultivation. *Pieris* sp. was abundant from 48th standard week to 9th standard week of the next year i.e. throughout the growing period. The peak population (1.98 per 5 plant) of *Pieris* sp. was found 51st SW (4th week of transplanting). The lowest population (0.22 per 5 plant) was found in the last week (9th SW) of growing period. *P. xylostella* was available from 3rd standard week to 9th standard week of the following year. *P. xylostella* population was observed (0.02 per 5 plant) at the 8th week of transplanting (second week of January i.e.3rd SW). The peak population (0.50 per 5 plant) of *P. xylostella* was observed 6th SW (11th week of transplanting). The lowest population (0.02 per 5 plant) was observed in the 3rd standard week.

Brevicoryne brassicae was ample from 49th standard week to 9th standard week of the next year i.e. throughout the growing period. *Brevicoryne brassicae* population was identified (0.04 per 5 plant) at the second week of transplanting (4thweek of November i.e. 49th SW). The highest population (238.62 per 5 plant) of *Brevicoryne brassicae* was identified 7th SW (12th week of transplanting) whereas, the lowest population (0.04 per 5 plant) was discovered in the 49th SW.

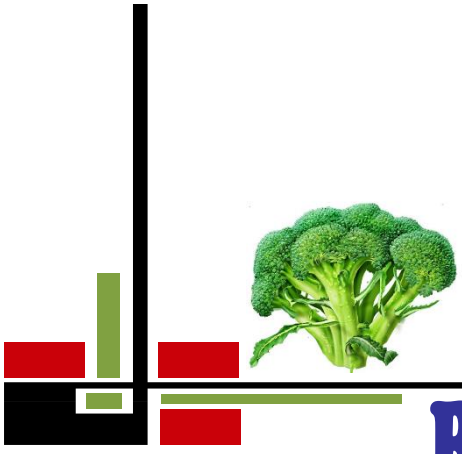
Presence of *P. cruciferae* was recorded from 3rd standard week to 9th standard week of the next year.*P. cruciferae* population was noticed (2.98 per 5 plant) at the 8th week of transplanting (2nd week of January i.e.3rd SW). The peak population (2.98

per plant) of *P. cruciferae* was found 3rd SW (8th week of transplanting) whereas, the lowest population (0.24 per 5 plant) was noticed in the last week (9th SW) of growing period.

In case of treatments, the lowest *Pieris* sp. population (0.54 per 5 plant) was obtained from Emamectin benzoate (T_2) which was statistically different from any other treatments. The highest population (2.14 per 5 plant) of *Pieris* sp. was found from control treatment (T_7).The lowest *P. xylostella population* (0.16 per 5 plant) was obtained from Emamectin benzoate (T_2) which was statistically different from any other treatments whereas, the highest population (0.94 per 5 plant) of *P. xylostella* was found from control treatment (T_7).

The lowest *Brevicoryne brassicae* population (18.33 per 5 plant) was obtained from Emamectin benzoate (T_2) which was statistically similar with (T_3). However, the highest population (172.54 per 5 plant) of *Brevicoryne brassicae* was found from control treatment (T_7). There was statistical and numerical variation among the different treatments used in the experiment. The lowest *P. cruciferae* population (0.96 per 5 plant) was obtained from Emamectin benzoate (T_2) which was statistically different from any other treatments. However, the highest population (3.04 per 5 plant) of *P. cruciferae* was found from control treatment (T_7).

The highest yield (23.14 ton/ha) of broccoli was obtained from Emamectin benzoate whereas, the lowest yield of broccoli was (19.75 ton/ha) which came from Control treatment.



Chapter VI

Recommendations

CHAPTER VI

RECOMMENDATIONS

Based on the above findings, the following recommendations are made-

1. Most of the insect pests are active at the later part of growing season. So, careful monitoring is important for successful deployment of management tactics.
2. Emamectin benzoate can be used as eco-safe insecticides to control insect pests of broccoli.
3. However, more research is needed to identify the best doses of Emamectin benzoate.
4. More preliminary studies needed to know the population abundance of insect pests and best suitable pesticide to control those pests.

Chapter VII

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CHAPTER VII

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APPENDICES

Appendix I: ANOVA table of effect of treatments against *Pieris* sp

Source	DF	SS	MS	F	P
Replication	2	0.03487	0.01743		
Treatment	6	5.32113	0.88686	51.10	0.0000
Error	12	0.20827	0.01736		
Total	20	5.56427			
Grand Mean	1.35				
CV	9.71				

Appendix II: ANOVA table of effect of treatments against *Plutella xylostella*

Source	DF	SS	MS	F	P
Replication	2	0.00877	0.00439		
Treatment	6	1.23596	0.20599	58.17	0.0000
Error	12	0.04250	0.00354		
Total	20	1.28723			
Grand Mean	0.53				
CV	11.08				

Appendix III: ANOVA table of effect of treatments against *Lipaphis erysimi*

Source	DF	SS	MS	F	P
Replication	2	1482.7	741.33		
Treatment	6	52477.8	8746.30	36.48	0.0000
Error	12	2877.3	239.78		
Total	20	56837.8			
Grand Mean	77.76				
CV	19.91				

Appendix IV: ANOVA table of effect of treatments against *P. cruciferae*

Source	DF	SS	MS	F	P
Replication	2	0.00309	0.00154		
Treatment	6	9.64805	1.60801	163.00	0.0000
Error	12	0.11838	0.00987		
Total	20	9.76951			
Grand Mean	2.045				
CV	4.86				