INCIDENCE OF INSECT PESTS ON CAULIFLOWER AND THEIR MANAGEMENT

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INCIDENCE OF INSECT PESTS ON CAULIFLOWER AND THEIR MANAGEMENT

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CERTIFICATE

This is to certify that the thesis entitled, 'Incidence Of Insect Pests On Cauliflower And Their Management 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 **Sharmeen Jahan Shapla,** Registration number: 14-06167 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, 2021
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Dedicated

To

My Beloved Parents

ABBREVIATIONS

Elaborated Form		Abbreviated Form
And others (Co-workers)	=	*et al.*
Gram	=	g
Coefficient of Variation	=	CV
Degree centigrade	=	^{o}C
Example	=	viz.
Least significant difference	=	LSD
Million tons	=	mt
Non-significant	=	NS
Per Hectare	=	ha_{-1}
Percentage	=	%
Nitrogen	=	N
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

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INCIDENCE OF INSECT PESTS ON CAULIFLOWER AND THEIR MANAGEMENT

ABSTRACT

The study was conducted in research field of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka in order to study the incidence of insect pests on cauliflower and management of major pests. Five treatments such as Sevin, Abamectin, Spinosad, Cypermethrin and control were used in this study. The experiment was conducted in a randomized complete block design (RCBD) with four replications. Eight insect pests such as diamond back moth (*Plutella xylostella* L.), cabbage butterfly (*Pieris brassica*e), tobacco caterpillar (*Spodoptera litura* Fab.), mustard aphid (*Lipaphis erysimi* (Kalt.), flea beetle (*Phyllotreta cruciferae* Goeze.), painted bug (*Bagrada cruciferarum* Kirk.), whitefly (*Bemisia tabaci* Genn.) and cabbage aphid (*Brevicornye brassicae* L.) was found to infest cauliflower in field of which the former four was frequently observed and the latter were appeared in traces. Population of diamondback moth, tobacco caterpillar, cabbage butterfly and aphid were gradually increased with the age of the crop and the peak population was observed at 45^{th} SW, at 48^{th} SW, at 45^{th} SW and at 51^{st} SW, respectively. In context of controlling insect pests of cauliflower, the lowest number of diamondback moth caterpillar population (0.42 larvae per plot), aphid (13.08 aphids per plot), tobacco caterpillar (0.98 larvae per plot) and cabbage caterpillar population (0.13 larvae per plot) obtained from Spinosad. The same treatment also gave the highest curd yield (51.48 t ha^{-1}) of cauliflower. Considering pest infestation, curd yield and environmental safety, spinosad may be used for the management of major insect pests of cauliflower.

CHAPTER I

INTRODUCTION

Vegetables are an important part of our balanced diet as they provide vital protective nutrients like minerals vitamins and crude fibre. Cauliflower, *Brassica oleracea* L. var. *botrytis* L. belonging to the family Brassicaceae is one of the most popular vegetable crops grown throughout the world in respect of area production and availability almost around the year. Cauliflower belongs to the cole group of vegetables which originated from wild ancestor *Brassica oleracea* var. sylvestris found along the coast of the Mediterranean Sea. It is rich in minerals (Phosphorus, Potassium, Calcium and Iron), Carbohydrate and vitamins (A, B1 and C). It has anti cancer properties, it protects against Bowel cancer due to the presence of Indole-3- carbinol.

The world trade market of cauliflower (*Brassica oleracea* L. var. *botrytis* L.) used to be occupied mainly by western countries. Until 2011, the total amount of world cauliflower import trade was 8.701 billion dollars, which was increased 39.30 times of that in 1961. The total amount of world cauliflower export trade was 11.363 billion dollars, which was increased 68.79 times of that in 1961 (Li *et al.*, 2014). The productivity and profitability of cauliflower cultivation in Bangladesh is high. It is the reason behind the position of Bangladesh in top ten list of cauliflower producer. A tropical location, lush greenery, moisture-rich loamy soil and production-friendly climate make Bangladesh one of the notable growers of a vast range of fruits and vegetables of impeccable quality.

One of the major limiting factors in the production of cauliflower is the extensive crop devastations caused due to increased pest menace. Cole crops are more prone to insect pests and diseases mainly due to their tenderness and softness as compared to other crops and virtual absence of resistance characters, because of intensive hybrid cultivation. Among the yield limiting factors, insect pests are great one and sometimes cause complete failure of the crop. The insect pests namely, aphid (*Brevicoryne brassicae* L. and *Lipaphis erysimi* K.), diamondback moth (*Plutella xylostella* L.), cabbage borer (*Hellula undalis* F.), cabbage looper (*Trichoplusia ni* H.), leaf webber (*Crocidolomia binotalis* Z.), painted bug (*Bagrada cruciferarum* K.), cabbage butterfly (*Pieris brassicae* L.) and tobacco caterpillar (*Spodoptera litura* Fab.) are important (Badjena and Mandal 2005).

Diamondback moth, *P. xylostella* (L.) has become the most destructive insect pest of Brassica vegetables (*B. oleracea* L.) worldwide. Crop damage is caused by larval feeding or the presence of larvae contaminating produce. Although they are small relative to other lepidopteran pests, larval densities can reach levels that result in total destruction of leaves, leading to tremendous economic losses. Damage occurs when first-instar larvae mine leaf tissue, while later instars consume leaf tissue from the underside of leaves, chewing irregular patches, and often leave the top epidermal layer and leaf veins with a window-like appearance.

Cabbage aphid (*L. erysimi* L.) is a common and destructive pest which in some seasons causes serious losses of cauliflower, broccoli, Brussels sprouts, cabbage, oilseed rape, and swede. Aphids cause damage and lower agricultural yields in several ways. They can build to high population densities, removing plant nutrients, and may damage plants by removing enough sap to cause withering and death. If not washed off, aphid honeydew excrement can build enough on plants to be a growth medium for sooty molds that impair photosynthesis (Kawada and Murai 1979).

The tobacco caterpillar, *S. litura* (Fabricus) is encountered as a sporadic pest feeding on crops and plants of economic importance mainly tobacco, cole crops, sunflower, castor, tomato, and soybean etc. It is found throughout the tropical and sub-tropical parts of the world. It is wide spread in Bangladesh and has been recorded on 63 plant species belonging to 22 families (Prasad and Bhattacharya, 1975) causing considerable damage by defoliation. The larvae attack the crop normally in the month of August and September during late vegetative and early, reproductive stages of the crop. The newly hatched larva, scrape the chlorophyll content and feed voraciously.

The cabbage butterfly, *P. brassicae*, also called large white, cabbage white, cabbage moth, or in India the large cabbage white, is a butterfly in the family Pieridae. As an oligophagous insect *P. brassicae* has been accredited with, or has been observed feeding upon, an extraordinarily large number of plants, but by far the most important of these belong to the Cruciferae family.

Farmers are using chemical pesticides and in a desperate to save their crop sometimes apply more than the required number of sprays survey conducted in Bangladesh reported excessive use of pesticides on cauliflower and cabbage. This overuse of pesticides leads to the problem of the pest developing resistance against the recommended pesticides, insecticides-induced resurgence of insect pest, adverse effect on non-target organism and pesticide Residue in food commodities and environment which leads to health problems as well as environmental pollution.

Pesticide is a key component of integrated pest management (IPM), help out an important role in increasing agricultural production. The sole use of older chemicals has lead to the problem of residues as farmer is dependent on the broad spectrum insecticide which has higher persistency. To overcome this problem a newer group of insecticides has been introduced such as neonicotinoids and Botanicals such thiamethoxam, spinosad, acetamiprid, emamectin benzoate etc.

However, to successfully implement the controlling measures, knowing the population dynamics and information of seasonal abundance of different insect pests is a pre-requisite.

Keeping above-mentioned information in view, the present study was undertaken to-

i. To study the seasonal incidence of major insect pests of cauliflower.

ii. To evaluate the effectiveness of some insecticides against major insect pests of cauliflower.

CHAPTER II

REVIEW OF LITERATURE

The present investigation was designed to study the succession of major insect pests of cauliflower (*Brassica oleracea* L var. *botrytis*) and their bio-rational management. A perusal of literature regarding the floral biology, global production scenario of cauliflower, succession, and seasonal abundance of major insect pests of cauliflower, the effectiveness of the treatments have made us believe that they may be utilized in improving the different aspects of cauliflower production. The reviews of literature relating to various above-mentioned aspects of cauliflower are elucidated under different sub-heads.

2.1. Taxonomic position and center of origin of cauliflower

The one indisputable taxonomic treatment of cauliflower appears to be that it belongs to the species *B. oleracea* L. Below the species level a generally accepted treatment is to classify cauliflower as *B. oleracea* L. convar. *botrytis* (L.) Alef. var. *botrytis* L., with the other component of convar. *botrytis* being var. *cymosa* Duch., the sprouting broccoli. However, subspecific treatments give undue importance to the presence or absence of a large, terminal, white curd. Moreover, they appear to be based on inadequate knowledge of the ranges of variation of cauliflower and its most closely related crop type, broccoli and bear little relationship to the phylogenetic relationships of these crops. In short, we believe the published taxonomies of cauliflower serve to confuse rather than clarify genetic relationships (Crisp and Tapsell 1993).

2.2. Phylogeny and center of origin

A wild, annual, eastern Mediterranean subspecies of *B. oleracea*, known as *B. nivea*, and characterized by its white flowers borne in a cyme, was domesticated several thousand years ago as a primitive form of broccoli, with terminal and perhaps lateral shoots of dense flower buds as the edible portion (Allen *et al.*, 1986).

This crop type was taken east, to southern China, where it developed into the only Chinese 'endemic' crop of *B. oleracea*, the Chinese broccoli or kale, sometimes known as *B. alboglabra.* This is a branched annual, usually with white flowers, although yellow-flowered forms occur, perhaps as a consequence of introductions of other *B. oleracea* crops within the last few centuries (Crisp 1982).

The ancestral broccoli was also taken west, resulting in many forms becoming established around the Mediterranean, probably as a consequence of hybridizations with other wild and cultivated *B. oleracea* crop types. Notably, hybridization with the yellow-flowered, racemose, biennial western European 'wild cabbage' gave rise to biennial types. At least 500 years ago, selection for increased terminal head size resulted (perhaps as a consequence of major gene mutation) in a greatly enlarged, immature floral button-the curd, associated with decreased lateral branching from the stem below the curd. This phenotype may have arisen repeatedly within the diverse broccoli gene pool, or may have spread by intentional or accidental introgression (Figdore *et al.* 1988, Gray 1982, Gustaffson 1982).

Over the course of several hundred years many local types of cauliflower (as characterized by a large terminal curd) and broccoli (with large terminal heads of tightly packed flower buds, or with many side branches) became stabilized around the Mediterranean and in Europe. Annual cauliflowers became important crops in several inland regions, and biennial cauliflowers (giving curds from late autumn until early summer) were developed in coastal regions where winter temperatures were buffered by the sea (Hoser-Krause *et al.* 1982).

Within the last two or three hundred years European colonization, notably by the British, resulted in diverse types of cauliflowers being taken to India and Australia, where genetic recombination gave distinct types, some of them adapted to tropical conditions. At least some of the adaptation shown by tropical cauliflowers may have arisen by mutation. Hoser-Krause and Gabryl (1978) identified a single dominant gene conferring 'tropical' characteristics to an Indian cultivar in comparison with a European annual cultivar; in further experiments, they found evidence of cytoplasmic effects on the tropical phenotype. Much recent breeding has concentrated on annual, white-curded types of cauliflower (and of annual, green-headed broccoli) with large, worldwide sales of seed. Regionally adapted types of both cauliflower and broccoli, many of them biennial types, have been neglected, or at best have been improved as open-pollinated populations.

As communications and marketing methods have changed, many of these older forms have diminished in importance, in some cases being replaced by the highly bred types of cauliflowers and broccolis. It should be clear from the foregoing argument that a taxonomy in which 'cauliflower' is characterized by a large, terminal, white curd correctly identifies the types now of major economic importance, but is too arbitrary to describe evolutionary or genetic relationships within the cauliflower/broccoli complex. There is a need, as for many types of crop plants, for a taxonomic treatment which addresses these relationships. New techniques of genomic analysis, such as the creation of restriction fragment length polymorphism linkage maps for *Brassica* should help in this respect (Song *et al.* 1988, Snogerup 1981).

2.3. Botany and floral biology of cauliflower

Cauliflower, i.e. *B. oleracea* var. *botrytis* has diploid chromosome No. as 2n = 2x = 18. In meiosis, pairing of homologous chromosomes occurs. Sometimes bivalents show a secondary pairing. In *B. oleracea*, for example, three groups of two bivalents and three groups of one bivalent each have been found like this. From this secondary pairing of mono-genomic *Brassica* species it has been concluded that they have a basic chromosome number of six i.e. *B. oleracea* can be indicated as AA BB CC DEF, *B. campestris* as AA BB CC DD EF and *B. nigra* as AB CD EE FF (Smyth 1995).

The stem of the vegetative cauliflower plant is rather short, and it thickens to about the same extent as that of cabbage. The leaves are large, generally oblong, the younger ones being nearly always sessile. In contrast to situation in other cole crops, buds do not usually arise in the leaf axils (Anthony *et al.* 1996). During the transition to the generative phase, which, in contrast to the situation in most other cole crops, is accomplished in many types of cauliflower in the first year, the peduncles in the axils of the bracts formed by the main growing point branch repeatedly, so that branches even of the fifth-order can arise.

At first, the numerous peduncles do not grow lengthwise but become thick and fleshy. Thus, a colorless, roughly spherical, terminal compact head arises, of which, the upper surface consists of vast numbers of naked apical meristems. The peduncles are composed of thin-walled parenchyma and vascular bundles which do not become woody.

The young „curd" is at first entirely covered by the foliage, on becoming visible it already has a diameter of over 5 cm. After some time the flower stems elongate, and a number of the apices develop into normal flowers. According to Sadik (1962), soon after floral primordia appear some of the 2^{nd} order branches bearing them elongate leaving other non-elongated 2^{nd} order branches behind. These later bear lateral floral primordia which abort.

Later, several 3rd order branches with floral primordia around their apex elongate leaving behind the rest of the 3rd order branches with abortive floral primordia.

These processes of elongation and abortion may be repeated till floral primordia develop into normal flowers. There are 4 sepals, 4 petals, 6 stamens, and two carpels. The carpels form a superior ovary with the false septum and two rows of campylotropous ovules. The androecium is tetradynamous, i.e. there are two short and four long stamens. The pollen grains are 30-40 μ in diameter and have three germination pores. The bright yellow petals become 15-25 mm long and about 10 mm wide. The sepals are erect.

The buds open under the pressure of the rapidly growing petals. This process starts in the afternoon, and usually, the flowers become fully expanded during the following morning. The anthers open a few hours later, the flowers being slightly protogynous. The flowers are pollinated by insects, particularly bees, which collect pollen and nectar.

The nectar is secreted by two nectaries situated between the basis of the short stamens and the ovary. Situated outside the basis of the pairs of long stamens are also two nectaries, but these are not active. Flowers are borne in racemes on the main stem and its branches. The inflorescence may attain a length of 1-2 m, but the slender pedicels are only 1.5-2 cm long. The fruits are glabrous siliques, 4-5 mm wide and sometimes over 10 cm long, with two rows of seeds lying along the edges of the replum (false septum, an outgrowth of the placentae).

A silique contains 10-30 seeds. Three to four weeks after the opening of the flower from which it is formed, the silique reaches its maximum length. When it is ripe, dehiscence takes place through the two valves breaking away from below upwards, leaving the seeds attached to the placentas (*Sharma et al.* 2004).

2.4. Health benefits of cauliflower

There is hardly any house where it is not regularly used as a vegetable. With the development of tropical types in cauliflower in addition to temperate types, it has now become possible to grow this vegetable almost throughout the year particularly in the Northern and central parts of India. Cauliflower growers may be benefited by growing this crop to a great extent near large cities or by sending the produce to distant places where they can fetch better prices. It is generally used as a cooked vegetable either singly or mixed with potato as fried or in curry form. Small pieces of cauliflower can be fried with besan for the preparation of pakoras. Grated cauliflower is used to prepare stuffed parathas. It is also used in the preparation of pickles with other vegetables.

Cauliflower has high nutritional value because of its high levels of antioxidant compounds, that is, molecules capable of slowing or preventing the oxidation of DNA, proteins, carbohydrates, and lipids. Oxidation reactions produce reactive oxygen species (ROS), which cause major endogenous damage in biological systems. Normal essential metabolic processes in the human body, as well as external sources, such as exposure to air pollutants, industrial chemicals, and cigarette smoking, cause the constant generation of ROS. ROS are chemically reactive species containing oxygen, namely superoxide radical anion ($^{-}O_2$), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH^-), and singlet oxygen ($^1O_2$). ROS include both free radicals, that is, molecular species that contain an unpaired electron and have a tendency to donate oxygen to other substances, and nonradical species. To gain stability, free radicals capture electrons quickly from donor compounds and the attacked compound becomes a free radical itself, which continues to attack other compounds thereby generating free radicals. The antioxidants are able to terminate these chain reactions by removing free radical intermediates and inhibit other oxidation reactions by being oxidized themselves

(Talreja and Moon 2015). Oxidative damage inflicted by ROS is also referred to as "oxidative stress," and reflects a shift in the prooxidant-antioxidant balance in favor of the former (Di Mascio *et al.* 1991). The damage caused by excessive production of ROS contributes to many common illnesses, such as cardiovascular disease, certain prenatal complications, malignant tumors, inflammations (e.g., rheumatic joint inflammation), cataracts, Parkinson‟s disease, and Alzheimer‟s disease, as well as accelerating the aging process.

Brassica extracts are reported to possess the cancer-preventive activity and antioxidant capacities (Cartea and Velasco 2008). The health benefits of cauliflower are related to its high levels of major antioxidants, such as ascorbic acid, polyphenols, or carotenoids, but most of the studies regarding the anticarcinogenic properties of Brassica vegetables have mainly been ascribed to glucosinolates and their hydrolytic and rearrangement products, named isothiocyanates. These compounds have shown multifaceted chemopreventive activities against cancer, including the modulation of phase 1 and phase 2 enzymes to block carcinogenesis, and induction of apoptosis and cell cycle progression to inhibit the growth of malignant cells (Tang *et al.* 2013). The potent chemopreventive activities of dietary isothiocyanates have been established in multiple cancer models, including bladder, colon, liver, lung, mammary gland, and esophagus, in both in vitro and in vivo systems. Most of these studies have focused on sulforaphane, an isothiocyanate derived from glucoraphanin, and indole-3-carbinol (I3C), an indole compound derived from the hydrolysis of glucobrassicin. Indole-3-carbinol is chemically unstable in aqueous and gastric acidic environments, such as those encountered under cell culture conditions and the acidic environment of the stomach in vivo. In acidic conditions, I3C is rapidly converted to numerous condensation products, of which 3, 3`-diindolylmethane (DIM) is the most active and effective metabolite, that have been shown to inhibit the growth of cancer cells (Cartea and Velasco 2008, Moiseeva *et al.* 2007). In particular, I3C and DIM have also been reported to have strong activity on estrogen metabolism and have gained attention for their potential chemopreventive activity in hormone-dependent tumors (such as breast, prostate, or cervical cancer).

Glucosinolate hydrolysis products from glucoiberin, glucoerucin, sinigrin, and progoitrin have also been reported to possess anticancer effects (Cartea and Velasco 2008). Higdon *et al.* (2007) reviewed a number of epidemiologic studies that provide some evidence that a high intake of cruciferous vegetables is associated with decreased human cancer risk. In their work, the authors underline that the protective effects may be influenced by individual genetic variation in the metabolism and elimination of isothiocyanates from the body. Isothiocyanates, such as sulforaphane, phenethyl isothiocyanate, and benzyl isothiocyanate, as well I3C, have been shown to block the carcinogen activation in phase I metabolization by inhibiting enzymes of the cytochrome P450 family and inducing phase II enzymes, such as glutathione S-transferases, thus accelerating the clearance of carcinogens from the body (Baena Ruiz and Salinas Hernandez 2016).

Cauliflower, as well as other Brassicaceae, also displays an interesting selenium metabolism, with the production of selenoamino acids, such as selenomethionine and selenocysteine. For this reason, the health benefits of cauliflower are also associated with the dietary intake of selenium. In fact, selenium deficiency seems related with reduced human fertility, reduced immune and cognitive function, heart disease, hyperthyroidism, as well as with an increased risk of certain types of cancer (Matich *et al.*, 2012). More than this, recently, Matich *et al.* (2012) reported the presence of selenium in the glucosinolates and their aglycones in cauliflower florets. These findings are considered of particular importance since some studies reported that synthetic selenium-containing isothiocyanates are more effective at suppressing cancers than their sulfur counterparts (Emmert *et al.* 2010, Sharma *et al*. 2009).

2.5. Global cauliflower production scenario

The world trade market of cauliflower (*Brassica oleracea* L. var. *botrytis* L.) used to be occupied mainly by western countries. Until 2011, the total amount of world cauliflower import trade was 8.701 billion dollars, which was increased 39.30 times of that in 1961. The total amount of world cauliflower export trade was 11.363 billion dollars, which was increased 68.79 times of that in 1961. In recent 50 years, cauliflower cultivation areas in China were increased 11.28 times and the total production was increased 22.09 times. China has become the largest cauliflower producing country in the world (*Li et al.* 2014).

In 2019 (Table 1), China produced 10.64M tons of cauliflower and was champion among the cauliflower producers globally. They solely shared 39.56% of production quantity in 2019. After China, India was the 2nd highest cauliflower producer worldwide and cut 33.78% global production share. They produced 9.08M tons cauliflower in 2019. The 3rd position was possessed by USA. They produced 1.25M tons cauliflower though it was comparatively lower than those of China and India. Subsequently, USA shared 4.64% of total cauliflower production in 2019. Production quantity was then followed by Mexico (717.42K tons), Spain (707.5K tons), Italy (368.15K tons), Turkey (315.28K tons) and Bangladesh (284.33K tons) sharing 2.67%, 2.63%, 1.37%, 1.17% and 1.06% of global cauliflower production (Tridge 2021).

Table 1. Top 10 Global cauliflower producers

Rank	Country	Production Quantity (tons)	% Share
1	China	10.64M	39.56
2	India	9.08M	33.78
3	USA	1.25M	4.64
4	Mexico	712.42K	2.67
5	Spain	707.5K	2.63
6	Italy	368.15K	1.37
7	Turkey	315.28K	1.17
8	Bangladesh	284.33K	1.06
9	Poland	282.50K	1.05
10	France	257.77K	0.96

According to a study, Per acre gross cost of production of cauliflower and cabbage were Tk. 93860.55 and Tk. 92135.8, respectively and the corresponding gross returns were Tk. 229407.4 and Tk. 230800, respectively. Per acre net returns of producing cauliflower and cabbage were Tk. 135546.85 and Tk. 138664.2, respectively. Benefit cost ratios of cauliflower and cabbage production $acre^{-1}$ were 2.44 and 2.50, respectively (Somajpoti *et al.* 2016).

The productivity and profitability of cauliflower cultivation in Bangladesh is high. It is the reason behind the position of Bangladesh in top ten list of cauliflower producer. A tropical location, lush greenery, moisture-rich loamy soil and production-friendly climate make Bangladesh one of the notable growers of a vast range of fruits and vegetables of impeccable quality.

2.6. Major insect pests of cauliflower

One of the major limiting factors in the production of cauliflower is the extensive crop devastations caused due to increased pest menace. Cole crops are more prone to insect pests and diseases mainly due to their tenderness and softness as compared to other crops and virtual absence of resistance characters, because of intensive hybrid cultivation. Among the yield limiting factors, insect pests are great one and sometimes cause complete failure of the crop. The insect pests namely, aphid (*Brevicoryne brassicae* Linn. and *Lipaphis erysimi* Kalt.), diamondback moth (*Plutella xylostella* Linn.), cabbage borer (*Hellula undalis* Fab.), cabbage looper (*Trichoplusia ni* Hub.), leaf webber (*Crocidolomia binotalis* Zell.), painted bug (*Bagrada cruciferarum* Kirk.), cabbage butterfly (*Pieris brassicae* Linn.) and tobacco caterpillar (*Spodoptera litura* Fab.) are important (Badjena and Mandal 2005).

2.6.1. Diamondback moth, *Plutella xylostella*

Diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), has become the most destructive insect pest of Brassica vegetables (*Brassica oleracea* L.) worldwide, with annual management costs estimated in the billions of dollars (Zalucki *et al.*, 2012). The importance of this insect is evidenced by the formation of the International Working Group on Diamondback Moth, as well as it being one of the few insects to have had a regular series of international conferences on its biology and management.

2.6.1.1. Host range of Diamondback moth, *Plutella xylostella*

P. xylostella is not native to the United States and is believed to have originated in either the Mediterranean region or southern Africa (Talekar and Shelton 1993, Kfir 1998). The assessment of its origin being in southern Africa is based on the diversity of parasitoids attacking *P. xylostella* as well as the large number of indigenous *Brassica* species present in that area (Kfir, 1998). Today, it can be found wherever crucifers are grown and is believed to be the most universally distributed of all Lepidoptera (Talekar and Shelton 1993). *P. xylostella* was first observed in North America in Illinois in 1854, but quickly spread across the continent (Capinera 2001). In warmer climates, *P. xylostella* overwinters as an adult. Although adults are weak fliers, they are known to move over long distances and reinvade areas annually. Movement also occurs when eggs, larvae, and pupae are moved on transplants from southeastern states to northern states (Shelton *et al.* 1996). Furthermore, these migrating insects are often resistant to many insecticides used by growers.

Larvae are specialists, feeding only on plants in the Brassicaceae, and although it has been reported that strains have adapted to pea, *Pisum sativum* L. (Löhr and Gathu 2002), it is unclear whether they will survive long-term in the field on peas. The Brassicaceae contains ~350 genera and >3,000 species of herbaceous plants. Originating in Europe and eastern Asia, it is a cool-season plant family that includes numerous cultivated crops. Plant chemicals common in this family, glucosinolates, are used by *P. xylostella* as egg-laying stimulants (Hillyer and Thorsteinson 1971, Nayar and Thorsteinson 1963). Virtually all cruciferous vegetables are attacked by *P. xylostella* including all varieties of *B. oleracea* as well as mustard, *Brassica* spp.; radish, *Raphanus sativus* (L.); turnip, *Brassica rapa* (L.); Chinese cabbage, *B. rapa* var. *pekinensis*; and watercress, *Nasturtium officinale* (W.T. Aiton) (Capinera 2001). *P. xylostella* also feeds on many cruciferous weeds common throughout the United States, including yellow rocket, *Barbarea vulgaris* (Aiton); shepherds purse, *Capsella bursa-pastoris* (L.); pepper weed, *Lepidium* spp.; and wild mustards, *Brassica* spp. These weeds serve as important alternate hosts, especially in spring before cruciferous vegetable crops are planted (Talekar and Shelton 1993).

2.6.1.2. Nature of damage by Diamondback moth, *Plutella xylostella*

Crop damage is caused by larval feeding or the presence of larvae contaminating produce. Although they are small relative to other lepidopteran pests, larval densities can reach levels that result in total destruction of leaves, leading to tremendous economic losses. For example, a single outbreak in California led to losses in excess of US$6 million (*Shelton et al.* 2000, Sances 1997). In addition, for crops such as broccoli, the presence of larvae in florets can result in the total rejection of shipments (Capinera 2001). Globally, a conservative estimate of the total costs associated with management of *P. xylostella* was US$4 –5 billion annually (Zalucki *et al.* 2012). Production of *Brassica* spp. in the United States over the past 20 years has averaged ~1.7 million tons per year, making up ~4% of the global production, with an estimated management cost for *P. xylostella* around US$150–200 million (FAOSTAT 2013, Zalucki *et al.* 2012).

Damage occurs when first-instar larvae mine leaf tissue, while later instars consume leaf tissue from the underside of leaves, chewing irregular patches, and often leave the top epidermal layer and leaf veins with a window-like appearance. Collards are grown primarily in the southeastern states and are particularly vulnerable to serious economic losses because *P. xylostella* has a strong preference for this crop (Mitchell *et al.* 2000, Harcourt 1957). Unlike most other Brassica vegetables, collard leaves, which *P. xylostella* larvae feed on, are the marketable portion of the crop.

2.6.1.3. Seasonal abundance of Diamondback moth, *P. xylostella*

According to the study of Ahmad and Ansari (2010), seasonal abundance of *P. xylostella* on cauliflower was significantly/non-significantly affected by temperature, humidity and rainfall as well as parasites in three localities of Aligarh i.e. Mathura Road, G.T. Road and Punjipur village from July 2004 to April 2005 and in the same months in 2005–2006. They found that the highest population of DBM was found on 18th September 2005 and then began to decrease and an increase was monitored in III week of March 2006, where 17.49 larvae and pupae/plant were monitored at a temperature fluctuating between 13.41 to 24.84°C and relative humidity of 59.30 to 89.00 percent. *P. xylostella* continued to infest even after 15th April 2006 where temperature ranged from 22.38 to 38.43°C and relative humidity was 42.80 to 71.00 percent.

A number of abiotic and biotic mortality factors interacting together that affect the natural intrageneration population dynamics of *P. xylostella* (Syed and Abro 2003, Keinmeesuke *et al*. 1992). A significantly high build-up of larval population of *P. xylostella* was monitored during rainy season (July-September) as compared to other factors (Nagarkatti and Jayanth 1982). Climatic conditions, including higher temperatures and decreased rainfall were cited as major factors which regulate the population dynamics of *P. xylostella* (Harcourt 1986) 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. Although egg production and larval survival of *P. xylostella* are inhibited by temperature above 30°C (Yamada and Kawasaki 1983).

Khaire *et al.* (1987) studied seasonal incidence of diamondback moth, *P. xylostella* on cabbage and observed that the incidence of diamondback moth reached its peak in the first fortnight of February. Gera and Bhatnagar (1992) found that larvae of diamondback moth, *P. xylostella* cause significant damage to cabbage. The infestation of the larvae of diamondback moth was noticed in the 2^{nd} week of December and maximum population was recorded in 1^{st} week of February.

Kandoria *et al.* (1996) reported that larvae of diamondback moth, *P. xylostella* were infesting cruciferous host plants throughout the year. The peak was recorded from September to October. Chaudhuri *et al.* (2001) observed that population of diamondback moth, *P. xylostella* reached to maximum in the last week in March on the spring season on cabbage crop. The larval population of diamondback moth showed positive correlation with average temperature, relative humidity and total rainfall and negative correlation with sunshine hours per day.

Shukla and Kumar (2004) reported that *P. xylostella* started attacking the cole crops initially in the first week of December and last week of November during 2000-01 and 2001-02, respectively. The population of *P. xylostella* touched its peak in the fourth week of January in both the years. The pest population was negatively correlated with mean temperature and mean relative humidity during 2000-01, while during 2001-02, a negative correlation with mean temperature and positive correlation with mean relative humidity was recorded.

2.6.2. Aphid, *Lipaphis erysimi*

Cabbage aphid (*L. erysimi* (L.)) is a common and destructive pest which in some seasons causes serious losses of cauliflower, broccoli, Brussels sprouts, cabbage, oilseed rape, and swede. By the time a crop has become heavily infested serious injury will already have occurred, so attacks must be checked early. This aphid can also transmit the virus that causes cauliflower mosaic disease**.**

2.6.2.1. Host range of Aphid, *Lipaphis erysimi*

Lipaphis erysimi is a cosmopolitan pest of cruciferous crops. It can occur in large colonies on the undersides of leaves or in inflorescences of many species and genera of Brassicaceae, including *Barbarea*, *Brassica*, *Capsella*, *Erysimum*, *Iberis*, *Lepidium*, *Matthiola*, *Nasturtium*, *Raphanus*, *Rorippa*, *Sinapis*, *Sisymbrium*, and *Thlaspi*. Often, the leaves are curled and turn yellow. It is a vector of about 10 non-persistent viruses, including Turnip mosaic virus and Cauliflower mosaic virus. It occurs throughout the world, but particularly is a pest in warmer climates, reproducing throughout the year by continuous parthenogenesis.

Although most *Lipaphis* populations throughout the world are continuously parthenogenetic, a holocycle does occur on cruciferous crops (*Brassica rapa*, *Raphanus sativus*) in western Honshu, Japan (Kawada and Murai 1979). These aphids have 2n= 8, and thus differ in karyotype from holocyclic populations of *L. erysimi* in Northern Europe. Chen and Zhang (1985) also reported 2n= 8 for *Lipaphis* in China. In West Bengal, *Lipaphis* populations are economically important on field crops of mustard, *Brassica nigra*, and here the common karyotype is also 2n= 8 (Kar and Khuda-Bukhsh, 1991). Sexual morphs have been reported from northern India, but populations there are probably mostly anholocyclic. Most permanently parthenogenetic *Lipaphis* populations throughout the world have a 9-chromosome karyotype, probably derived from the 8chromosome form by dissociation of one autosome to produce a small, unpaired element.

2.6.2.2. Nature of damage by cabbage aphid, *Lipaphis erysimi*

Aphid damage is among the most serious of agricultural and horticultural problems. A pest aphid species may affect only a very specific crop, a group of related crop hosts (e.g., crucifers), or may be quite polyphagous within and between plant families. Many of the notoriously polyphagous aphid pests represent sibling species complexes that are morphologically identical but differ in karyotype. Generally, such aphid pests comprise anholocyclic clones, or biotypes, that differ in host preferences, the ability to transmit diseases, or resistance to pesticides.

Aphids cause damage and lower agricultural yields in several ways. They can build to high population densities, removing plant nutrients, and may damage plants by removing enough sap to cause withering and death. If not washed off, aphid honeydew excrement can build enough on plants to be a growth medium for sooty molds that impair photosynthesis and promote other fungal diseases. Salivary secretions of some aphids are phytotoxic, causing stunting, leaf deformation, and gall formation, which is of particular concern to horticulture.

Even if otherwise asymptomatic, aphid-feeding effects may affect plant hormone balances changing host metabolism to their advantage and essentially hijacking the plant‟s physiological functions. The most serious problem posed by aphids is the vectoring of plant viruses. Virus-infected plants often show an aphid-attractive yellowing and have increased free amino acids, so aphids benefit by virus transmission. Stylet-borne viruses, occurring on the aphid‟s epidermis, are not aphid specific. They are acquired quickly and transmitted during rostral probing of the plant‟s epidermis. These are non-persistent viruses whose infectiousness is lost when the aphid molts.

Circulative viruses, in contrast, live in the aphid‟s gut and require an incubation period before successful transmission. They are persistent viruses and an aphid, once infected, remains a vector for life. Circulative viruses have fairly specific virus -aphid - plant linkages and any given virus is transmitted by only one or few aphid species.

2.6.2.3. Seasonal abundance of aphid, *Lipaphis erysimi*

Sachan and Srivastava (1972) studied the seasonal incidence of insect pests of cabbage at Jobner (Rajasthan) from 1967 to 1970 i.e. three successive years. They reported four important pests of cabbage, viz., cabbage borer, *Hellula undalis* (Fab.); cabbage looper, *Trichoplusia ni* (Fab.); diamondback moth, *Plutella xylostella* (L.) and aphid, *Lipaphis erysimi* (Kalt.). Aphids appear in the month of November and remains low until middle of December, after which it starts increasing. Rise in temperature after winter favors multiplication of aphid population and high temperature after March onwards has adverse effect on it.

Agarwal and Dadheech (1990) studied the incidence of aphid, *L. erysimi* on some cruciferous crops during Rabi 1988-89 and reported that *L. erysimi* appeared in November on cauliflower, cabbage and mustard crops and peaked during last week of January to first week of February. A significant negative correlation was observed in pest population and temperature, while there was a positive correlation with relative humidity.

Swami (1995) studied the incidence of aphid, *L. erysimi* on cabbage crop during 1994-95 and reported that the infestation of aphid started in the first week of December and increased slowly up to second week of January and then increased rapidly to the extent of 50 aphids per plant in the last week of January when the mean temperature and relative humidity, were 15.60^0C and 57.05 per cent, respectively. Increase in pest population was negatively correlated with mean temperature and positively correlated with mean relative humidity.

Patidar and Dadheech (2000) observed that aphid, *L. erysimi* appeared in the last week of November on cabbage with its peak in second week of January. Malik et al. (2000) reported that the population of cauliflower aphid, *B. brassicae* fluctuated from 51^{st} metrological week to 4^{th} meteorological week. The correlation between aphid population and maximum-minimum temperatures were negative and with morning relative humidity it was positive.

Chaudhuri *et al.* (2001) studied the fluctuation of aphid, *L. erysimi* population on cabbage and their reaction with prevailing weather conditions of terai region of West Bengal during winter and spring season. They observed that the population of aphid reached maximum during 3^{rd} week of March on spring crop. The population of aphids was recorded in both the season but it was higher on spring crop. During winter seasons the aphid population was negatively correlated with temperature, sunshine and total rainfall and positively with average relative humidity and during spring season it was positively correlated with relative humidity and total rainfall.

Nayak *et al*. (2001) studied the seasonal abundance of the aphid, *L. erysimi* on different cruciferous crops at weekly intervals from the first week of December to second week of February. The population of aphid per plant was lowest (3.51) on turnip and highest (6.08) on cabbage. The maximum aphid population was recorded in the second week of January, i.e., 42.95, 22.95, 22.30, 17.35, 16.32 and 11.72 aphids per plant, on Indian mustard, cabbage, cauliflower, knoll khol, radish and turnip, respectively, thereafter, the aphid number declined. Overall, the mean aphid population during the season was highest (10.59) on radish and lowest (6.97) on turnip. Zaz (2001) studied the incidence of cabbage aphid, *B. brassicae* on cauliflower and cabbage crops and recorded maximum aphid population (17.4 aphids /plant) on cauliflower followed by cabbage with 52.8 aphids per plant. The aphid population exhibited non-significant positive and nonsignificant negative correlation with temperature in cauliflower and cabbage, respectively, whereas, it showed a significant negative correlation with relative humidity and rainfall.

Sood (2004) studied on the seasonal population fluctuation of the aphids on cabbage and their predators in treated (Monocrotophos 0.04%, four sprays and endosulfan 0.05%, two sprays) and untreated plots during 1994-95 and 1995-96 at Pantnagar, North India and reported three aphid species, namely *M. persicae, L. erysimi* and *B. brassicae* attacking this crop. However, *M. persicae* was the most abundant aphid species. The peak population of aphid was recorded in 3rd week of February and last week of January in untreated plots, while in the treated plots its peak occurred in 2nd week of February and 2nd week of January during 1995 and 1996, respectively. The peak predators (syrphids and coccinellids) population in treated plots was recorded significantly lower than that of in the untreated plots.

Rao and Lal (2005) studied the seasonal incidence of mustard aphid, *L. erysimi* and diamondback moth, *P. xylostella* on cabbage at Division of Entomology IARI, New Delhi, during 1997-98 and 1998-99. The peak population of *L. erysimi* was observed during fourth week of January. Maximum and minimum temperatures and relative humidity did not showed any significant correlation with the incidence of *L. erysimi* whereas, maximum temperature showed a positive correlation with the population build-up of *P. xylostella*.

Wagle *et al.* (2005) studied the seasonal incidence of aphid, *B. brassicae* and its natural enemies in relation to weather parameters on cabbage during 2004-05 at Allahabad, U.P. and reported that the incidence of aphid commenced from 22 days after sowing, i.e., second fortnight of January (3^{rd} standard week) and reached its peak during first fortnight of March (10^{th} standard week), thereafter a declining trend was observed. The aphid population exhibited non-significant positive correlation with maximum and minimum temperatures and sunshine hours whereas, negative correlation with wind velocity.

Bhavani and Punnaiah (2006) studied the seasonal incidence of aphid, *L. erysimi* in relation to weather parameters. They observed highest population of aphid on cabbage during second week of February, while the minimum population during last week of March. The minimum temperature exerted significant negative effect while, the morning and evening relative humidity showed significant positive relationship with aphid population.

2.6.3. Tobacco caterpillar, *Spodoptera litura* Fab

The tobacco caterpillar, *Spodoptera litura* (Fabricus) (Lepidoptera: Noctuidae) is encountered as a sporadic pest feeding on crops and plants of economic importance mainly tobacco, cole crops, sunflower, castor, tomato, and soybean etc. It is found throughout the tropical and sub-tropical parts of the world. It is wide spread in Bangladesh and has been recorded on 63 plant species belonging to 22 families (Prasad and Bhattacharya 1975) causing considerable damage by defoliation. The insect is reported to complete varying number of generations round the year on various crops.

2.6.3.1. Host range of Tobacco caterpillar, *Spodoptera litura* F

Spodoptera litura is reported to feed on 150 species of plants (Rao *et al.* 1993) causing 26-100 per cent yield loss under field conditions (Dhir *et al.*, 1992); more than 180 crops (*Isman et al.* 2007). It is polyphagous pest, reported damaging more than 112 species of plants belonging to 44 families, of which 40 species are known from India (Chari and Patel 1983) and many other countries (Shivayogeshwara *et al.* 1991). Among the main crop species attacked by *S. litura* in the tropics are *Colocasia esculenta*, cotton, flax, groundnuts, jute, lucerne, maize, rice, soyabeans, tea, tobacco, vegetables (aubergines, Brassica, Capsicum, cucurbit vegetables, Phaseolus, potatoes, sweet potatoes, Vigna etc.). Other hosts include ornamentals, wild plants, weeds and shade trees.

2.6.3.2. Nature of damage by Tobacco caterpillar, *Spodoptera litura* F

The larvae attack the crop normally in the month of August and September during late vegetative and early, reproductive stages of the crop. The newly hatched larva, scrape the chlorophyll content and feed voraciously. This gives the appearance of yellowish white web on the leaves. As the caterpillar matures, they completely defoliate the leaves leaving only midribs and stalks. Larval feeding is vigorous as it advances in age. The soft pods are chewed by the larvae and the thick pods are bored and feed on grain. The habit of larvae is to hide under the plants, cracks and crevices of soil debris during the day time and feeds during night hours. The incidence could be noticed by the faecal pellets left on the leaves (Punithavalli *et al.* 2013). On most crops, damage arises from extensive feeding by larvae, leading to complete stripping of the plants. On cauliflower, leaves are heavily attacked and bolls have large holes in them from which yellowish-green to dark-green larval excrement protrudes.

2.6.3.3. Seasonal abundance of Tobacco caterpillar, *Spodoptera litura* F

Zaz and Kushwaha (1983) studied the abundance of *S. litura* (Fab.) and its natural enemies on cabbage and cauliflower in both Kharif and Rabi seasons and reported that the pest was most abundant on cauliflower in mid-August and November, and on cabbage in early March, but in smaller number than on cauliflower. The pest population on cauliflower showed a significant negative correlation with the average and maximum temperatures in the first crop and a significant positive correlation in the second and a significant positive correlation with relative humidity in both crops.

In Japan, Nakagawa *et al.* (1986) reported seasonal occurrences of adults of four major pests of sweet potato. Adults of *S. litura* were captured from August to November, the highest number of adult catches was observed during midSeptember. According to Lee (1989), the highest number of *S. litura* moths were trapped during December to January and lowest numbers during March to June. The study clearly revealed that high temperature and humidity reduced adult activity between mid-June and October.

Nandihalli *et al*. (1989) studied the population dynamics of *S. litura* using light and pheromone traps and observed that the pest was active throughout the year but higher density observed during July-January, however, there was a significant negative correlation between number of catches and average minimum and maximum temperatures for both traps, and a positive correlation with average morning relative humidity for light trap catches only.

Mishra and Sontakke (1992) monitored the activity of adults of *S. litura* through pheromone traps and reported three population peaks during August to October. The peaks were observed in late August, late November and mid-December of 1987. Similarly in 1989, the pest showed three peaks first during late June, second in early September and third in early October. However, during 1988 the pest attained a peak in early November but substantial population was recorded from early February to mid- March. They further showed that among different meteorological factors, only relative humidity significantly influenced the trap catches.

Kasana *et al.* (1996) reported that from mid-August the population of *S. litura* increased rapidly and the peak population was reached by mid-October. During the 2^{nd} half of October, the population suddenly declined. During the month of November the population remained very low and the larval population almost came to an end by the beginning of December.

Prasad and Wadhwani (2005) revealed first appearance of *S. litura* in 27^{th} and 28^{th} meteorological week and reached to its peak in 34^{th} and 36^{th} meteorological week during 2002 and 2003, respectively, and reported that the correlation between the pest population and the biotic components were significant and positive indicating that the pest incidence was also affected by different other parameters like maximum and minimum relative humidity and average rainfall.

2.6.4. Cabbage butterfly, *Pieris brassicae*

Pieris brassicae, the cabbage butterfly, also called large white, cabbage white, cabbage moth, or in India the large cabbage white, is a butterfly in the family Pieridae. It is a close relative of the small white, *Pieris rapae*. The large white is common throughout Europe, North Africa, and Asia to the Himalayas often in agricultural areas, meadows and parkland. It has managed to establish a population in South Africa and in 1995 it was predicted to spread to Australia and New Zealand (Anon. 1995).

2.6.4.1. Host range of Cabbage butterfly, *Pieris brassicae*

As an oligophagous insect *P. brassicae* has been accredited with, or has been observed feeding upon, an extraordinarily large number of plants, but by far the most important of these belong to the Cruciferae family. This close association between the butterfly and the Cruciferae is manifest in the highly specialized sensory system of the larva and imago and their responses to chemical substances produced by the plant.

Five main plant families, the Cruciferae, Tropaeolaceae, Capparaceae, Resedaceae and the Papilionaceae, have been exploited by *P. brassicae*. These are designated as principal plant families since *P. brassicae* may be found regularly in the wild on any of these species. Eighty-three species of food plant belong to this first group, the largest number of species belonging to the genus Brassica. Wild crucifers playa very important part in supporting first generation larvae of *P. brassicae* in several countries, but most important of all, many crops suffer severe damage (Ansari *et al.* 2012).

A secondary and in some cases doubtful category of *P. brassicae* food plants has been made up to include only those species on which *P. brassicae* has been or would be expected to be found occasionally in the wild. These comprise only eight species from seven other plant families. There are also 15 other species belonging to 10 families including another member of the Umbelliferae (found also in the secondary group) which *P. brassicae* larvae have been induced to eat in the laboratory under unnatural conditions (Lytan and Firake 2012).

2.6.4.2. Nature of damage by Cabbage butterfly, *Pieris brassicae*

The females deposit the eggs singly on the host plants. After 4-8 days, the eggs hatch and the larvae feed and develop through five instars in 10-14 days. When not feeding, the larvae lie along the ribs on the underside of the leaves. Moiseeva (1984) reported that a single larva of *P. brassicae* consumed 61-69 cm^2 of cabbage leaf during its development. Larvae prefer to feed on the youngest (head and wrapper) leaves of cabbage (Hoy and Shelton 1987). 84% of feeding damage is caused by the fifth instar (Wei *et al.* 1983). When mature, larvae fasten themselves to the lower leaf surfaces by silk bands.

2.6.4.3. Seasonal abundance of Cabbage butterfly, *Pieris brassicae*

Gupta (1984) reported that adults appear in mid-February and eggs were laid soon after. There were at least 4 generations before September on cauliflower. Larvae of the first generation were also observed to feed on other Brassica crops (mainly radish and mustard) and also on wild crucifers. It was also reported that the sudden appearance of *P. brassicae* in February is due to migration and the exclusion of overwintering pupae.

Zuranska and Ciepielewska (1985) reported in the Olsztyn region, Poland that the first larvae appeared after 6 days and a large number of eggs was laid in early August and early September, while larval abundance was greatest in mid- August and September. The time of appearance of adults, eggs and larvae and population size depend on weather conditions, especially temperature; high temperatures and low precipitation were favorable.

Mustafaeva (1989) reported in the Lenkoran region of Azerbaijan the seasonal occurrence, number of generations and percentage of the population entering diapause of *Pieris brassicae* which were mainly influenced by changes in day length and ambient temperature. Sachan and Gangwar (1990) reported the incidence of insect pests of cabbage, cauliflower and knol-khol at shillong area of Meghalaya, India, in 1968-1978. *Pieris brassicae* was the major pest and found throughout the year, with maximum activity from February to October.

Chaudhuri *et al.* (2001) investigated the seasonal incidence of several insect pests infesting cabbage cv. Sabitri grown during winter and spring in a field in West Bengal, India, during 1996-98. Cabbage butterfly populations showed positive correlation with average relative humidity and total rainfall. Singh *et al.* (2002) conducted a field experiment in Manipur, India during 1996-97 and 1997-98 to investigate the population dynamics of *Pieris brassicae* on Chinese cabbage. *P. brassicae* infestation was observed throughout the year. Pest was observed from November to February in the heading stage, and from March to June in the ratoon stage. Lal and Ram (2004) reported that cabbage butterflies were an emerging serious pest of Brassica oilseeds in Eastern Uttar Pradesh and other parts of India during Rabi 2001 and 2002. It has been found to cause severe damage to *B. campestris* var. *sarson* in February 2002 and *B. carinata* in March of the same year.

2.6.5. Chemical control of pest complex of cauliflower

Ram and Pathak (1992) reported the effectiveness of carbaryl and dimethoate in reducing *P. brassicae* infestation on cabbage in field trials in Manipur, India. Eleven insecticides were evaluated for control of *P. brassicae* in cabbage cv. Pride of India grew at Barapani, Meghalaya, India, during 1991-92. Plants were sprayed twice, once at the preheading stage and again at post-heading. Overall, fenvalerate gave virtually 100% control of *P. brassicae*, followed by deltamethrin (97.3%), cypermethrin (96.8%), malathion (96.08%) and fenitrothion (93.3%). Chlorpyrifos, quinalphos and diflubenzuron were the least effective of the tested insecticides. The highest yield was obtained in fenvalerate-treated plots. The costbenefit ratio was also highest for fenvalerate (Thakur and Deka 1997).

Destruxins produced by the entomogenous fungus *Metarhizium anisopliae* have been tested for their effects on first instar larvae of *P. brassicae*. Different concentrations of crude destruxin, pure destruxin A, pure destruxin E and a synthetic analogue, Hpy-6 dtx E, were used. First-instar larvae of *P. brassicae* were very sensitive to crude destruxin, exhibiting high mortality levels after 36 hours (Eilenberg and Thomsen 1998).

The use of insecticides in an integrated control programme has to be undertaken with care due to their toxicity to natural enemies. Eleven insecticides at the recommended field dosages were evaluated for their toxicity to the braconid *Cotesia glomerata*. Diflubenzuron, fenvalerate, cypermethrin and deltamethrin proved very safe, whereas malathion, chlorpyrifos and quinalphos proved toxic within 24 hours. Residual toxicity of fenitrothion dropped significantly within 7 days of treatment whereas malathion had significantly high residual toxicity up to 21 days. It was concluded that the use of the above mentioned synthetic pyrethroids and diflubenzuron on cabbage at the recommended dosages was safe to *C. glomerata*. In the case of fenitrothion, release of *C. glomerata* should not be made until 7 days after spraying (Thakur and Deka 1995).

Field studies have been conducted in India using two formulations of neem (extracts of *Azadirachta indica*) against larvae of *P. brassicae* in cabbage fields. Larval mortality was highest 7 days after treatment, with death-rates varying between 73.33 and 86.66%. The neem formulations were safer than the parasitoid *Cotesia glomerata*, which parasitized the *P. brassicae* larvae (Dhaliwal *et al*. 1998). Neem also reduced the survival of *P. brassicae* larvae feeding on cabbage leaves treated with the neem extract (Grisakova *et al.* 2006).

1% azadirachtin water emulsions showed repellent action to *P. brassicae* (Luik and Viidalepp 2001). Aqueous extracts of *Melia azedarach* leaves and seeds have also been shown to have significant antifeedant and deterrent action towards *P. brassicae* (Sharma and Gupta, 2009). Leatemia and Isman (2004) found crude seed extracts of Annona squamosa to be effective against *P. brassicae*. Mixtures of *Piper retrofractum* (Piperaceae) + *Annona squamosa* (Annonaceae) extracts and *Aglaia odorata* (Meliaceae) + *A. squamosa* extracts were found to be effective against *P. brassicae* (Dadang and Djoko 2009).

Klokocar-Šmit *et al.* (2007) investigated the effects of formulations based on *B. thuringiensis* subsp. *kurstaki* and spinosad on *P. brassicae* instars 2, 3, 4 and 5 and found the effect of insecticides to be inversely proportional to larval instars. Spinosad was more effective in inducing mortality and reducing leaf damage by all larval instars than formulations based on *B. thuringiensis* subsp. *kurstaki*. Harris and Maclean (1999) also reported superiority of Spinosad over other pesticides against this pest.

CHAPTER III

MATERIALS AND METHODS

Present study was conducted in the research field of department of entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the rabi season of 2019-20 with a view to assessing the succession i.e. seasonal abundance (incidence and infestation) of major insect pests of cauliflower as well as to study the efficacy of some promising insecticides against pest complex of cauliflower. The materials and methods used for conducting the experiment presented in this chapter under the following headings.

3.1. Description of experimental site

The experiment was conducted during the period from September 2020 to January 2019. Field work was conducted in the experimental area of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental site is situated at 23.074^0/N latitude and 90.0035^0/E longitude with an altitude of 8.2 meter from sea level. In terms of climate, the experimental site is under the subtropical climate and its climatic conditions are characterized by low temperature and scanty rainfall during the winter i.e. rabi season. Soil of the experimental site belongs to “The Modhupur Tract”, AEZ-28. However, the experimental site was flat having a provision of available irrigation and an ample drainage system.

3.2. Planting materials

Hybrid Cauliflower seed White Shark was purchased from local market in order to conduct the current experiment.This variety is black rot disease tolerant, fruits are glowing white, and average fruit weight 1000-1500 g.


Plate 1. Experimental field and healthy cauliflower.

3.3. Treatments of the experiment

There are seven treatments including control (absolute) used in this experiment. Followings are the name of the treatments and respective doses.

Table 2. Treatments of the experiment

Treatment Number	Name of the Treatment	Group	Dose
T_1	Sevin 85SP	Carbamate	2.0 g L^{-1} of water at 14 days interval
T_2	Abamectin 1.8EC	Biopesticide	1.5 ml L^{-1} of water at 14 days interval
T_3	Spinosad 45SC	Biopesticide	0.5 ml L^{-1} of water at 14 days interval
T_4	Cypermethrin 10EC	Synthetic Pyrethroid	1.0 ml L^{-1} of water at 14 days interval
T_5	Control	-	-

3.4. Experimental design and layout

Present study was designed in a single factor randomized complete block design (RCBD) with four replications, where the experimental site was divided into four blocks allocating the replications to assemble homogeneous soil conditions. Every block was divided into five-unit plots as treatments. Raised bunds were used as identifiers for ease of treatment demarcation. However, the total numbers of experimental plots were 5 × 4 = 20. Each plot size was 3.6 m × 1.6 m. Eventually, 0.5 m and 0.5 m distance were maintained between two blocks and two plots respectively.

3.5. Seedbed preparation and seed sowing

Cauliflowers are normally transplanted so that better results are gained provided that the seedlings are raised in seedbed. For the current experiment, the seedbed was 60-120 cm wide and 20-25 cm high. To begin with, the clods of earth and stubble were removed. Then well composted farmyard manure and fine sand were added. Subsequently, the seedbed was brought to fine tilth condition. Over the length of the seedbed, lines were drawn 10-15 cm apart. The seeds were sown thinly spaced on the lines and pressed gently. The seeds were covered with fine sand and straw. The seedbeds were watered twice a day to ensure sufficient moisture for germination. After germination the straw was removed.

3.6. Main field preparation and seedling transplanting

After five weeks of sowing, the seedlings were transplanted to the field. Seedlings were hardened a week before transplanting by reducing the application of water. In order to avoid excessive damage to the roots, seedlings were thoroughly watered again 12-14 hours before they were taken out of the seedbed. Seedlings of 15-25 cm tall with 3-5 true leaves were selected for transplanting. In order to reduce the transplanting shock, transplanting was done in the afternoon.

Soon after the transplanting had been done, the plants were watered immediately. Spacing between plants and rows was maintained as per recommendation of Bangladesh Agricultural Research Institute (BARI). The common spacing is 45 cm between plants and 70 cm between rows. The holes for the plants were made deep enough so that the lowest leaves were at ground level. The soil was pressed firmly around the root, and watered around the base of the plant to settle the soil.

3.7. Manure and fertilizers

To get high yields, cauliflowers need to be fertilized. There are two groups of crop nutrients: organic manures and chemical fertilizers. Well decomposed cow dung was applied at the time of final land preparation. 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 (Table 3) were applied.

Table 3. Fertilizer and manure used in the experiment

Name of manure and fertilizers	Total Amount (Kg ha^{-1})	Last plough (Kg ha^{-1})	Before transplanting (Kg ha^{-1})	15 DAT	35 DAT
Cow dung/ FYM	10,000	5,000	5,000	-	-
Urea	150	-	-	75	75
TSP	150	75	75	-	-
MoP	120	-	-	60	60
Gypsum	100	100	-	-	-
Boric Acid	3	3	-	-	-
Ammonium molybdate	1	1	-	-	-

3.8. Intercultural operations

Irrigation was done 4-5 days after planting. Subsequently, at 8-10 days interval or as required Irrigation was done. The „joe" in the post-irrigated land was broken down for normal growth of cauliflower. The field was kept weed free. Fertilizer application was done in time. Irrigation was done after top dressing of fertilizer.

Drains should always be kept clean for irrigation and drainage.

Plate 2. Caterpillar of diamondback moth observed in the experiment.

3.9. Data collection

3.9.1. Data collection for studying the succession of insect pests in cauliflower field

3.9.1.1. Data collection on the incidence of Diamondback moth (DBM) in the cauliflower field

Untreated plots were selected for study so that no intervene was occurred. There were four untreated plots throughout the experiment from which data were recorded to study different insect pests. Diamondback moth was one of the major insect pests observed in the current study. Cauliflower plants were carefully observed to record the number of larvae of DBM, *Plutella xylostella.* Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Counting was done after 10 days of transplanting and once in a week up to final harvesting.

3.9.1.2. Data collection on the incidence of Aphid in the cauliflower field

The population of adult and nymph of aphid were recorded randomly from five plants of each untreated plots (four) in the experiment. Counting was done after 10 days of transplanting and once in a week up to final harvesting. Upper and lower surface of cauliflower leaves were carefully observed to count the number of aphids.

3.9.1.3. Data collection on the incidence of tobacco caterpillar

Tobacco caterpillar was one of the major insect pests observed in the current study. Cauliflower plants were carefully observed to record the number of larvae of tobacco caterpillar, *Spodoptera litura.* Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Counting was done after 10 days of transplanting and once in a week upto final harvesting.

Plate 3. Tobacco caterpillar observed in the experiment.

3.9.1.3. Data collection on the incidence of Cabbage butterfly in the cauliflower field

Tobacco caterpillar was regarded one of the major insect pests observed in the current study. Cauliflower plants were carefully observed to record the number of larvae of cabbage butterfly, *Pieris brassicae.* Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Counting was done after 10 days of transplanting and once in a week upto final harvesting.

3.9.2. Data collection for studying the efficacy of pesticides in controlling insect pests in cauliflower field

3.9.2.1. Diamondback moth (DBM)

Cauliflower plants were carefully observed to record the number of larvae of DBM, *Plutella xylostella.* Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Counting was done after 10 days of transplanting and 24 hours after each spray.

3.9.2.2. Aphid

Cauliflower plants were carefully observed to record the number of nymph and adult of aphid. Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Upper and lower surface of leaves were carefully observed. Counting was done after 10 days of transplanting and 24 hours after each spray.

3.9.2.3. Tobacco caterpillar

Cauliflower plants were carefully observed to record the number of larvae of tobacco caterpillar, *Spodoptera litura.* Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Counting was done after 10 days of transplanting and 24 hours after each spray.

3.9.2.4. Cabbage caterpillar

Cauliflower plants were carefully observed to record the number of larvae of cabbage caterpillar, *Pieris brassicae.* Counting was taken from randomly selected 5 (five) plants in each plot under 4 (four) replications. Counting was done after 10 days of transplanting and 24 hours after each spray.

3.10. Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance for different treatments. The analysis of variance was performed by using the STAT-10 Program. The significance of the difference among the treatment combinations was estimated by Tukey's HSD Test at 5% level of probability.

CHAPTER IV
RESULT AND DISCUSSION

The result regarding incidence of insect pests of cabbage and the effect of some biopesticides and insecticides have been presented and discussed under the following sub-headings.

4.1. Incidence of insect pests of cauliflower in the field

Cauliflower was found to infest with eight insect pests such as diamond back moth (*Plutella xylostella* L.), cabbage butterfly (*Pieris brassica*e), tobacco caterpillar (*Spodoptera litura* Fab.), mustard aphid (*Lipaphis erysimi* (Kalt.), flea beetle (*Phyllotreta cruciferae* Goeze.), painted bug (*Bagrada cruciferarum* Kirk.), whitefly (*Bemisia tabaci* Genn.) and cabbage aphid (*Brevicornye brassicae* L.) (Table 4). Among them, the former four was frequently observed in the field and other four insect pests were appeared in traces. Hence, observations in respect to these insects were not incorporated and succession and effect of different treatments of the first four insects have been presented and discussed herein.

Table 4. List of insect pests found in the experimental field during the rabi season 2019-20

Sl.	Name of the insect	Scientific name	Family	Order	Nature of pest
1.	Diamondback moth	*Plutella xylostella* (L.)	Plutellidae	Lepidoptera	Chewing
2.	Cabbage butterfly	*Pieris brassicae*	Pieridae	Lepidoptera	Chewing
3.	Tobacco cutworm	*Spodoptera litura* (Fab.)	Noctuidae	Lepidoptera	Chewing
4.	Mustard aphid	*Lipaphis erysimi*	Aphididae	Hemiptera	Sucking
5.	Flea beetle	*Phyllotreta cruciferae* (G.)	Chrysomelidae	Coleoptera	Cutting
6.	Painted bug	*Bagrada cruciferarum* (K.)	Pentatomidae	Hemiptera	Sucking
7.	Whitefly	*Bamicia tabaci* G.	Aleyrodidae	Homoptera	Sucking
8.	Cabbage aphid	*Brevicornye brassicae* (L.)	Aphididae	Hemiptera	Sucking

4.2. Seasonal abundance of Diamondback moth during Rabi season 2019-20

It is found that larvae (caterpillar) of diamondback moth (*P. xylostella*) infested the cauliflower field from the initial stage of cultivation (Table 5). The larvae appeared in the cauliflower field up to the maturity stage. In the current experiment, *P. xylostella* was present from the 42^{nd} standard week of 2019 to 3^{rd} standard week of the next year i.e. throughout the growing period. Number of diamondback moth population was found 2.1 per plot at the first week of transplanting (second week of October i.e. 42^{nd} SW) which was followed by 43^{rd} and 44^{th} SW (1.8 and 2.4 caterpillar per plot). The peak population (2.7 per plot) of diamondback moth was found 45th SW (4th week of transplanting). However, the population was then fluctuated throughout the growing period. Pest infestation was decreased to 1.9 per plot in the next week (46th SW) and then further decreased to 1.6 per plot in the 47th SW. This trend was followed up to the 48th SW (7th week of transplanting). The population was then increased to 1.4 larvae per plot in the next and faced a gradual reduction (1.2 per plot) in pest population in the 9th week of transplanting (51st SW). The lowest population (0.6 per plot) was found in the next week (52nd SW i.e 10th week of transplanting) of growing period. The population of DBM caterpillar was found 1.6, 1.2, 1.8, and 2.1 per plot on the 53rd, 1st, 2nd and 3rd standard week respectively. In the present investigation, the seasonal abundance of diamondback moth of cauliflower was studied for the year, 2019-20 which will be helpful in preparing the proper schedule for effective management of this pest. The study revealed that the cauliflower crop was infested by a major pest, diamondback moth, *P. xylostella*. This insect pest has also been reported as a serious insect pest of cabbage crop by Meena and Sharma (2003) who reported diamondback moth as regular and major pest of cauliflower. The present finding is in partial conformity with that of Shukla and Kumar (2004) and Goud *et al.* (2006) who reported that the infestation of pest started from the second week of November and reached to peak in the last week of January to the first week of February. Ahmad and Ansari (2010) observed that population of diamondback moth started to build up as soon as the cauliflower crop was transplanted. Ahmad *et al.* (2012) observed that the maximum population at 31^0C which is more as compared to the present study.

Table 5. Seasonal abundance of diamondback moth during rabi season 2019-20

Date of observation	Standard week	Week after transplant	No. diamondback moth/ plot
12.10.2019	42	1	2.1
20.10.2019	43	2	1.8
28.10.2019	44	3	2.4
05.11.2019	45	4	2.7
13.11.2019	46	5	1.9
21.11.2019	47	6	1.6
29.11.2019	48	7	0.9
07.12.2019	50	8	1.4
15.12.2019	51	9	1.2
23.12.2019	52	10	0.6
31.12.2019	53	11	1.6
08.01.2020	1	12	1.2
16.01.2020	2	13	1.8
24.01.2020	3	14	2.1

4.3. Seasonal abundance of aphid during rabi season 2019-20

It is evident that (Table 6) both nymph and adult aphid (*Lipaphiserysimi*) was abundant in the cauliflower field of current experiment from the early stage of cultivation. This insect was present in the cauliflower field up to the maturity stage. In the current experiment, *L. erysimi* was present from the 42nd standard week of 2019 to 3rd standard week of the next year i.e. throughout the growing period. Number of aphid population was found 81.5 per plot at the first week of transplanting (second week of October i.e. 42nd SW). A slight increase (93.2 per plot) in aphid population was observed in the next week (43rd SW). The pest population experienced a gradual increase in the following 44th (98.4 aphids per plot) and 45th SW (112.5 aphids per plot). A sharp increase in aphid population was found in next four (04) consecutive weeks. The abundance of aphid in 46th, 47th, 48th and 50th SW was 136.8, 175.25, 187.2, and 201.4 per plot respectively. The peak population (221.5 aphids per plot) of was found from 51st SW (9th week of transplanting). However, the population was then decreased throughout the growing period. Pest infestation was decreased to 193.2 per plot in the next week (10th week of transplanting) and then further decreased to 132.6 per plot in the 53rd SW. This trend was followed up to the last week of transplanting). The population was then decreased to 102.2 aphids per plot in the next and faced a gradual reduction (102.2 per plot) in pest population in the following week of transplanting (1st SW). In the 13th week of transplanting the aphid population was 66.4 per plot. However, the lowest population (52.8 per plot) was found in the last week of transplanting. Singh *et al*. (2012) conducted a study on the seasonal abundance of mustard aphid (*L. erysimi* Kalt.) on cauliflower (*Brassica oleracea*var. *botrytis* Linn.). They reported that aphids appeared on cauliflower from the very beginning of growing period during 1st week of January, reached its peak (275.12 aphids per plant with 100% infestation) during 2nd week of February and continued till end of March. Its abundance and infestation had significant positive association with environmental factors. On the other hand, Mishra *et al.* (2018) reported that the pest (aphid) commenced from last week of August 0.66 aphids/3 leaves/plant and gradually increased up to fourth week of October (i.e. 44.17 aphids/3 leaves/plant). There was a gradual decrease in population in fifth week of October and subsidized in next three weeks. The present findings are in partial confirmation with Raja *et al.* (2014) who reported that the peak incidence of *B. brassicae* was in September and also reported that the severity of aphid infestation has been reported to be inconsistent in different crop seasons on *brassica*. Rohilla *et al.* (1987) reported peak aphid infestation in the last week of February while Aslam (2005) reported peak aphid infestation in the second week of March. Palande *et al.* (2004) reported from the findings that aphid infestation is location specific and governed with the seasonal effect of weather conditions.

Table 6. Seasonal abundance of aphid during rabi season 2019-20

Date of observation	Standard week	Week after transplant	Aphid/plot
12.10.2019	42	1	81.5
20.10.2019	43	2	93.2
28.10.2019	44	3	98.4
05.11.2019	45	4	112.5
13.11.2019	46	5	136.8
21.11.2019	47	6	175.25
29.11.2019	48	7	187.2
07.12.2019	50	8	201.4
15.12.2019	51	9	221.5
23.12.2019	52	10	193.2
31.12.2019	53	11	132.6
08.01.2020	1	12	102.2
16.01.2020	2	13	66.4
24.01.2020	3	14	52.8

4.4. Seasonal abundance of tobacco caterpillar during Rabi season 2019-20

Tobacco caterpillar (*S. litura*) was observed in the cauliflower field of current experiment from the early stage of cultivation (Table 7) and it was continued in the up to the maturity stage. *S. litura* was recorded from the 42nd standard week of 2019 to 3rd standard week of the next year i.e. throughout the growing period. Number of *S. litura* population was found 4.2 per plot at the first week of transplanting (second week of October i.e. 42nd SW). A slight increase (4.4 per plot i.e. the highest population) in tobacco caterpillar population was observed in the next week (43rd SW). The pest population experienced a gradual decrease in the following 44th (3.8 caterpillar per plot), 45th SW (3.6 caterpillar per plot), 46th SW (3.4 caterpillar per plot), and 47th SW (2.8 caterpillar per plot). A sharp increase in caterpillar population was found in next week. The abundance of caterpillar in 48th SW was 4.4 (the highest population) per plot. Caterpillar population was counted same (3.8 caterpillar per plot) in 50th and 51st SW (8th and 9th week of transplanting). However, the population was then decreased throughout the growing period except for 53rd SW. Pest infestation was decreased to 2.4 per plot in the next week (10th week of transplanting) and then slightly increased to 2.6 per plot in the 53rd SW. The population was then decreased to 2.2 caterpillars per plot in the next and faced a gradual reduction (1.8 per plot) in pest population in the following week of transplanting (2nd SW). However, the lowest *S. litura* population (1.6 per plot) was found in the last week of transplanting. Mishra *et al.* (2018) reported that the pest commenced from the 35th SMW and continued till 47th SMW which ranged from 0.38 to 3.12 larvae per plant and exist in the field with 0.38 larvae per plant during 47th SMW. However, the highest peak activity (3.12 larvae per plant) was recorded in the 43rd SMW coinciding with the fourth week of October. There was a gradual decrease in the larval population from the fifth week of October and subsidized in next three weeks. Palande et al. (2004) studied the seasonal incidence of cabbage pests in relation to weather and reported that the tobacco leaf eating caterpillar, *S. litura* occurred in kharif and part of rabi seasons and these results are in confirmation with present investigation. Rao *et al.* (2014) concluded that during the month of September optimum temperature and relative humidity was attained which lead in abundance and flourishing population of *S. litura*. The peak population was attained in the month of September showed in conformity with (Babu *et al*. 2015) they reported that larval population of *S. litura* was found during the month of August to mid-October after that its population was sharply decreased in the month late October.

Table 7. Seasonal abundance of tobacco caterpillar during rabi season 2019-20

Date of observation	Standard week	Week after transplant	Tobacco caterpillar/ plot
12.10.2019	42	1	4.2
20.10.2019	43	2	4.4
28.10.2019	44	3	3.8
05.11.2019	45	4	3.6
13.11.2019	46	5	3.4
21.11.2019	47	6	2.8
29.11.2019	48	7	4.4
07.12.2019	50	8	3.8
15.12.2019	51	9	3.8
23.12.2019	52	10	2.4
31.12.2019	53	11	2.6
08.01.2020	1	12	2.2
16.01.2020	2	13	1.8
24.01.2020	3	14	1.6

4.5. Seasonal abundance of cabbage butterfly during Rabi season 2019-20

It is evident that (Table 8) larvae of cabbage butterfly (*P. brassicae*) was abundant in the cauliflower field of current experiment from the beginning of cultivation. This caterpillar was present in the cauliflower field up to the early maturity stage. In the current experiment, *P. brassicae* was present from the 42^{nd} standard week of 2019 to 52^{nd} standard week of that year i.e. early maturity stage. Number of *P. brassicae* population was found 1.2 per plot at the first week of transplanting (second week of October i.e. 42^{nd} SW). A slight increase (1.5 per plot) in cabbage butterfly caterpillar population was observed in the next week (43^{rd} SW). The pest population experienced a gradual increase in the following 44^{th} (1.9 caterpillar per plot) SW which was followed by 45^{th} SW (2.4 caterpillar per plot). This weeks' population was the highest among all weeks of transplanting. However, cabbage butterfly population decreased gradually from 46^{th} SW. Abundance of cabbage caterpillar in 46^{th} SW, 47^{th} SW, 48^{th} SW,50^{th} SW, 51^{st} SW were observed 1.8, 1.6, 1.4, 0.98, and 0.6 caterpillar per plot respectively. The lowest caterpillar population (0.4 larva per plant) was observed in 53^{rd} SW (11^{th} week of transplanting). However, no cabbage caterpillar was observed in 12^{th}, 13^{th} and 14^{th} week of transplanting. Gupta (1984) revealed in Jammu that the pest appeared in the 43^{rd} standard week and remained active up to 7^{th} standard week, with the peak population (58.10 larvae per plant) in the 50^{th} standard week. However, the pest population was not significantly correlated with the abiotic factors. Younas et al. (2004) reported that the highest average of *P. brassicae* was recorded in the first week of November and the lowest average of 0.67 larvae/plant was recorded in the first week of December. Matin *et al.* (1992) revealed that the pest appeared in the 43^{rd} standard week and remained active up to 7^{th} standard week, with the peak population in the 50^{th} standard week. However, the pest population was not significantly correlated with the abiotic factors. Rogowska and Szwejda (2002) studied the population dynamics of *Pieris rapae* and the number of larvae per plant varied from 1.2 to 1.7. *P. rapae* was observed at the beginning of July in all years. The pest was initially observed at the end of August in 1997, in the second fortnight of July in 1998, and at the beginning of June in 1999. In all years, infestation lasted up to the second half of November, suggesting that two generations developed per year.

Table 8. Seasonal abundance of cabbage butterfly during rabi season 2019-20

Date of observation	Standard week	Week after transplant	Cabbage butterfly (Larvae/plot)
12.10.2019	42	1	1.2
20.10.2019	43	2	1.5
28.10.2019	44	3	1.9
05.11.2019	45	4	2.4
13.11.2019	46	5	1.8
21.11.2019	47	6	1.6
29.11.2019	48	7	1.4
07.12.2019	50	8	0.98
15.12.2019	51	9	0.6
23.12.2019	52	10	0.4
31.12.2019	53	11	0
08.01.2020	1	12	0
16.01.2020	2	13	0
24.01.2020	3	14	0

4.6. Effect of treatments against diamondback moth during rabi season 2019-20

There was varying degree of diamondback moth infestation in the experimental field during rabi season of 2019-20 (Table 9). Number of diamondback moth caterpillar amid the treatment regime ranged from 0.42 larvae per plot to 2.37 larvae per plot. The lowest number of diamondback moth caterpillar population (0.42 larvae per plot) was obtained from T_3 (Spinosad). It was significantly different lower than that of other treatments in the experiment. It was followed by T_2 (Abamectin) and the population was counted 1.23 larvae per plot. Similar to the T_3, it also showed statistically significant variation from other treatments of the experiment. Later on, the population count of DBM caterpillar was 1.71 larvae per plot from T_4 (Cypermethrin) and 1.89 larvae per plot from T_1

(Sevin). Though numerically differed, there was no statistical variation between T_1 and T_4. Lastly, the highest diamondback moth caterpillar population (2.37 larvae per plot) was obtained from T_5 (control) i.e. untreated treatment. However, there was statistically significant difference between control and other treatments of the current study. Irungu (2010) reported that in the larval damage rating, spinosad treatment showed better management of diamondback moth and cabbage looper than Lambdacyhalothrin. Zhao *et al.* (2002) conducted a study to evaluate the toxicity of insecticides to the diamondback moth, *P. xylostella*. Leaf-dip and direct dip bioassays for diamondback moth larvae and residual bioassays for adults of diamondback moth were used to assess mortalities. Larval mortalities at field rates were significantly higher with spinosad when compared with other insecticides in the larval-dip bioassay 72 h after treatment. In the leaf-dip and residual bioassays spinosad caused 100% mortalities to diamondback moth larvae and adults, respectively, 72 h after treatment. This corroborates findings by Sparks *et al.* (1998) who reported that spinosad was a neurotoxin with a contact mode of action, and Bret *et al.* (1997) who found that in addition to contact action, spinosad is a stomach poison, and that mortality due to ingestion was five to ten times greater than through contact. This may explain the relatively faster mortality of DBM larvae compared to that of eggs. The fast action of spinosad against larvae is a desirable property as this is the damaging developmental stage of the pest.

Table 9. Effect of treatments against Diamondback moth during rabi season 2019-20

Treatments	Treatments name	Number of diamondback moth larvae plot^{-1}	Percent decrease over control
T_1	Sevin	1.89 b	20.25
T_2	Abamectin	1.23 c	48.01
T_3	Spinosad	0.42 d	82.27
T_4	Cypermethrin	1.71 b	27.84
T_5	Untreated	2.37 a	-
CV (%)		**12.94**	
$lsd_{0.05}$		**0.31**	
SE		**0.14**	

In a column, mean followed by the same letter(s) are not significantly different at 5% level of probability by least significance difference test.

4.7. Effect of treatments against aphid during rabi season 2019-20 Varying degrees of aphid infestation was observed in the experimental field during rabi season of 2019-20. Number of aphid nymphs and adults amid the treatment regime ranged from 13.08 aphids per plot to 132.95 aphids per plot (Table 10). It is obvious that aphid infestation was quiet higher in the experimental plots. The lowest aphid population (13.08 aphids per plot) was obtained from T_3 (Spinosad). It was significantly different (statistically) than that of other treatments in the experiment. It was followed by T_2 (Abamectin) and the population was counted 41.51 aphids per plot. Similar to the T_3, it also showed statistically significant variation from other treatments of the experiment. Later on, the population count of aphid nymph and adult was 65.92 per plot from T_4 (Cypermethrin) which shows statistical variation from other treatments in the experiment. This was followed by 112.33 aphid per plot from T_1 (Sevin). There was no statistical variation between T_1 and other treatments of the experiment. Lastly, the highest aphid population (132.95 per plot) was obtained from T_5

(control) i.e. untreated treatment. However, there was statistically significant difference between control and other treatments of the current study. The present study reveals that Spinosad has high efficacy, a broad insect pest spectrum. Spinosad is a mixture of spinosyns A and D derived from the naturally occurring soil actinomycetes, *Saccharopolyspora spinosa* (Sparks *et al.* 1998). It has been classified as an environmentally and toxicologically reduced – risk insecticide (Cleaveland 2001). Spinosad is both a nerve poison and a stomach poison, so it kills aphid that it contacts and those that consume it on foliage they eat. The present study showed that spinosad was very effective in the control *L. erysimi*. Radha (2013) argued that spinosad could be as alternatives to chemical insecticides for the control of aphids to reduce the pesticide load in the environment. Akbar et al. (2010) reported that amongst bioinsecticides, spinosad was found to be more persistent in cabbage leaves and heads (average half life, 3.47 days) as compared to biosal (average half life, 1.66 days). Due to the higher persistency, aphids are controlled more effectively by the application of spinosad.

Table 10. Effect of treatments against aphid during rabi season 2019-20

Treatments serial	Treatments name	Aphid/plot	Decrease over control (%)
T_1	Sevin	112.33 b	15.51
T_2	Abamectin	41.51 d	68.77
T_3	Spinosad	13.08 e	90.16
T_4	Cypermethrin	65.92 c	50.41
T_5	Untreated	132.95 a	-
CV (%)		**9.98**	
$lsd_{0.05}$		**11.24**	
SE		**5.16**	

In a column, mean followed by the same letter(s) are not significantly different at 5% level of probability by least significance difference test.

4.8. Effect of treatments against tobacco caterpillar during rabi season 2019-20

It is evident (Table 11) that there was varying degree of tobacco caterpillar (*S. litura*) infestation in the experimental field during rabi season of 2019-20. Number of tobacco caterpillar amid the treatment regime ranged from 0.98 larvae per plot to 3.50 larvae per plot. The lowest abundance of tobacco caterpillar population (0.98 larvae per plot) was obtained from T_3 (Spinosad). It was significantly different than that of other treatments in the experiment. It was followed by T_2 (Abamectin) and the population was counted 1.79 larvae per plot. Similar to the T_3, it also showed statistically significant variation from other treatments of the experiment. Later on, the population count of tobacco caterpillar was 2.34 larvae per plot from T_4 (Cypermethrin) and 2.68 larvae per plot from T_1 (Sevin). Though numerically differed, there was no statistical variation between T_1 and T_4. Lastly, the highest tobacco caterpillar population (3.50 larvae per plot) was obtained from T_5 (control) i.e. untreated treatment. However, there was statistically significant difference between control and other treatments of the current study. Santis *et al.* (2012) examined the toxicity of spinosad against different larval instars of *Spodoptera exigua* and concluded that spinosad is most toxic to the 3rd instar larvae of *S. exigua* as well rate of mortality was increase rapidly even after only 3 hours of application the scored mortality % is 71-95. Sabri *et al.* (2017) found that Spinosad (Tracer® 480 SC) proved as most toxic insecticide against *Spodoptera litura* larvae with LC_{50} 19.53 before indoxacarb (Avaunt 15.8% EC) and after methoxyfenozide (Runner 240 SC) with 21.85 and 16.04. Ahmad and Gull (2017) conducted a study on field populations of *S. litura* for their susceptibility to diverse chemical classes, namely insect growth regulators, diamides, spinosyns, avermectins, indoxacarb, and thiocyclam by using a diet overlay bioassay during 2008-2013. They found no or a very low resistance was recorded to chlorfluazuron, lufenuron, triflumuron, methoxyfenozide, chlorantraniliprole, flubendiamide, spinosad, spinetoram, emamectin benzoate, indoxacarb, and thiocyclam. On the other hand, Resistance to flufenoxuron and abamectin was low to moderate in some populations of *S. litura*. Karabhantanal and Awaknavar (2004) and Ali *et al.* (2002) agree with the results of the present study. They conducted experiments to observe the toxicity of spinosad and other insecticides to second instar larvae of *H. armigera*. They found spinosad more toxic than other insecticides as spinosad caused a higher mortality rate for a specific time.

Table 11. Effect of treatments against tobacco caterpillar during rabi season 2019-20

Treatment serial	Treatment name	Tobacco caterpillar/plot	Percent decrease over control
T_1	Sevin	2.68 b	23.42
T_2	Abamectin	1.79 c	48.85
T_3	Spinosad	0.98 d	72
T_4	Cypermethrin	2.34 b	33.14
T_5	Untreated	3.50 a	-
CV (%)		**10.45**	
$lsd_{0.05}$		**0.36**	
SE		**0.16**	

In a column, mean followed by the same letter(s) are not significantly different at 5% level of probability by least significance difference test.

4.9. Effect of treatments against cabbage butterfly (larvae) during rabi season 2019-20

Varying degrees of *P. brassicae* infestation on cabbage was observed in the experimental field during rabi season of 2019-20. Number of *P. brassicae* caterpillar among the treatment regime ranged from 0.13 larvae per plot to 1.29 larvae per plot. It is obvious that this pest infestation was quiet lower in the experimental plots compared to other insect pests. The lowest caterpillar population (0.13 larvae per plot) was obtained from T_3 (Spinosad). It was significantly different (statistically) than that of other treatments in the experiment. It was followed by T_2 (Abamectin) and the population was counted 0.51 larvae per plot. Similar to the T_3, it also showed statistically significant variation from other treatments of the experiment. Later on, the population count of cabbage caterpillar was 0.80 larave per plot from T_4 (Cypermethrin) which shows statistical variation from other treatments in the experiment. This was followed by 1.02 larave per plot from T_1 (Sevin). There was no statistical variation between T_1 and other treatments of the experiment also. Lastly, the highest cabbage caterpillar population (1.29 larvae per plot) was obtained from T_5 (control) i.e. untreated treatment. However, there was statistically significant difference between control and other treatments of the current study. According to the study of Klokočar-Šmit *et al.* (2007), Spinosad induced high mortality of all larval instars of *P. brassicae* already after 24 hrs and it probably could be used at a lower rate for the control of this pest. However they argued that for effective control, the optimum timing of Spinosad treatment should be directed primarily at the newly hatched larvae, although large larvae are easily controlled too. Singh *et al.* (2015) reported that against *P. brassicae* spinosad 2.5 SC registered significantly the lowest mean leaf damage of 24.30 per cent as against 87.38% in untreated check, closely followed by myco-jaal 10 SC (*Beauveria bassiana*) with a record of 26.59 per cent leaf damage but, differed significantly between them. Spinosad's mode of action is invariably toxic for *P. brassicae* at the rates applied. Routes of activity involve both ingestion and contact activity. Spinosad acts as a neurotoxicant and its route of activity is translaminar. Some authors have estimated that it takes 1-2 days to achieve > 90% mortality of small larvae (< 5 mm) and 2 days for large larvae (> 10 mm) (Palumbo, 1999).

Table 12. Effect of treatments against cabbage butterfly (larvae) during rabi season 2019-20

Treatment serial	Treatment name	Cabbage butterfly (larvae/plot)	Percent decrease over control
T_1	Sevin	1.02 b	20.93
T_2	Abamectin	0.51 d	60.46
T_3	Spinosad	0.13 e	89.92
T_4	Cypermethrin	0.80 c	37.98
T_5	Untreated	1.29 a	-
CV (%)		**12.82**	
$lsd_{0.05}$		**0.14**	
SE		**0.06**	

In a column, mean followed by the same letter(s) are not significantly different at 5% level of probability by least significance difference test.

4.10. Effect of treatments on the yield of cauliflower during rabi season 2019-20

Yield of cauliflower in the current experiment was influenced by different treatments (Figure 4). It is evident that the highest yield (51.48 ton/ha) of cauliflower was obtained from T_3 (Spinosad). It was statistically significant from any other treatments used in the experiment. Second highest yield of cauliflower in the experiment was obtained from T_2 (Abamectin) and the yield was 47.26 ton/ha which was also differed statistically from other treatments. Later on 43.58 ton/ha and 41.41 ton/ha cauliflower was obtained from T_4 (Cypermethrin) and T_1 (Sevin) respectively which showed statistical similarity between them. Lastly, the lowest yield (38.5 ton/ha) of cauliflower was obtained from control treatment.

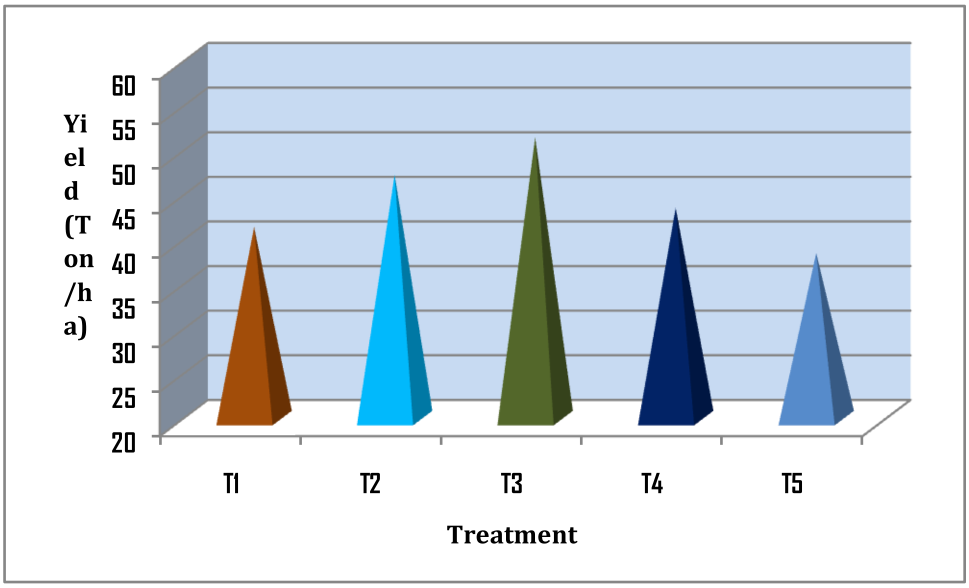

Figure 1. Effect of treatments on the yield of cauliflower during rabi season 2019-20.

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Present study was undertaken to observe the incidence and infestation of major insect pests of cauliflower as well as to assess the efficacy of some promising insecticides against the major insect pests of cauliflower. Research work was carried out in the research field of the department of entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during rabi season of 2019-20. There were five (05) treatments and four replication per treatment used for the experiment. The total research plot was divided into 20 units in a randomized complete block design (RCBD) in order to distribute the treatments. Sevin, Abamectin, Spinosad, Cypermethrin, and control treatment were used as treatments in the experiment.

During field observations, eight insect pests such as diamond back moth (*Plutella xylostella* L.), cabbage butterfly (*Pieris brassica*e), tobacco caterpillar (*Spodoptera litura* Fab.), mustard aphid (*Lipaphis erysimi* (Kalt.), flea beetle (*Phyllotreta cruciferae* Goeze.), painted bug (*Bagrada cruciferarum* Kirk.), whitefly (*Bemisia tabaci* Genn.) and cabbage aphid (*Brevicornye brassicae* L.) was found to infest cauliflower of which diamond back moth, cabbage butterfly, tobacco cutworm, and mustard aphid were observed as major insect pests. Diamondback moth, *P. xylostella* was present from the 42nd standard week of 2019 to 3rd standard week of the next year i.e. throughout the growing period. The peak population (2.7 per plot) of diamondback moth was found 45th SW (4th week of transplanting). However, the population was then fluctuated throughout the growing period.

Aphid, *L. erysimi* was present from the 42nd standard week of 2019 to 3rd standard week of the next year i.e. throughout the growing period. The peak population

(221.5 aphids per plot) of was found from 51^{st} SW (9^{th} week of transplanting). However, the population was then decreased throughout the growing period. Similarly, *S. litura* was present from the 42^{nd} standard week of 2019 to 3^{rd} standard week of the next year i.e. throughout the growing period. A sharp increase in caterpillar population was found after 47^{th} SW. The abundance of caterpillar in 48^{th} SW was 4.4 (the highest population) per plot. Cabbage butterfly, *P. brassicae* was present from the 42^{nd} standard week of 2019 to 52^{nd} standard week of that year i.e. early maturity stage. The pest population experienced a gradual increase after 44^{th} (1.9 caterpillar per plot) SW which was followed by 45^{th} SW (2.4 caterpillar per plot). This weeks' population was the highest among all weeks of transplanting. However, cabbage butterfly population decreased gradually from 46^{th} SW.

In context of controlling insect pests of cauliflower, the lowest number of diamondback moth caterpillar population (0.42 larvae per plot) was obtained from T_3 (Spinosad). On the other hand, the highest diamondback moth caterpillar population (2.37 larvae per plot) was obtained from T_5 (control) i.e. untreated treatment. The lowest aphid population (13.08 aphids per plot) was obtained from T_3 (Spinosad). It was significantly different (statistically) than that of other treatments in the experiment. The highest aphid population (132.95 aphids per plot) was obtained from T_5 (control) i.e. untreated treatment. However, there was statistically significant difference between control and other treatments of the current study.

The lowest abundance of tobacco caterpillar population (0.98 larvae per plot) was obtained from T_3 (Spinosad). It was significantly different than that of other treatments in the experiment. However, the highest tobacco caterpillar population (3.50 larvae per plot) was obtained from T_5 (control) i.e. untreated treatment.

However, there was statistically significant difference between control and other treatments of the current study.

Lastly, the lowest cabbage caterpillar population (0.13 larvae per plot) was obtained from T_3 (Spinosad). It was significantly different (statistically) than that of other treatments in the experiment. However, the highest cabbage caterpillar population (1.29 larvae per plot) was obtained from T_5 (control) i.e. untreated treatment. However, there was statistically significant difference between control and other treatments of the current study.

In the context of yield, the highest yield (51.48 ton/ha) of cauliflower was obtained from T_3 (Spinosad). However, the lowest yield (38.5 ton/ha) of cauliflower was obtained from control treatment.

Followings are the major findings of the experiment; besides, several concluding remarks and recommendations are given-

- ❖ Cauliflower plants are mostly affected by diamondback moth, mustard aphid, cabbage butterfly, and tobacco caterpillar. The degree of infestation varied throughout the growing period.
- ❖ Early to mid-vegetative stage is the most susceptible stage of cauliflower for insect pest infestation.
- ❖ Highest yield obtained from the plot where lowest number of insects were observed.
- ❖ Spinosad is the most effective insecticide against pest complex of cauliflower.
- ❖ However, more research and multilocation trials should be conducted to find out the best doses and time to apply spinosad for the best control of cauliflower insect pests.

CHAPTER VI

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