EFFECT OF INTERCROPPING ON INCIDENCE OF PESTS AND PREDATORS IN CAULIFLOWER FIELDS

SIRAJUM MUNIRA TINA

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA-1207, BANGLADESH

DECEMBER, 2020

EFFECT OF INTERCROPPING ON INCIDENCE OF PESTS AND PREDATORS IN CAULIFLOWER FIELDS

BY

SIRAJUM MUNIRA TINA

REGISTRATION NO. 18-09127

A Thesis

Submitted to the Department of Entomology, Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JULY-DECEMBER, 2020

Approved by:

Prof. Dr. Md. Abdul Latif **Supervisor** **Department of Entomology** **SAU, Dhaka**	**Prof. Mst. Nur Mohal Akhter Banu** **Co-supervisor** **Department of Entomology** **SAU, Dhaka**

Prof. Dr. Md. Mizanur Rahman
Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY
Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled **"EFFECT OF INTERCROPPING ON INCIDENCE OF PESTS AND PREDATORS IN CAULIFLOWER FIELDS"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **SIRAJUM MUNIRA TINA, Registration no. 18-09127** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2020
Place: Dhaka, Bangladesh

Prof. Dr. Md. Abdul Latif
Supervisor
Department of Entomology
SAU, Dhaka

DEDICATED

TO

MY BELOVED

PARENTS

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah, the Cherisher and Sustainer of the world. His blessings have enabled the author to complete her Thesis.

The author expresses her heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to her adorable teacher, venerable Supervisor, **Prof. Dr. Md. Abdul Latif,** Department of Entomology, Sher-e-Bangla Agricultural University for his planning, painstaking and scholastic guidance, support, extraordinary kind concern, everlasting encouragement, inestimable cooperation and intellectual encircling the till final preparation of the Thesis.

She expresses her profuse gratitude, cordial appreciation and gratefulness to her thoughtful, Co-supervisor, **Professor Dr. Mst. Nur Mohal Akhter Banu,** Department of Entomology, Sher-e-Bangla Agricultural University, for her valuable suggestions, guidance constant encouragement and inestimable during the entire period of study.

With due regards, she thanks the Chairman, Department of Entomology, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. She also acknowledges with deep regards the help and cooperation received from her respected teachers and staff of the Department of Entomology, Sher-e-Bangla Agricultural University while carrying out this work.

She expresses her heartiest gratitude, sincere appreciation, indebtedness and deep sense of respect to her parents for their sincere and affectionate support and love, extraordinary kind concern, everlasting encouragement and inestimable cooperation during the entire period of study.

Dated: December, 2020 **The Author**

SAU, Dhaka

EFFECT OF INTERCROPPING ON INCIDENCE OF PESTS AND PREDATORS IN CAULIFLOWER

BY

SIRAJUM MUNIRA TINA

ABSTRACT

An experiment was conducted in the central experimental field of SAU, Dhaka, Bangladesh during the period from November, 2019 to February, 2020 to evaluate the effect of intercropping on incidence of pests and predators in cauliflower fields. The experiment was laid out in Randomized Complete Block Design replicated with three times. Seven treatments were tested for the study which are intercropped with tomato (T_1), marigold (T_2), garlic (T_3), coriander (T_4), radhuni (T_5), fenugreek (T_6) and control (sole cauliflower) (T_7). The results showed that, the highest insects pests was found in control field and lowest insect incidence was found in the field intercropped with coriander. Among the insect pests, whitefly was the major and found maximum number in control cauliflower field as well as intercropped fields with tomato, marigold, coriander, radhuni and fenugreek. In case of arthropod predator, field spider was major and found in control cauliflower and integrated with tomato, marigold, garlic, radhuni and fenugreek. Considering the pests reduction, T_4 performed best and reduced the number of aphid, whitefly, stripped beetle, leaf miner and diamond back moth over control (43.89%, 61.15%, 75.93%, 64.66% and 51.91%, respectively). It also reduced percent plant infestation over control (57.57%) and increased the number of predator arthropods like lady bird beetle and field spider over sole cauliflower (103.00% and 245.12%, respectively). T_4 also showed the best performance in terms of plant height, card length, card diameter and yield of cauliflower (36.45 cm, 18.23 cm, 15.37 cm and 24.71 t/ha, respectively). From this study, it can be concluded that cauliflower intercropping with coriander showed the antagonistic effect to the insect pests of cauliflower and also showed positive effect on the yield of cauliflower than the sole cultivation.

ABBREVIATIONS AND ACRONYMS

Abbreviation	**Full meaning**
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
DAS	Days after sowing
et al.	And others
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
MP	Muriate of Potash
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
TSP	Triple Super Phosphate

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Horticulture-based food varieties, namely fruit, vegetables and nuts, are important for the daily diet as these contain micronutrients, fibre, vegetable proteins and bio-functional components. Consumption of fruits and vegetables is vital for a diversified and nutritious diet. Rural consumption of leafy and non-leafy vegetables has remained more or less the same over the past two decades after increasing over the preceding 30 years. Fruit consumption has declined in rural areas after more than doubling in the 1970s. With an average national per capita consumption of 23 g of leafy vegetables, 89 g of non-leafy vegetables and 14 g of fruit, the average Bangladeshi eats a total of 126 g of fruit and vegetables daily. This is far below the minimum daily consumption of 400 g of vegetables and fruit recommended by FAO and the World Health Organization (WHO, 2003). Cauliflower is cultivated in 8689.41 ha land (BBS 2014) in Bangladesh. Cauliflower is one of several vegetables in the genus *Brassica*, which is in the family Brassicaceae and only the head is eaten as edible white flesh called "curd" (Fritz*et al.* 2017). Cauliflower is low in fat, but high in dietary fiber, folate, water, and vitamin C, possessing a high nutritional density. A high intake of cauliflower has been associated with reduced risk of aggressive prostate cancer. Raw cauliflower is contain 92% water, 5% carbohydrates, 2% protein, and contains negligible fat. A 100 gram reference amount of raw cauliflower provides 25 calories, and has a high content (20% or more of the Daily Value, DV) of vitamin C (58% DV) and moderate levels of several B vitamins and vitamin K (13-15% DV). Contents of dietary minerals are low (7% DV or less).Cauliflower (*Brassica oleracea* var. *botrytis*) is widely used in salads, boiled vegetable, cooked in curries, pickling as well as dehydrated vegetable.

Pest problem is one of the major constraints for achieving higher production in these crops. There are many insects that infest cauliflower such as cabbage caterpillar/tobacco caterpillar, aphid, diamondback moth, semilooper, cutworm, cabbage armyworm, whitefly etc. (Butani and Jotwani 1984). Farmers usually used spray insecticide many times for control the pests but it lead to environmental hazard to growers and consumers and development of resistance of target pest (David and Kumaraswarni 1989) with also negative impact on natural enemies (Tewari and Moorthy 1985). Among the different cropping systems like multiple cropping, intercropping, relay cropping, succession cropping, intercropping is the most suitable practice to stabilize the production. Intercropping is the growing of two or more crops/varieties simultaneously on the same area of land. The crops may or may not be sown or harvested at the same time (Kabiraj *et al.* 2017). An agronomic practice like intercropping found as a useful technique in controlling large number of crop pests. Intercropping can affect the microclimate of the agro-ecosystem, which ultimately produce an unfavorable environment for pest and increase the population of predators that can control the harmful pests (Singh and Singh 1987). The risk due to weeds, disease, pests and climatic factors are reduced in the intercropping (Arnonymous 1975). Inter/mixed cropping, a traditional agricultural practice of cultivating two or more crops in the same space at the same time, is an old and commonly used cropping practice, which aims to match efficiently crop demands to the available growth resources and labor.

Intercropping is an age-old practice of growing simultaneously two or more crops in the same piece of land. It is a technique of crop intensification in time and space wherein the competition between crops may occur during the part or whole of crop growth period. It has been a common practice followed by the farmer of India, Africa, Srilanka, West Indies and Bangladesh. Cauliflower is medium to long duration crop. Very short duration vegetables and other crops can be efficiently taken up in the field of cauliflower for better utilization of growth resources. In this regard on the basis of important considerations of intercropping some vegetable crops viz., French bean, pea, beet, carrot, palak, coriander were selected as suitable intercrops to be grown with cauliflower (Kabiraj*et al.* 2017). The increasing concern on agricultural sustainability favours the maintenance of the intercropping systems, due to anpositive effect on soil conservation and improvementof soil fertility (Jarenyama *et al.* 2000), more stable yields of intercropping systems using natural resources more effectively (Horwith 1985), and its great potential for pest and disease reduction (Theunnissen 1997).

Intercropping, through more effective use of water, nutrients and solar energy, can significantly enhance crop productivity compared tothe growth of sole crops (Midmore 1993). Intercropping or polyculture is also used for one crop as a trap for insects and may serve as a breeding place for predators. Intercropping also helps to reduce weed populations, insect pest infestation and risk of complete crop failure (Amede 2001, Islam *et al.* 2013). Intercropping system becomes more productive and profitable when it is done properly by selecting compatible crops (Begum *et al.* 2010) and increasing vegetable productivity (Rashid 1987).

Under the above perspective, intercropping or polyculture has been thought to be an eco-friendly option for the management of insect pests with the presence of natural enemy or predators. Therefore, the study was conducted to achieve the following objectives:

OBJECTIVES

1. To survey the insect pests of cauliflower and their predators in the field.
2. To explore the effect of intercropping or polyculture on the incidence of pests and predators in cauliflower field.
3. To know the best combination of intercropping with cauliflower base on relative yield and pests incidence.

CHAPTER II

REVIEW OF LITERATURE

Cauliflower is an important vegetable crop in Bangladesh, but the crop cultivation faces various problems including the incidence of insect pest. Among the insect pests, aphid, whitefly, leaf miner, diamond back moth etc. are the major pests of cauliflower. Different management practices are the present but intercropping of cauliflower with other crops are very limited. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following sub-headings.

2.1. General review of insect pest of cauliflower

2.1.1 Diamond back moth

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

A. Nomenclature/ Taxonomic position

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Plutellidae

Genus: *Plutella*

Species: *Plutella xylostella*

B. Origin and distribution

The diamondback moth (*Plutella xylostella*), sometimes called cabbage moth, is a European moth believed to originate in the Mediterranean region that has since spread worldwide. The moth has a short life cycle (14 days at 25°C), highly fecund and capable of migrating long distances. It is one of the most important pests of cole crops in the world and will usually only feed on plants that produce glucosinolates (Talekar and Shelton 1993).

C. Life cycle

Eggs are laid in groups of 1-6 on the lower surface of the leaf. Moths can lay up to 300 eggs. The eggs are very small and difficult to spot. The larvae that emerge from the eggs, start feeding on the underside of the older leaves of mostly older plants; but will also feed on the young growing points of seedlings.

The larvae can reach maturity in between 10 and 14 days in summer and in winter it takes a bit longer. The larvae can go through up to 5 instars before going over to pupating. Pupation can take place on the underside of the leaf or under debris in the soil. The pupa develops within a loosely spun cocoon attached to the leaves and stems of plants. The new generation of moths can emerge as quickly as 1 week after pupating. The whole cycle can be completed in 3 to 4 week. Four to six generations can occur per season. Hot dry conditions favor survival and reproduction, making control difficult (Moyer 1999).

D. Nature of damage

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

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

2.1.2 Aphid

Aphid, (family:Aphididae), also called plant louse, greenfly etc. A group of sap-sucking, soft-bodied insects (Homoptera) that are about the size of a pinhead, most species of which have a pair of tube like projections (cornicles) on the abdomen. These are serious plant pests and may stunt plant growth, produce plant galls, transmit plant virus diseases and cause the deformation of leaves, buds, and flowers. Moreover, individuals within a species can vary widely in colour.

A. Scientific classification

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hemiptera

Family: Aphididae

Genus: *Aphis*

Specis: *A. fabae*

B. Origin and distribution

Aphids are distributed worldwide, but are most common in temperate zones. In contrast to many taxa, aphid species diversity is much lower in the tropics than in the temperate zones (Zyla *et al.* 2017). They can migrate great distances, mainly through passive dispersal by riding on winds. For example, the current lettuce aphid, *Nasonovia ribisnigri*, is believed to have spread from New Zealand to Tasmania in this way (Pip Courtney 2005). Aphids have also been spread by human transportation of infested plant materials, making some species nearly cosmopolitan in their distribution (John *et al.* 2009).

Winged aphids may also rise up in the day as high as 600m where they are transported by strong winds (Berry and Taylor 1968, Isard *et al.* 1990). For example, the currant-lettuce aphid, *Nasonovia ribisnigri*, is believed to have spread from New Zealand to Tasmania through easterly winds (Hill 2012).

The black bean aphid may have originated in Europe and Asia, but it is now one of the most widely distributed species of aphids. It is found throughout temperate areas of Western Europe, Asia and North America and in the cooler parts of Africa, the Middle East, and South America (AphID 2012). In the warmer parts of its range, apterous individuals can survive the winter and they may continue to reproduce asexually all year round (HYPP 2013). It is known to be migratory (Johnson 1963).

C. Life cycle

Aphid has both sexual and asexual generations in its life cycle. It also alternates hosts at different times of year. The primary host plants are woody shrubs and eggs are laid on these by winged females in the autumn. The adults then die and the eggs overwinter. The aphids that hatch from these eggs in the spring are wingless females known as stem mothers. These are able to reproduce asexually, giving birth to live offspring, nymphs, through parthenogenesis (Chinery and Michael 1993). The lifespan of a parthenogenetic female is about 50 days and during this period, each can produce as many as 30 young (Berim, 2009). The offspring are also females and able to reproduce without mating, but further generations are usually winged forms. These migrate to their secondary host plants, completely different species that are typically herbaceous plants with soft, young growth (HYPP 2013, Berim 2009, Chinery and Michael 1993).

Further parthenogenesis takes place on these new hosts on the undersides of leaves and on the growing tips. All the offspring are female at this time of year and large populations of aphids develop rapidly with both winged and wingless forms produced throughout the summer. Winged individuals develop as a response to overcrowding and they disperse to new host plants and other crops. By midsummer, the number of predators and parasites has built up and aphid populations cease to expand (RIR 2013). As autumn approaches, the winged forms migrate back to the primary host plants. Here, both males and sexual females are produced parthogenetically, mating takes place and these females lay eggs in crevices and under lichens to complete the lifecycle. Each female can lay six to ten eggs which can survive temperatures as low as −32°C (−26°F) (HYPP 2013, Berim 2009, Chinery and Michael 1993). More than 40% of the eggs probably survive the winter, but some are eaten by birds or flower bugs, and others fail to hatch in the spring (Way and Banks 1964).

D. Nature of damage

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

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

2.1.3 Whitefly

The whitefly, *Bemisiatabaci* (Gennadius) (Homoptera: Aleyrodidae) is a very complex species consists of at least 24 biotypes in tropical and sub-tropical region around the world (Ahmed *et al.* 2009). *Bemisiatabaci* is a genetically different groups of insect that morphologically indistinguishable (Boykin *et al.* 2007). Two predominantly aggressive biotypes, known as B and Q, are distributed everywhere around the world (Martinez-Carrillo and Brown, 2007) whereas, in Bangladesh yet B or Q biotype are absent but indigenous biotype BW1 and BW2 recorded recently (Jahan 2012). The *B. tabaci* is not genetically consistent. Based on mitochondrial DNA markers, the *B. tabaci* complex can be placed into five major groups according to their geographical origin: (1) New World (US, Mexico, Puerto Rico), (2) Southeast Asia (Thailand, Malaysia), (3) Mediterranean basin (Southwest Europe, North Africa, Middle East), (4) Indian subcontinent (Bangladesh, India, Myanmar, Nepal and Pakistan), (5) Equatorial Africa (Cameroon, Mozambique, Uganda, and Zambia) (Frohlich *et al.* 1999).

A. Nomenclature

Kingdom: Animalia
- Phylum: Arthropoda
  - Class: Insecta
    - Order: Hemiptera
      - Family: Aleyrodoidea
        - Genus: *Bemisia*
          - Species: *B. tabaci*

B. Origin and distribution

Bemisiatabaci was described over 100 years ago and has since become one of the most important pests worldwide in subtropical and tropical agriculture as well as in greenhouse production systems. It adapts easily to new host plants and geographical regions and has now been reported from all global continents except the Antarctica. In 4.0 ha last decade, international transport of plant material and people have contributed to geographical spread of this pests. *Bemisia tabaci* has been recorded from more than 600 plant species (Oliveira *et al.* 2001).

C. Life cycle

Egg: Adult whitefly females usually lay between 200 and 400 eggs. Eggs are pyriform or ovoid and possess a pedicel that is a peg like extension of the chorion.

Nymph: The eggs hatch, and the young whiteflies gradually increase in size through four nymphal stages called instars. The first nymphal stage (crawler) is rarely visible even with a hand lens. The crawler move around for several hours before settling to begin feeding. Later nymphal stages are immobile, oval, and flattened, with greatly reduced legs and antennae, like small scale insects.

Adult: Adult whiteflies are about 1⁄10 to 1⁄16 inch long and have four broad, delicate wings and are covered with a white powdery wax. The wings of *Bemisia tabaci* are held tent-like above the body and slightly apart, so that the yellow tinged body is more apparent. Adult females tend to lay eggs randomly, either singly or in scattered groups, usually on the under-surface of leaves, whereas the glasshouse whitefly usually lays its eggs in a semi-circle.

D. Nature of damage

Whiteflies suck phloem sap and large populations can cause leaves to yellow, appear dry, or to fall off of plants. Due to the excretion of honeydew plant leaves can become 5 sticky and covered with a black sooty mould. The honeydew attracts ants, which interfere with the activities of natural enemies that may control whiteflies and other pests. Feeding by the immature whiteflies can cause plant distortion, silvering of leaves and possibly serious losses in some vegetable crops. This devastating global insect pest caused damage directly by sucking the plant sap from phloem, indirectly by excreting honeydews that produce sooty mould, and by spreading 111 plant virus diseases.

2.2 Intercropping or polyculture

Intercropping is one of the cropping strategies that have been recognized to improve the food security situation and incomes for the farmers (Mahfuza 2012).

Sweet gourd is an important vegetable sown with wide spacing, and may be grown in both rabi and kharif season. Different winter vegetables (cabbage, cauliflower, radish, lettuce and tomato) may be grown in association with sweet gourd. However, some farmers of Panchagar and Khulna districts have been practicing sweet gourd intercropping with tomato and cauliflower instead of sole cropping (Kakon *et al*. 2018).

Kakon *et al.* (2018) showed that, sweet gourd equivalent yields (SEY) in all intercropping systems were higher than sole sweet gourd (35.89 t ha^{-1}) indicating higher productivity of intercropping systems and also providing higher BCR (2.98). Similar results were mentioned by Alom*et al.* (2013) and Islam *et al.* (2013).

Kabiraj *et al.* (2017) showed that, intercropping system of cauliflower + french bean followed by cauliflower + pea recorded the most promising result of LER with the values of 1.23 and 1.21, respectively. The high efficiency of intercropping found in this study is in agreement with the findings of Baumann *et al.* (2001), Malhotra and Kumar (1995) and Prabhakar and Sukhla (1990) who explained this phenomenon by the complementary use of growth resources in vegetable production.

To maintain yield and quality in intercropping systems, complementarity in patterns of resource use must be taken into account. Cultivars suitable for intercropping should enhance the complementary effects between species (Baumann *et al.* 2001).

Advantages of intercropping with legumes have been demonstrated in numerous studies; tomato orokra with cowpea (Olasantan 1991), cabbage with bean (Poniedzialek *et al.*1989), watermelon with soybean (Sharaiha and Hattar 1993), chilli with bean (Costa and Perera 1998).

When the values of land equivalent ratio appear to be greater than 1 under intercropping system, this usually indicates the efficiency of this system over thesole cropping system (Vandermeer 1989).

Yildirim and Guvenc (2005) reported that, the highest value of LER was obtained in cauliflower intercropped with leaf lettuce and gave a LER of 1.32, 1.35 and 1.36 in 2000–2002, respectively.

Baumann *et al.* (2001), Costa and Perera (1998), Malhotra and Kumar (1995) and Shukla (1990), who explained this phenomenon by the complementary use of growth resources in vegetable production.

Yildirim and Guvenc (2005) also conducted a study on intercropping of cauliflower with other crop and concluded that, intercropping based on cauliflower could not only use limited areas for crop production more efficiently but also increase income for small farmers with limited resources. Higher returns under intercropping systems explained the suitability of intercropping systems to be adopted on a commercial scale. This positive effect of intercropping on net income in this study was in agreement with the results of Erdogan and Karatas (2000) in cucumber, pepper and tomato: lettuce, Abidin *et al.* (1989) in garlic: bean, Quayyum and Akanda (1990) in cabbage: bean, Prabhakar and Shukla (1991) in okra: bean intercrops.

Varghese (2000) indicated that intercropping with six different vegetables did not affect N, P and K content of cabbage compared to sole cabbage. Similarly, Santos *et al.* (2002) reported that concentrations of N, P, K and Ca in leaves of intercropped broccoli with cauliflower and bean were similar to the mono crop ones. This could be explained by the efficient use of available resources per unit area for different crops (Shultz *et al.* 1987, Sharaiha and Hattar 1993). Greater nutrient uptake by intercropping has been shown by several authors (Varghese 2000, Morris and Garrity 1993, Woolley and Davis 1991). Intercrop studies have shown that root competition for immobile macro-nutrients like P and K is unlikely (Midmore 1993). Furthermore, Coolman and Hoyt (1993) and Zhou *et al.* (2000) noted that intercropping can improve N-use. Complementary use of resources such as nutrients is likely to result when the intercrops explores a larger soil mass (Francis 1989).

Fukai and Trenbath (1993) reported that intercropping is most productive when intercrops differ greatly in growth duration so that their maximum requirements for growth resources occur at different times. In the study, the differences of growth rhythm, time of maturity or resource use of main and intercrops might be expected to reduce or postpone competition between crops. Moreover, after intercrops harvest, cauliflower may have taken full advantage of all available resources to complete its growth. Splitstoesser (1990) and Peirce (1987) reported that short season vegetables (e.g. peas, lettuce, kohlrabi, green onion) planted between full season vegetables for complementary depth and spread of root systems preclude serious competition for light, water and nutrients. They also pointed out that short duration vegetables can be harvested in time to make room for the later maturing ones.

This non-significant effect of bean as an intercrop on yield of cauliflower in this study was in agreement with the results of Poniedzialek and Kunicki (1995), Poniedzialek *et al.* (1989), Sharma *et al.* (1988) in cabbage: bean, Subhan (1991) in tomato: bean and of Itulya *et al.* (1997) in collard: cowpea intercrops. This may be attributed that intercropping with a legume can improve N-use (Itulya *et al.* 1997) and the legume can release biologically fixed N to the non-legume (Ofori and Stern 1987).

Omar *et al.* (1989) reported thatradish root exudates had the greatest effect in reducingthe germination of cabbage which later reduced the growth. Kocacaliskan (2001) reported that radish with allelopathic effects can affect adversely growth and yield of other crops.

CHAPTER III

MATERIALS AND METHODS

The present study regarding the effect of intercropping on incidence of pests and predators in cauliflower fields has been conducted during November 2019 to February 2020 in the experimental fields of Sher-e-Bangla Agricultural University, Dhaka. Required materials and methodology are described below under the following sub-headings.

3.1 Location

The experiments were conducted in the experimental farm of SAU, Dhaka situated at latitude 23º46' N and longitude 90º23'E with an elevation of 8.45 meter the sea level. Laboratory studies were done in the laboratory of Entomology department, SAU.

3.2 Climate

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

3.3 Soil

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

3.4 Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production (Plate 1). The target land was divided into 21 equal plots (3m×1m) with plot to plot distance of 0.50 m and block to block distance is 0.75 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment were followed immediately after land preparation.

3.5 Manure and fertilizer

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

3.6 Design of experiment and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 7 unit plots. The size of the unit plot was 3 m×1 m. The block to block and plot-to-plot distance was 0.75 m and 0.5 m, respectively.

3.7 Collection of seed and raising of seedlings

The seeds of selected Cauliflower variety BRRI cauliflower 1 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing, the germination test of seeds was done and on an average, 90% germination was found for this variety. Seeds were then sown on October 2019 in seedbed containing a mixture of equal proportion well decomposed cow dung and loam soil. After sowing seeds, the seedbeds were irrigated regularly. After germination, the seedlings were sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week. Other crops (tomato, marigold, garlic, coriander, radhuni and fenugreek) seed were collected from Siddik bazar, Dhaka.All seed were tested (germination test) before sowing in the seed bed. These seed were also sowed on seed bed separately. Frequent irrigation was provided to the seedlings when necessary.

3.8 Seedling transplanting

The 30 days old healthy and uniform sized seedlings of cauliflower variety (BRRI cauliflower 1) was transplanted on November 2019 in the main field (Plate 2). Each plot contains 12 seedlings of cauliflower with 2 rows followed by 60cm x 40cm (row to row and plant to plant distance, respectively).

As intercropping Seedlings of tomato, marigold, garlic, coriander, radhuni and fenugreek also transplanted to the selected plots.

3.9 Cultural practices

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

3.10 Treatments

The experiment was evaluated to determine the effect of intercropping on incidence of pests and predators in cauliflower fields (Plate 8). The intercropping of cauliflower with tomato, marigold, garlic, coriander, radhuni, fenugreek to be used as treatment in the study are given bellow:-

T_1= Intercropping cauliflower with tomato

T_2= Intercropping cauliflower with marigold

T_3= Intercropping cauliflower with garlic

T_4= Intercropping cauliflower with coriander

T_5= Intercropping cauliflower with radhuni

T_6= Intercropping cauliflower with fenugreek

T_7= Control (Sole cropping of cauliflower)

3.11 Data collection

For data collection five plants per plot were randomly selected and tagged. Data collection was started at vegetative stage to cauliflower card harvesting stage. The data were recorded on number of aphid, whitefly, stripped beetle, leaf miner and diamond back moth, number of infested plant by the insects, number of beneficial insects. The following parameters were considered during data collection.

3.11.1 Number of insect pests of cauliflower and number of infested leaves caused by different insect pests

Data were collected on the number of aphid, whitefly, stripped beetle, leaf miner and diamond back moth and number of infested plants caused by insect pests from randomly selected 5 tagged plants per plot and counted separately for each treatment (Plate 4, Plate 5, Plate 6).

3.11.2 Number of beneficial arthropod

Data were collected on the number of beneficial arthropods such as lady bird beetle, spider etc. per plot and counted separately for each treatment through visual observation in the field.

3.11.3 Height of the cauliflower plant

Data were collected on the height of cauliflower plants from five randomly select plants per plot. For collecting data, height was measured from the ground level to the tip of the card of cauliflower.

3.11.4 Length and diameter of card of cauliflower

Data were collected on the length and diameter of cauliflower card from five randomly select plants per plot during harvesting time. Length and diameter were measured in cm and recorded separately (Plate 7).

3.11.5 Weight of cauliflower card

After harvesting of cauliflower, weight of card was measured in gm separately and recorded.

3.12 Calculation

3.12.1 Percent of infested plants by insect pests

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

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

3.12.2 Percent reduction over control

The number insect pests from different treatment plots and untreated control plot were recorded and the percent reduction of insect infestation was calculated using the following formula:

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

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.13 Statistical analysis

Data statistically analyzed by randomized complete block design through MSTAT-C software and Duncan's multiple range tests was used to determine the levels of significant differences among different intercropping practices.

Plate 1: Land preparation

Plate 2: Seedling transplanting

Plate 3: Main field of cauliflower

Plate 4: Larvae of diamond back moth on leaves

Plate 5: Stripped beetle on cauliflower

Plate 6: Aphid on cauliflower leaf

Plate 7: Healthy cauliflower

Plate 8: Cauliflower intercropping with tomato

CHAPTER IV

RESULTS AND DISCUSSION

The experimental studies included investigation on the effect of intercropping on incidence of pests and predators in cauliflower field. The data have been presented and discussed and possible interactions are made under the following sub-headings:

4.1 Insect pests and beneficial arthropods in cauliflower field

To study the insect pests and beneficial arthropods in different crop fields was carried out at central experimental farm of SAU campus. Aphid, whitefly, stripped beetle, leaf minor, diamond back moth, lady bird beetle and field spider were found in the fields of control and cauliflower fields intercropped with tomato, coriander, fenugreek and marigold. In case of aphid, the highest population (43.90%) was found in control field, which was followed by tomato (24.39%) and marigold (14.63%) intercropped fields. Whereas, the lowest population was found in intercropping field with coriander (7.32%) and fenugreek (9.76%) intercropped fields and no infestation was recorded in garlic and radhuni intercropping fields (Table 1).

In terms of whitefly, the highest population (41.86%) was found in tomato intercropping field, which was followed by control (18.60%) and fenugreek intercropping field (13.95%). Whereas, the lowest population was found in radhuni (6.98%), marigold (9.30%) and coriander (9.30%) intercropped fields and no infestation was recorded in garlic intercropping field (Table 1).

In terms of stripped beetle, the highest population (50.00%) was found in control cauliflower field, which was followed by garlic (23.08%) and tomato (15.38%) intercropped fields. Whereas, the lowest population was found in intercropping fields of fenugreek (3.85%) and radhuni (7.69%) and no infestation was recorded in intercropping field of coriander and marigold (Table 1).

In terms of leaf miner and diamond back moth, the population of insect was found in cauliflower field (100.00% and 100.00%, respectively) (Table 1).

In case of lady bird beetle, the highest population (37.50%) was found on tomato plants intercropped with cauliflower, which was followed by control cauliflower (31.25%), marigold (12.50%) and fenugreek (12.50%) intercropped fields. Whereas, the lowest population was found in coriander plants (6.25%) intercropped field and no infestation was recorded in garlic plants and radhuni intercropped fields (Table 1).

In case of field spider, the highest population (33.33%) was found on marigold intercropped filed, which was followed by control cauliflower field (20.00%), tomato (13.33%), garlic (13.33%) and fenugreek (13.33%) intercropped fields. Whereas, the lowest population was found in fields intercropped with radhuni (6.67%) and no infestation was recorded in coriander intercropping fields (Table 1).

Table 1: Percent insect and beneficial arthropods incidence in different crop field

Crops	**Aphid**	**Whitefly**	**Stripped beetle**	**Leaf miner**	**Diamond back moth**	**Lady bird beetle**	**Field spider**
Cauliflower sole crop	43.90	18.60	50.00	100.00	100.00	31.25	20.00
Cauliflower + Tomato	24.39	41.86	15.38	0.00	0.00	37.50	13.33
Cauliflower + Marigold	14.63	9.30	0.00	0.00	0.00	12.50	33.33
Cauliflower + Garlic	0.00	0.00	23.08	0.00	0.00	0.00	13.33
Cauliflower + Coriander	7.32	9.30	0.00	0.00	0.00	6.25	0.00
Cauliflower + Radhuni	0.00	6.98	7.69	0.00	0.00	0.00	6.67
Cauliflower +Fenugreek	9.76	13.95	3.85	0.00	0.00	12.50	13.33
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

According to this study, the highest insect pests was found in cauliflower field and lowest insect incidence was found in garlic intercropped fields. Again, whitefly was recorded in maximum crop fields namely control cauliflower, tomato, marigold, coriander, radhuni and fenugreek intercropping fields. In case of beneficial (predator) arthropod, field spider was found in control cauliflower, tomato, marigold, garlic, radhuni and fenugreek intercropped field. This findings is more or less similar with Yildirim and Guvenc (2005), Karatas (2000) and Quayyum and Akanda (1990).

4.2 Effect of management practices on insect pests incidence

4.2.1 Incidence of aphid

The effect of management practices on number of aphid per five tagged plants at different days after transplanting (DAT) is shown in Table 2. Significant variations were observed among the treatments. At 30 DAT, the highest number of aphid was recorded in T_7 (7.05aphids), which was statistically different from other treatments and followed by T_6 (6.52 aphids) and T_5 (5.79 aphids). On the other hand, the lowest number of aphid was recorded in T_4 (3.80 aphids), which was statistically similar with T_1 (3.89 aphids) and followed by T_3 (4.90 aphids) and T_2 (5.11 aphids). More or less similar trends of aphid population were also recorded at 60 and 90 DAT (Table 2).

In case of average number of aphids, the highest number of aphid was recorded in T_7 (8.02aphids), which was statistically different from other treatments and followed by T_6 (7.14 aphids) and T_5 (6.54 aphids). On the other hand, the lowest number of aphid was recorded in T_4 (4.50 aphids), which was statistically similar with T_1 (4.88 aphids) and followed by T_3 (5.68 aphids) and T_2 (6.05 aphids).

Considering the reduction over control, the highest reduction (43.89%) of number of aphid was observed in T_4, followed by T_1 (39.15%), T_3 (29.18%) and T_2 (24.56%). Whereas, the lowest reduction (10.97%) of aphid population over control was observed in T_6 followed by T_5 (18.45%).

Table 2: Effect of different treatments on the number of aphid per five tagged plants at different DAT

Treatments	Number of aphid per five tagged plants				% reduction over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	3.89 e	4.72 e	6.03 e	4.88 f	39.15
T_2	5.11 d	6.01 c	7.04 d	6.05 d	24.56
T_3	4.90 d	5.52 d	6.62 d	5.68 e	29.18
T_4	3.80 e	4.34 e	5.36 f	4.50 f	43.89
T_5	5.79 c	6.29 c	7.56 c	6.54 c	18.45
T_6	6.52 b	6.83 b	8.04 b	7.14 b	10.97
T_7	7.05 a	8.16 a	8.86 a	8.02 a	0
LSD (0.05)	0.13	0.46	0.46	0.36	-
CV (%)	4.26	4.51	3.83	3.46	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of aphid over control (43.89%). As a result, the order of rank of efficacy of the treatments applied against the number of aphids per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Kabiraj *et al.* (2017) and Malhotra and Kumar (1995).

4.2.2 Incidence of whitefly

The effect of management practices on number of whitefly per five tagged plants at different days after transplanting (DAT) is shown in Table 3. Significant variations were observed among the treatments in terms of whitefly infestation. At 30 DAT, the highest number of white fly was recorded in T_7 (4.21whitefly), which was statistically different from other treatments followed by T_6 (3.65 whitefly) and T_5 (3.52 whitefly). On the other hand, the lowest number of white fly was recorded in T_4 (1.60 whitefly), which was statistically different from other treatments and followed by T_1 (2.56 whitefly), T_3 (2.88 whitefly) and T_2 (3.30 whitefly). More or less similar trends of number of white fly were also recorded at 60 DAT and 90 DAT (Table 3).

In case of average number of whitefly, the highest number of white fly was recorded in T_7 (5.20 whitefly), which was statistically different from other treatments followed by T_6 (4.52 whitefly) and T_5 (4.04 whitefly). On the other hand, the lowest number of white fly was recorded in T_4 (2.02 whitefly), which was statistically different from other treatments followed by T_1 (3.02 whitefly), T_3 (3.42 whitefly) and T_2 (3.92 whitefly).

Considering the reduction over control, the highest reduction (61.15%) of number of whitefly over control was observed in T_4, which was followed by T_1 (41.92%), T_3 (34.23%) and T_2 (24.62%). Whereas, the lowest reduction (13.08%) of number of whitefly over control was observed in T_6 and followed by T_5 (22.31%).

Table 3: Effect of different treatments on the number of whitefly per five tagged plants at different DAT

Treatments	Number of whitefly per five tagged plants				% reduction over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	2.56 d	2.82 e	3.70 d	3.02 e	41.92
T_2	3.30 bc	3.99 c	4.48 c	3.92 c	24.62
T_3	2.88 cd	3.34 d	4.02 d	3.42 d	34.23
T_4	1.60 e	1.90 f	2.57 e	2.02 f	61.15
T_5	3.52 b	3.85 c	4.74 c	4.04 c	22.31
T_6	3.65 b	4.60 b	5.32 b	4.52 b	13.08
T_7	4.21 a	5.22 a	6.18 a	5.20 a	0
LSD (0.05)	0.47	0.51	0.35	0.33	-
CV (%)	8.90	8.17	4.67	5.22	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of whitefly over control (61.15%). As a result, the order of rank of efficacy of the treatments applied against the number of whitefly per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Kabiraj *et al.* (2017) and Malhotra and Kumar (1995).

4.2.3 Incidence of stripped beetle

The effect of management practices on number of stripped beetle per five tagged plants at different days after transplanting (DAT) is shown in Table 4. Significant variations were observed among the treatments in terms of stripped beetle infestation. At 30 DAT, the highest number of stripped beetle was recorded in T_7 (1.98 stripped beetle), which was statistically similar with T_6 (1.85 stripped beetle) followed by T_5 (1.45 stripped beetle). On the other hand, the lowest number of stripped beetle was recorded in T_4 (0.36 stripped beetle), which was statistically different from other treatments followed by T_1 (0.76 stripped beetle), T_3 (0.97 stripped beetle) and T_2 (1.12 stripped beetle). More or less similar trends of number of stripped beetle were also recorded at 60 DAT and 90 DAT (Table 4).

In case of average number of stripped beetle, the highest number of stripped beetle was recorded in T_7 (2.16 stripped beetle), which was statistically different from other treatments followed by T_6 (1.99 stripped beetle) and T_5 (1.72 stripped beetle). On the other hand, the lowest number of stripped beetle was recorded in T_4 (0.52 stripped beetle), which was statistically different from other treatments followed by T_1 (0.96 stripped beetle), T_3 (1.16 stripped beetle) and T_2 (1.33 stripped beetle).

Considering the reduction over control, the highest reduction (75.93%) of number of stripped beetle over control was observed in T_4, which was followed by T_1 (55.56%), T_3 (46.30%) and T_2 (38.43%). Whereas, the lowest reduction (07.87%) of number of stripped beetle over control was observed in T_6 followed by T_5 (20.37%).

Table 4: Effect of different treatments on the number of stripped beetle per five tagged plants at different DAT

Treatments	Number of stripped beetle per five tagged plants				% reduction over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	0.76 d	0.95 d	1.15 d	0.96 f	55.56
T_2	1.12 c	1.33 c	1.53 c	1.33 d	38.43
T_3	0.97 c	1.19 c	1.32 d	1.16 e	46.30
T_4	0.36 e	0.47 e	0.74 e	0.52 g	75.93
T_5	1.45 b	1.73 b	1.98 b	1.72 c	20.37
T_6	1.85 a	1.96 a	2.15 ab	1.99 b	07.87
T_7	1.98 a	2.15 a	2.35 a	2.16 a	0
LSD (0.05)	0.20	0.22	0.20	0.08	-
CV (%)	9.88	9.04	7.36	3.17	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of stripped beetle over control (75.93%). As a result, the order of rank of efficacy of the treatments applied against the number of stripped beetle per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Baumann *et al.* (2001) and Prabhakar and Sukhla (1990).

4.2.4 Incidence of leaf miner

The effect of management practices on number of leaf miner per five tagged plants at different days after transplanting (DAT) is shown in Table 5. Significant variations were observed among the treatments in terms of leaf miner infestation. At 30 DAT, the highest number of leaf miner was recorded in T_7 (2.18 leaf miner), which was statistically similar with T_6 (2.04 leaf miner) followed by T_5 (1.78 leaf miner). On the other hand, the lowest number of leaf miner was recorded in T_4 (0.62 leaf miner), which was statistically different from other treatments followed by T_1 (0.84 leaf miner), T_3 (0.97 leaf miner) and T_2 (1.29leaf miner). More or less similar trends of number of leaf miner were also recorded at 60 DAT and 90 DAT (Table 5).

In case of average number of leaf miner, the highest number of leaf miner was recorded in T_7 (2.32 leaf miner), which was statistically different from other treatments followed by T_6 (2.14 leaf miner) and T_5 (1.94 leaf miner). On the other hand, the lowest number of leaf miner was recorded in T_4 (0.82 leaf miner), which was statistically different from other treatments followed by T_1 (1.04 leaf miner), T_3 (1.06 leaf miner) and T_2 (1.44 leaf miner).

Considering the reduction over control, the highest reduction (64.66%) of number of leaf miner over control was observed in T_4, which was followed by T_1 (55.17%), T_3 (54.31%) and T_2 (37.93%). Whereas, the lowest reduction (07.75%) of number of leaf miner over control was observed in T_6 and followed by T_5 (19.98%).

Table 5: Effect of different treatments on the number of leaf miner per five tagged plants at different DAT

Treatments	Number of leaf miner per five tagged plants				% reduction over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	0.84 d	1.06 e	1.22 e	1.04 e	55.17
T_2	1.29 c	1.45 d	1.59 d	1.44 d	37.93
T_3	0.97 d	1.07 e	1.15 ef	1.06 e	54.31
T_4	0.62 e	0.84 f	0.99 f	0.82 f	64.66
T_5	1.78 b	1.95 c	2.09 c	1.94 c	19.98
T_6	2.04 a	2.13 b	2.26 b	2.14 b	07.75
T_7	2.18 a	2.32 a	2.46 a	2.32 a	0
LSD (0.05)	0.18	0.17	0.16	0.13	-
CV (%)	7.54	6.58	5.75	5.08	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of leaf miner over control (64.66%). As a result, the order of rank of efficacy of the treatments applied against the number of leaf miner per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Baumann *et al.* (2001) and Prabhakar and Sukhla (1990).

4.2.5 Incidence of diamond back moth

The effect of management practices on number of diamond back moth per five tagged plants at different days after transplanting (DAT) is shown in Table 6. Significant variations were observed among the treatments in terms of diamond back moth infestation. At 30 DAT, the highest number of diamond back moth was recorded in T_7 (3.48 diamond back moth), which was statistically different from others followed by T_6 (3.19 diamond back moth) and T_5 (2.84 diamond back moth). On the other hand, the lowest number of diamond back moth was recorded in T_4 (1.57 diamond back moth), which was statistically different from other treatments followed by T_1 (1.89 diamond back moth), T_3 (2.12 diamond back moth) and T_2 (2.46 diamond back moth). More or less similar trends of number of diamond back moth were also recorded at 60 DAT and 90 DAT (Table 6).

In case of average number of diamond back moth, the highest number of diamond back moth was recorded in T_7 (3.66 diamond back moth), which was statistically different from other treatments followed by T_6 (3.36 diamond back moth) and T_5 (2.98 diamond back moth). On the other hand, the lowest number of diamond back moth was recorded in T_4 (1.76 diamond back moth), which was statistically different from other treatments followed by T_1 (2.01 diamond back moth), T_3 (2.27 diamond back moth) and T_2 (2.71 diamond back moth).

Considering the reduction over control, the highest reduction (51.91%) of number of diamond back moth over control was observed in T_4, which was followed by T_1 (45.08%), T_3 (37.98%) and T_2 (25.96%). Whereas, the lowest reduction (08.20%) of number of diamond back moth over control was observed in T_6 and followed by T_5 (18.58%).

Table 6: Effect of different treatments on the number of diamond back moth per five tagged plants at different DAT

Treatments	Number of diamond back moth per five tagged plants				% reduction over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	1.89 f	1.94 f	2.18 f	2.01 f	45.08
T_2	2.46 d	2.71 d	2.96 d	2.71 d	25.96
T_3	2.12 e	2.26 e	2.42 e	2.27 e	37.98
T_4	1.57 g	1.78 g	1.91 g	1.76 g	51.91
T_5	2.84 c	2.98 c	3.12 c	2.98 c	18.58
T_6	3.19 b	3.33 b	3.55 b	3.36 b	08.20
T_7	3.48 a	3.67 a	3.82 a	3.66 a	0
LSD (0.05)	0.18	0.09	0.13	0.05	-
CV (%)	4.11	2.18	2.79	1.42	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of diamond back moth over control (51.91%). As a result, the order of rank of efficacy of the treatments applied against the number of diamond back moth per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Baumann *et al.* (2001) and Prabhakar and Sukhla (1990).

4.2.6 Plant infestation caused by insect pests

Significant variations were observed among the treatments in terms of number of infested plants per plot. The highest number of infested plants per plot was recorded in T_7 (11.00 plants), which was statistically different from others followed by T_6 (9.00 plants) and T_5 (8.00 plants). On the other hand, the lowest number of infested plants per plot was recorded in T_4 (4.67 plants), which was statistically different from other treatments followed by T_1 (6.00 plants), T_3 (6.33 plants) and T_2 (7.00 plants) (Table 7).

In case of percent plant infestation, the highest plant infestation was recorded in T_7 (61.11%), which was statistically different from other treatments followed by T_6 (50.00%) and T_5 (44.44%). On the other hand, the lowest plant infestation was recorded in T_4 (25.93%), which was statistically different from other treatments followed by T_1 (33.33%), T_3 (35.18%) and T_2 (38.89%).

Considering the reduction over control, the highest reduction (57.57%) of percent plant infestation over control was observed in T_4, which was followed by T_1 (45.46%), T_3 (42.43%) and T_2 (36.36%). Whereas, the lowest reduction (18.18%) of percent plant infestation over control was observed in T_6 and followed by T_5 (27.28%).

Table 7: Effect of different treatments on percent plant infestation by different insect pests of cauliflower

Treatments	Total number of plants	Number of infested plants	% plant infestation	% reduction over control
T_1	18	6.00 e	33.33 e	45.46
T_2	18	7.00 d	38.89 d	36.36
T_3	18	6.33 de	35.18 de	42.43
T_4	18	4.67 f	25.93 f	57.57
T_5	18	8.00 c	44.44 c	27.28
T_6	18	9.00 b	50.00 b	18.18
T_7	18	11.00 a	61.11 a	0
LSD (0.05)	-	0.77	4.30	-
CV (%)	-	6.11	6.12	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the percent plant infestation over control (57.57%). As a result, the order of rank of efficacy of the treatments applied against the plant infestation caused by different insect pests of cauliflower was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Baumann *et al.* (2001) and Prabhakar and Sukhla (1990).

4.3 Effect of management practices on predator arthropods

4.3.1 Incidence of lady bird beetle

The effect of management practices on the number of lady bird beetle per five tagged plants at different days after transplanting (DAT) is shown in Table 8. Significant variations were observed among the treatments in terms of incidence of lady bird beetle. At 30 DAT, the highest number of lady bird beetle was recorded in T_4 (3.88 lady bird beetle), which was statistically different from others followed by T_1 (3.59 lady bird beetle) and T_3 (3.23lady bird beetle). On the other hand, the lowest number of lady bird beetle was recorded in T_7 (1.88 lady bird beetle), which was statistically different from other treatments followed by T_6 (2.21 lady bird beetle), T_5 (2.54 lady bird beetle) and T_2 (2.84 lady bird beetle). More or less similar trends of number of lady bird beetle were also recorded at 60 DAT and 90 DAT (Table 8).

In case of average number of lady bird beetle, the highest number of lady bird beetle was recorded in T_4 (4.06 lady bird beetle), which was statistically different from other treatments followed by T_1 (3.73 lady bird beetle) and T_3 (3.44 lady bird beetle). On the other hand, the lowest number of lady bird beetle was recorded in T_7 (2.00 lady bird beetle), which was statistically different from other treatments followed by T_6 (2.43 lady bird beetle), T_5 (2.77 lady bird beetle) and T_2 (3.10 lady bird beetle).

Considering the increase over control, the highest increase (103.00%) of number of lady bird beetle over control was observed in T_4, which was followed by T_1 (86.50%), T_3 (72.00%) and T_2 (55.00%). Whereas, the lowest increase (21.50%) of number of lady bird beetle over control was observed in T_6 and followed by T_5 (38.50%).

Table 8: Effect of different treatments on the number of lady bird beetle per five tagged plants at different DAT

Treatments	Number of lady bird beetle per five tagged plants				% increase over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	3.59 b	3.75 b	3.85 b	3.73 b	86.50
T_2	2.84 d	3.11 d	3.34 d	3.10 d	55.00
T_3	3.23 c	3.47 c	3.61 c	3.44 c	72.00
T_4	3.88 a	4.08 a	4.23 a	4.06 a	103.00
T_5	2.54 e	2.78 e	2.99 e	2.77 e	38.50
T_6	2.21 f	2.45 f	2.62 f	2.43 f	21.50
T_7	1.88 g	1.97 g	2.16 g	2.00 g	0
LSD (0.05)	0.12	0.13	0.16	0.11	-
CV (%)	2.52	2.61	2.86	1.92	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in increasing the number of lady bird beetle over control (103.00%). As a result, the order of rank of efficacy of the treatments applied against the number of lady bird beetle per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Costa and Perera (1998) and Sharaiha and Hattar (1993).

4.3.2 Incidence of field spider

The effect of management practices on the number of field spider per five tagged plants at different days after transplanting (DAT) is shown in Table 9. Significant variations were observed among the treatments in terms of incidence of field spider. At 30 DAT, the highest number of field spider was recorded in T_4 (2.67 field spider), which was statistically different from others followed by T_1 (2.35 field spider) and T_3 (1.99 field spider). On the other hand, the lowest number of field spider was recorded in T_7 (0.64 field spider), which was statistically different from other treatments followed by T_6 (0.88 field spider), T_5 (1.23 field spider) and T_2 (1.49 field spider). More or less similar trends of number of field spider were also recorded at 60 DAT and 90 DAT (Table 9).

In case of average number of field spider, the highest number of field spider was recorded in T_4 (2.83 field spider), which was statistically different from other treatments followed by T_1 (2.49 field spider) and T_3 (2.20 field spider). On the other hand, the lowest number of field spider was recorded in T_7 (0.82 field spider), which was statistically different from other treatments followed by T_6 (1.06 field spider), T_5 (1.47 field spider) and T_2 (1.69 field spider).

Considering the increase over control, the highest increase (245.12%) of number of field spider over control was observed in T_4, which was followed by T_1 (203.66%), T_3 (168.29%) and T_2 (106.10%). Whereas, the lowest increase (29.27%) of number of field spider over control was observed in T_6 and followed by T_5 (79.27%).

Table 9: Effect of different treatments on the number of spider per five tagged plants at different DAT

Treatments	Number of field spider per five tagged plants				% increase over control
	30 DAT	60 DAT	90 DAT	Average	
T_1	2.35 b	2.46 b	2.68 b	2.49 b	203.66
T_2	1.49 d	1.69 d	1.90 d	1.69 d	106.10
T_3	1.99 c	2.21 c	2.39 c	2.20 c	168.29
T_4	2.67 a	2.82 a	2.99 a	2.83 a	245.12
T_5	1.23 e	1.45 e	1.73 e	1.47 e	79.27
T_6	0.88 f	1.04 f	1.27 f	1.06 f	29.27
T_7	0.64 g	0.85 g	0.98 g	0.82 g	0
LSD (0.05)	0.14	0.18	0.17	0.09	-
CV (%)	5.17	5.87	4.96	3.18	-

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping in increasing the number of field spider over control (245.12%). As a result, the order of rank of efficacy of the treatments applied against the number of field spider was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Costa and Perera (1998) and Sharaiha and Hattar (1993).

4.4 Effect of different treatments on yield attributing characters of cauliflower

Plant height (cm): The effect of management practices on plant height of cauliflower is shown in Table 10. Significant variations were observed among the treatments in terms of plant height (cm). The highest plant height was recorded in T_4 (36.45 cm), which was statistically different from others followed by T_1 (34.71 cm) and T_3 (34.19 cm). On the other hand, the lowest plant height was recorded in T_7 (28.66 cm), which was statistically different from other treatments followed by T_6 (30.82 cm), T_5 (31.28 cm) and T_2 (33.36 cm).

Card length (cm): The effect of management practices on card length of cauliflower is shown in Table 10. Significant variations were observed among the treatments in terms of card length (cm). The highest card length was recorded in T_4 (18.23 cm), which was statistically different from others followed by T_1 (17.56 cm) and T_3 (16.34 cm). On the other hand, the lowest card length was recorded in T_7 (12.35 cm), which was statistically different from other treatments followed by T_6 (13.17 cm), T_5 (14.54 cm) and T_2 (15.84 cm).

Card diameter (cm): The effect of management practices on card diameter of cauliflower is shown in Table 10. Significant variations were observed among the treatments in terms of card diameter (cm). The highest card diameter was recorded in T_4 (15.37 cm), which was statistically different from others followed by T_1 (14.76 cm) and T_3 (14.34 cm). On the other hand, the lowest card diameter was recorded in T_7 (12.48 cm), which was statistically different from other treatments followed by T_6 (13.17 cm), T_5 (13.58 cm) and T_2 (13.86 cm).

Table 10: Effect of different treatments on yield attribution characteristics of cauliflower

Treatments	Plant height (cm)	Card length (cm)	Card diameter (cm)
T_1	34.71 b	17.56 b	14.76 b
T_2	33.36 d	15.84 d	13.86 d
T_3	34.19 c	16.34 c	14.34 c
T_4	36.45 a	18.23 a	15.37 a
T_5	31.28 e	14.54 e	13.58 e
T_6	30.82 f	13.17 f	13.17 f
T_7	28.66 g	12.35 g	12.48 g
LSD (0.05)	0.31	0.28	0.09
CV (%)	0.56	1.07	0.36

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping showed the best performance in terms of plant height, card length and card diameter (36.45 cm, 18.23 cm and 15.37 cm, respectively). As a result, the order of rank of efficacy of the treatments applied was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Yildirim and Guvenc (2005) and Baumann *et al.* (2001).

4.5 Effect of different treatments on yield of cauliflower

Single card weight (g): The effect of management practices on single card weight of cauliflower is shown in Table 11. Significant variations were observed among the treatments in terms of single card weight (g). The highest single card weight was recorded in T_4 (823.88 g), which was statistically different from others followed by T_1 (813.30 g) and T_3 (804.96 g). On the other hand, the lowest single card weight was recorded in T_7 (722.67 g), which was statistically different from other treatments followed by T_6 (754.83 g), T_5 (786.71 g) and T_2 (795.42 g).

Yield/plot (kg): The effect of management practices on yield of cauliflower per plot is shown in Table 11. Significant variations were observed among the treatments in terms of yield per plot (kg). The highest yield per plot was recorded in T_4 (14.83 kg), which was statistically different from others followed by T_1 (14.64 kg) and T_3 (14.49 kg). On the other hand, the lowest yield per plot was recorded in T_7 (13.01 kg), which was statistically different from other treatments followed by T_6 (13.59 kg), T_5 (14.16 kg) and T_2 (14.32 kg).

Yield (t/ha): The effect of management practices on card yield of cauliflower per hectare is shown in Table 11. Significant variations were observed among the treatments in terms of card yield (t/ha). The highest card yield was recorded in T_4 (24.71 t/ha), which was statistically different from others followed by T_1 (24.40 t/ha) and T_3 (24.15 t/ha). On the other hand, the lowest card yield was recorded in T_7 (21.68 t/ha), which was statistically different from other treatments followed by T_6 (22.65 t/ha), T_5 (23.60 t/ha) and T_2 (23.86 t/ha).

Table 11: Effect of different treatments on yield of cauliflower

Treatments	Single card weight (gm)	Yield/plot (kg)	Yield/ha (ton)
T_1	813.30 b	14.64 b	24.40 b
T_2	795.42 d	14.32 d	23.86 d
T_3	804.96 c	14.49 c	24.15 c
T_4	823.88 a	14.83 a	24.71 a
T_5	786.71 e	14.16 e	23.60 e
T_6	754.83 f	13.59 f	22.65 f
T_7	722.67 g	13.01 g	21.68 g
LSD (0.05)	3.20	0.05	0.09
CV (%)	0.24	0.23	0.24

[DAT = Day After Transplanting, In a column, numeric value represents the mean of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability]

[T_1: Cauliflower intercropping with tomato; T_2: Cauliflower intercropping with marigold; T_3: Cauliflower intercropping with garlic; T_4: Cauliflower intercropping with coriander; T_5: Cauliflower intercropping with radhuni; T_6: Cauliflower intercropping with fenugreek; T_7: Untreated control.]

From these above findings it was revealed that, among the different treatments, T_4 comprised with cauliflower and coriander intercropping showed the best performance in terms of yield of cauliflower (24.71 t/ha). As a result, the order of rank of efficacy of the treatments applied was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$. This findings is more or less similar with Yildirim and Guvenc (2005) and Baumann *et al.* (2001).

4.6 Relationship between number of insect pests and yield of cauliflower

4.6.1 Aphid

Correlation study was done to establish the relationship between number of aphid per five tagged plant and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between the number of aphid per five tagged plant and yield of cauliflower (Figure 1). It was evident from the Figure 1 that the regression equation $y = -0.8346x + 28.683$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9373$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of aphid per five tagged plants and yield of cauliflower, i.e., the yield decreased with the increase of the number of aphid per five tagged plants during the growing season of cauliflower.

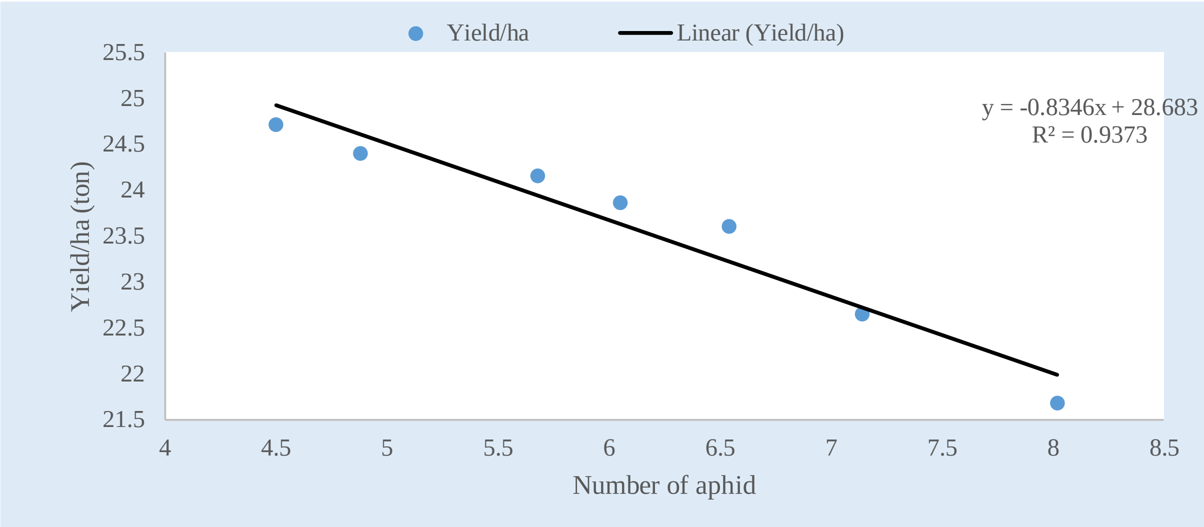


Figure 1: Relationship between number of aphid and yield of cauliflower

4.6.2 Whitefly

Correlation study was done to establish the relationship between number of whitefly per five tagged plant and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between the number of whitefly per five tagged plant and yield of cauliflower (Figure 2). It was evident from the Figure 2 that the regression equation y = -0.9562x + 27.149 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8626) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of whitefly per five tagged plants and yield of cauliflower, i.e., the yield decreased with the increase of the number of whitefly per five tagged plants during the growing season of cauliflower.

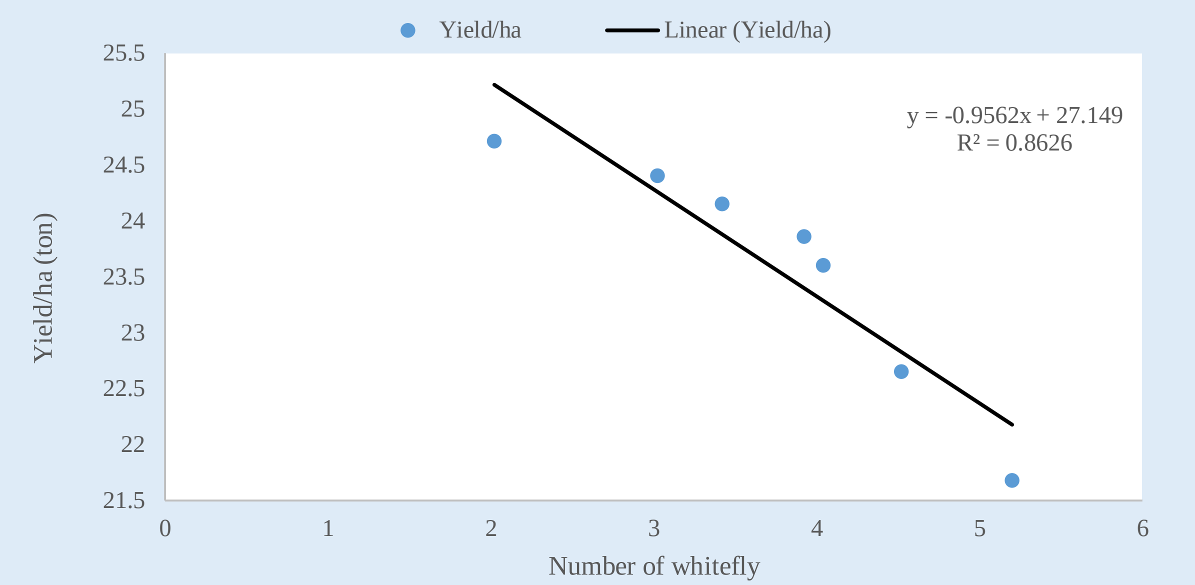


Figure 2: Relationship between number of whitefly and yield of cauliflower

4.6.3 Stripped beetle

Correlation study was done to establish the relationship between number of stripped beetle per five tagged plant and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between the number of stripped beetle per five tagged plant and yield of cauliflower (Figure 3). It was evident from the Figure 3 that the regression equation y = -1.6993x + 25.967 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8705) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of stripped beetle per five tagged plants and yield of cauliflower, i.e., the yield decreased with the increase of the number of stripped beetle per five tagged plants during the growing season of cauliflower.

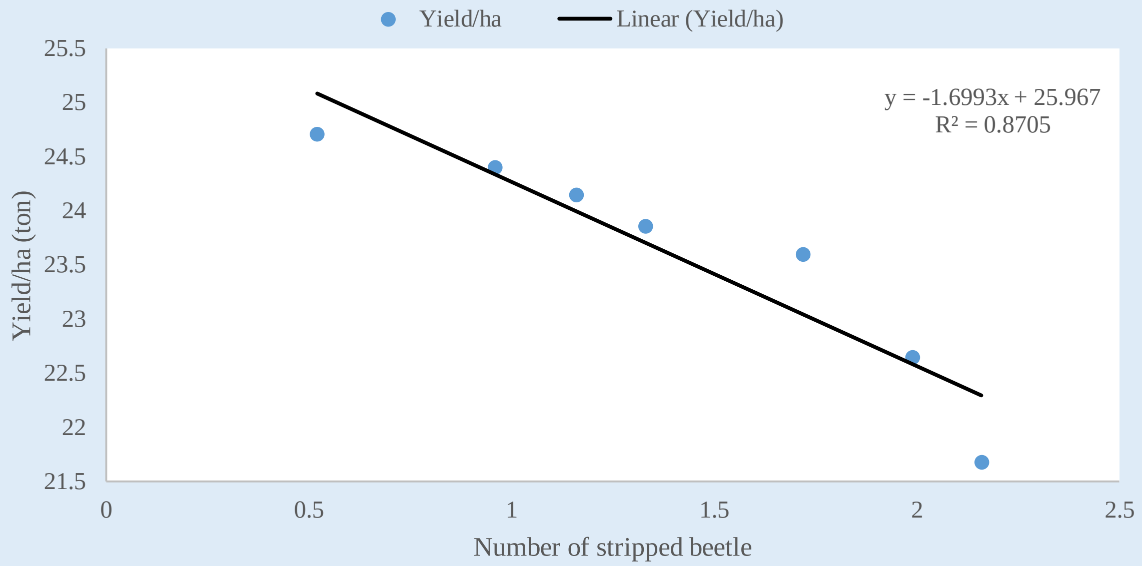


Figure 3: Relationship between number of stripped beetle and yield of cauliflower

4.6.4 Leaf miner

Correlation study was done to establish the relationship between number of leaf miner per five tagged plant and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between the number of leaf miner per five tagged plant and yield of cauliflower (Figure 4). It was evident from the Figure 4 that the regression equation y = -1.6645x + 26.137 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8672) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of leaf miner per five tagged plants and yield of cauliflower, i.e., the yield decreased with the increase of the number of leaf miner per five tagged plants during the growing season of cauliflower.

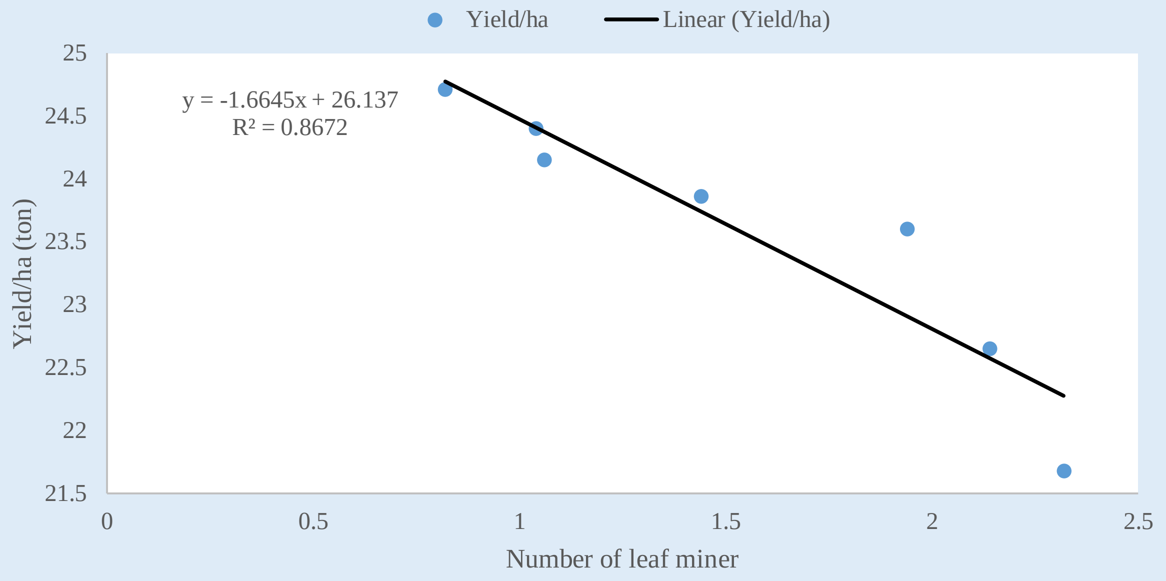


Figure 4: Relationship between number of leaf miner and yield of cauliflower

4.6.5 Diamond back moth

Correlation study was done to establish the relationship between number of diamond back moth per five tagged plant and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between the number of diamond back moth per five tagged plant and yield of cauliflower (Figure 5). It was evident from the Figure 5 that the regression equation y = -1.4453x + 27.45 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9108) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between the number of diamond back moth per five tagged plants and yield of cauliflower, i.e., the yield decreased with the increase of the number of diamond back moth per five tagged plants during the growing season of cauliflower.

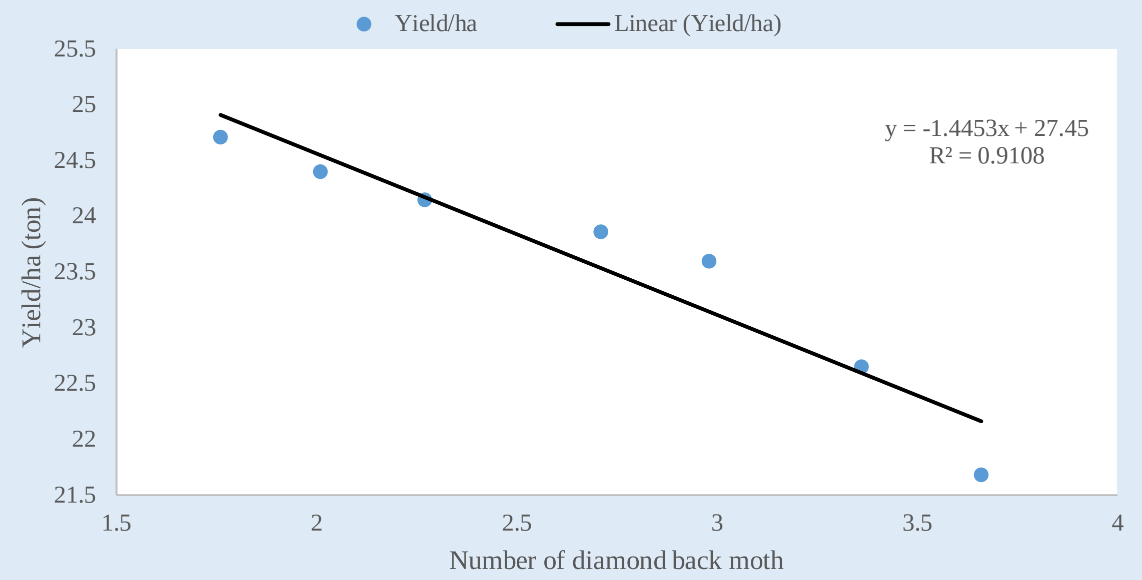


Figure 5: Relationship between number of diamond back moth and yield of cauliflower

4.7 Relationship between yield attributing characteristics and yield of cauliflower

4.7.1 Plant height

Correlation study was done to establish the relationship between plant height (cm) and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between plant height (cm) and yield of cauliflower (Figure 6). It was evident from the Figure 6 that the regression equation y = -0.3832x + 11.018 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9156) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between plant height (cm) and yield of cauliflower, i.e., the yield increased with the increase of plant height during the growing season of cauliflower.

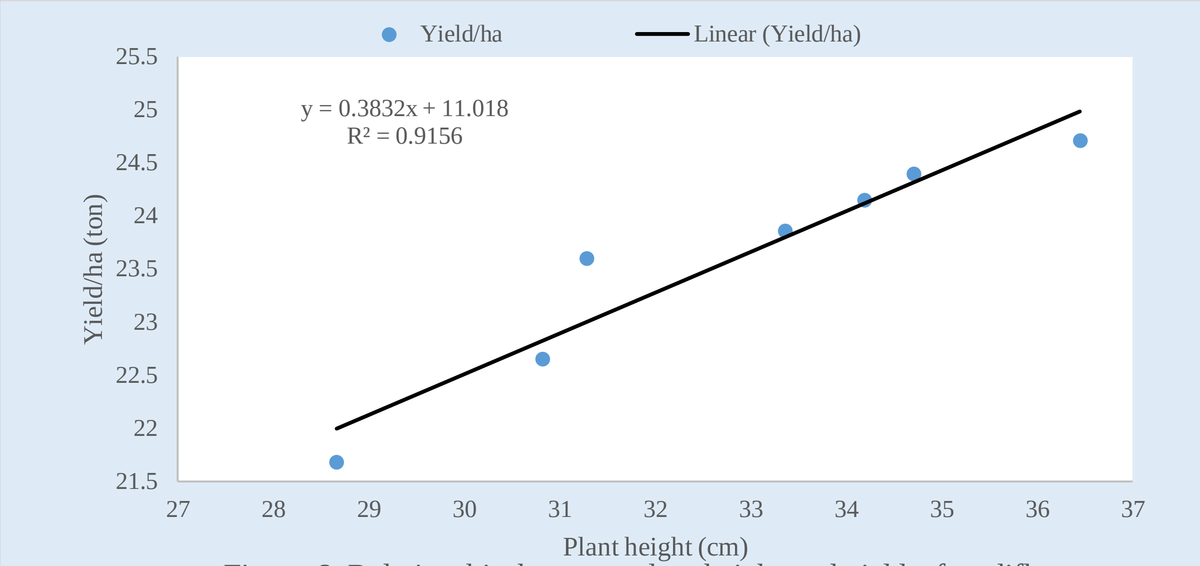


Figure 6: Relationship between plant height and yield of cauliflower

4.7.2 Card length (cm)

Correlation study was done to establish the relationship between card length (cm) and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between card length (cm) and yield of cauliflower (Figure 7). It was evident from the Figure 7that the regression equation y = -0.4687x + 16.345 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9254) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between card length (cm) and yield of cauliflower, i.e., the yield increased with the increase of card length during the growing season of cauliflower.

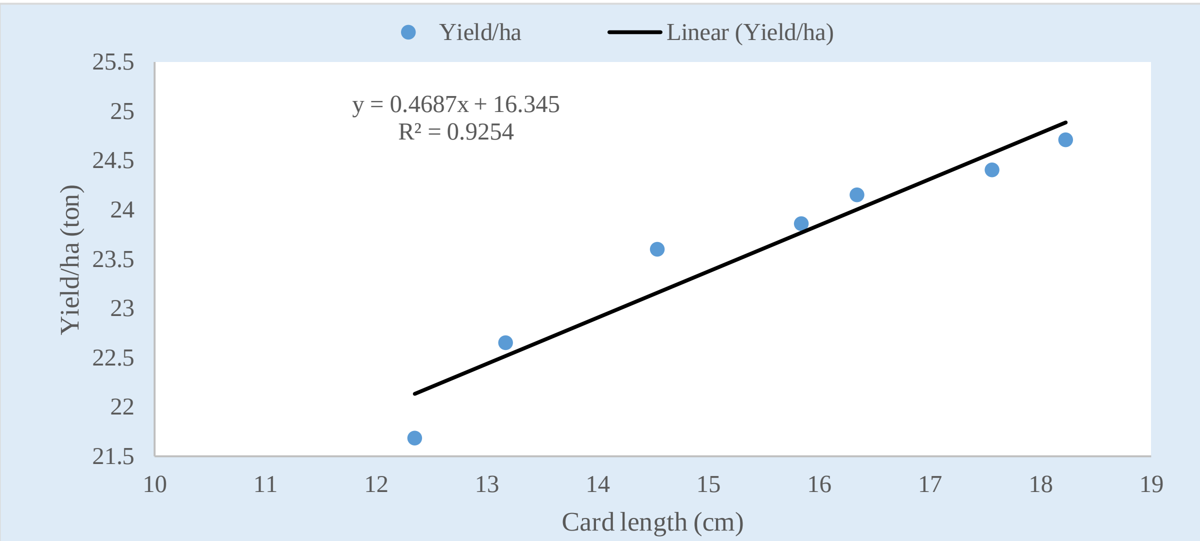


Figure 7: Relationship between card length and yield of cauliflower

4.7.3 Card diameter (cm)

Correlation study was done to establish the relationship between card diameter (cm) and yield (t/ha) of cauliflower. From the study it was revealed that, significant correlation was observed between card diameter (cm) and yield of cauliflower (Figure 8). It was evident from the Figure 8 that the regression equation y = -1.0417x + 9.0608 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9118) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between card diameter and yield of cauliflower, i.e., the yield increased with the increase of the card diameter during the growing season of cauliflower.

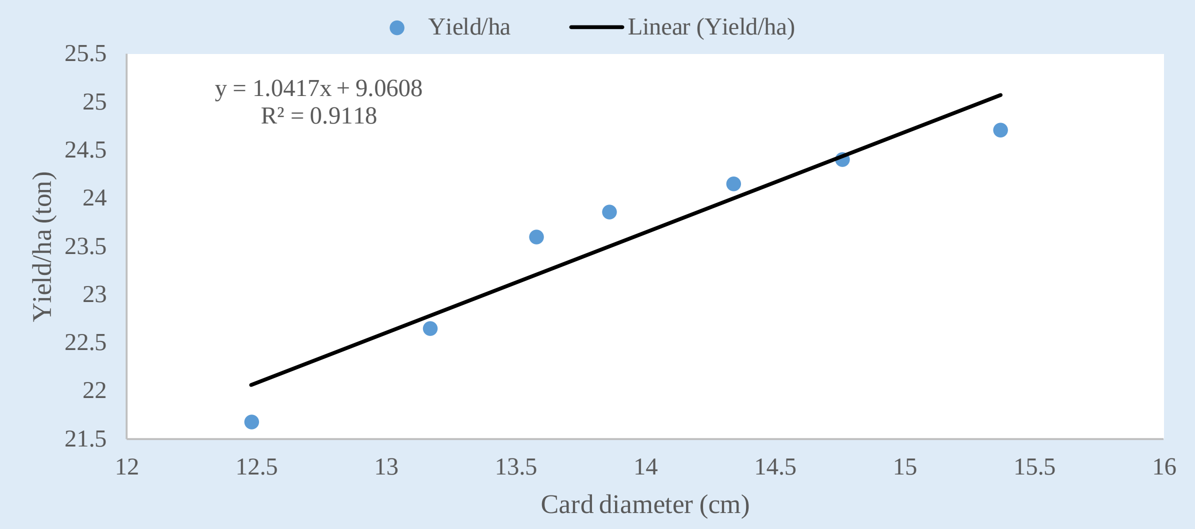


Figure 8: Relationship between card diameter and yield of cauliflower

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2019 to February 2020 to evaluate the effect of intercropping on incidence of pests and predators in cauliflower field. The experiment consisted of intercropping of cauliflower with different crops.

Summary

The highest insect pests was found in cauliflower field and lowest insect incidence was found in coriander field. Again, whitefly was recorded in maximum crop fields namely cauliflower, tomato, marigold, coriander, radhuni and fenugreek field. In case of predator arthropod, field spider was found in cauliflower, tomato, marigold, garlic, radhuni and fenugreek field.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of aphid over control (43.89%). As a result, the order of rank of efficacy of the treatments applied against the number of aphids per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of whitefly over control (61.15%). As a result, the order of rank of efficacy of the treatments applied against the number of whitefly per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of stripped beetle over control (75.93%). As a result, the order of rank of efficacy of the treatments applied against the number of stripped beetle per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of leaf miner over control (64.66%). As a result, the order of rank of efficacy of the treatments applied against the number of leaf miner per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the number of diamond back moth over control (51.91%). As a result, the order of rank of efficacy of the treatments applied against the number of diamond back moth per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in reducing the percent plant infestation over control (57.57%). As a result, the order of rank of efficacy of the treatments applied against the plant infestation caused by different insect pests of cauliflower was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in increasing the number of lady bird beetle over control (103.00%). As a result, the order of rank of efficacy of the treatments applied against the number of lady bird beetle per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping in increasing the number of field spider over control (245.12%). As a result, the order of rank of efficacy of the treatments applied against the number of field spider per five tagged plants was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping showed the best performance in terms of plant height, card length and card diameter (36.45 cm, 18.23 cm and 15.37 cm, respectively). As a result, the order of rank of efficacy of the treatments applied was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Among the different treatments, T_4 comprised with cauliflower and coriander intercropping showed the best performance in terms of yield of cauliflower (24.71 t/ha). As a result, the order of rank of efficacy of the treatments applied was $T_4 > T_1 > T_3 > T_2 > T_5 > T_6 > T_7$.

Conclusion

From the present study, it may be concluded that cauliflower was the most susceptible host for insect pests and whitefly has most diversified host rang. The overall study also revealed that, cauliflower intercropping with coriander showed the best performances in case of reducing the number of aphid, whitefly, stripped beetle, leaf miner and diamond back moth (reduced over control 43.89%, 61.15%, 75.93%, 64.66% and 51.91%, respectively) and decreased plant infestation 57.57% than control. It also increased the number of lady bird beetle and field spider as predator arthropod. It also increased the yield attributing characteristics and yield of cauliflower.

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

1. Intercropping of cauliflower and coriander should be practiced for commercial cultivation.
2. Further study should be needed in different locations of Bangladesh and different combination of intercropping with cauliflower.

CHAPTER VI

REFERENCES

Abidin, Z., Subhan, R. and Basuki, R.S. (1989). Experiments on multiple cropping of garlic with red bean and red pepper. *Hort. Abst.* **59**(3): 1968.

Ahmed, M.Z., Shatters, R.G., Ren, S.X., Jin, G.H., Mandour, N.S. and Qiu, B.L. (2009). Genetic distinctions among the Mediterranean and Chinese populations of *Bemisia tabaci* Q biotype and their Wolbachia infection. *J. Appl. Entomol.* **133**: 733-741.

Alom, M.S., Nag, B.L., Islam, M.N., Ahmed, F. and Akther, S. (2013). Performance of different crop species with pointed gourd (*Trichosanthes dioica* Roxb.). *Bangladesh J. Agril. Res.* **38**(3): 523-529.

Amede, T. and Nigatu, Y. (2001). Interaction of Components of Sweet potato-maize-Intercropping under the Semi-arid conditions of the Rift-Valley, Ethiopia. *Trop. Agri.* 78(1): 1-7.

AphlD. (2012). Aphid-an overview. *Aphis fabae*. Aphid. *Science direct.* 2012. Retrieved 2013-01-02.

Arnon, I. (1975). Physiological aspects of dry land farming. **In:** Gupta, V.S. (ed.), Physiological principles of dry land crop production. Oxford and IBH pub. pp. 95.

Baumann, D.T., Bastiaans, L. and Kropff, M.J. (2001). Competition and crop performance in a leek-celery intercropping system. *Crop Sci*. **41**: 764–774.

BBS. (2014). In Bangladesh cauliflower has cultivated in 21472 acre land. Statistical Year Book of Bangladesh, Statistics and Informatics Division Ministry of Planning, Bangladesh Bureau of Statistics (BBS).

Begum, S., Islam, M.N., Rahman, M.T., Chowdhury, J.A. and Haque, M.I. (2010). Suitability study of different chili varieties for intercropping with sweet gourd. *J. Exp. Biosci.* **1**(2): 1-4.

Berim, M.N. (2009). *Aphis fabae* Scopoli - Black Bean Aphid. Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries. *Agro. Atlas*. Retrieved 2013-01-03.

Berry, R.E. and Taylor, L.R. (1968). High-Altitude Migration of Aphids in Maritime and Continental Climates. *J. Ani. Eco*. **37**(3): 713–722. doi:10.2307/3084. JSTOR 3084.

Boykin, L.M., Shatters, R.G., Rosell, R.C., McKenzie, C.L., Bagnall, R., De Barro, P. and Frohlich, D.R. (2007). Global relationships of *Bemisia tabaci* (Hemiptera: Aleyrodidae) revealed using Bayesian analysis of mitochondrial COI DNA sequences. *Mol. Phylogenet. Evol.* **44**: 1306-1319.

Butani, D.K. and Jotwani, M.G. (1984). Insects in vegetable. Periodical Expert Book Agency. Vivek-Vihar, India. pp. 69-79.

Chinery and Michael. (1993). Collins Field Guide to the Insects of Britain and Northern Europe. Harper Collins. ISBN 0002199181.

Coolman, R.M. and Hoyt, G.D. (1993). Increasing sustainability by intercropping. *Hort. Technol*. **3**: 309–311.

Costa, W.A.J.M. and Perera, M.K.K.W. (1998). Effects of bean population and row arrangement on the productivity of chilli/dwarf bean intercropping in Sri Lanka. *J. Agron. Crop Sci*. **180**(1): 53–58.

David, P.M.M. and Kumaraswarmi, T.L. (1989). Influence of synthetic pyrethroids on the population of red spider mite *Tetranychus dnnabarinus* Boisduval in bhendi. *J. Tamilnadu Agril. Univ.* **17**(2): 271-274.

FAO/WHO. (2003). Diet, nutrition and the prevention of chronic diseases. Report of a joint FAO/WHO. Expert Consultation. WHO Technical Report Series 916. Geneva. World Health Organization.

Erdogan, H. and Karatas, A. (2000). An investigation on intercroppingproduction of tomato, cucumber and pepper together withcrisphead and cos lettuce in heated glasshouse by geothermal energy. **In:** Proceedings of the Vegetable Symposium, 11–13September, Isparta, Turkey. pp. 296–302.

Francis, C.A. (1989). Biological efficiencies in multiple-cropping systems. *Adv. Agron*. **42**: 1–42.

Fritz, V.A., Rosen, C.J., Grabowski, M.A., Hutchison, W.D., Becker, R.L., Tong, C., Wright, J.A. and Nennich, T.T. (2017). Growing broccoli, cabbage and cauliflower in Minnesota. University of Minnesota Extension, Garden - Growing Vegetables. Retrieved: 26 February 2017.

Frohlich, D.R., Torres-Jerez, I., Bedford, I.D., Markham, P.G. and Brown, J.K. (1999). A phylogeographical analysis of the *Bemisia tabaci* species complex based on mitochondrial DNA markers. *Mol. Ecol.* **8**: 1683-1691.

Fukai, S. and Trenbath, B.R. (1993). Processes determining intercrop productivity and yields of component crops. *Field Crops Res*. **34**: 247–271.

Godfrey, L.D. and Trumble, J.T. (2009). UC IPM Pest Management Guidelines: Celery. *UC IPM Online*. Retrieved 2013-01-03.

Hill, L. (2012). The current lettuce aphid, *Nasono viaribisnigri* arrives in Tasmania: Part 1. *Victorian Entomologist*. **42**(2): 29–31.

Horwith, B. (1985). A role for intercropping in modern agriculture. *Bio-Science*. **35**: 5.

HYPP. (2013). Beet leaf aphid, Bean aphid, Black bean aphid. HYPP Zoology. Retrieved 2013-01-02.

Isard, S.A., Irwin, M.E. and Hollinger, S.E. (1990). Vertical Distribution of Aphids (Homoptera: Aphididae) in the Planetary Boundary Layer. *Enviro. Entom.* **19**(5): 1473–1484.

Islam, M.N., Rahman, M.S., Ahmed, F., Alom, M.S. and Akhteruzzaman, M. (2013). Performance of different HYV mustard varieties with sugarcane (*Sacchaarum officinarum*) as intercrop in farmers' fields. *Bangladesh J. Agril. Res.* **38**(1): 137-143.

Itulya, F.M., Mwaja, V.N. andMasiunas, J.B. (1997). Collard-cow pea intercrop response to nitrogen fertilization, redroot pig weed density, and collard harvest frequency. *Hort. Sci*. **32**(5): 850–853.

Jahan, S.M.H. (2012). Occurrence of two genotypic clusters of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in Bangladesh. *Eco-friendly Agril. J.* **5**(8): 114-122.

Janmaat, A.F. (2003). Rapid evolution and the cost of resistance to *Bacillus tlturingicnsis* in greenhouse populations of cabbage loopers, *Trichoplusiani*. *Proc. Biol. Sci.* pp. 63-70.

Jarenyama, P., Hesterman, O.B., Waddington, S.R. and Harwood, R.R. (2000). Relay-intercropping of sunnhemp and cowpea into a small holder maize system in Zimbabwe. *Agron. J.* **92**: 239–244.

John M.T., Kasprowicz, L., Malloch, G.L. and Fenton, B. (2009). Tracking the global dispersal of a cosmopolitan insect pest, the peach potato aphid. *BMC Ecol*. **9**: 13.

Johnson, C.G. (1963). The aerial migration of insects, pp. 188-194. **In:** Eisner, T. and Wilson, E.O. [Eds.]. The insects. W.H. Freeman, San Francisco.

Kabiraj, J., Das, R., Das, S.P. and Mandal, A.R. (2017). A study on cauliflower (*Brassica oleracea* var *botrytis*) based intercropping system. *Intl. J. Curr. Microbiol. App. Sci.* **6**(7): 2595-2602.

Kocacaliskan, I. (2001). Allelopathy. Department of Biology, Dumlupýnar University, Kütahya, Turkey. p. 132.

Mahfuza, S.N., Islam, M.N., Hannan, A., Akhteruzzaman, M. and Begum, S. (2012). Intercropping of different vegetables and spices with pointed gourd. *J. Exp. Biosci*. **3**(1): 77-82.

Malhotra, S. and Kumar, N. (1995). Performance of potato vegetables intercropping systems under dry-temperate conditions of north-western Himalayas. *Indian J. Agron*. **40**(3): 394–397.

Martinez-Carrillo, J.L. and Brown, J.K. (2007). First report of the Q biotype of *Bemisia tabaci* in southern Sonora, Mexico. *Phytoparasitica.* **35**: 282-284.

Midmore, D.J. (1993). Agronomic modification of resource use and intercrop productivity. *Field Crops Res*. **34**: 357–380.

Morris, R.A. and Garrity, D.P. (1993). Resource capture and utilization in intercropping: non-nitrogen nutrients. *Field Crops Res*. **34**: 319–334.

Moyer, D. (1999). Pest Management Recommendations for Commercial Vegetable and Potato Production, Cornell Cooperative Extension, Cornell University. pp. 206-209.

Ofori, F. and Stern, W.R. (1987). Cereal-legume intercropping systems. *Adv. Agron*. **41**: 41–89.

Olasantan, F.O. (1991). Response of tomato and okra to nitrogen fertilizer in sole cropping and intercropping with cowpea. *Hort. Sci*. **66**: 191–199.

Oliveira, M.R.V., Henneberry, T.J. and Anderson, P. (2001). History, current status, and collaborative research projects for *Bemisia tabaci*. Publications from USDA-ARS / UNL Faculty. p. 352.

Omar, N.M., Gomaa, H.M., Bhairy, A.G. and Ali, A.H. (1989). Seed germination and seedling growth of tomato as affected by root exudates of cabbage, cauliflower and radish. *Egyptian J. Hortic*. **6**(2): 165–171.

Peirce, L.C. (1987). Vegetables. Characteristics, Production and Marketing. Willey, New York, USA. p. 433.

Pip Courtney. (2005). Scientist battles lettuce aphid. *Landline.* Retrieved January 1, 2007.

Poniedzialek, M. and Kunicki, E. (1995). The Suitability of several French bean cultivars for late maturing cabbage intercropping. *Ogrodnictwo*. **22**: 5–16.

Poniedzialek, M., Zacharias, A., Kunucki, E. and Suchodolska, R. (1989). Effect of cabbage, French bean and snap bean intercropping on the level and quality of yield. *Folia Hort*. **1**(2): 37–51.

Prabhakar, B.S. and Shukla, V. (1990). Crop land use efficiency in sequential intercropping systems with vegetables. *Indian J. Hort*. **47**(4): 427–430.

Prabhakar, B.S. and Shukla, V. (1991). Crop land use efficiency sequential intercropping systems with vegetables. *Hort. Abst*. **61**(9): 7856.

Quayyum, M.A. and Akanda, M.E.M. (1990). Productivity and profitability of cabbage intercropped vegetables. *Hort. Abst*. **60**(9): 7201.

Rashid, M.A. (1987). Effect of intercropping cabbage and Batisak at varying plant population levels. M.Sc. (Ag.) Thesis, Department of Horticulture, BAU, Mymensingh.

RIR. (2013). Black bean aphid. Rothamsted Insect Research. *Rothamsted Research*. Retrieved 2013-01-03.

Santos, R.H.S., Gliessman, S.R. and Cecon, P.R. (2002). Crop Interactions in broccoli intercropping. *Biol. Agric. Hortic*. **20**: 51–75.

Sharaiha, R.K. and Hattar, B. (1993). Intercropping and poultry manure effects on yields of corn, watermelon and soybean grown in a calcareous soil in the Jordan Valley. *J. Agron. Crop Sci*. **171**: 260–267.

Sharma, R.P., Patil, R.R. and Arora, P.N. (1988). Spatial arrangement and methods of planting in cabbage (*Brassica oleraceaconvar capitata* var. *capitata*) intercropping. *Indian J. Agric. Sci*. **58**(9): 673–677.

Shultz, B., McGuinness, H., Horwith, B., Vandermeer, J., Phillips,C., Perfecto, I., Rosset, P., Ambrose, R. and Hansen, M. (1987). Effect of planting densities, irrigation, and hornworm larvae on yields in experimental intercrops of tomatoes and cucumbers. *J. American Soc. Hort. Sci.* **112**(5): 747–755.

Singh, R.N. and Singh, K.M. (1987). Influence of intercropping on succession and population buildup of insect pests in early variety of red gram. *Indian Ecol*. **7**(2): 22-26.

Splitstoesser, W.E. (1990). Vegetable Growing Handbook. Van Nostr and Reinhold, New York, USA. p. 362.

Subhan, I. (1991). Effect of intercropping with *Phaseolus vulgaris* L. on growth and yield of tomato *Solanumly copersicum* L. *Hort. Abstr*. **61**(4): 2863.

Talekar, N.S. and Shelton, A.M. (1993). Biology, ecology and management of the diamondback moth. *Annu. Rev. Entomol.* **38**: 275-301.

Tewari, G.G. and Moorthy, P.N.K. (1985). Selective toxicity of some synthetic pyrethroids and conventional insecticides to aphid predator, *Menochilusse xmaculatus* Fabricious. *Indian J. Agril. Sci.* **55**(1): 40-43.

Theunnissen, J. (1997). Intercropping in field vegetables as an approach to sustainable horticulture. *Outlook Agric*. **26**(2): 95–99.

Vandermeer, J. (1989). The Ecology of Intercropping. Cambridge University Press, Cambridge, UK. p. 237.

Varghese, L. (2000). Indicators of production sustainability in intercropped vegetable farming on montmorillonitic soils in India. *J. Sustain. Agric*. **16**(4): 5–17.

Walsh, B. and Furlong, M.J. (2008). Imidacloropid treatment of seedling roots as a component of integrated pest management in Brassica crops. **In:** The Management of Diamondback Moth and Other Crucifer Pests. Proceedings of the Fifth International Workshop. Shelton *et al.* (Eds.). China Agricultural Science and Technology Press, Beijing, China. pp. 338 – 344.

Way, M. J. and Banks, C. J. (1964). Natural mortality of eggs of the black bean aphid, *Aphis fabae* Scop., on the spindle tree, *Euonymus europaeus* L. *Annals App. Bio*. **54**(2): 255–267. doi:10.1111/j.1744-7348.1964.tb01189.x.

Willey, R.W. (1979). Intercropping, its importance and research need. Part I. Competition and yield advantages. *Field Crop Abstract*. **32**(1-10): 73-85.

Woolley, J. and Davis J.H.C. (1991). The agronomy of intercropping with beans. **In:** Common Beans: Research for Crop Improvement. CAB International, Colombia. Schoonhoven, A. and Oyset, M. (Eds.). p. 980.

Yi.dirim, E. and Guvenc, I. (2005). Intercropping based on cauliflower: more productive, profitable and highly sustainable. *European J. Agron.* **22**: 11-18.

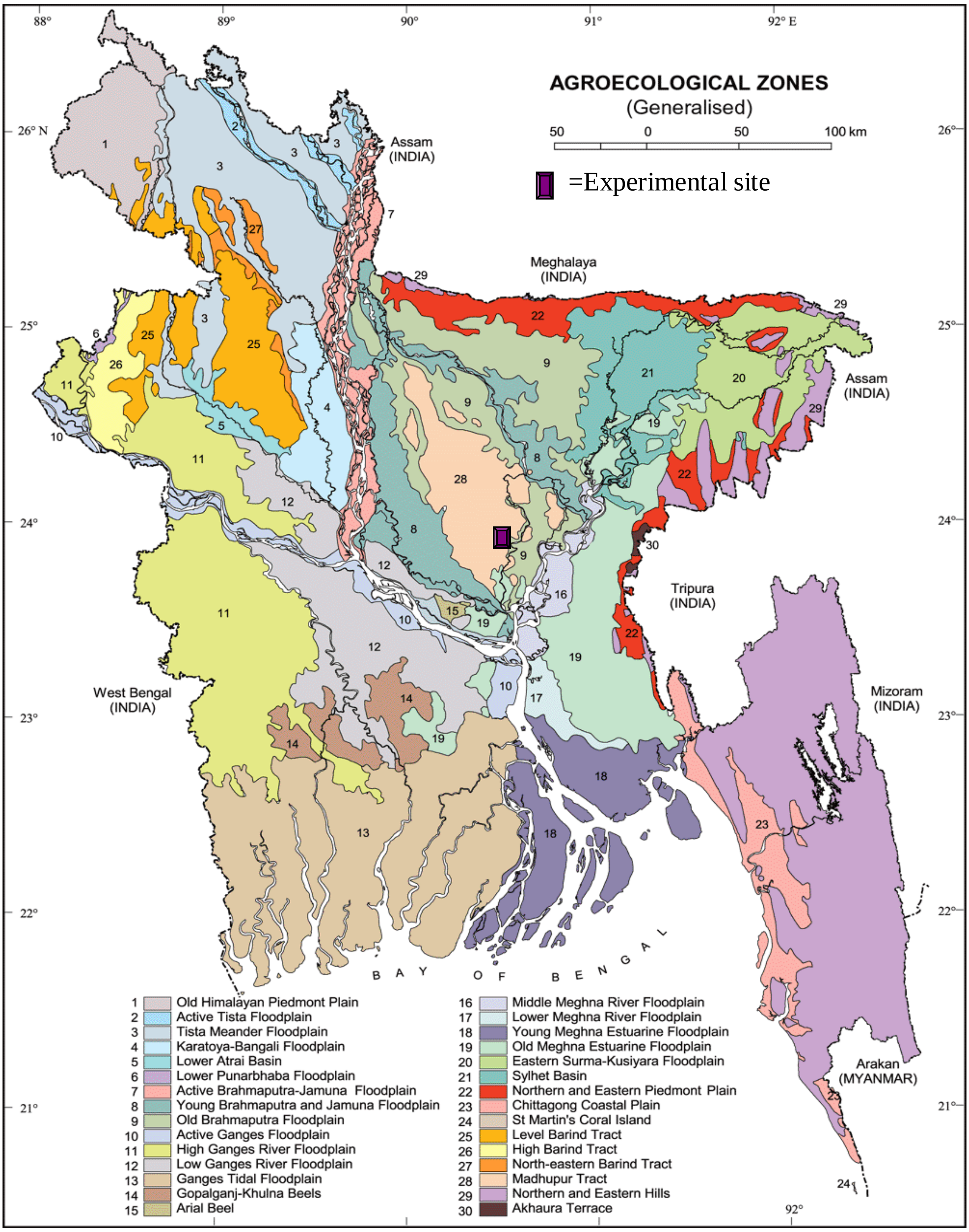
Zhou, X., Madramootoo, C.A., MacKenzie, A.F., Kaluli, J.W. and Smith, D.L. (2000). Corn yield and fertilizer N recovery in water-table-controlled corn-rye-grass systems. *European J. Agron*. **12**: 83–92.

Żyła, D., Homan, A. and Wegierek, P. (2017). Polyphyly of the extinct family Oviparosiphidae and its implications for inferring aphid evolution (Hemiptera, Sternorrhyncha). *PLOS One*. **12**(4): e017479.

CHAPTER VII

APPENDIXES

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



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

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

Chemical composition:

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

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

Appendix III. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from October 2019 to March 2020

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2019	26.82	14.04	78	00
November, 2019	22.78	11.50	75	00
December, 2019	23.50	13.40	69	00
January, 2020	26.10	14.70	66	33
February, 2020	33.40	20.60	58	12
March, 2020	34.5	22.82	63	173.4

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207