POTENTIAL OF SOME BIORATIONAL INSECTICIDES IN CONTROLLING BEAN APHID OF COUNTRY BEAN

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June 2021

POTENTIAL OF SOME BIORATIONAL INSECTICIDES IN CONTROLLING BEAN APHID OF COUNTRY BEAN

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REGISTRATION NO. 14-05999

A Thesis
Submitted to the faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements for the
degree of

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2021

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CERTIFICATE

This is to certify that the thesis entitled ***"POTENTIAL OF SOME BIORATIONAL INSECTICIDES IN CONTROLLING BEAN APHID OF COUNTRY BEAN"*** *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****, embodies the result of a piece of bona fide research work carried out by* ***SHAHNAJ PARVIN****,* ***Registration No. 14-05999*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah (SWT), who enabled me to pursue my education in Agriculture discipline and to complete this thesis for the degree of Master of Science (MS) in Entomology.

I am proud to express my deepest gratitude, deep sense of respect immense indebtedness to my Supervisor, Professor **Dr. S. M. Mizanur Rahman**, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka for his constant supervision, invaluable suggestion, scholastic guidance, continuous inspiration, constructive comments and encouragement during my research work and guidance in preparation of manuscript of the thesis.

I express my sincere appreciation, profound sense, respect and immense indebtedness to my respected Co-supervisor Professor **Dr. Md. Razzab Ali**, Department of Entomology, SAU, Dhaka for providing me with all possible help during the period of research work and preparation of thesis.

I would like to express my deepest respect and boundless gratitude to my honorable teachers and staffs of the Department of Entomology, SAU, Dhaka for their valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and research work.

Cordial thanks are also due to all field workers of SAU farm for their co-operation to complete my research work in the field.

I would like to express my last but not least profound and grateful gratitude to my beloved parents, friends and all of my relatives for their inspiration, blessing and encouragement that opened the gate of higher studies in my life.

Date: June 2021 **The Author**

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By

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ABSTRACT

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh to evaluate the potential of some biorational insecticides in controlling bean aphid of country bean (BARI seem-1) during the period from October 2019 to February 2020. The experiment consists of the following management practices: T_1: Azadirachtin (Bioneem plus 1 EC) + Spinosad (Success 2.5 SC); T_2: Thiamethoxam (Aktara 25% WG) + Spinosad (Success 2.5 SC); T_3: Imidacloprid (Imitaf 20 SL) + Spinosad (Success 2.5 SC); T_4: Farmers' practice (spraying Malathion 57 EC weekly); T_5: Control. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. In consideration of total growing period, the %pod infestation by number, the lowest number of infested pods plant^{-1} was observed from T_3 (7.65), whereas the highest pod infestation was found from T_5 (17.75). The highest no. of healthy inflorescence plant^{-1} was observed from T_3 (55.75) while the lowest no. was observed from T_5 (39.00) treatment. The highest yield hectare^{-1} was found from T_3 (21.25 ton/ha), while the lowest yield hectare^{-1} was found from T_5 (16.675 ton/ha) treatments. From this study it may be concluded that the treatment T_3 which consists of spraying of Imitaf 20 SL @2 ml/L of water at weekly interval and Success 2.5 SC @0.1 ml/L of water at alternate week was more effective among the management practices for controlling bean aphid of country bean which was followed by spraying Aktara 25% WG @0.5 g/L of water at weekly interval and Success 2.5 SC @0.1 ml/L of water at alternate week.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL AND ABBREVIATION	FULL FORM
%	Percent
@	at the rate of
AEZ	Agro-ecological Zone
Agric.	Agriculture
Agril.	Agricultural
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CV%	Percent of Co-efficient of Variance
et al.	and others
etc.	et cetera
g	Gram
i.e.	that is
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
MP	Muriate of Potash
MT	Metric Ton
No.	Number
°C	Degree centigrade
RCBD	Randomized Complete Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
Viz.	Namely

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Country bean (*Lablab purpureus* Lin.) is one of the most common vegetables in the Leguminosae (Papilionaceae) family grown all over Bangladesh. This bean is widely known as *Seem*, Hyacinth bean, Indian bean, Egyptian kidney bean, and Bonavist bean (Rashid 1999). Its tender pods and seeds are used as vegetables; however, ripened and dry seeds are used as pulses. It is rich in nutritious value, the protein content of the country bean ranges from 20 to 28% (Schaaffausen 1963).

Country beans have now become a year-round crop instead of growing only in winter (Hossain *et al.* 2009). Thus the value of the country bean is quite important. Since more than 70% of the vegetables are produced in the Rabi season, yet Kharif season varieties can play a critical role in dealing with off-season vegetable deficiency (Hossain and Awrangzeb 1992). This crop is grown in all over the tropical countries of the world, such as Bangladesh. Approximately 12,000 ha are cultivated in Bangladesh and 50,000 metric tons of pods are produced per year (BBS 2015).

Country bean is attacked by a huge number of insect pest species. More than 50 arthropod pests have been recorded in East Africa and the vicious effects of these insects differ across the continent (Singh 1983). In addition to the 50 insects, there might have been several other insect pests and mites causing crop destruction, but they have been overlooked due to the inconspicuous presence and behaviors of those pests. Due to the abundance of crop all the year round, infestation of numerous insect pests has also been increased. The key insect species are aphids, thrips, and pod borers. They cause both quantitative and qualitative losses. Among them, aphids are more serious to bean production in the region. It causes tremendous crop losses by swallowing inflorescence sap, young twigs and pods. They serve as vectors for spreading plant viruses by swallowing sap. They also deposit honeydew secretion, which helps in the growth of sooty moulds. Around 12-30% of country bean losses due to this insect pest are recorded (Hossain 1990).

Many forms of prevention mechanisms are used to eliminate the pest population and thereby to protect their crops from insect pest infestation (Rahman and Rahman 1988, Begum 1993). There are many pest management approaches for handling bean aphid, such as natural and applied biological (Karim 1995) and chemical control strategies (Rahman and Rahman 1988).

Present insect pest control activities in Bangladesh are focused almost exclusively on insecticides. Farmers are applying a number of insecticides at a very high frequency and dosage on the bean to save the seed from the pest complex. Unscrupulous application of chemical insecticides to combat insect pests leads to pest resurgence, secondary pest outbreak, extinction of natural enemies. This activity not only raises production costs but also creates environmental pollution and public health hazards (Rashid *et al.* 2003) and increases insect resistance (Ekesi 1999).

In view of this scenario, it is important to establish such management strategies that are not only successful in their execution, but also safer for non-target species. The current research has therefore been undertaken with a view to creating an environmentally sustainable and bio-rational control package against aphid attacking bean.

Considering the above facts, the experiment has been undertaken with the following objectives:

- To know the infestation status of bean aphid in country bean.
- To evaluate the potentiality of biorational insecticide against bean aphid.
- To identify the effective biorational insecticide in controlling bean aphid.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Bean is one of the most important vegetable-cum-pulse crops in Bangladesh as well as in many countries around the world. Crop production faces a variety of difficulties, including pest infestation. Among insect pests, bean aphid is known to be one of the main pests of country bean. Farmers typically control insect pests by using various chemicals. Knowledge on the control of bean insect pests using chemical and nonchemical treatments is very scanty. An effort has been made in this chapter to review the applicable research works applied to this manuscript. The following information is given under the following headings:

2.1 General review of bean aphid

2.1.1 Nomenclature

Kingdom: Animalia

Phylum: Arthropoda

Class: Hexapoda

Order: Hemiptera

Series: Sternorrhyncha

Family: Aphididae

Genus: *Aphis*

Species: *Aphis fabae*

2.1.2 Biology of bean aphid

The bean aphid is a hemimetabolous insect. So, it has three stages to complete life cycle *viz*. egg, nymph and adult.

Egg

In October, females normally lay eggs on tree or shrub stems. In temperate zones, bean aphid overwinters as an egg in one of its main hosts. Initially, the eggs will shortly become glossy black. It is just in the egg form only the aphid pass in the winter season. In warmer areas, the aphid reproduces continually without developing egg. This is a mechanism called parthenogenesis.

Every female can lay 6 to 10 eggs that can withstand temperatures as low as -32° C (26° F) (Tsitsipis and Mittler 1976). More than 40% of the eggs are likely to survive the winter, but some are eaten by birds or flower bugs, and others fail to hatch in the spring.

Nymph

The nymphs are dark, but bear four pairs of white transverse bars on the dorsal surface of the abdomen. Most of the authors report four instars. For example, the durations indicated are 2, 2, 1.5 and 2.5 days for instars 1-4, respectively, when reared at approximately 20° C (Tsitsipis and Mittler 1976). However, only three instars were recorded, with durations of approximately 2.3, 3 and 2.5 days (Ogenga-Latigo and Khaemba 1985). Total nymphal development time requires 5-10 days at 28°-17° C, respectively.

The life cycle of a parthenogenetic female is approximately 50 days and, during this time, each will produce as many as 30 young. The offspring are also females and are able to reproduce without breeding, but the next generations are generally winged. Parthenogenesis occurs on the undersides of the leaves and on the rising tips.

Adult

Bean aphid is dark olive-green to dull-black in colour. The length of the body is 1.8-2.4 mm in females, with males being marginally smaller. The appendices appear to be black, although the tibiae can be pale in section. The wings are transparent. In some crops, bean aphid can be mistaken with another black species, cowpea aphid, *Aphis craccivora* Koch; adults of this latter species are glossy black with white legs and have a smaller average size.

Reproduction occurs shortly after the adult stage has been achieved, usually for a period of around 3-6 days. They reproduce both alate and apterous females. The adult develops roughly 85-90 nymphs during her reproductive period, which is estimated to be 20-25 days. The bulk of the offspring are produced in the first 5-10 days of the reproductive cycle. Reproduction increases with temperatures up to a threshold of around 24° C and decreases. The reproductive period is followed by a post-reproductive period of about 7 days (Frazer 1972). Apterous females give birth to more and larger nymphs than alatae (Dixon and Wratten 1971).

The winged aphids disperse freely, but their final nature relies primarily on wind and wind-breaks, since they do not have good flight forces. Thus, the leeward side of the hills and the wind-breaks are the places where the aphids accumulate. They are often deposited more deeply on the margins of crops. Since small fields have a proportionally higher "edge" aphid mean density often appears to be higher in small plantations. Dispersals of up to 30 km often occur.

Cammell (1981) offered an outstanding description of bean aphid ecology. Tsitsipis and Mittler (1976) presented details on plant and artificial media breeding aphids. Keys to bean aphid identification and most common aphid identification are found in Palmer (1952) and Blackman and Eastop (1984). Stoetzel *et al.* (1996) published a key for cotton aphids that is also useful for separating bean aphids from most other common aphids infesting vegetables.

2.1.3 Host range of bean aphid

Bean aphid can feed on a wide range of host plants, but it seems to prefer plants in the Chenopodiaceae family as summer hosts. Vegetables affected include asparagus, beet, carrot, corn, faba bean, lettuce, lime bean, onion, pea, spinach and squash. It also attacks potatoes, sunflowers, tobacco and tomatoes. It is known to be a very serious pest in Bangladesh because it spreads viruses to crops. Flowers such as nasturtium and dahlia generally support this insect, as do many plants, including curly dock, *Rumex cripus*; lambs quarters, *Chenopodium album*; and shepherd spurs, *Capsella bursapastoris*. The winter or primary bean aphid hosts are *Euonymus* spp. and *Viburnum* spp. In Europe, the abundance of bean aphid is positively associated with the abundance of the spindle flower, *Euonymus europaeus* (Way and Cammell 1982).

Host tastes, species and age of the leaf are included in two conflict variables. Offered spindle and beet leaves on growing plants during the year, winged aphids shifted from one to the other based on the successful growth status of each plant and the sentence of each host plant. Thus, in late summer and fall, the leaves of the beet were old and not attractive to the aphids relative to the leaves of the spindle, while in the morning, the new, unfolding leaves of the beet were more attractive than those of the spindle.

2.1.4 Nature of damage of bean aphid

Aphides cause direct damage to the host plant by extracting plant sap, which provides important food materials that facilitate aphid and plant growth. Since phloem sap is richer in sugars than the amino acids that aphids need to expand, most of the sap is excreted as honeydew. When aphid populations are extremely high, this sugar-rich honeydew can cover the surface of the leaf, creating an ideal substrate for the growth of sooty mould fungi, which affects the quality of the pods produced. In addition, these fungi, combined with honeydew, decrease the productivity of the plant's breathing and photosynthesis and the final production. In addition to direct feeding activity, black bean aphid is capable of spreading over 42 non-persistent and persistent plant viruses (McKinlay 1992).

Studies concerned with the impact of various insect species on crops are often agronomic. Reductions in plant biomass, leaf area and yield have been recorded for various aphid host systems (Wu and Thrower 1981, Barlow and Messmer 1982, Hurej and van der Werf 1993). The extent of injury to aphid has been reported to depend on insect-plant combinations (Hawkins *et al.* 1985) and at the plant growth stage at the time of infestation (Birch 1985). As growth persists, plants are typically more likely to survive insect attacks and compensate for harm (Salazar 1976). There is also evidence that minor aphid infestation of field beans may marginally increase yield, possibly due to apical growth (Bouchery and Jacky 1977).

Injury induced by several types of herbivorous arthropods is well known to modify the rate of photosynthesis, respiration, stomatal activity and transpiration of host plants (Warrington *et al.* 1989, Welter 1989, Macedo *et al.* 2003, Peterson *et al.* 2004, Aldea *et al.* 2005, Delaney and Higley 2006), in addition to the alteration in protein and carbohydrate content of plant tissue (Capinera 1981). In the case of leaf-consuming insects, the results of feeding can be quantified by estimating the absent photosynthetic tissues. Current findings of plant insect injury and gas exchange reactions include leafmass ingestion injury (Peterson *et al.* 2004). Injuries arising from sap-sucking, mesophyll feeding and leaf mining insects have been even less investigated. It is difficult, however to determine the harm caused by aphid feeding on the basis of viable symptoms of injury, which become most noticeable to the occurrence of intense infestation. During aphid feeding, several physiological functions may be impaired until the host plants display any evidence of identifiable symptoms suggested by distortion of leaflets or stunting of infested plants. Although some attention has been paid to the indirect impact of herbivory on photosynthesis (Peterson *et al.* 2004, Macedo *et al.* 2005, Delaney and Higley 2006), its possible influence on leaf water status is not well known.

As gas exchange is the primary mechanism for evaluating plant growth, production and ultimately fitness (Peterson and Higley 1993, Macedo *et al.* 2003), photosynthesis, respiration and water vapor characterization is required to sufficiently understand how arthropod injury affects these primary metabolic parameters and to establish general plant response models (Peterson 2001). Unfortunately, the mechanisms underlying indirect effects of foliar disruption on many physiological processes are still poorly known and vary significantly for various combinations of plant-insects (Hunter 2001, Peterson *et al.* 2004). Virtually very little is learned about plant physiological reactions to *Aphis fabae* damage.

Some species of ant prefer to feed on this exudation and can be seen clambering over colonies of aphids on nettles and other plants to catch them. Some species of ants 'farm' aphids by holding them in the nest below the ground where they suck liquids from the roots. The ant, then is gathering the honey dew while it is egested.

2.2 Yield loss caused by bean aphid

Bean is commonly known as '*Seem'* in Bangladesh. The fresh pods and green seeds are eaten after boiling or used in curries. Mature seeds are used as pulse, often as soup as well as are occasionally sun-dried and stored for use as vegetable. This bean is also grown for fodder and as a cover crop (Begum 1993). In Bangladesh total land area under bean cultivation is 49,192 acres and the production is 1,22,091 MT during 2014-

2015 (BBS 2015). The farmers of Bangladesh face significant yield loss of country bean every year due to severe attack of various insect pests. The yield loss in country bean due to insect pests is reported to be about 12-30% (Hossain 1990). According to Das (1998), Islam (1999) insect pests attacking country bean are different species of aphid including *Aphis fabae*, *Aphis craccivora* Koch. *Aphis medicaginis* Koch., and bean pod borer *Maruca testulalis*.

Both nymphs and adults of aphid suck cell sap of infested plants and while feeding they inject a toxin along with the salivary secretion into host plants. They also secrete honeydew, which by enhancing the growth of sooty moulds, interferes with the photosynthetic ability of plants (El-Defrawi 1987, El-Fatah 1991, Rizkalla *et al.* 1994). In addition, the pest may transmit virus diseases to plants. According to Singh and Allen (1980), the pest causes up to 40% reduction of crop yields in Asia. Attle *et al.* (1987) reported as high as 100% yield reduction of different bean crops due to aphid infestation. As country bean is attacked by many pests and cause considerable damage, pest management is essential.

Current management practices of insect pests are based almost entirely on chemical insecticides as they give quick result. As most of our people are illiterate, they use pesticides more than the standard requirement indiscriminately. For example, farmers of Bangladesh particularly of intensive country bean growing areas like Jessore apply insecticides 84 to 140 times in a growing season (Anonymous 2006). This over use, misuse and the way of using which cause drifting loss to the nearest crop and in the atmosphere which results in pest resurgence, stimulation of the reproductive rate in certain pests, secondary pest outbreaks, mortality of beneficial insects, resistance of pest species and finally environmental pollution (Alam *et al.* 2005).

2.3 Pest complex of country bean

The pest spectrum of a crop can differ geographically and temporally (Pedigo 1999). Variations of bean pest complexes seem to have existed in various countries and parts of the season. More than 50 arthropod pests have been recorded in East Africa and the vicious effects of these insects differ across the continent (Singh 1983). In addition to the 50 insects known so far, there might have been several other insect pests and mites causing crop destruction, but they have been overlooked due to the inconspicuous presence and behaviors of those pests. However, despite the existence of a large number of arthropod pests, only a few occur more regularly and can inflict major crop damage. These are primarily bean flies, black bean aphids and pod borers in many East African countries.

Many vicious arthropods fall out in America and some of them do considerable harm to a variety of legume crops, including beans. Legume pod borer was widespread in Hawaii, causing serious damage to beans, including lima beans (Holdaway and Look 1942).

In India, country bean has been reported to be attacked by more than 57 species of pestiferous arthropods (Govindan 1974). In northern India, country beans have been reported to be frequently attacked by the galerucid beetle, *Madurasia obscurella* Jacob (Coleoptera: Chrysomelidae), which may cause economic damage to the crop (Gupta and Singh 1978). Naresh and Nene (1968), and Saxena (1973 and 1976) have also reported that galerucid beetles and some other insect pests including various aphid species; hooded hopper, *Leptocentrus taurus* Fb. (Homoptera: Membracidae); leaf beetle, *Sagra carbunculus* Hope (Coleoptera: Chrysomelidae); leaf-eating caterpillars, *Plusia oricalchea* Fb. (Lepidoptera: Pyralidae); leaf miner, *Cosmopterix* sp. (Lepidoptera: Pyralidae); leaf weevil, *Blosyron oniscus* and *Alcides collaris* P. (Coleoptera: Curculionidae); pod borer, *Maruca* sp. (Lepidoptera: Pyralidae); and mites, *Tetracychas* sp. (Acarina), attack country beans in different parts of India and the subcontinent. Singh (1983) also reported that there may have been 30 more species of arthropods associated with bean crops, but their inconspicuous existence possibly led them to be overlooked.

In Myanmar, 14 arthropod pests have been reported to be attacked by beans (Shroff 1920), although it is not clear which are of significant importance in terms of damage.

In Bangladesh, country bean has been frequently reported to be infested with numerous species of aphids including *Aphis craccivora* and *A. medicagenis* Koch (Homoptera: Aphididae); bean bug, *Coptosoma cribrarium* Fb. (Hemiptera: Plataspidae); green semi-looper, *Plusia oricalchea* Fb. (Lepidoptera: Pyralidae); hooded hopper, *Leptocentrus tarus* Fb. (Homoptera: Membracidae); leaf miner, *Cosmopterix* spp. (Diptera: Agromyzidae); leaf weevil, *Blosyrus onisctts* (Coleoptera: Curculionidae); pod borer, *Maruca* sp. (Lepidoptera: Pyralidae); shoot borer, *Sagra carbunchulus* H.

and, *S. femorata* D. (Lepidoptera: Pyralidae); shoot weevil, *Alcides collaris* P. (Coleoptera: Curculionidae) and the mite, *Tetranychus* spp. (Acarina) (Alam 1969, Begum 1993, Karim 1993, 1995, Das 1998, Islam 1999). Of these insect pests, only a few species are present in most parts of the world and can also inflict economic damage. Alam (1969) reported that there have been nine species of arthropod pests in country bean fields on a regular basis, while only three species of insects, including aphid, bean bug, leaf miner and one species of mite, caused economic damage to the crop in Bangladesh in the 1970s. It appears that there has been a change in the selection of arthropod pest species in crop fields, especially in Central Bangladesh, over time. In 1990s, the major arthropod pests of country beans in Bangladesh were the aphid, *A. fabae*, pod borer, *M. Vitrata* and *Helicoverpa armigera*, and *Tetranychus* sp, the red mite. Das (1998) recorded that there were five species of arthropods causing significant damage to the country bean, including aphid, *A. fabae*; leafminer, *Cosmopteris* sp.; leaf paster, *Heterorhabditis indica*; pod borer, *Maruca vitrata* and the mite, *Tetranychus* sp. in different places of Bangladesh. It seems like a black bean aphid, *Aphis fabae*, and a pod borer, *Maruca Vitrata* is widespread everywhere in Bangladesh (Karim 1995, Das 1998, Islam 1999) and pest infestation can sometimes be so extreme that the economy of bean growers can be seriously affected in that country.

Among the major insect pests, legume pod borer (*Maruca vitrata* F.) is prevalent in the tropics and sub-tropics due to its broad host range, destructiveness and widespread distribution (Taylor 1967, Raheja 1974). In most areas of its distribution, the population of *Maruca Vitrata* also exceeds economic threshold levels causing tremendous economic losses; in order to eliminate such dangerous populations of pests, it is often important to enforce protection measures, particularly insecticides (Taylor 1967). In Bangladesh, pod borers have frequently targeted numerous crops, including beans, and have caused tremendous crop damage (Alam 1969, Rahman and Rahman 1988, Karim 1993). Interests in this analysis were also based on the legume pod borer.

On the other hand, aphid was found to be a significant pest in grain legumes. Owing to their high reproductive ability and sedentary habits, the aphid population may always be too high to be of interest to farmers. In addition, aphids can transmit diseases to plants that make them a potential crop pest, especially under favorable environmental conditions of the pest. Aphid, *Aphis fabae* is cosmopolitan in distribution and insects inflict damage to various crops in the temperate, tropic and subtropics continents (Hill 1983, Butani and Jotwani 1984). In general, aphid colonies begin with a few individuals coming from an infested area. Upon arrival, the insects multiply easily and build up the colony. In country beans, aphids suck the plant sap from the underside of young leaves, tender twigs and shoots (Hill 1983, Singh 1983, Butani and Jotwani 1984, York 1992). When plants are heavily infested, leaf distortion and stunting are normal, often resulting in poor fruit setting (Hill 1983; Butani and Jotwani 1984, York 1992). In addition to the damage caused by feeding, aphids also damage the crop by serving as a vector for diseases (Butani and Jotwani 1984). While aphids may cause harm through sucking plant sap and spreading diseases, unless their population is exceptionally large, aphids typically cause little damage by direct feeding activities. In addition, aphid colonies are also naturally suppressed by a network of pests, including ladybird beetles (Coleoptera: Coccinellidae), lacewings (Neuroptera: Chrysopidae), syrphid flies (Dipetra: syrphidae), numerous species of insect parasitoids and other natural enemies. As a result, in most crop fields, aphid species do not need the suppression of artificial pest control methods (Pedigo 1999). Here discussion will be dedicated mostly to the bean aphid and further discussed in detail in the following sections.

2.4 Control of insect pest in country bean

Bean aphid, one of the most widely occurring and destructive insect pests of various leguminous crops, including bean, has attracted attention from people interested in science and industry across continents (Singh and Allen 1980). There have been growing interests in managing the insect pest of the country bean. Several approaches, including cultural, mechanical, biological and chemical methods are available for pest control in field crops. Despite the existence of multiple pest control strategies, the use of synthetic chemical insecticides continues to be the most effective way of managing legume pests, a pattern associated with most pests in field crops (Debach and Rosen 1991, Pedigo 1999). The administrative activities shall be checked and discussed below. For simplicity, the process was explored in two main categories: non-chemical control and chemical control.

2.4.1 Non-chemical control

Farmers believe that insecticides are the best way to combat insect pests. This conceptual makeup has resulted from their tradition of using insecticides to combat insect pests that have been attacking their crops for many years (Islam 1999). Giving pesticides free of charge to farmers, the government helped to promote and grow the habit of indiscriminate use of pesticides among farmers. This is a serious fundamental problem.

2.4.2 Cultural control

The population of black bean aphid is also naturally suppressed by environmental influences, including temperature, humidity and photoperiod (Karim 1995). Temperature seems to be one of the main variables for the climate.

Cropping mechanism is deeply affected by bean aphid infestation. Intercropping has been successfully used as a cultural method of managing bean aphid. Bean aphid damage in monocrop has been reported to be greater than maize-cowpea-sorghum crop as intercrops (Amoako-Atta and Omolo 1982, Amoako-Atta *et al.* 1983, Fisher *et al.* 1987, Omolo *et al.* 1993). Karel (1984 and 1993) also recorded that the occurrence of bean aphid was slightly lower than in pure stalls. In comparison, Alghali (1993), Ofuya (1991), Natarajan *et al.* (1991), Patnaik *et al.* (1989) and Saxena *et al.* (1992) reported no impact of intercropping on the occurrence of *Aphis fabae*.

This indicates that the effectiveness of the adoption of the cropping method and the time taken to cut the bean aphid infestation will differ based on the crop and seasonal time.

2.4.3 Use of Botanicals

The use of locally available plants, such as *Derris*, *Nicotiana* and *Ryania*, is an ancient method of managing pests during the prehistoric period. Pesticide plants were commonly used until the 1940s, when they were alternated with synthetic pesticides because they were easier to treat and lasted longer. Pesticides are compounds or mixtures of substances used to deter, kill, repel, trap, sterilize or reduce pests. In some of the developing countries, pesticide intake is almost 3000 g/ha. Over-enthusiast application of synthetic insecticides contributed to unintended concerns at the time of

their introduction. Pesticides are typically of a persistent nature. According to World Health Report-2002, as a direct result of pesticide contamination 200,000 people are killed annually worldwide (Guilbert 2003). Furthermore, the use of synthetic chemicals has also been limited due to their carcinogenicity, teratogenicity, high and acute residual toxicity, hormonal imbalance potential, sperm toxicity, long degradation times and food residues (Dubey *et al.* 2011, Pretty 2009, Feng and Zheng 2007, Khater 2012).
The plant kingdom is known as the most effective manufacturer of chemical compounds, synthesizing many of the products used in defense against various pests (Ismam and Akhtar 2007).

Botanical extracts cause insecticidal action, pest repellency, anti-feeding and insect growth control, toxicity to nematodes, mites and other pests, as well as antifungal, antiviral and antibacterial properties against pathogens (Prakash and Rao 1986, Prakash and Rao 1997).

2.4.4 Biological control

Pest populations in various crop fields are considerably reduced by biological control agents such as predators, parasitoids, and diseases. Across continents, studies on the predatory fauna of bean aphids and legume pod borers have been conducted (Usua and Singh 1977, Okeyo-Owuor *et al.* 1991). In general, determining the involvement of predators in insect population decrease in the field is challenging (Debach and Rosen 1991, Pedigo 1999). This is due to the fact that predators often consume their victim rapidly, leaving no trace or traces of the predation. As a result, there is limited knowledge on predatory management of pod borers.

It has been shown that parasitoids inflict considerable mortality on most insect pests by stinging and direct feeding activity during the process of host selection for oviposition, as well as by killing parasitized larvae and pupae (Debach and Rosen 1991).

Natural enemies, parasitoids and predators are the primary causes of decrease in hazardous insect pest populations (Pfadt 1980). Biological control agents (spider, ant, lady bird beetle, *Orious*, mirid bug, Lygus, *Chrysoperla*, *Trichogramma* etc.), botanicals (neem oil or biosal and tobacco extracts) and microbial control (*Bacillus* *thuringiensi*s) should be integrated for economic management of insect pests (Arora *et al.* 1996, Abro *et al.* 2004 and Memon *et al.* 2004).

2.4.5 Chemical control

According to Hara (2000), Biorational insecticides are synthetic or natural compounds that effectively control insect pests, but have low toxicity to non-target organisms (such as humans, animals and natural enemies) and the environment.
Biorational approaches in pest management incorporated pesticides which have specificity, safety to non-target organisms, decompose quickly, thereby resulting in lower exposures compared to conventional pesticides. According to the Environmental Protection Agency (EPA) of the United States of America, bio-pesticides are of three main categories namely microbial pesticides (in which a microorganism like bacterium, fungus, virus or protozoan is the active ingredient), botanical pesticides (substances of plant origin) and biochemical pesticides (Rosell *et al*. 2008). Use of biorational pesticides against insect pest however, a recent approach, which has drawn special attention to the entomologist all over the world. Biorational approaches such as plant extracts and oils are used in management programs of insect pests (Soares *et al*. 2019). Botanical extracts and oils have toxic effect on insect pests and incapacitate their growth and reproduction (Ahad *et al*. 2016, Mazumder *et al*. 2016).

In Bangladesh, management of aphid and pod borer in country bean field is mostly relied on synthetic chemical insecticides because of its quick action and favorable costbenefit ratio. Only a few attempts have been made to evaluate biorational management practices against insect pests (Miah *et al*. 2017). Considering the above facts of country bean and problems occurred due to the infestation of aphid and pod borer, the study is conducted to find out the effective biorational approaches for management of bean aphid of country bean.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The study was conducted at the Sher-e-Bangla Agricultural University (SAU) experimental farm, Sher-e-Bangla Nagar, Dhaka-1207, during the period from Oct 2019 to Feb 2020 to evaluate the efficiency of some biorational insecticides against bean aphid in the field of country bean in winter. The materials and techniques used to perform the experiment are discussed under the following heading and sub-headings:

3.1 Experimental site

The experimental field was located at 23º 77.4´ N latitude and 90º 33.5´ E longitude at an altitude of 9 meters above the sea level. The field experiment was set up on the medium high land of the experimental farm.

3.2 Weather condition

The climate of experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October.

3.3 Soil character

The soil type of the experimental field is Shallow Red Brown Terrace soil and the soil belongs to Tejgaon Serious in the Agroecological Zone, Madhupur Tract (AEZ-28). The soil was clay loam with a texture on the upper ground, olive-gray with a typical fine to medium distinct from the Madhupur Tract (UNDP 1988, FAO 1988). The experimental field was above the flood level and ample sunlight and irrigation and drainage services were available during the experimental era. The soil was having a texture of silty clay loam with pH and organic matter 5.8 and 1.12%, respectively.

3.4 Land Preparation

The main field was ploughed extensively by a tractor disk plough followed by harrowing. The stubbles of the crops and the weeds were cleared from the field and the soil was labeled prior to sowing. The arrangement of the field was rendered in line with the plan, immediately after the planning of the ground. During final soil preparation, 10 t/ha of decomposed cow-dung was combined with soil. In each plot measuring 3.0 m at an altitude of 2.5 m, four pits were prepared for seed sowing.

3.5 Manures and Fertilizers application

Recommended doses of Urea, TSP and MoP fertilizer at rates of 30, 90, 65 kg/ha were used, respectively. The entire dosage TSP and half the amount of MoP were administered in the soil pits 4-5 days before the seed was sown. The remaining sum of Urea and MoP was used as a ring around the seedlings at 30 days and 45 days after seedlings emergence.

3.6 Sowing of the seeds in the fields

The seeds were planted directly in the main field. There were four pits in each bed. The pits were prepared by a combination of equal proportion of well-decomposed cow-dung and loamy soil. Until sowing, the seeds were treated with Sevin dust to avoid contact with the ant. In each trap, 4/5 seeds were planted. Irrigation was given as per requirement. After one week, most of the seeds were germinated, making sure there were three seedlings in each pit.

3.7 Experimental material

BARI seem-1 was selected as experimental material for the experiment (Plate-1).

3.8 Treatments of the experiment

The experiment consists of the following management practices:

T_1 = Azadirachtin (Bioneem plus 1 EC) + Spinosad (Success 2.5 SC)

T_2 = Thiamethoxam (Aktara 25% WG) + Spinosad (Success 2.5 SC)

T_3 = Imidacloprid (Imitaf 20 SL) + Spinosad (Success 2.5 SC)

T_4 = Farmers’ practice (spraying Malathion 57 EC weekly)

T_5 = Untreated control

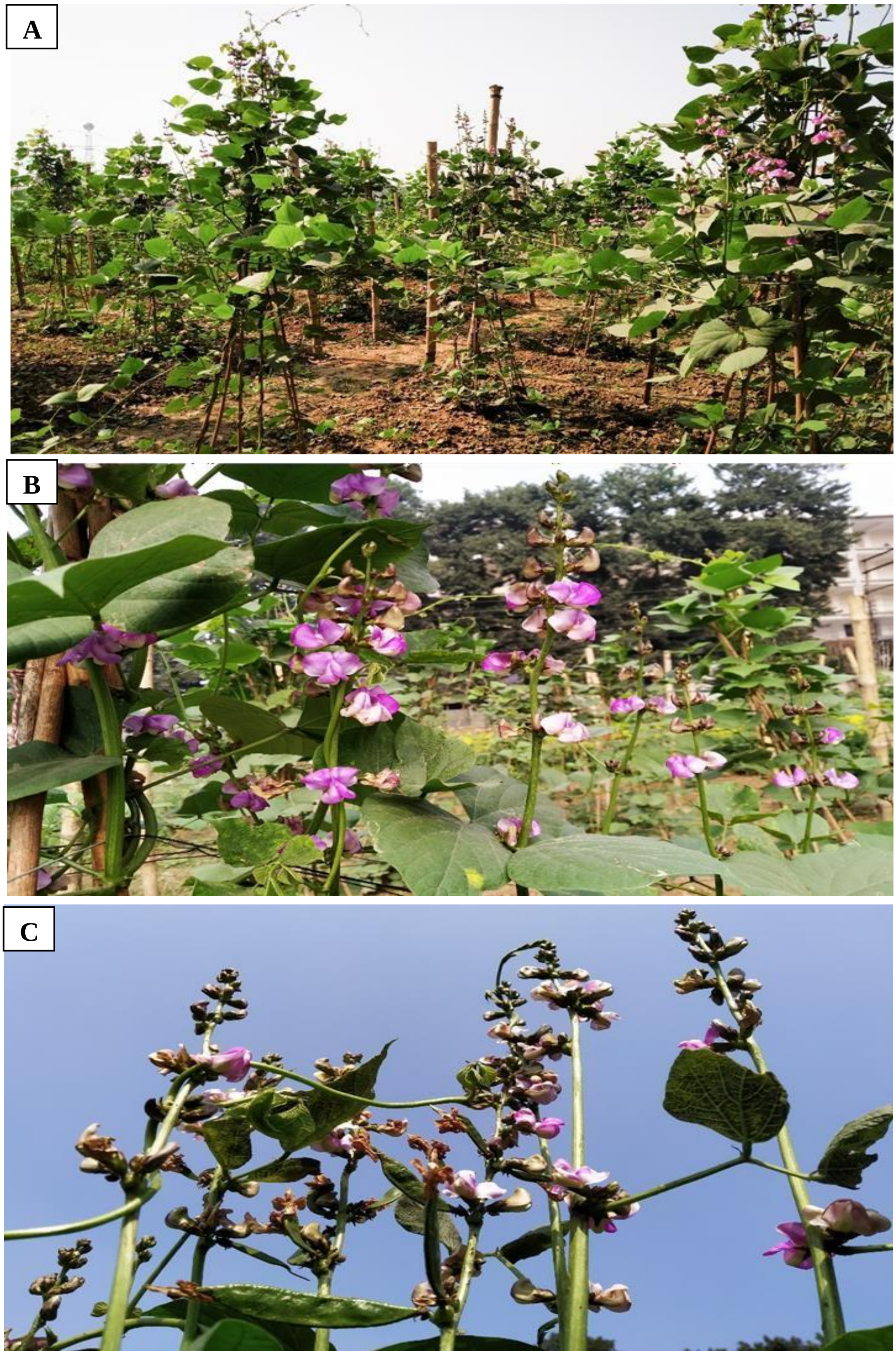

Plate 1: Experimental plot with BARI seem-1 variety, A) field at a glance, B) flowering stage, C) fruiting stage

3.9 Planting material collection

The seeds of country bean variety BARI seem-1 was collected from Bangladesh Agricultural Research Institution (BARI), Gazipur, Dhaka.

3.10 Pesticide collection

Bioneem plus 1 EC, Malathion 57 EC and Aktara 25% WG were collected from the farm of Sher-e-Bangla Agricultural University, Dhaka-1207. Success 2.5 SC and Imitaf 20SL were collected from nearby nursery.

3.11 Experimental layout and design

The experiment was constructed in the Randomized Complete Block Design (RCBD). The whole experimental area was split into four blocks. Each block was divided into five plots of land. Two neighboring unit plots were separated by 0.5 m and the blocks were separated by 1.0 m. Each experimental plot has a surface area of 3.0 m x 2.8 m and a total area of 13 m x 18 m. Each treatment combination was randomized inside the blocks and replicated four times (Plate 2).

3.12 Preparation for spraying experimental treatment

Bioneem plus 1 EC was applied at the rate of 1ml/L, Aktara 25% WG was applied at the rate of 0.5 g/L, Imitaf 20 SL was applied at the rate of 2ml/L, Success 2.5 SC was applied at the rate of 0.1ml/L and Malathion 57 EC was applied at the rate of 1ml/L to the field.

3.13 Intercultural operation

After germination, the plants were irrigated by watering can and then irrigated to the surface. After 15 days of germination, the propping of each plant with bamboo sticks (1.75 m) was provided at an altitude of around 1.5 m above ground level for additional support to enable natural creeping. All the bamboo sticks in each row were fastened tightly by a galvanized wire to allow the vines to crawl along. Weeding and mulching were performed in the plots, whenever necessary.

3.14 Crop sampling

Three plants from each plot of each treatment were randomly marked with the help of sample card.

Plate 2: The experimental plot with country bean at vegetative stage

3.15 Data collection

Data were recorded on the following parameters:

- Visual counting of aphid at different stages of plant growth
- Number of inflorescence plant^{-1}
- Number of flower for 5 inflorescences
- Number of infested flower for 5 inflorescences
- Number of healthy flower for 5 inflorescences
- Total number of pods plant^{-1}
- Number of healthy pods plant^{-1}
- Number of infested pods plant^{-1}
- Length and girth of 5 healthy pods (cm)
- Length and girth of 5 infested pods (cm)
- Weight of 5 healthy pods (g)
- Weight of 5 infested pods (g)
- Total weight of healthy pods (g)
- Total weight of infested pods (g)
- Total yield plot^{-1} (kg)
- Total yield hectare^{-1}

3.16 Procedure of data collection

3.16.1 Incidence of insects

Among the plants, 3 plants of each plot have been carefully observed for the identification of insect pest attacks. Both adult and nymph were counted and registered. The data collected was split into the early, mid and late stage of fruiting stage.

3.16.2 Counting of Aphid

The number of aphids in 3 selected plants of each plot was counted at an interval of 7 days at each harvest during the early, mid and late fruiting stages of the plants. The top 10 cm apical twigs of 5 randomly selected inflorescences of selected plants were cut and taken to the laboratory in separate bags to count the number of aphid plants^{-1} and 5 randomly aphid infested pods of selected plants were obtained by hand-picked counting of aphid plants^{-1}.

With the aid of a gentle camel hair brush, the aphids were collected from the infested plant sections and put on a sheet of white paper. The number of aphids was then counted with the aid of a magnifying glass and a tally counter. The infested twigs and inflorescences were closely examined. So at the time of counting, the single aphid could not escape.

3.16.4 Number of healthy pods plant^{-1}

Number of healthy pods from each plot was counted at early, mid and late pod development stage (Plate 3).

3.16.5 Number of infested pods plant^{-1}

Number of infested pods was counted at early, mid and late pod development stages (Plate 4).

Plate 3: Healthy pods of country bean in experimental field

Plate 4: Infested pod of country bean attacked by pod borer attacked by bean aphid

3.16.6 Estimation of % pod infestations

The number of healthy and infested pods was counted and the percentage of pod infestation was determined using the following formula:

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

3.16.7 Weight of healthy pods plant^{-1}

Weight of healthy pods of selected plants from each plot was recorded at early, mid and late pod developmental stage.

3.16.8 Weight of infested pods plant^{-1}

Weight (g) of infested pods of selected plants from each plot was recorded at early, mid and late pod developmental stage.

3.16.9 Estimation of weight of % pod infestations

The weight of healthy and infested pods was measured and the percent pod infestation in weight basis was calculated using the following formula:

$$\% \text{ Pod infestation} = \frac{\text{Number of infested pods}}{\text{Total number of pods}} \times 100$$

3.16.10 Number of healthy flowers inflorescence^{-1}

Number of healthy flowers from each plot was counted at early, mid and late flowering stage (Plate 5).

3.16.11 Number of infested flowers inflorescence^{-1}

Number of infested flowers from each plot was counted at early, mid and late flowering stage (Plate 6).

Plate 5: Healthy flowers in inflorescence

Plate 6: Infested flowers in inflorescence

3.16.12 Number of pods inflorescence^{-1}

During the reproductive stage of the plant total numbers of pods from each individual inflorescence were recorded in each treatment.

3.16.13 Pod length (cm)

Pod length was taken of randomly selected twenty pods and the mean length was expressed on per pod basis.

3.16.14 Pod yield plot-1 (kg)

Total weight of collected pods of country bean from each plot was weighted, recorded and expressed in kilogram.

3.16.15 Pod yield hectare^{-1} (ton)

Pods yield of country bean per plot was converted into hectare.

3.17 Statistical analyses

Data on the various parameters as well as the yield of the country bean were statistically analyzed to determine the relevant variations between the results of the different treatments. The significance of variations between mean treatment values for different parameters was calculated by the Duncan's Multiple Range Test (DMRT) at a 5 percent probability level (Gomez and Gomez 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULT AND DISCUSSION

The study was carried out to investigate the efficacy of various treatment strategies in controlling bean aphid of country bean. Data were collected on the parameters of number of insect pest plant^{-1}, number and weight of healthy pod, infested pod and percentage of pod infestation in number and weight, yield contributing characteristics, and yield of country bean. The outcomes of several parameters have been given and discussed, and possible interpretations have been given under the following headings:

4.1 Incidence of insect pest

The occurrence of key insect pests of country bean was tracked throughout the cropping season. The investigation discovered bean aphid. Insect pests were collected from each plant throughout the reproductive stage, which was classified into early, mid, and late pod development phases based on the length of the reproductive stage, in order to examine the efficacy of various treatments.

4.1.1 Early pod bearing stage

It is evident that population abundance of aphid in country bean plants differed significantly during early pod bearing stage as influenced by different treatments. It is seen from Table 1 that the lowest number (9.25 aphid inflorescence^{-1}) of aphid population was found from T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 12.5 aphid inflorescence^{-1} and 14 aphid inflorescence^{-1} (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). However, there was no significant difference between T_1 and T_2. Eventually there was no significant variation between T_1 and T_4. Number of aphid population in T_4 (Malathion 57 EC) was 16 aphid inflorescence^{-1}. However, the highest population (18.75) was found from T_5 (control). Combination of imidacloprid and spinosad was very effective and could be an important management tactics for controlling aphid in country bean (Table 1).

Table 1. No. of aphid per inflorescence at early pod bearing stage

Treatment	No. of Aphid/ inflorescence	Decrease over control (%)
T_1	14.00 bc	25.33
T_2	12.50 c	34.93
T_3	9.25 d	50.66
T_4	16.00 b	14.66
T_5	18.75 a	-
$Lsd_{0.05}$	2.09	-
CV (%)	6.57	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.1.2. Mid pod bearing stage

At mid pod bearing stage statistically significant variation was recorded for aphid due to interaction effect of different management practices. It is seen from Table 2 that the lowest number (16.50 aphid inflorescence^{-1}) of aphid population was found from T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 21.25 aphid inflorescence^{-1} and 19.50 aphid inflorescence^{-1} (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). However, there was no significant difference between T_1 and T_2. Number of aphid population in T_4 (Malathion 57 EC) was 24.75 aphid inflorescence^{-1}. However, the highest population (27.50 aphid inflorescence^{-1}) was found from T_5 (control). Combination of imidacloprid and spinosad was very effective and could be an important management tactics for controlling aphid in country bean (Table 2).

Table 2. No. of aphid per inflorescence at mid pod bearing stage

Treatment	No. of Aphid/ inflorescence	Decrease over control (%)
T_1	19.50 c	29.09
T_2	21.25 c	22.72
T_3	16.50 d	40.00
T_4	24.75 b	10.00
T_5	27.50 a	-
$Lsd_{0.05}$	2.09	-
CV (%)	14.23	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.1.3 Late pod bearing stage

At late pod bearing stage statistically significant variation was recorded for aphid due to interaction effect of different management practices. It is seen from Table 3 that the lowest number (11.50 aphid inflorescence^{-1}) of aphid population was found from T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 14.75 aphid inflorescence^{-1} and 16.25 aphid inflorescence^{-1} (T_2 which denotes Thiamethoxam + Spinosad and T1 which denotes Azadirachtin + Spinosad respectively). However, there was no significant difference between T_1 and T_2. Number of aphid population in T_4 (Malathion 57 EC) was 19.75 aphid inflorescence^{-1}. However, the highest population (23.66 aphid/ inflorescence) was found from T_5 (control). Combination of imidacloprid and spinosad was very effective and could be an important management tactics for controlling aphid in country bean (Table 3).

Table 3. No. of aphid per inflorescence at late pod bearing stage

Treatment	No. of Aphid/ inflorescence	Decrease over control (%)
T_1	16.25 c	31.32
T_2	14.75 c	37.65
T_3	11.50 d	51.39
T_4	19.75 b	16.52
T_5	23.66 a	-
$Lsd_{0.05}$	2.72	-
CV (%)	7.08	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.2.1 Effect of treatments on the number of infested inflorescence

In case of combined effect of different treatment management was recorded for aphid. It is seen from Table 4 that the lowest number (10.25 aphid inflorescence^{-1}) of aphid population was found from T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 12.75 aphid inflorescence^{-1} and 14.50 aphid inflorescence^{-1} (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). Eventually there was no significant variation between T_1 and T_4. Number of aphid population in T_4 (Malathion 57 EC) was 15.75 aphid/ inflorescence. However, the highest population (17.50 aphid inflorescence^{-1}) was found from T_5 (control). Combination of imidacloprid and spinosad was very effective and could be an important management tactics for controlling aphid in country bean (Table 4).

Table 4. Effect of treatments on the number of infested inflorescence

Treatment	No. of infested inflorescence	Decrease over control (%)
T_1	14.50 b	17.14
T_2	12.75 c	37.25
T_3	10.25 d	41.42
T_4	15.75 b	10.00
T_5	17.50 a	-
$Lsd_{0.05}$	1.25	-
CV (%)	13.92	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.2.2 Effect of treatments on the number of healthy inflorescence

It is evident that the treatments used in the experiment have varying degree of impact on the number of healthy inflorescence. It is found that the highest number (55.75) of healthy inflorescence obtained from T_3, which showed significant variation from any other treatment with a 42.94% increase over control treatment. However the lowest number (39.00) of healthy inflorescence obtained from control treatment. It was statistically similar with T_4 (42.00) (Table 5).

Table 5. Effect of treatments on the number of healthy inflorescence

Treatment	No. of healthy inflorescence	Increase over control (%)
T_1	45.75 c	17.31
T_2	50.75 b	30.12
T_3	55.75 a	42.94
T_4	42.00 d	7.69
T_5	39.00 d	-
$Lsd_{0.05}$	3.43	-
CV (%)	13.26	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.3.1 Effect of treatments on the number of infested flower per inflorescence

The treatments used in the experiment have varying degree of impact on the number of infested inflorescence. It is found that the highest number of infested inflorescence obtained from T_5 (9.75). However the lowest number of infested inflorescence obtained from T3 (1.50), which was statistically similar with T_2 (3.75) (Table 6).

Table 6. Effect of treatments on the number of infested flower per inflorescence

Treatment	No. of infested flower/ inflorescence	Decrease over control (%)
T_1	5.50 bc	43.58
T_2	3.75 cd	61.53
T_3	1.50 d	84.61
T_4	6.75 b	30.76
T_5	9.75 a	-
$Lsd_{0.05}$	2.66	-
CV (%)	12.05	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.3.2 Effect of treatments on the number of healthy flower per inflorescence

It is evident that the treatments used in the experiment have varying degree of impact on the number of healthy flower inflorescence^{-1}. It is found that the highest number of healthy flower inflorescence^{-1} obtained from T_3 (13.75), which showed significant variation from any other treatment with a 266.66% increase over control treatment. However the lowest number of healthy flower inflorescence-1 obtained from T_5 (3.75) (Table 7).

Table 7. Effect of treatments on the number of healthy flower per inflorescence

Treatment	No. of healthy flower/ inflorescence	Increase over control (%)
T_1	8.50 bc	126.66
T_2	10.25 b	173.33
T_3	13.75 a	266.66
T_4	7.25 c	93.33
T_5	3.75 d	-
$Lsd_{0.05}$	2.52	-
CV (%)	12.85	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.4.1 Effect of treatments on the number of healthy pod at early pod bearing stage

Significant variation were observed in number of healthy pods over control at early pod development stage for different management practices in controlling insect pests of country bean. The highest number of healthy pods per plant was observed from T_3 (92.25). On the other hand, the lowest number of healthy pods per plant was observed from T_5 (63.50) (Table 8).

Table 8. Effect of treatments on the number of healthy pod at early pod bearing stage

Treatment	No. of healthy pod	Increase over control (%)
T_1	75.75 c	19.29
T_2	82.75 b	30.31
T_3	92.25 a	45.27
T_4	69.50 d	9.44
T_5	63.50 e	-
$Lsd_{0.05}$	1.98	-
CV (%)	11.15	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.4.2 Effect of treatments on the number of infested pod at early pod bearing stage

At early pod bearing stage statistically significant variation was recorded for aphid due to interaction effect of different management practices. The highest number of infected pods per plant was observed from T_4 (15.25) which was statistically similar with T_5 (15.75) and followed by T_1 (11.75) and T_2 (9.50). On the other hand, the lowest number of infected pods per plant was observed from T_3 (5.00) (Table 9).

Table 9. Effect of treatments on the number of infested pod at early pod bearing stage

Treatment	No. of infested pod	Decrease over control (%)
T_1	11.75 ab	25.39
T_2	9.50 b	39.68
T_3	5.00 c	68.25
T_4	15.25 a	3.17
T_5	15.75 a	-
$Lsd_{0.05}$	2.05	-
CV (%)	15.68	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.4.3 Effect of treatments on the number of healthy pod at mid pod bearing stage

Table 10 indicated that the number of healthy pods and increase over control at mid pod development stage showed statistically significant differences for different management practices in controlling aphid of country bean. It is found that the highest number of healthy pods obtained from T_3 (142.25), which showed significant variation from any other treatment with a 54.20% increase over control treatment. However the lowest number of healthy pods obtained from control treatment T_5 (92.25).

Table 10. Effect of treatments on the number of healthy pod at mid pod bearing stage

Treatment	No. of healthy pod	Increase over control (%)
T_1	120.50 b	30.62
T_2	130.25 b	41.19
T_3	142.25 a	54.20
T_4	108.75 c	17.88
T_5	92.25 d	-
$Lsd_{0.05}$	3.5	-
CV (%)	14.19	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.4.4 Effect of treatments on the number of infested pod at mid pod bearing stage

At mid pod bearing stage statistically significant variation was recorded for aphid due to interaction effect of different management practices. The highest number of infected pods per plant was observed from T_5 (21.50). On the other hand, the lowest number of healthy pods per plant was observed from T_3 (7.25) (Table 11).

Table 11. Effect of treatments on the number of infested pod at mid pod bearing stage

Treatment	No. of infested pod	Decrease over control (%)
T_1	14.75 b	31.39
T_2	10.75 c	50.00
T_3	7.25 d	66.27
T_4	17.50 b	18.60
T_5	21.50 a	-
$Lsd_{0.05}$	3.17	-
CV (%)	9.83	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.4.5 Effect of treatments on the number of healthy pod at late pod bearing stage

Significant variation were observed in number of healthy pods over control at late pod development stage for different management practices in controlling insect pests of country bean. The highest number of healthy pods per plant was observed from T_3 (73.75) which showed significant variation from any other treatment with a 41.14% increase over control treatment. It was statistically similar with T_2 (69.50). On the other hand, the lowest number of healthy pods per plant was observed from T_5 (52.25) (Table 12).

Table 12. Effect of treatments on the number of healthy pod at late pod bearing stage

Treatment	No. of healthy pod	Increase over control (%)
T_1	64.75 b	23.92
T_2	69.50 a	33.01
T_3	73.75 a	41.14
T_4	59.25 c	13.39
T_5	52.25 d	-
$Lsd_{0.05}$	2.69	-
CV (%)	11.26	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.4.6 Effect of treatments on the number of infested pod at late pod bearing stage

At late pod bearing stage significant variation were observed in number of infested pods over control for different management practices in controlling insect pests of country bean. The highest number of infested pods per plant was observed from T_5 (17.75) which was statistically similar with T_4 (15.50). On the other hand, the lowest number of infested pods per plant was observed from T_3 (7.65) which was statistically similar with T_2 (9.50) (Table 13).

Table 13. Effect of treatments on the number of infested pod at late pod bearing stage

Treatment	No. of infested pod	Decrease over control (%)
T_1	13.25 b	25.35
T_2	9.50 c	47.14
T_3	7.65 c	56.90
T_4	15.50 a	12.85
T_5	17.75 a	-
$Lsd_{0.05}$	2.18	-
CV (%)	7.67	-

In a column, numeric data represents the mean value of 4 replications, and means followed by different letter are significantly different at 5% level as per Least Significant Difference (LSD) test.

[T_1: Azadirachtin (Bioneem plus 1 EC @1 ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2ml/L) + spinosad (Success 2.5 SC @0.1 ml/L); T_4: Malathion 57 EC @1 ml/L weekly; T_5: Untreated Control]

4.5 Yield of country bean under different treatments

Statistically significant variation was observed in respect of total yield of country bean under different treatments used in the present studies. T_3 (Imidacloprod + Spinosad) showed the highest total yield (21.25 ton/ha) which was significantly different from other treatments. Whereas the lowest total yield (16.675 ton/ha) was recorded for T_5 (Control) which was closely followed by T_4 (Malathion) and they were statistically identical (Figure 1).

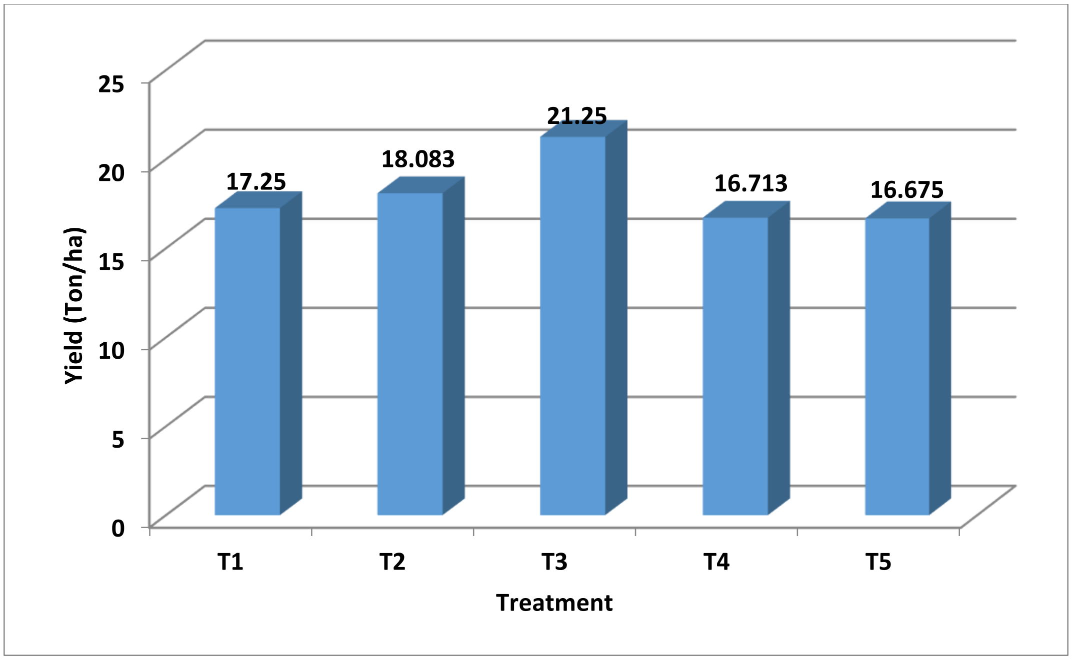

Figure 1: Yield of country bean under different treatment

Chapter V

Summary and Conclusion

CHAPTER V
SUMMARY AND CONCLUSION

5.1 SUMMARY

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to evaluate the performance of different management practices in controlling bean aphid of country bean (BARI seem-1) during the period from October 2019 to February 2020. The experiment consists of the following management practices: T_1: Azadirachtin (Bioneem plus 1 EC@1 ml/L) + Spinosad (Success 2.5 SC @0.1 ml/L); T_2: Thiamethoxam (Aktara 25% WG @0.5 g/L) + Spinosad (Success 2.5 SC @0.1 ml/L); T_3: Imidacloprid (Imitaf 20 SL @2 ml/L) + Spinosad (Success 2.5 SC @0.1 ml/L); T_4: Farmers' practice (spraying Malathion 57 EC @1 ml/L weekly); T_5: Untreated Control. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Data on the parameters of number of aphid per inflorescence, number of healthy and infested inflorescence, number of healthy and infested flower per inflorescence, number of healthy and infested pods, yield of country bean under different treatment were observed.

Among five treatments, it was observed that T_3 (Spraying Imitaf 20 SL @2 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval) was the most effective treatment for reducing insect pests infestation at early, mid and late pod development stages. . In case of bean aphid, the lowest number plant^{-1} was observed in T_3 (Spraying Imitaf 20 SL @2 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval) and closely followed by T_2 (Spraying Aktara 25% WG @0.5 g/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval) and T_1 (Spraying Bioneem plus 1 EC @1 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval). While the highest number was observed in T_5 (Control) which was followed by T_4 (Spraying Malathion 57 EC @1 ml/L of water of infested plant parts at 7 days interval).

It is evident that population abundance of aphid in country bean plants differed significantly during early pod bearing stage as influenced by different treatments. The lowest number (9.25 aphid/inflorescence) of aphid population was found from T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 12.5 aphid inflorescence^{-1} and 14 aphid inflorescence^{-1} (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). However, there was no significant difference between T_1 and T_2. Eventually there was no significant variation between T_1 and T_4. Number of aphid population in T_4 (Malathion 57 EC) was 16 aphid inflorescence^{-1}. However, the highest population (18.75) was found from T_5 (control). Combination of Imidacloprid and Spinosad was very effective and could be an important management tactics for controlling aphid in country bean.

At mid pod bearing stage statistically significant variation was observed for aphid due to interaction effect of different management practices. The lowest number (16.50 aphid/ inflorescence) of aphid population was found in T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 21.25 aphid/ inflorescence and 19.50 aphid/ inflorescence (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). However, there was no significant difference between T_1 and T_2. Number of aphid population in T_4 (Malathion 57 EC) was 24.75 aphid inflorescence^{-1}. However, the highest population (27.50 aphid/ inflorescence) was found in T_5 (control). Combination of Imidacloprid and Spinosad was very effective and could be an important management tactics for controlling aphid in country bean.

At late pod bearing stage statistically significant variation was observed for aphid due to interaction effect of different management practices. The lowest number (11.50 aphid/ inflorescence) of aphid population was found in T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 14.75 aphid/ inflorescence and 16.25 aphid/ inflorescence (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). However, there was no significant difference between T_1 and T_2. Number of aphid population in T_4 (Malathion 57 EC) was 19.75 aphid/ inflorescence. However, the highest population (23.66 aphid inflorescence^{-1}) was found in T_5 (control). Combination of Imidacloprid and Spinosad was very effective and could be an important management tactics for controlling aphid in country bean.

In case of combined effect of different treatment management was observed for aphid. It is seen from Table 4 that the lowest number (10.25 aphid inflorescence^{-1}) of aphid population was found in T_3 (Imidacloprid + Spinosad) which is significantly different from any other treatment. The number of aphid population was 12.75 aphid inflorescence^{-1} and 14.50 aphid inflorescence^{-1} (T_2 which denotes Thiamethoxam + Spinosad and T_1 which denotes Azadirachtin + Spinosad respectively). Eventually there was no significant variation between T_1 and T_4. Number of aphid population in T_4 (Malathion 57 EC) was 15.75 aphid inflorescence^{-1}. However, the highest population (17.50 aphid/ inflorescence) was found in T_5 (control). Combination of imidacloprid and spinosad was very effective and could be an important management tactics for controlling aphid in country bean.

It is evident that the treatments used in the experiment have varying degree of impact on the number of healthy inflorescence. It is found that the highest number (55.75) of healthy inflorescence obtained in T_3, which showed significant variation from any other treatment with a 42.94% increase over control treatment. However the lowest number (39.00) of healthy inflorescence observed from control treatment. It was statistically similar with T_4 (42.00).

The treatments used in the experiment have varying degree of impact on the number of infested inflorescence. It is found that the highest number of infested inflorescence obtained in T_5 (9.75). However the lowest number of infested inflorescence observed from T_3 (1.50), which was statistically similar with T_2 (3.75).

It is evident that the treatments used in the experiment have varying degree of impact on the number of healthy flower inflorescence^{-1}. It is found that the highest number of healthy flower inflorescence^{-1} obtained in T_3 (13.75), which showed significant variation from any other treatment with a 266.66% increase over control treatment. However the lowest number of healthy flower inflorescence^{-1} observed in T_5 (3.75).

Significant variation were observed in number of healthy pods over control at early pod development stage for different management practices in controlling insect pests of country bean. The highest number of healthy pods per plant was observed in T_3 (92.25). On the other hand, the lowest number of healthy pods per plant was observed in T_5 (63.50).

At early pod bearing stage statistically significant variation was observed for aphid due to interaction effect of different management practices. The highest number of infected pods per plant was observed in T_4 (15.25) which was statistically similar with T_5 (15.75) and followed by T_1 (11.75) and T_2 (9.50). On the other hand, the lowest number of infected pods per plant was observed in T_3 (5.00).

Table 10 indicated that the number of healthy pods and increase over control at mid pod development stage showed statistically significant differences for different management practices in controlling aphid of country bean. It is found that the highest number of healthy pods obtained in T_3 (142.25), which showed significant variation from any other treatment with a 54.20% increase over control treatment. However the lowest number of healthy pods obtained in control treatment T_5 (92.25).

At mid pod bearing stage statistically significant variation was observed for aphid due to interaction effect of different management practices. The highest number of infected pods per plant was observed in T_5 (21.50). On the other hand, the lowest number of healthy pods per plant was observed in T_3 (7.25).

Significant variation were observed in number of healthy pods over control at late pod development stage for different management practices in controlling insect pests of country bean. The highest number of healthy pods per plant was observed in T_3 (73.75) which showed significant variation from any other treatment with a 41.14% increase over control treatment. It was statistically similar with T_2 (69.50). On the other hand, the lowest number of healthy pods per plant was observed in T_5 (52.25).

At late pod bearing stage significant variation were observed in number of infested pods over control for different management practices in controlling insect pests of country bean. The highest number of infested pods per plant was observed in T_5 (17.75) which was statistically similar with T_4 (15.50). On the other hand, the lowest number of infested pods per plant was observed in T_3 (7.65) which was statistically similar with T_2 (9.50).

Statistically significant variation was observed in respect of total yield of country bean under different treatments used in the present studies. T_3 (Imidacloprod + Spinosad) showed the highest total yield (21.25 ton/ha) which was significantly different from other treatments. Whereas the lowest total yield (16.675 ton/ha) was observed for T_5

(Control) which was closely followed by T_4 (Malathion) and they were statistically identical.

5.2 CONCLUSION

The present study revealed that the increased yield hectare^{-1} of country bean with the increase rate of number of inflorescences plant^{-1}, number of flower for 10 inflorescences, number of healthy flower for 10 inflorescences, total number of pods, number of healthy pods and decrease rate of infested flower for 10 inflorescences, number of infested pods, increased rate of length of 20 healthy pods, weight of 20 healthy pods (g), total weight of healthy pods (g) and even the highest length (cm), and decreased rate of weight of 20 infested pods (g), highest total weight of infested pods (g) along with increased total yield (kg) pods might be obtained by using the treatment T_3 (Spraying Imitaf 20 SL @2 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval). Whereas the treatment T_2 (Spraying Aktara 25% WG @0.5 g/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval) gave better results than the treatment T_1 (Spraying Bioneem plus 1 EC @1 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval) and T_4 (Spraying Malathion 57 EC @1 ml/L of water of infested plant parts at 7 days interval) used in this experiment.

From the above description, it can be concluded that, spraying of Imitaf 20 SL @2 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval reduced the infestation of bean aphid of country bean of variety BARI seem-1.

5.3 RECOMMENDATIONS

From this study it may be recommended that the treatment T_3 which consists of spraying of Imitaf 20 SL @2 ml/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval can be used successfully for reducing the infestation of bean aphid of country bean of variety BARI seem-1. The treatment T_2 (Spraying Aktara 25% WG @0.5 g/L of water of infested plant parts at 7 days interval + Success 2.5 SC @0.1 ml/L of water of infested plant parts at 7 days interval) was the second best treatment in the experiment. However, further study of this experiment is needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

References

REFERENCES

Abro, G.H., Memon, A.J., Syed, T.S. and Shaikh, A.A. (2004). Infestation of *Earias spp.* On on cotton and okra grown as mono and mix crops. *Pakistan J. Biol. Sci.* **7**(6): 937-942.

Ahad, M.A., Nahar, M.K., Amin, M.R., Suh, S.J. and Kwon, Y.J. (2016). Effect of weed extracts against pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) of mung bean. *Bangladesh J. Agril. Research*, **41**(1): 75-84.

Alam, M.Z. (1969). Insect Pests of Vegetables and Their Control in East Pakistan. The Agriculture Information Service (AIS), Department of Agriculture; 3, R.K. Mission Road, Dhaka-3, East Pakistan, p.146.

Alam, M.Z., Rouf, F.M.A., Rahman, A.K. and Cork, A. (2005). Determination of the status of different borer pest complex of country bean. Annual Report, Entomology Division, BARI, Gazipur. pp. 32-37.

Aldea, M., Hamilton, J.G., Resti, J.P., Zangerl, A.R., Berenbaum, M.R. and, DDeeLucia, E.H. (2005). Indirect effects of insect herbivory on leaf gas exchange in soybean. Plant, Cell and Environment, **28**(3): 402–411.

Alghali, A.M. (1993). The effects of some agrometeorological factors on fluctuation of the legume pod borer, *Maruca testulali*s Geyer (Lepidoptera: Pyralidae), on two cowpea varieties invarieties in Nigeria. *Insect Sci. Applic*. **14**(1): 55-59.

Amoako-Atta, B. and Omolo, E.O. (1982). Yield losses caused by the stem-pod-borer complex within intercropping systems in Kenya. *Insect Sci. Applic*. **4**: 39-46.

Amoako-Atta, B., Omolo, E.O. and Kidega, E.K. (1983). Influence of maize, cowpea and sorghum intercropping systems on stem-pod borer infestations, *Insect Sci. Applic*. **4**: 47-57.

Anonymous. (2006). Bangladesh Crop Protection Association's Sales Record. Bangladesh Crop Protection Association (BCPA). Dhaka, Bangladesh.

Arora, R.K., Dhillon, M.K. and Singh, H. (1996). Management of pest complex in okra research summation. *Annl. Agric. Biol. Res.* **1**(1/2): 37-45.

Attle, A.A., Eliheneidy, A.H. and El-Kady, E.A. (1987). Studies on the aphid, *Aphis craccivora* in Egypt. Bull. De La Societe. *Entomol. d'Egypte.* **66**: 319-324.

Barlow A. and, Messmer, I. (1982). Pea aphid (Homoptera: Aphididae) induced changes in some growth rates of pea plants. *J. Economic Entomology*, **75**: 765–768.

BBS (Bangladesh Bureau of Statistics). (2015). Statistical Year book of Bangladesh, Bangladesh Bureau of Statistics, Government of the People's Republic of Bangladesh, Dhaka.

Begum, R.A. (1993). Techniques of growing legume vegetable, In: M.L. Chadha, A.K.M.A. Hossain and S.M.M. Hossain, (Eds.). Intensive Vegetable Growing and its Utilization. A compilation of lecture materials of training course held at BARI, Joydebpur, Gazipur, Bangladesh in collaboration with AVRDCBARC/BARI-USAID. 22-25 November 1993. pp. 92-128.

Birch, N. (1985). Field evaluations of resistance to black bean aphid, *Aphis fabae*, in close relatives of the faba bean, *Vicia faba*. *Annals of Applied Biol*., **106**: 561–596.

Blackman, R.L. and, Eastop, V.F., (1984). Aphids on The World's Crops: An Identification Guide. John Wiley and Sons, New York.

Bouchery, Y., and Jacky, F. (1977). Determination de la periode de I'attaque d' *Aphis fabae* Scop. (Homoptera: Aphididae) le plus dommagable pour la feverole de printemps *Vicia fabae* L.

Butani, D.K. and Jotwani. M.G. (1984). Insects in Vegetables. Periodical Expert Book Agency, D-42, Vivek- Vihar, Delhi- 110032, India, pp. 69-79, 91-93.

Cammell, M. E. (1981). The black bean aphid, *Aphis fabae*. Biologist, **28**: 247-258.

Capinera, J.L. (1981). Some effects of infestation by bean aphid, *Aphis fabae* Scopoli, on carbohydrate and protein levels in sugarbeet plants, and procedures for estimating economic injury levels. Zeitschrift für angewandte Entomologie, **92**: 374–384.

Das, G.P. (1998). Major Insect and Mite Pests of Important Crops and Stored Products of Bangladesh. Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701, Bangladesh, pp. 11-12.

Debach, P. and Rosen, D. (1991). Biological Control by Natural Enemies. Cambridge University Press, Cambridge, United Kingdom.

Delaney, K.J., and Higley, L.G. (2006). An insect countermeasure impacts plant physiology: midrib vein cutting, defoliation and leaf photosynthesis. Plant, Cell and Environment, **29**: 1245–1258.

Dixon, A.F.G., and Wratten, S.D. (1971). The role of aphids in wood formation. I. The effect of the sycamore aphid, *Drepanosiphum platanoides* (Schr.) (Aphididae), on the growth of sycamore, *Acer pseudoplatanus* (L.). *J. Applied Ecology*. **8**: 165-179.

Dubey, N.K., Shukla, R., Kumar, A., Singh, P. and Prakash, B. (2011). Global Scenario on the application of Natural products in integrated pest management. In: Dubey, N.K. (Ed.), Natural Products in Plant Pest Management, Dubey, N.K., CABI, Oxfordshire, UK. pp. 1-20.

Ekesi, S. (1999). Insecticide resistance in field populations of the legume pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae), on cowpea, *Vigna unguiculata* (L.), Walp in Nigeria. *Int. J. Pest Management*, **45**(1): 57-59.

El-Defrawi, G.M. (1987). Studies on insect vectors of virus diseases infesting Leguminacae in Egypt. Ph.D Thesis, Faculty of Agriculture, Ain, Shams Univ. Egypt.

El-Fatah, A.S.M. (1991). Studies on insect infesting leguminous plants. M.Sc. Thesis, Faculty of Agriculture, Zagazig University.

Feng, W. and Zheng, X. (2007). Essential oil to control *Alternaria alternata in vitro* and *in vivo*. Food Control, **18**: 1126-1130.

Fisher, N.M., Raheja, A.K. and Elemo, K.A. (1987). Insect pest control for cowpea in crop mixtures. *Exp. Agric*. **23**: 9-20.

Frazer, B.D. (1972). Life tables and intrinsic rates of increase of apterous black bean aphids and pea aphids on broad bean (Homoptera: Aphididae). *Can. Entomol*. **104**: 1717-1722.

Gomez, K.A. and Gomez, A. (1984). Statistical Procedure for Agricultural Research—Hand Book. John Wiley & Sons, New York.

Govindan, R. (1974). Insects of the field bean. *Lablab niger* var. *lignosus* (Medikus) with special reference to the biology and ecology of the pod borer, *Adisura atkinsoni* Moore (Lepidoptera: Noctuidae). M.Sc. (Agri.) Thesis. U.A.S., Bangalore, p.92.

Guilbert, J.J. (2003). The World Health Report 2002-Reducing Risks, Promoting Health Life. Education for Health Change in Learning and Practice, **16**(2):230.

Gupta, P.K. and Singh, J. (1978). Galerucid grub, *Madurasia obscurella* Jacoby (Coleoptera; Chrysomelidae) and its feeding activity. *Newsletter soil Biology and Ecology*, **1**(2): 4-5.

Hara, A.H. (2000). Finding alternative ways to control alien pests – part 2: New insecticides introduced to fight old pests. *Hawaii Landscape,* **4**(1) 5.

Hawkins C.D.B., Aston M.I., Whitecross, M.I. (1985). Aphid induced changes in growth indices of three leguminous plants: unrestricted infestation. *Canadian Journal of Botany*, **63**: 2454–2459.

Hill, D.S. (1983). Agricultural Insect Pests of the Tropics and Their control. Cambridge University Press. London-New York, pp. 746.

Holdway, F.G. and Look, W.C. (1942). Insect pests of the garden bean in Hawaii. *Prop. Hawaii. Entomol. Soc.*, **11**: 249-260.

Hossain, A. and Awrangzeb, S.N.H. (1992). VEGETABLE Production Policies: Plans And Future Direction. pp. 21-30.

Hossain, M. S., Rahman, M. M., Alam, M. Z., Miah, M. I. H. and Akhter, S. (2009). Effect of variety and planting dates on the incidence of pod borer (*Maruca vitrata* F.) in year round country bean. *Bangladesh J. Entomol.,* **19**(2): 33-44.

Hossain, Q. T. (1990). Status and management of vegetable pests in Bangladesh. P. 28.

Hunter M.D. (2001). Effects of elevated atmospheric carbon dioxide on insect-plant interactions. *Agricultural and Forest Entomology*, **3**: 153–159.

Hurej M., van der Werf, W. (1993). The influence of black bean aphid, *Aphis fabae* Scop. and its honeydew on the photosynthesis of sugarbeet. *Annals of Applied Biology*, **122**: 189–200.

Islam, M.A. (1999). Integrated Pest (Insects) Management of Vegetables. Consultancy Report, 18 November 1998 - 17 May 1999. AVRDC - USAID Bangladesh Project, Horticulture Research Center, BARI, Gazipur- 1701.

Isman, M.B. and Akhtar, Y. (2007). Plant natural products as a source for developing environmentally acceptable insecticides. In: Shaaya, I., R. Nauen and A.R.

Horowitz (Eds.). Insecticides Design Using Advanced Technologies, Springer, Berlin, Heidelberg, pp. 235-248.

Karel, A.K. (1993). Effects of intercropping with maize on the incidence and damage caused by pod borers of common beans. *Environ. Entomol*., **22**: 1076- 1083.

Karel, A.K. (1984). Incidence and control of pod borers on common beans (*Phaseolus vulgaris* L). *Ann. Rep. Bean Imp. Coop.,* **27**: 189-190.

Karim, M.A. (1995). Management of insect pest of vegetables. In: M.L. Chadha, K.U. Ahmad, S. Shanmugasundaram and A. Quasem (eds.) Vegetable Crops Agribusiness. Proceedings of a workshop held at BARC, Dhaka, Bangladesh 24 May 1995. AVRDC, BARC and BARI.

Karim, M.A. (1993). Vegetable protection (Insect). Consultancy Report. AVRDC - USAID (ARP II) Project, 3l December 1992 - 29 April 1993. Horticulture Research Center, BARI, Joydebpur, Gazipur. pp. 6-53.

Khater, H.F. (2012). Ecosmart biorational insecticides: alternative insect control strategies. In: Perveen, F. (Ed.). Insecticides: Advances in Integrated Pest Management, InTech, Rijeka, Croatia, pp.17-60.

Macedo, T.B., Bastos, C.S., Higley, L.G., Ostlie, K.R. and Madhavan, S. (2003). Photosynthetic responses of soybean to soybean aphid (Homoptera: Aphididae) injury. J. Econ. Entomol., 96: 188–193.

Macedo, T.B., Peterson, R.K.D., Weaver, D.K. and Morrill, W.L. (2005). Wheat stem sawfly, *Cephus cinctus* Norton, impact on wheat primary metabolism: an ecophysiological approach. *Environmental Entomology*, **34**: 719–725.

Mazumder, R., Amin, M.R., Rahman, M.M., Hossain, M.S. and Hoque, M.Z. (2016). Bio-rational management of pod borer in green pea field. *Bangladesh J. Entomol.*, **26**: 11-19.

McKinlay, R.G. (1992). Vegetable Crop Pests. Macmillan Press, London. 406 pp.

Memon, A.J., Abro, G.H. and Syed, T.S. (2004). Varietal Resistance of okra against *Earias* spp. *Journal of Entomology*, **1**: 1-5.

Miah, M.N.A., Miah, M.R.U. and Alam, M.Z. (2017). Determining chemical composition of cattle urine and indigenous plant extracts. *International Annals of Science*, **3**: 23-26.

Naresh, J.S. and Nene, Y.L. (1968). Survey and evaluation of economic importance of insect pests of pulses. Annual Report 1968-69. Uttar Pradesh Agricultural University, Pantnagar, pp. 177 -178.

Natarajan, N., Rao, P.V.S. and Gopal, S. (1991). Effect of intercropping of pulses in cereals on the incidence of major pests. *Madras Agric. J.*, **78**: 59-67.

Ofuya, T.I. (1991). Observations of insect infestation and damage in cowpea (*Vigna unguiculata*) intercropped with tomato *Lycopersicon esculentum* in a rain forest area of Nigeria. *Exp. Agric.,* **21**: 407-412.

Ogenga-Latigo, M.W. and Khaemba, B.M., (1985). Some Aspects of the Biology of the Black Bean Aphid, *Aphis faba*e Scopoli Reared on the Common Bean *Phaseolus vulgaris* L. *Int. J. Tropical Insect Sci.,* **6**(5): 591-593.

Okeyo-Owuor, J.B., Oloo, G.W. and Agwaro, P.O. (1991). Natural Enemies of legume pod-borer, *Maruca testulalis* (Geyer). 200 (Lepidopteda: Pyralidae) in small farming systems of Western Kenya. *Insect Sci. Appl.,* **12**: 35-42.

Omolo, E.O., Niyambo, S., Simbi, C.O.J. and Ollimo, P. (1993). The role of host plant resistance and intercropping in integrated pest management (IPM) with specific reference to *Oyugis* project. *Hort. I. Trop. Pest Manage.,* **39**: 265-272.

Palmer, M.A., (1952). Aphids of the Rocky Mountains Region. Thomas Say Foundation, **5**: 1-452.

Patnaik, N.C., Dash, A.N. and Mishra, B.K. (1989). Effect of intercropping on the incidence of pigeon pea pests in Orissa, India. *Pigeon pea Newslett.,* **9**: 24-25.

Pedigo, L.P. (1999). Entomology and Pest Management. Prentice and Hall Incorporation, London.

Peterson, R.K.D. (2001). Photosynthesis, yield loss, and injury guilds. In: Biotic Stress and Yield Loss, R.K.D. Peterson and L.G. Higley (Eds.) Boca Raton, FL: CRC Press. pp. 83–98.

Peterson, R.K.D. and Higley, L.G. (1993). Arthropod injury and plant gas exchange: current understandings and approaches for synthesis. *Trends in Agricultural Sciences: Entomology*, **1**: 93–100.

Peterson, R.K.D., Shannon C.L. and Lenssen A.W. (2004). Photosynthetic responses of Legume species to leaf-mass consumption injury. *Environmental Entomology*, **33**: 450–456.

Pfadt, R.E. (1980). Fundamentals of Applied Entomology. Macmillan Company, New York. pp. 99-126.

Prakash, A. and Rao, J. (1986). Evaluation of plant products as antifeedants against the rice storage insects. Proceedings from the Symposium on Residues and Environmental Pollution, October 2, 1986, Muzaffarnagar, pp. 201-205.

Prakash, A. and Rao, J. (1997). Botanical Pesticides in Agriculture. 1st Edn., CRC Press Inc., Baton Rouge, Florida. p. 461.

Pretty, J. (2009). The Pesticide Detox: Towards a More Sustainable Agriculture. Earthscan, London.

Raheja, A.J. (1974). Report on the insect pests of grain legumes in Northern Nigeria. In: Proceedings of 1st IITA Grain Legume Improvement Workshop, 1973. International Institute for Tropical Agriculture, Ibadan, pp. 295-299.

Rahman, M.M. and Rahman, M.S. (1988). Timing and frequency of insecticide application against *Maruca testulalis* (Geyer) infesting short-duration pigeon pea in Bangladesh. *Legume-Research*. **11**(14): 173-179.

Rashid, M.M. (1999). *Shabji Biggan* (in Bengali), Rashid Publishing House, Dhaka 1206. pp. 307-409.

Rashid, M.J., Sambasivan, M. and Johari, J. (2003). The influence of corporate culture and organizational commitment on performance. *J. Management Development* **22**(8): 708-728.

Rizkalla, L.R., Makkour, M.A., El-Sherbeeny, M.H. and Soih, M.B. (1994). A new virus disease affecting faba bean (*Vicia faba* L.) in Egypt. 6th Annual Report of Nile valley Regional Program on Cool Season. Food Legumes. pp. 197-203.

Rosell, G., Quero, C., Coll, J. and Guerrero, A. (2008). Biorational insecticides in pest management. *J. Pesticide Science*, **33**: 103-121.

Salazar, J.A. (1976). Analysis of the damage caused by the black bean aphid (*Aphis fabae* Scop.) to field bean (*Vicia faba* L.). PhD Thesis. University of London.

Saxena, H.P. (1973). Insects of kharif pulses. In: Bulletin on Pest Management on Plant Protection Training, Farm Adv. Unit, Directorate of Extension, Ministry of Agriculture and Irrigation, New Delhi. pp. 263-264.

Saxena, H.P. (1976). Pest problem in pulse crops. *Proc. National Acad. Sci. B.* **46**(122): 173-176.

Saxena, K.B., Jayasekera, S.J.B.A. and Ariyaratne, H.P. (1992). Pigeon pea Adoption and Production Studies in Sri Lanka. Department of Agriculture. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, and Andhra Pradesh.

Schaaffhausen, R.V. (1963). *Dolichos lablab* or Hyacinth bean, its use for feed, food and soil improvements. *Economic Botany*, **17**: 146-153.

Shroff, K.D. (1920). A list of the pests of pulses in Burma. Rep. Proc. 3rd Entomol. Meet., Pusa, pp. 343-346.

Singh, J.P. (1983). Crop Protection in the Tropics. Vikas Publishing House Pvt. Ltd. New Delhi-, India. pp.192-202.

Singh, S.R. and Allen, D.T. (1980). Pests, diseases, resistance, and protection in cowpeas. In: R.J. Summerfield and A.H. Bunting, (eds). Advances in Legume Science. Royal Botanical Garden, Kew, and Ministry of Agriculture, Fisheries and Food, London. pp. 419-443.

Soares, M.A., Campos, M.R., Passos, L.C., Carvalho, G.A., Haro, M.M., Lavoir, A.V. and Desneux, N. (2019). Botanical insecticide and natural enemies: a potential combination for pest management against *Tuta absoluta*. *J. Pest Sci.,* **92**: 14331443.

Stoetzel, M.B., Miller, G.L., O'Brien, P.J. and Graves, J.B. (1996). Aphids (Homoptera: Aphididae) colonizing cotton in the United States. *Florida Entomologist,* **79**: 193-205.

Taylor, T.A. (1967). The bionomics of *Maruca testulalis* Gey. (Lepidoptera: Pyralidae), a major pest of cowpea in Nigeria. *J. West Africa Sci. Assoc.*, **12**: 111-129.

Tsitsipis, J.A. and Mittler, T.E. (1976). Development, growth, reproduction and survival of apterous virginoparae of *Aphis fabae* at different temperatures. *Entomologia Experimentalis et Applicata*, **19**(1): 1-10.

Usua, E.J. and Singh, S.R. (1977). Parasites and predators of the cowpea pod borer, *Maruca testulalis* (Lepidoptera: Pyralidae), *Nigerian J. Entomol.*, **3**(1): 100102.

Warrington, S., Cottam, D.A. and Whittaker, J.B. (1989). Effects of insect damage on photosynthesis, transpiration and SO_2 uptake by sycamore. *Oecologia*, **80**: 136–139.

Way, M.J. and Cammell, M.E. (1982). The distribution and abundance of the spindle tree, *Euonymus europaeus*, in Southern England with particular references to forecasting infestations of the black bean aphid, *Aphis fabae*. *J. Appl. Ecology,* **19**(3): 929-940.

Welter, S.C. (1989). Arthropod impact on plant gas exchange. In: Plant-Insect Interactions. Vol. I, E.A. Bernays (Ed.), Boca Raton, CRC Press, Florida, pp. 135–150.

Wu, A. and Thrower, L.B. (1981). The physiological association between *Aphis craccivora* Koch and *Vigna sesquipedali*s Fruw. *New Phytologist*, **88**: 89–102.

York, A. (1992). Pest of cucurbits crops: marrow, pumpkin, squash, melon and cucumber. In: R.G. Mckinlay (eds.), Vegetable Crop Pest. Houndmills, Basingstoke, Hampshire and London. pp.13-161.