MANAGEMENT OF BEAN POD BORER USING SOME BOTANICALS, PHEROMONE TRAPS AND CHEMICAL INSECTICIDES

LUBNA AKTAR

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2016

MANAGEMENT OF BEAN POD BORER USING SOME BOTANICALS, PHEROMONE TRAPS AND CHEMICAL INSECTICIDES

BY

LUBNA AKTAR

REGISTRATION NO. : 15-06983

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: JULY-DECEMBER, 2016

Approved By:

Prof. Dr. Md. Razzab Ali **Supervisor** **Department of Entomology** **SAU, Dhaka**	**Ayesha Akter** **Co-Supervisor** **Department of Entomology** **SAU, Dhaka**

Dr. Mst. Nur Mohal Akhter Banu
Chairman
Examination Committee
Department of Entomology
SAU, Dhaka

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, "**MANAGEMENT OF BEAN POD BORER USING SOME BOTANICALS, PHEROMONE TRAPS AND CHEMICAL INSECTICIDES**" submitted to the **Faculty of Agriculture**, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **Lubna Aktar**, **Registration No. 15-06983** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2016
Place: Dhaka, Bangladesh

Prof. Dr. Md. Razzab Ali
Supervisor
Department of Entomology
SAU, Dhaka

Dedicated

To My

Beloved Parents

ACKNOWLEDGEMENT

At first, the author takes the opportunity to express her deepest sense of gratefulness to Almighty Allah who enables the author to complete her research work for the degree of Master of Science (MS) in Entomology.

The author really does not have adequate words to express her heartfelt sense of gratification, ever indebtedness and sincere appreciation to her benevolent teacher and research supervisor, Dr. Md. Razzab Ali, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207, for his constant help, scholastic guidance, planning experiment, valuable suggestions, timely and solitary instructive criticism for successful completion of the research work as well as preparation of this thesis.

It is a great pleasure for the author to express her sincere appreciation, profound sense, respect and immense indebtedness to her respected co-supervisor, Ayesha Akter, Assistant Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for providing her with all possible help during the period of research work and preparation of the thesis.

The author would like to express her deepest respect and boundless gratitude to the Chairman and all the teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 for their sympathetic co-operation and inspiration 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 her research work in the field.

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

Dated: December, 2016 **The Author**

SAU, Dhaka

MANAGEMENT OF BEAN POD BORER USING SOME BOTANICALS, PHEROMONE TRAPS AND CHEMICAL INSECTICIDES

BY
LUBNA AKTAR

ABSTRACT

A field experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University to find out the effective as well as hazards free management practice(s) of bean pod borer infesting country bean, cultivated during Rabi season (October, 2016 to February, 2017). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental treatments were T_1 comprised of spraying of neem oil @ 3ml/L of water at 7 days interval; T_2 comprised of spraying of neem seed kernel extract @ 0.5ml/L water at 7 days interval; T_3 comprised of setting up of 1 lure with pheromone trap per plot; T_4 comprised of spraying of Fytomax 0.03 EC @ 0.4 ml/L of water at 7 days interval; T_5 comprised of spraying of Actara 25 WG @ 0.3 g/L of water at 7 days interval; T_6 comprised of spraying of Cot 10 EC @ 0.4 ml/L of water at 7 days interval; T_7 comprised of T_1 and T_3; T_8 comprised of T_2 and T_3 and T_9 comprised of untreated control. Fytomax 0.03 EC (T_4) contributed to produce the highest number of inflorescence, flower bud and fruit by number at early stage (74.73 inflorescence/plot; 64.51 flower bud/five tagged inflorescence and 29.75 fruit/ five tagged inflorescence respectively), mid stage (80.50 inflorescence/plot; 69.93 flower bud/ five tagged inflorescence and 35.83 fruit/ five tagged inflorescence respectively) and late stage (78.16 inflorescence/plot; 66.22 flower bud/ five tagged inflorescence and 31.51 fruit/ five tagged inflorescence respectively); total weight of fruit (159190 gm/plot) and reduced the maximum inflorescence infestation, flower bud infestation and fruit infestation over control at early stage (81.44%, 87.21% and 89.66% respectively), mid stage (80.85%, 83.51% & 80.07% respectively) and late stage (82.05%, 87.21% & 90.27% respectively). The highest yield (23.59 ton/ha) was recorded in T_4 which contributed to increase the highest yield (89.63%) over control. The highest benefit cost ratio (53.13) was also found for T_4 and the lowest BCR (7.49) for T_5. The highest number of lady bird beetle (5.40 lady bird beetle/five vines/plot/inspection), black ant (6.27 black ant/five vines/plot/inspection), spider (5.33 spider/five vines/plot/inspection), syrphid fly (5.17 syrphid fly/five vines/plot/inspection) and honeybee (4.37 honeybee/five vines/plot/inspection respectively) was recorded in $T_{4,}$ where the lowest number of lady bird beetle (1.33 lady bird beetle/five vines/plot/inspection), black ant (1.17 black ant/five vines/plot/inspection), spider (1.13 spider/five vines/plot/inspection), syrphid fly (1.87 syrphid fly/five vines/plot/inspection) and honeybee (1.07 honeybee/five vines/plot/inspection respectively) was recorded in T_6. Considering the social acceptance and environmental safety point of view, T_4 comprising Fytomax 0.03 EC was the most effective management practices by reducing the bean pod borer infestation and increasing the population of beneficial arthropods, thereby increasing the yield of country bean.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

The country bean, *Lablab purpureus* Linnaeus belonging to the family Leguminosae is a delicious vegetable crop in Bangladesh (Thompson, 1951). At present average per capita daily consumption of vegetables in Bangladesh is 26 gm as against the reported requirement of balanced nutrition of vegetables is 200gm per capita (Haque, 1991). At this rate, annual requirement of vegetables is about 5.48 million tons. Bangladesh has a deficiency in vegetables with an annual production of only 2.5 million tons including potato and sweet potato (Anon., 1993). In 2012-13 fiscal years, country bean was cultivated in Bangladesh covering 42129 acres of land and the total production was 93055 metric tons, which contributed 2.21 metric tons/acre (BBS, 2013). This production is too low to fulfill the nutritional requirements of the people. In order to lessen the shortage attempt is needed to increase the country bean production. The major vegetables grown in Rabi season are different kind of beans which appear as one of the most important group of vegetables in our daily food. Its young fruits and unripe seeds are used as vegetables, dry seeds are used as pulse and the biomass after the harvest is used as fodder. The green fruits contain 4.5% protein (Rashid, 1993). The green fruits and dry seeds are also fairly rich in calcium and vitamin C (Grubben, 1997).

It is grown almost in all districts of Bangladesh. Its concentration is found in Dhaka, Jessore, Comilla, Noakhali and Chittagong but for the last ten years country bean have been seen growing extensively in Jessore, Khulna, and Chittagong region as well (Aditya, 1993).

Among the different limiting factors, high incidences of insect pests have limited the crop into its low yield and poor quality (Rashid, 1993). Among insect pests, the bean pod borer, *Maruca testulalies* G. (Bakar *et. al.*, 1980; Butani and Jotwani, 1984) is the most important and cause enormous quantity of yield losses in every season and every year by boring tender or mature fruits. Although no regular statistical records are kept, as per conservative estimate the yield loss in country bean due to this pest is reported to be about 12-30% (Hossain, 1990) by attacking the crop making clusters of leaves and young shoots of the plant at the early stage of plant growth. Later at flowering and fruit setting stages of plants, larvae bore into reproductive organs, where the insect feeds internally (Rahman, 1989; Karim, 1993; Begum, 1993; Sharma, 1998). Although different methods of controlling the pest are available, growers in Bangladesh, however, frequently use chemical insecticides in order to protect country beans from damages due to pod borer attacks (Rahman, 1989; Begum, 1993; Karim, 1994 and 1995). Since, Bean pod borers (*Maruca testulalis*) frequently feed internally on infested plant parts while living inside the clusters or fruits, insecticide applications, particularly a single application, may often fail to provide successful control of the pest (Rahman, 1989; Begum, 1993). A research result illustrated that on an average farmers applied insecticides 33 times (minimum 12 and maximum 100 times) throughout the cropping season of country bean in Jessore region of Bangladesh (Hasanuzzoha, 2004). This findings revealed that the hazardous situation of country bean by the application of chemical pesticides in Bangladesh. This type of indiscriminate use of pesticides also resulted killing of natural enemies, environmental pollution, resistance development of pests against pesticides and residual toxicity in the produces. As a result, judicious applications of insecticides and non-chemical approaches are required for controlling this pest considering the environmental friendly management of bean pod borer. Now-a-days, neem oil and other neem based extracts are very new and unexploited approaches in this context.

The pheromonal trapping of adult moth of the species also almost hazards free tools for controlling this pest. Therefore, the present study was conducted to determine the effectiveness of some botanicals and pheromone traps and their combinations in comparison with chemical insecticides against bean pod borer, *Maruca testulalis* with the following objectives:

i. To find out the level of infestation caused by bean pod borer infesting country bean;
ii. To find out the efficacy of botanicals, sex pheromone and chemical insecticides in suppressing bean pod borer;
iii. To find out the impacts of botanicals, sex pheromone and chemical insecticides on beneficial arthropods during the management of bean pod borer;
iv. Economic analysis of the management practices used in the study.

CHAPTER II

REVIEW OF LITERATURE

Bean pod borer, *Maruca testulalis*, is one of the most important pests of country bean; (*Lablab purpureus*) is highly prone to damage by this pest in Bangladesh. Because of the difficulties associated with the control of this pest by chemical insecticides, farmers experienced great losses in country beans. Therefore, the judicious use of pesticides along with bio-pesticides is important. The literatures on the eco-friendly management utilizing several non-hazardous components to combat this pest are very sporadic. For the purpose of this study, the most relevant information's are given below under the following sub-headings:

2.1 Systemic position of bean pod borer

Phylum: Arthropoda
Class: Insecta
Sub-class: Pterygota
Order: Lepidoptera
Family: Pyralidae
Genus: *Maruca testulalis*

2.2 Seasonal distribution of bean pod borer

Legume pod borer population build-up is related to the cumulative rainfall and the number of rainy days between crop emergences to flowering. The insect is multivoltine; having at least two over lapping generations in a year in most places of its distribution (Sharma, 1998). Legume pod borer is likely to differ in its seasonal distribution spatially even within a host plant and temporally within the growing season of a particular host plant. Again, the weather pattern varies across continents, and therefore, the seasonal distribution of the insect is likely to vary regionally as well. In Nigeria, the insect reaches to its peak infestation levels during June and July

(Taylor, 1998). The first generation adults developing from the initial stock-generation in cowpea fields appears in July and the second generation between July and September. When host plants become scarce, or the prevailing environment becomes less favorable, the insects possibly migrate from South to North guided by air-movements of the inter-tropical convergence zone, and again head toward South in November-December (Taylor, 1998). Within a 24-hour timeframe, adults of the insects are more active from dusk to midnight, with a peak occurrence between 20:00 and 21:00 hr (Akinfenwa, 1995). In Kenya, pod borer populations are low during the short rainy season, although infestation continues unless flower and fruit production ceases (Okeyo-Owuor *et al*., 1983). At ICRISAT Headquarters, moth catches were greatest between early November to mid December in the light traps (Srivastava *et al*., 1992) with peak catches occurring during November.

In Sri Lanka, Saxena *et al.* (1992) observed a high larval density in host crops planted in mid-October. In Bihar of India, Akhauri *et al.* (1994) observed that on early pigeon pea the larval density increased from mid-October to the end of November, with the occurrence of peak larval density in the last week of November. Sharma (1998) reported that the presence of significant relationships between the peak occurrence of pod borers and cumulative rainfall and number of rainy days between crop emergences to flowering.

In Bangladesh, Alam (1989) studied the infestation levels of *M. vitrata* on different plant parts of country beans in Gazipur and Jessore. They found that the patterns of seasonal occurrence varied in flowers and fruits in both localities. However, the authors did not provide any information regarding the seasonal distribution of the pest in either locality. But they reported that fruits experienced the more infestation than did flowers. Rahman and Rahman (1988) in a study observed that the insect attacked the Rabi-season pigeon peas from mid December until the crop was harvested in early February in Gazipur. The authors found in the same study that legume pod borer larvae occurred with their peaks during the second week of January to the beginning of February. However, according to them, the insect population may vary depending on the plant parts present; they found larval peak population in flowers around the middle of January, after which the population declined in flowers. On the other hand, the insect tended to occur increasingly in pigeon pea fruits until the end of January. Such difference in the seasonal distribution of the pest infestation in different plant parts of the same host plant is presumably because of the preference of one part to the other, a phenomenon very common in insects. The suitability of a particular plant part as a feeding unit may also change over time. This may also be the case with pigeon peas causing a decline in frequency of infestation on flowers, while increasing the frequency of infestation on fruits, as found in the study of Rahman and Rahman (1988).

2.3 Pest status and host range of bean pod borer

The legume pod borer, *(Maruca vitrata* F.), is a polyphagous insect, which has been reported to feed on various types of plants, both cultivated and wild. Among the host plants, the most frequent ones are *Cajanus cajan*, *Vigna unguiculata, Phaseolus lunatus,* and *Pueraria phaseoloides*. Jayaraj (1982) reported that *Heliothis* could breed on a wide range of plants. The crops attacked in many countries were maize, sorghum, oats, barley, pearl millet, chickpea, pigeon pea, cowpea, peas, various beans, cotton, sunflower, safflower, tobacco, tomato, brinjal, cucurbits, sweet potato, groundnut, flax, citrus, sun hemp, potato etc.

Bhatnagar and Davies (1978) observed that 50 species of crop plants and 48 species of wild and weed species of plants found for attacking by *H. armigera* at Patancheru, Andhra Pradesh, India, whereas 96 crops and 61 weeds and wild species have been recorded elsewhere in India. The most important carryover weed hosts in the hot summer season are *Datura metel*, *Acanthospernium hispidum* and *Gynandropsis gynandra* for *H. armigera, H. assulta* and *H. pelligera*.

Reed and Pawar (1982) reported that *H. armigera* was the dominant and primary pest of cotton, maize and tomatoes in some countries of Africa, Europe, America, Australia and Asia. In India, it was a dominant pest on cotton in some areas and in most of the areas, on several other crops particularly pigeon pea and chickpea. On both the major pulse crops, *H. armigera* commonly destroyed more than 50% of the yield. Garg (1997) studied the host range of *H. armigera* in the Kumaon Hills, India and found that the larvae of *H. armigera* infested different plant parts of variety of crops like wheat, barley, maize, chickpea, pea, tomato, pigeon pea, lentil, onion and okra. He also found that chickpea appeared to be the most susceptible crop followed by pigeon pea, tomato and pea. In addition to these cultivated plants, it was also observed on some wild grasses and ornamental plants such as roses and chrysanthemums.

Fitt (1998) cited from an experiment conducted in the south Asian region that *Helicoverpa* was a serious pest of cotton, chickpea, pigeon pea, groundnut, cowpea, okra, tomato, castor, sunflower, maize, sorghum and many other crops.

2.4 Biology of bean pod borer

2.4.1 Host preference for oviposition

Parsons *et al.* (1991) observed that chickpea was most attractive for oviposition of pod borer; while Reddy (1993) and Loganathan (1992) reported that pigeon pea was the preferred host for oviposition.

Vijayakumar and Jayaraj (1981) studied the preferred host plants for oviposition by *H. armigera* found in descending order, pigeon pea > field pea > chickpea > tomato > cotton > chilies > mungbean > sorghum.

2.4.2 Mating and oviposition

The eggs were laid singly, late in the evening, mostly after 21:00 hr to midnight. On many host plants, the eggs were laid on the lower surface of the leaves, along the midrib. Eggs were also laid on buds, flowers and in between the calyx and fruit (Continho, 1985). Roome (1995) studied the mating activity of *H. armigera* and reported that from 02:00 to 04:00 hr the males flew above the crop while the females were stationary and released a pheromone. During this period males were highly active and assembled around females. Singh and Singh (1975) observed that the pre-oviposition period range from 1 to 4 days, oviposition period 2 to 5 days and post-oviposition period 1 to 2 days. Eggs were laid late in the evening, generally after 21:00 hours and continued up to midnight. However, maximum numbers of egg were laid between 21:00 and 23:00 hours. The moths did not oviposit during the daytime. Loganathan (1992) observed peak mating activity at 04.00 hr.

Dhurve and Borle (1986) reported that the fruit damage in gram (*Cicer arietinum* L.) by *H. armigera* was the lowest when the crop was sown between 30 October and 4 December. The yield was significantly higher in 30 October and 27 November sowings.

Tayaraj (1982) reported that oviposition usually started in early June, with the onset of pre-monsoon showers, adults possibly emerging from diapausing pupae and also from larvae that had been carried over in low numbers on crops and weeds during the summer. Reproductive moths were recorded throughout the year ovipositing on the host crops and weeds with flowers. The pest multiplied on weeds, early-sown corn, sorghum, mungbean and groundnut before infesting pigeon pea in October-November and chickpea in November-March.

Zalucki *et al.* (1986) observed that females laid eggs singly or in groups of 2 or 3, on flowers, fruiting bodies, growing tips and leaves. During their two weeks life span, females laid approximately 1400 eggs.

According to Bhatt and Patel (2001), the pre-oviposition period ranged from 2 to 4 days, oviposition period 6 to 9 days and post-oviposition period 0 to 2 days. Moth oviposited 715 to 1230 eggs with an average of 990.70 ± 127.40.

2.4.3 Egg

The eggs of *H. armigera* are nearly spherical, with a flattened base, giving a somewhat dome-shaped appearance, the apical area surrounding the micropyles smooth, the rest of the surface sculptured in the form of longitudinal ribs, The freshly laid eggs are 0.4 to 0.55 mm in diameter, yellow-white, glistening, changing to dark brown before hatching. The incubation period of the eggs is longer in cold weather and shorter in hot weather, being 2 to 8 days in South Africa and 2.5 to 17 days in the United States and 2 to 5 days in India (Srivastava and Saxena, 1978).

2.4.4 Larva

The newly hatched larva is translucent and yellowish white in color, with faint yellowish orange longitudinal lines. The head is reddish brown, thoracic and anal shields and legs brown and the setae dark brown. The full-grown larva is about 35 to 42 mm long; general body color is pale green, with one broken stripe along each side of the body and one line on the dorsal side. Short white hairs are scattered all over the body. Prothorax is slightly more brownish than meso and metathorax. Singh and Singh (1975) reported that the underside of the larva is uniformly pale. The general color is extremely variable; and the pattern may be in shades of green, straw yellow and pinkish to reddish brown or even black.

Temperature affects the development of the larva considerably. The larval stage lasted for 21 to 28 days on chickpea (Srivastava and Saxena, 1978); 2 to 8 days on maize silk; 33.6 days on sunflower corolla (Continho, 1985).

There are normally six larval instars in *H. armigera* (Bhatt and Patel, 2001), but exceptionally, during the cold season, when larval development is prolonged, seven instars regularly found in Southern Rhodesia.

2.4.5 Pupa

Singh and Singh, (1975) reported that the pupa is 14 to 18 mm long, mahogany-brown, smooth-surfaced and rounded both anteriorly and posteriorly, with two tapering parallel spines at the posterior tip. The pupa of *H. armigera* undergoes a facultative diapause. The non-diapause pupal period for *H. armigera* was recorded as 14 to 40 days in the Sudan Gezira, 14 to 57 days in Southern Rhodesia, and 14 to 37 days in Uganda and 5 to 8 days in India (Jayaraj, 1982). According to Bhatt and Patel (2001), the pupal period ranged from 14 to 20 days in Gujarat, India.

2.4.6 Adult

The female *H. armigera* is a stout-bodied moth, 18 to 19 mm long, with a wingspan of 40 mm. The male is smaller, wing span being 35 mm. Forewings are pale brown with marginal series of dots; black kidney shaped mark present on the underside of the forewing; hind wings lighter in color with dark colored patch at the apical end. Tufts of hairs are present on the tip of the abdomen in females (ICRISAT, 1982). The female lived long. The length of life is greatly affected by the availability of food, in the form of nectar or its equivalent; in its absence, the female fat body is rapidly exhausted and the moth dies when only 3 to 6 days old. (Jackai, 1981).

The longevity of laboratory reared males and females were 3.13 ± 0.78 and 6.63 ± 0.85 days, respectively (Singh and Singh, 1975). According to Bhatt and Patel (200l), adult period in male ranged from 8 to 11 days with an average of 9.15 ± 0.90 days and in females 10 to 13 days with an average of 11.40 ± 0.91 days.

Plate 1: Larva of bean pod borer

Plate 2: Adult moth of bean pod borer

2. 5 Nature of damage of legume pod borer

Maruca vitrata (Fabricius) is a tropical insect that attacks several species of plants, primarily the legume plants, although pod borers in the genus *Maruca* are polyphagous in nature (Rahman, 1989; Babu, 1989 and Taylor, 1978). Babu (1989) reported that hyacinth bean, which is also known as the country bean, is the most favorable food plant for *M. vitrata* (*testulalis*). Generally the insect infestation begins at the terminal plant parts (Jayaraj, 1982). At the early stage of plant growth, the insect attacks plant leaves, fastens the leaves together to clusters and feed while living inside the tunnels of clusters (Singh, 1983; Das and Islam, 1985; Rahman, 1989; Karim, 1993). However, the insect prefers ovipositing at the flower bud stage, suggesting that at earlier stages of plant growth, infestations of legume pod borer may not be conspicuous. Pod borer infestation is more frequent from fruiting stage of plants. As soon as buds and flowers appear on plants, many of the insect larvae can be present moving from buds/flowers to buds/flowers and bore into them. Sharma (1998) reported that a single larva can consume 4-6 flowers before the larval development is completed. The attacked buds and flowers subsequently wither and may fall down. Later the insects move into fruits and bore into the fruits; the insect would occasionally bore into peduncle and stems of host plants (Taylor, 1978). Generally, one larva bores into a single fruit, although there have been instances where two or more larvae entered into a single fruit (Das, 1998). In such a case, when more than one larva enter into a single fruit, cannibalism might be occurring, a phenomenon very common in most leaf miners. However, there has been little research in this regard for legume pod borers.

The first and second instars larvae feed mostly on the inner walls of the young fruits and scrap inside the bored fruits/flowers. The larvae of later instars, in most cases, enter into the fruits, bore into the seeds and feed these parts by making circular holes. The entry holes are often difficult to visualize, as the holes are often plugged with the faecal excretion of the pest. In instances where the extruded frass can be seen from the outside, it is rather an obvious indicator of pod borer infestation. The infesting larva can consume the entire seeds within a fruit. After entering into a fruit, the larva usually does not leave it until the food is totally exhausted. The infested fruit often becomes unfit for human consumption.

Although the insect has been found to feed on different plant parts as explained above, Karel (1993) in a study observed that more than 52% of the larval populations were feeding on flowers, and about 38% larvae were feeding on fruits. In contrast, he found only about 10% of the larvae to be feeding on leaves. The result is consistent with Sharma (1998), who concluded that the order of preference of different plant parts is flowers > flower buds > terminal shoot > fruits and seeds. As a result of the insect infestations, crop yields can often be severely affected (Singh and Taylor, 1978).

Plate 3: Healthy inflorescence

Plate 4: Infested inflorescence

Plate 5: Bean pod borer moth laying eggs on flower bud

Plate 6: Larva inside the damaged flower bud

Plate 7: Healthy fruits of country bean **Plate 8: Infested fruits of country bean**

Plate 9: Severely infested fruit **Plate 10: Larvae inside the fruit**

2.6 Yield loss caused by pod borer

M. vitrata (testulalis) is a very important pest causing profound damages to legume crops including the country beans in Bangladesh. Singh and Taylor (1978), Rahman (1989) and Rahman and Rahman (1988) found that pod borer infestation may cause great reduction of yields of the infested crops. However, these authors did not provide any information with respect to the amount of percentage of yield reduction caused by the pest attack. Nevertheless, there have been several reports on quantified effects of the pest infestation on various crops. Singh and Allen (1990) reviewed the infestation of pod borers in field and horticultural crops across Africa, Asia, south Central America and Australia, and concluded that the insect can cause 20 – 60% damage to host crops. Karel (1993) in Tanzania reviewed that the pod borer infestation could reduce seed yields of local French bean cultivars by 20%-50%. In Kenya, the insect was found to cause 80% reduction of cowpea production. Rahman (1989) found the insect to cause as high as 100% infestation of black gram leaves, the effect of infestation at such high levels are likely to be profound on yield of the crop. Rahman (1991) observed that bean pod borers could cause as high as 38% reduction of the yields of pigeon peas in Bangladesh. Ohno and Alam (1989) reported that pod borer damage in cowpea was 54.4% at harvest, although the reduction of seed yield of cowpeas was estimated only 20%. Sarder and Kundu (1987) observed the pod borer infestation in four bean cultivars and reported that the borers caused up to 7% reduction of country bean yield in Bangladesh. Kabir *et al.* (1983) reviewed pod borer infestations on 32 different genotypes of country beans in Jamalpur, Bangladesh and found that the insect caused up to 17% damage to country bean pods. But for country beans the magnitude of infestation would be more severe, as infested pods are likely to be unfit and unacceptable for human consumption.

2.7 Generations

Rahman (1991) observed three generations of *H. armigera* each year in China while Reddy (1993) reported that the pest completed four generations from September to March under western Tanganyika conditions. Singh and Singh (1975) reported that *H. armigera* passed through four generations in the Punjab, India; one on chickpea during March; two on tomato, from the end of March to May; and one on maize and tomato in July-August. Bhatt and Patel (2001) observed that seven to eight generations of *H. armigera* were present each year in Andhra Pradesh, India.

2.8 Management of bean pod borer

Bean pod borer is the major pest causes considerable economic damage of country bean. It is important to manage or control the pest before its outbreak. Usually farmers try to control this pest using chemical insecticides but they failed because the larva lives in the flower bud of country bean and they do not consider economic injury level that is hazardous to the environment. So, the judicious use of pesticide with bio-pesticide is important in the management of bean pod borer and it will be helpful in minimizing environmental hazard. The development and use of botanical pesticides become an integral part of the integrated pest management (IPM) strategies.

2.8.1 Management with neem oil and neem seed kernel extracts

Botanical pesticides can be employed as an alternative source to control pests with biodegradable concern, reductive contamination in environment and human health hazards (Grainge and Ahmed, 1988; Devlin and Zettel, 1999). Botanical pesticides are also special because they can be produced easily by farmers for sustainable agriculture and small industries (Roy *et al*., 2005).

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

Neem oil and neem seed kernel extracts are used as botanicals in the experiment. Neem oil is a naturally occurring pesticide found in seeds from the neem tree (*Azadirachta indica*). It is the most important of the commercially available products of neem for organic farming and medicines. It has been used for hundreds of years to control pests and diseases. The seeds and leaves of the neem tree contain terpenoids with potent anti-insect activity. One of the most active terpenoids in neem seeds “azadirachtain” which acts as an antifeedant and growth disrupter against a wide range of insect pest at microgram levels.

Azadirachtin is the most potent growth regulator and antifeedant (Warthen *et al.,* 1978; Butterworth and Morgan, 1968). The triterpenoid azadirachtin was first isolated from the seeds of the tropical neem tree by Butterworth and Morgan (1968). Its definite structural formula, which resembles somewhat that of ecdysone (Kraus *et al.,* 1985 and Bilton *et al.,* 1985). The active terpenoids in neem leaves include nimbin, deactylnimbin and thionemone (Simmonds *et al.,* 1992).

According to Roy *et al.* (2005), Neem oil (fresh) @ 2.5ml/L caused the lowest mortality of lady bird beetle (9.37%) and stink bug (16.09%) while Sumialpha 5 EC @ lml/L and Sumithion 50 EC @ 1.5 ml/L water caused the highest mortality of the predator, lady bird beetle (33.78%) and Stink bug (50.59%).

Azadirachtin is a limonoid alleliochemical (Broughton *et al.,* 1986; Butterworth and Morgan, 1968) present in the fruits and other tissues of the tropical neem tree (*Azadirachta indica*). The fruit is the most important aspect of neem that affects insects in various ways.

Crude neem extracts deters settling and reduces feeding in *M. persicae* (Griffiths *et al*., 1989). The females of some lepidopterous insects are repelled by neem treated plant products or other substrates and not laid eggs on them under laboratory conditions.

Azadirachtin is a potent insect antifeedant. Antifeedancy is the result of effects on deterrent and other chemoreceptors. The antifeedant effects of azadirachtin have been reported for many species of insects. Reduction of feeding also observed after topical application or injection of neem derivatives, including AZA and alcoholic neem seed kernel extract. This means that the reduction of food intake by insects is not only gustatory which means that sensory organs of the mouth parts also non-gustatory regulate it. These two phagodeterrent/antifeedant effects were called primary and secondary (Schmutterer, 1995).

Botanicals possess an array of properties including insecticidal activity and insect growth regulatory activity against many insect pests and mites (Rajasekaran and Kumaraswami, 1985; Prakash *et al*., 1987 and 1990). Repellent activity of neem against oviposition by Lepidopterous pests has also been reported for *Spodoptera litura* (Joshi and Sitaramaiah, 1989), *Cnaphalocrocis medinalis* (Saxena *et al*., 1992) and *Earies vittella* (Sojitra and Patel, 1992).

Lakshmanan (2001) reported effectiveness of neem extract alone or in combination with other plant extracts in managing lepidopteron pest's viz., *E. vittella*, *Chilo partellus* swinhoe, *Helicoverpa armigera* and *S. litura*. Maximum reduction (65.7%) in bollworm infestation was observed in garlic treated plot.

Application of neem seed kernel extract (5%) was found to be the most effective botanical against pod borer in pigeon pea and recorded maximum grain yield (Girhepuje *et al.,* 1997).

During last two decades neem oil and extracts from seeds have been evaluated as plant protectant against a wide range of arthropods and nematode pests in several countries of the world.

2.8.2 Management with pheromone trap

Pheromones are a class of semio-chemicals that insects and other animals release to communicate with other individuals of the same species. The key to these entire behavioral chemical is that they leave from the body of the first organism, pass through the air (or water) and reach the second organism, where they are detected by the receiver. In insects, these pheromones are detected by the antennae. Since pheromone is naturally occurring biological products, they are environmentally safe, non target organisms are not affected, insect are less likely to develop resistance and moreover they are effective at incredibly low concentrations. Sex pheromones have been utilized in the insect pest control program through population monitoring, survey, mass-trapping, mating disruption and killing the target pest in the trap (Bottrell, 1999).

In Bangladesh the adoption of sex pheromone traps by Syngenta Bangladesh Ltd. has been paralled by the govt. of Bangladesh's adoption of the concept of IPM (Integrated Pest management) whereby the more toxic pesticides are replaced by sustainable and environmentally benign mean of pest and disease control.

The use of pheromone has also been reported against legume pod borer. In Kenya, pheromone traps were used against the bean pod borer *Maruca vitrata* (Okeyo-Owuor *et al.*, 1983). The pheromone used has been a female sex pheromone. Generally, the sex pheromones could be successfully used as mating disruptors and prevent pod borers from rising to population levels damaging the crop (Botrell, 1999). Three sex pheromone components have been used successfully in field trapping experiments and for pest population monitoring of *M. vitrata.* and these are (E, E)-10,12-Hexadecadienal (E10, E12-16: Ald), (E,E)-10,12-Hexadecadien-1-ol (E10, E12-16: OH) and (E)-10-Hexadecenal (E10-16: Ald) were identified as the sex pheromone components of *M. vitrata* (McNeil, 1991).

2.8.3 Management with chemical insecticides

Farmers in Bangladesh depend on synthetic insecticides because they are readily available, highly promoted, inexpensive, easy to apply and quick acting. A number of reports revealed that a hundred of insecticides are used against bean pod borer. Most of the cases the farmers reduced their spray interval. A report showed that the vegetables growers of Jessore region of Bangladesh spayed insecticides almost every day or every alternate day in their bean field (Anonymous, 1993). Some of the farmers spray insecticides in their vegetable field even 84 times in one season. Majority of the farmers were found to sell their produce harvested residues with bean that causes health hazards to the consumers.

Rahman, (1989) reviewed that bean pod borer control is dominated by chemical approaches. In India, a number of insecticides have been evaluated for the control of pod borer in pulses including pigeon pea but no such trial has so far been conducted on country bean in Bangladesh. Several commonly used insecticides such as endosulfan, carbaryl, methomyl, monocrotophos have been found effective against *Maruca testulalis* G. on cowpea (Singh, 1978; Lalasangi, 1988). Cypermethrin was sprayed at 0.2 kg/ha to control different densities of M. *testulalis* larvae when infestation in flowers reached 10, 20, 30, 40 and 50% in 1985 and 10, 20 and 30% in 1986 (Ogunwolu, 1990). Four sprays of 0.08% cypermethrin (at 50% flowering, at 100% flowering and at 100% fruit setting) afforded complete protection against *Maruca testulalis* on pigeon pea in Bangladesh in winter season of 1987-88 but dimethoate was not as effective as cypermethrin (Rahman and Rahman, 1988).

A schedule of insecticide sprays using decis (Deltamethrin) and systoate (Dimethoate) on 35, 45, 55 and 65 days after planting was investigated in Benin in 1985 to determine the most effective treatment against the *M. testulalis* on cow pea (Atachi and Sourokou, 1989). Broadley (1977) obtained control of *M. testulalis* with methomyl when applied at 337-450 g/ha. Because of hidden nature of larval and pupal stages of the pest, it is difficult to control legume pod borer by chemical or other conventional means. Application of deltamethrin, cypermethrin or fenvalerate @ 0.008% or dimethoate, fenitrothrin, malathion, quinalphos or monocrotophos @

0.008% or endosulfan 0.10% one at flowering and then at fruit setting stage would be highly effective.

Foliar application of cypermethrin (0.008%) or dimethoate (0.07%) at flowering or when egg numbers reached 2 per meter row, and then repeated at 10-15 days interval provided effective protection against *M. vitrata* (Rahman, 1991). However, at lower infestation, insecticide application would not be economically advisable (Rahman, 1989).

Application of deltamethrin, cypermethrin or fenvalerate or cyfluthrin (Bethroid 0.50 EC) at the rate of 1.0 ml/1 liter of water may be helpful for the control of the bean pod borer (Karim, 1995). Dandale *et al.* (1984) reported the superiority of cypermethrin, fenvalerate and endosulfan in reducing pod borer infestation in red gram. Spraying of synthetic pyrethroid insecticides at the rate of 1 ml per liter of water has been recommended for the control of the pest (Karim, 1993).

Hossain, (2015) reported that the number of flowers, fruits, and seeds per plant was significantly greater in plots treated with insecticides based on the economic threshold level of 10 larvae per 100 flowers (3 insecticide applications) than in the untreated plots. The differences in the number of flowers, fruits, and seeds per plant were not significant between plots sprayed 3 and 4 times. It has been concluded that 10 larvae per 100 flowers can be considered as a tentative threshold for *M. vitrata* on pigeon pea.

Application of Sumithion 50 EC @ 1.5 ml/L water and Furadan 5G @ 1.5kg/ha+ Ripcord 10 EC @ l ml/L rendered the highest parasitization of pod borer larvae by braconids (70.96%) and tachinid (88.11%). Decis 2.5EC @ lml/L ensured the highest (46.70 %) yield increase over control. (Mollah *et al.*, 2009).

Among the various control measures so far been reported for the management of the bean pod borer, chemical control appeared as comparatively effective and predominant one. In controlling moths still mostly used organic phosphorus esters. In this group classified active compounds are chlorine pirifos-methil, phenitrotion and acephate (Pedigo, 1999). Sufficient efficacy in this relation can attain also with pyrethroids (cypermethrin, deltamethrin, lambda-cyhalothrin, betacyfluthrin and tefluthrin).

Chlorantraniliprole is the first member of anthranilic diamides, and is potent within the insect order Lepidoptera (Temple *et al*., 2009). Chlorantranilprole is relatively harmless to beneficial arthropods, and has not been found to exhibit cross resistance with existing insecticides (Lahm *et al.*, 2009).

CHAPTER III

MATERIALS AND METHODS

The present study was conducted to evaluate the eco-friendly management of bean pod borer on country bean at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2016 to February, 2017.

3.1 Location of the study

The experiments were conducted in the experimental field under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka.

3.2 Characteristics of soil

The soil of the experimental area was silty loam belonging to the Non-Calcareous Dark grey Floodplain soils under the Agro Ecological Zone 12. The selected site was a well drained medium high land.

3.3 Season of the study

The study was conducted during Rabi season (October, 2016 to February, 2017).

3.4 Materials used

The country bean BARI seam-1 was cultivated in the field during Rabi season for combating bean pod borer using different management practices.

3.5 Design of experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Total 27 plots were made for conducting the experiments. The whole experimental plot was 22.5m long and 9 m broad, which was divided into 3 equal blocks. Each of the 3 equal blocks has 9 plots assigned for 9 treatments. The size of a unit plot was 2 m long and 1.5 m broad. Distance of 1 m between blocks and 1 m between the plots was kept to facilitate different intercultural operations.

3.6 Replication

Each treatment of the experiment was replicated with three times in the field of country bean.

3.7 Treatment

The bean pod borer will be controlled using following management practices:

Treatment	Item	Dose/Rate
T_1	Neem oil	3 ml neem oil and 10 ml trix mixed with 1 liter of water at 7 days interval
T_2	Neem seed kernel extract	0.5 ml neem seed kernel extract mixed with 1 liter of water at 7 days interval
T_3	Pheromone trap	1 lure with trap per plot was placed
T_4	Fytomax 0.03 EC	0.4 ml per liter of water @ 7 days interval
T_5	Actara 25 WG	0.3 g per liter of water @ 7 days interval
T_6	Cot 10 EC	0.4 ml per liter of water @ 7 days interval
T_7	T_1+ T_3	3 ml neem oil and 10 ml trix mixed with 1 liter of water at 7 days interval along with 1 lure with trap per plot was placed
T_8	T_2+ T_3	0.5 ml neem seed kernel extract mixed with 1 liter of water at 7 days interval along with 1 lure with trap per plot was placed
T_9	Untreated Control	No treatment was used

3.8 Land preparation

The experimental field was ploughed to bring soil into desirable final tilth by four operations of ploughing followed by laddering. The stubble and weeds were removed. The field was divided into three blocks. Each block was divided again into nine plots considering equal in size. Plot size will be 2m long and 1.5m width. Block to block distance and plot to plot distance were 1 and 1m respectively. In each plot two pits were prepared considering 0.65 meter distance. The soils of each pit will dig considering 30 cm for each length, breadth and depth.

Plate 11: Experimental plot preparation

3.9 Manures and fertilizers application

Recommended doses of fertilizer comprising Urea, TSP and MP at the rate of 30, 90 and 65 kg/ha respectively were applied. Entire dose of TSP and half amount of MP were applied to the soil of the pit 4-5 days before the seedling transplanting. The rest amount of Urea and MP were top dressed at 30 days and 45 days after transplanting (BARC, 1997).

3.10 Collection of seed and seedling rising

The seeds of country bean (BARI bean-1) were collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The seeds were sown in the organic matter containing polythene bags. The germination test was done prior to sowing seeds in the polythene bags. The seeds showing at least 80% germination was considered for seedling rising. After germination, the seedlings were placed to partly sunny place for hardening.

Plate 12: Seedlings raising in polybags

3.11 Seedling transplantation

The 15 days old seedlings grown in the polybags were transplanted on last week of October, 2016 in the pits of the randomly selected each unit plot. At the time of transplanting, the polybags were cut and removed carefully in order to keep the soil intact with the root of the seedlings. The seedlings were transplanted in the pits with the entire soil ball. The seedlings were watered until they got established.

3.12 Intercultural operations

After transplanting the plants were initially irrigated by watering can and later on surface irrigation was given. After 7 days of transplanting, propping of each plant by bamboo sticks (1.75 m) was provided up to 1.5 m high from ground level for additional support to allow normal creeping. All the bamboo sticks in each row were fastened strongly by a galvanized wire to allow the vines to creep along. Weeding and mulching in the plots were done, whenever necessary.

3.13 Treatment application

Various treatments as mentioned earlier were applied just two week after transplantation of the seedlings to the respective sub-plot of the country bean in the main field and continued up to last harvest of the fruits.

Plate 13: Experimental plot at vegetative stage

Plot 14: Experimental plot at reproductive stage

3.15 Preparation of botanical insecticides

3.15.1 Neem oil

Neem oil (*Azadirachta indica)* was used as botanical insecticide in bean pod borer management in the experiment. Neem oil was collected from the local market Siddique Bazar, Dhaka. The required spray volume was prepared by mixing 75 ml neem oil (3%), 1 ml Trix (liquid detergent as mixing agent) with 2.5 liters of water. The detergent was used to break the surface tension of water and to help the solubility of neem oil in water. This preparation might have repelling and antifeedent actions against bean pod borer. The mixture was sprayed at each 7 days interval in the selected plots.

3.15.2 Neem seed kernel extract

The mature and dried neem seeds were collected from the neem tree found in the Horticulture Garden of SAU. Then seeds were roasted at 60ºC to 80ºC for 1 to 2 days by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of this powder was taken into a beaker and 250 ml water was added into it. Then the beaker was shaken by electric stirrer for 30 minutes thoroughly the mixture. The aqueous mixture then filtered using Whatmen no. 1 paper filter and preserved the aqueous extracts in the refrigerator at 4°c for future experimental use.

3.15.3 Pheromone trap

Sex pheromone trap with lure and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, just above the crop canopy. The soap water was replaced by new soap water at an interval of one day. At each day the number of insects trapped was recorded. In case of trapping, number of trapped bean pod borer was counted.

Plate 15: Pheromone trap hanging in the experimental field

Plate 16: Trapped adult bean pod borer moth

3.16 Data collection

Data were recorded on the following parameters:

- Total number of inflorescence per plot
- Number of infested inflorescence per plot
- Number of flower bud per 5 tagged inflorescences
- Number of infested flower bud per 5 tagged inflorescences
- Total number of fruits per 5 tagged inflorescences
- Number of infested fruits per 5 tagged inflorescences
- Weight of total fruits (g) per 5 tagged inflorescences
- Weight of infested fruits (g) per 5 tagged inflorescences
- Number of beneficial arthropods per plot
- Total yield (kg)

3.17 Procedure of data collection

3.17.1 Number of inflorescence

During the reproductive stage of country bean plant total numbers of inflorescences from each plot were recorded at 7 days interval in each treatment.

3.17.2 Number of infested inflorescence

During the reproductive stage of the plant total numbers of infested inflorescences from each plot were recorded at 7 days interval in each treatment.

3.17.3 Number of flower bud per 5 tagged inflorescences

Five inflorescences from each individual plot were selected randomly and the data on number of total and infested flower buds were recorded by regular observation at 7 days interval in each treatment.

3.17.4 Number of fruits per 5 tagged inflorescences

Harvestable mature fruits were collected from randomly selected 5 inflorescences and sorted into infested and non-infested ones at weekly interval after careful examination on the presence of hole and excreta.

3.17.5 Weight of fruits per 5 tagged inflorescence

Harvestable mature fruits were collected from randomly selected 5 inflorescences into total and infested ones at weekly interval and weighted them separately from each plot.

3.17.6 Number of beneficial arthropods per plot

Data were collected from five tagged vines per plot on beneficial arthropods such as lady bird beetle, black ant, spider, syrphid fly, honeybee etc. by visual counting at seven days interval.

3.17.7 Yield of fruits

For the estimation of yield per plot total fruits were collected and weight recorded, from each plot, at each time of data collection.

3.18 Data calculation

3.18.1 Percent of inflorescence infestation

Percent of inflorescence infestation by number was calculated using the following formula:

$$\text{\% Inflorescence infestation} = \frac{\text{No.of infested inflorescences}}{\text{Total no. of inflorescences}} \times 100$$

3.18.2 Percent reduction of inflorescence infestation

Percent reduction of inflorescence infestation by number over control was calculated using the following formula:

$$\text{\% Reduction of inflorescence infestation over control} = \frac{x_2 - x_1}{x_2} \times 100$$

Where, x_1 = the mean value of the treated plot

x_2 = the mean value of the untreated plot

3.18.3 Percent of flower bud infestation

Percent of flower bud infestation by number was calculated using the following formula:

$$\text{\% Flower bud infestation} = \frac{\text{No.of infested flower buds}}{\text{Total no. of flower buds}} \times 100$$

3.18.4 Percent reduction of flower bud infestation

Percent reduction of flower bud infestation by number over control was calculated using the following formula:

$$\text{\% Reduction of flower bud infestation over control} = \frac{x_2 - x_1}{x_2} \times 100$$

Where, x_1 = the mean value of the treated plot

x_2 = the mean value of the untreated plot

3.18.5 Percent of fruit infestation by number and weight

Percent of fruit infestation by number and weight was calculated using the following formulas:

$$\text{\% Fruit infestation (Number)} = \frac{\text{No.of infested fruits}}{\text{Total no. of fruits}} \times 100$$

$$\text{\% Fruit infestation (Weight)} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

3.18.6 Percent reduction of fruit infestation by number and weight

Percent reduction of fruit infestation by number and weight over control was calculated using the following formula:

$$\text{\% Reduction of fruit infestation over control} = \frac{x_2 - x_1}{x_2} \times 100$$

Where x_2 = the mean value of the treated plot

x_2 = the mean value of the untreated plot

3.19 Economic analysis of the treatment

Economic analysis in terms of benefit cost ratio (BCR) was analyzed on the basis of total expenditure of the respective management practices along with the total return from that particular treatment. In this study BCR was calculated for a hectare of land.

3.19.1 Treatment wise management cost/variable cost

This cost was calculated by adding all costs incurred for labors and inputs for each management treatment including untreated control during the entire cropping season. The plot yield (kg/plot) of each treatment was converted into ton/ha yields.

3.19.2 Gross Return (GR)

The yield in terms of money that was measured by multiplying the total yield by the unit price of country bean (Tk 25/kg).

3.19.3 Net Return (NR)

The Net Return was calculated by subtracting treatment wise management cost from gross return.

3.19.4 Adjusted Net Return (ANR)

The ANR was determined by subtracting the net return for a particular management treatment from the net return with control plot. Finally, BCR for each management treatment was calculated by using the following

formula:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}}$$

3.20 Statistical analysis of data

Analysis of variance was done with the help of computer package MSTAT program (Gomez and Gomez, 1976). The data recorded on different parameters were subjected to analysis of variance (ANOVA) and the means were compared according to Least Significant Difference Test (LSD) at 0.01% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and explanation of the results obtained from the experiment on the incidence of bean pod borer in country bean and their management. The data have been presented and discussed and possible interpretations are made under the following sub-headings:

4.1 Effect of management practices on inflorescence infestation

4.1.1 Inflorescence infestation of country bean by bean pod borer at early flowering stage

The effect of management practices on inflorescence infestation by number at early flowering stage has been shown in Table 1. Significant variations were observed among the treatments in terms of bean pod borer infestation on inflorescence of country bean. The highest number (74.73) of inflorescences per plot was recorded in T_4, which was statistically similar with T_7 (70.09) and T_8 (64.18), followed by T_1 (58.16) and T_2 (57.28). On the other hand, the lowest number (40.84) of inflorescences per plot was recorded in T_9, which was statistically similar with T_5 (43.07) and T_3 (48.06). Accordingly, the lowest number (10.33) of infested inflorescence per plot was recorded in T_4, which was statistically similar with T_7 (12.33) and T_8 (15.00).

Considering the level of infestation, the lowest percent (13.59%) of inflorescence infestation by number was recorded in T_4, which was statistically similar with T_7 (17.59%) and T_8 (21.91%). On the other hand, the highest percent (73.24%) of inflorescence infestation by number was recorded in T_9 which was statistically similar with T_5 (66.64%) and T_3 (47.03%).

Considering the reduction of inflorescence infestation, the highest reduction (81.44%) of inflorescence infestation over control was observed in T_4, followed by T_7 (75.98%) and T_8 (70.08%). whereas, the lowest reduction (9.01%) of inflorescence infestation over control was observed in T_5.

Table 1. Effect of management practices on inflorescence infestation of country bean by bean pod borer at early flowering stage

Treatment	% inflorescence infestation by number at early flowering stage			
	Total no. of inflorescence per plot	No. of infested inflorescence per plot	% inflorescence infestation	% reduction of inflorescence infestation over control
T_1	58.16 bc	16.00 bc	28.27 bcd	61.40
T_2	57.28 bc	19.67 bc	31.25 bcd	57.33
T_3	48.06 cd	23.30 ab	47.03 b	35.79
T_4	74.73 a	10.33 d	13.59 d	81.44
T_5	43.07 d	28.33 a	66.64 a	9.01
T_6	50.47 cd	23.00 ab	35.27 bc	51.84
T_7	70.09 a	12.33 cd	17.59 cd	75.98
T_8	64.18 ab	15.00 cd	21.91 cd	70.08
T_9	40.84 d	29.33 a	73.24 a	-
$LSD_{(0.01)}$	11.33	6.92	4.71	-
CV (%)	8.40	14.65	18.55	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, T_2= Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, $T_7 = T_1 + T_3$, $T_8 = T_2 + T_3$, T_9=Untreated control]

From the above findings it was revealed that the lowest inflorescence infestation (13.59 %) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of inflorescence infestation over control was 81.44%. As a result, the order of efficacy of management practices in terms of inflorescence infestation reduction is $T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9$.

4.1.2 Inflorescence infestation of country bean by bean pod borer at mid flowering stage

The effect of management practices on inflorescence infestation by number at mid flowering stage has been shown in Table 2. Significant variations were observed among the treatments in terms of bean pod borer infestation on inflorescence of country bean. The highest number (80.50) of inflorescences per plot was recorded in T_4, which was statistically similar with T_7 (78.83) and T_8 (75.34), followed by T_1 (67.48) and T_2 (66.75). On the other hand, the lowest number (45.25) of inflorescences per plot was recorded in T_9, which was statistically similar with T_5 (51.00) and T_3 (51.25).

Accordingly, the lowest number (11.67) of infested inflorescence per plot was recorded in T_4, which was statistically similar with T_7 (16.67) and T_8 (17.00), followed by T_1 (22.67), T_2 (23.33 inflorescence/plot) and T_6 (26.00).

Considering the level of infestation, the lowest percent (14.55%) of inflorescence infestation by number was recorded in T_4, which was statistically similar with T_7 (21.17%) and T_8 (22.57%), followed by T_1 (33.49%) and T_2 (34.39%). On the other hand, the highest percent (75.99%) of inflorescence infestation by number was recorded in $T_{9,}$ which was statistically similar with T_5 (62.60%) and T_3 (62.58%).

Considering the reduction of inflorescence infestation, the highest reduction (80.85%) of inflorescence infestation over control was observed in T_4, followed by T_7 (72.14%) and T_8 (70.30%). whereas, the lowest reduction (17.62%) of inflorescence infestation over control was observed in T_5.

Table 2. Effect of management practices on inflorescence infestation of country bean by bean pod borer at mid flowering stage

Treatment	% inflorescence infestation by number at mid flowering stage			
	Total no. of inflorescence per plot	No. of infested inflorescence per plot	% inflorescence infestation	% reduction of inflorescence infestation over control
T_1	67.48 bc	22.67 bc	33.49 bc	55.93
T_2	66.75 bc	23.33 bc	34.39 bc	54.74
T_3	51.25 de	31.33 ab	62.58 a	17.65
T_4	80.50 a	11.67 d	14.55 d	80.85
T_5	51.00 de	32.00 ab	62.60 a	17.62
T_6	60.00 cd	26.00 abc	45.53 b	40.08
T_7	78.83 ab	16.67 cd	21.17 cd	72.14
T_8	75.34 ab	17.00 cd	22.57 cd	70.30
T_9	45.25 e	34.00 a.	75.99 a	-
$LSD_{(0.01)}$	11.43	6.36	16.07	-
CV (%)	7.49	11.18	16.35	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, $T_7 = T_1 + T_3$, $T_8 = T_2 + T_3$, T_9=Untreated control]

From the above findings it was revealed that the lowest inflorescence infestation (14.55%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of inflorescence infestation over control was 80.85%. As a result, the order of efficacy of management practices in terms of inflorescence infestation reduction is $T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9$.

4.1.3 Inflorescence infestation of country bean by bean pod borer at late flowering stage

The effect of management practices on inflorescence infestation by number at late flowering stage has been shown in Table 3. Significant variations were observed among the treatments in terms of bean pod borer infestation on inflorescence of country bean. The highest number (78.16) of inflorescences per plot was recorded in T_4, which was statistically similar with T_7 (70.30) and T_8 (69.61), followed by T_6 (61.32) and T_3 (61.29). On the other hand, the lowest number (42.22) of inflorescences per plot was recorded in T_9, which was statistically similar with T_5 (46.00) and T_2 (46.66). Accordingly, the lowest number (10.33) of infested inflorescence per plot was recorded in T_4, which was statistically similar with T_7 (13.67) and T_8 (14.00), followed by T_6 (18.33).

Considering the level of infestation, the lowest percent (13.11%) of inflorescence infestation by number was recorded in T_4, which was statistically similar with T_7 (19.82%) and T_8 (20.13%) and T_6 (30.42%) and T_3 (33.41%), followed by T_1 (39.23%). On the other hand, the highest percent (73.02%) of inflorescence infestation by number was recorded in T_9, which was statistically similar with T_2 (55.64%) and T_5 (59.22%).

Considering the reduction of inflorescence infestation, the highest reduction (82.05%) of inflorescence infestation over control was observed in T_4, followed by T_7 (72.86%) and T_8 (72.43%). whereas, the lowest reduction (18.90%) of inflorescence infestation over control was observed in T_5.

Table 3. Effect of management practices on inflorescence infestation of country bean by bean pod borer at late flowering stage

Treatment	% inflorescence infestation by number at late flowering stage			
	Total no. of inflorescence per plot	No. of infested inflorescence per plot	% inflorescence infestation	% reduction of inflorescence infestation over control
T_1	53.00 cd	20.67 bc	39.23 bc	46.27
T_2	46.66 d	25.33 ab	55.64 ab	23.80
T_3	61.29 bc	20.33 bc	33.41 cd	54.25
T_4	78.16 a	10.33 e	13.11 d	82.05
T_5	46.00 d	27.00 a	59.22 ab	18.90
T_6	61.32 bc	18.33 cd	30.42 cd	58.34
T_7	70.30 ab	13.67 de	19.82 cd	72.86
T_8	69.61 ab	14.00 de	20.13 cd	72.43
T_9	42.22 d	30.33 a	73.02 a	-
$LSD_{(0.01)}$	13.26	5.92	16.07	-
CV (%)	9.47	12.40	19.46	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, $T_7 = T_1 + T_3$, $T_8 = T_2 + T_3$, T_9=Untreated control]

From the above findings it was revealed that the lowest inflorescence infestation (13.11 %) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of inflorescence infestation over control was 82.05%. As a result, the order of efficacy of management practices in terms of inflorescence infestation reduction is $T_4>T_7>T_8>T_6>T_3>T_1>T_2>T_5>T_{9.}$

4.2 Effect of management practices on flower bud infestation

4.2.1 Flower bud infestation of country bean by bean pod borer at early flowering stage

The effect of management practices on flower bud infestation by number at early flowering stage has been shown in Table 4. Significant variations were observed among the treatments in terms of bean pod borer infestation on flower bud of country bean. The highest number (64.51) of flower bud per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (62.99) and T_8 (60.71), followed by T_1 (55.22). On the other hand, the lowest number (34.67) of flower bud per five tagged inflorescence was recorded in T_9, which was statistically similar with T_5 (37.80). Accordingly, the lowest number (3.27) of infested flower bud per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (3.53) and T_8 (4.33), followed by T_1 (5.40).

Considering the level of infestation, the lowest percent (5.08%) of flower bud infestation by number was recorded in T_4, which was statistically similar with T_7 (5.63%), T_8 (7.14%), followed by T_1 (9.89%). On the other hand, the highest percent (39.71%) of flower bud infestation by number was recorded in T_9, which was statistically different from all other treatments.

Considering the reduction of flower bud infestation, the highest reduction (87.21%) of flower bud infestation over control was observed in T_4, followed by T_7 (85.82%) and T_8 (82.02%). Whereas the lowest reduction (18.06%) of flower buds infestation over control was observed in T_5.

Table 4. Effect of management practices on flower bud infestation of country bean by bean pod borer at early flowering stage

Treatment	% flower bud infestation at early flowering stage			
	Total no. of flower bud per five tagged inflorescence	**No. of infested flower bud per five tagged inflorescence**	**% flower bud infestation**	**% reduction of flower bud infestation over control**
T_1	55.22 bc	5.40 c	9.89 d	75.09
T_2	49.33 cd	8.00 b	16.22 c	59.15
T_3	46.61 d	9.03 b	18.77 c	52.73
T_4	64.51 a	3.27 d	5.08 e	87.21
T_5	37.80 e	12.30 a	32.54 b	18.06
T_6	48.17 d	8.03 b	17.30 c	56.43
T_7	62.99 a	3.53 d	5.63 de	85.82
T_8	60.71 ab	4.33 cd	7.14 de	82.02
T_9	34.67 e	13.77 a	39.71 a	-
$LSD_{(0.01)}$	6.44	1.69	4.29	-
CV (%)	5.27	9.44	10.63	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, T_2= Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, $T_7 = T_1 + T_3$, $T_8 = T_2 + T_3$, T_9=Untreated control]

From the above findings it was revealed that the lowest flower bud infestation (5.08%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of flower bud infestation over control was 87.21%. As a result, the order of efficacy of management practices in terms of flower bud infestation reduction is $T_4 > T_7 > T_8 > T_1 > T_2 > T_6 > T_3 > T_5 > T_9$.

4.2.2 Flower bud infestation of country bean by bean pod borer at mid flowering stage

The effect of management practices on flower bud infestation by number at mid flowering stage has been shown in Table 5. Significant variations were observed among the treatments in terms of bean pod borer infestation on flower bud of country bean. The highest number of (69.93) flower bud per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (69.00) and T_8 (67.77), followed by T_1 (61.00). On the other hand, the lowest number (36.00) of flower bud per five tagged inflorescence was recorded in T_9, which was statistically similar with T_5 (42.51). Accordingly, the lowest number (5.00) of infested flower bud per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (5.53) and T_8 (6.43), followed by T_1 (7.40).

Considering the level of infestation, the lowest percent (7.17%) of flower bud infestation by number was recorded in T_4, which was statistically similar with T_7 (8.05%), T_8 (9.48%) and T_1 (12.22%). On the other hand, the highest percent (43.49%) of flower bud infestation by number was recorded in T_1, which was statistically different from all other treatments.

Considering the reduction of flower bud infestation, the highest reduction (83.51%) of flower bud infestation over control was observed in T_4, followed by T_7 (81.49%) and T_8 (78.20%). Whereas the lowest reduction (24.21%) of flower buds infestation over control was observed in T_5.

Table 5. Effect of management practices on flower bud infestation of country bean by bean pod borer at mid flowering stage

Treatment	% flower bud infestation at mid flowering stage			
	Total no. of flower bud per five tagged inflorescence	No. of infested flower bud per five tagged inflorescence	% Flower bud infestation	% reduction of flower bud infestation over control
T_1	61.00 b	7.40 c	12.22 d	71.90
T_2	53.67 c	10.00 b	18.88 c	56.59
T_3	52.84 c	11.03 b	20.90 c	51.94
T_4	69.93 a	5.00 d	7.17 d	83.51
T_5	42.51 d	14.00 a	32.96 b	24.21
T_6	52.84 c	10.18 b	19.31 c	55.60
T_7	69.00 a	5.53 d	8.05 d	81.49
T_8	67.77 ab	6.43 cd	9.48 d	78.20
T_9	36.00 d	15.57 a	43.49 a	-
$LSD_{(0.01)}$	7.58	1.61	5.23	-
CV (%)	5.66	7.13	11.42	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

From the above findings it was revealed that the lowest flower bud infestation (7.17%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of flower bud infestation over control was 83.51%. As a result, the order of efficacy of management practices in terms of flower bud infestation reduction is T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9.

4.2.3 Flower bud infestation of country bean by bean pod borer at late flowering stage

The effect of management practices on flower bud infestation by number at late flowering stage has been shown in Table 6. Significant variations were observed among the treatments in terms of bean pod borer infestation on flower bud of country bean. The highest number (66.22) of flower bud per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (65.91) and T_8 (65.41), followed by T_1 (55.00), T_6 (51.33) and T_3 (50.17). On the other hand, the lowest number (34.00) of bud flower per five tagged inflorescence was recorded in T_9, which was statistically similar with T_5 (39.12). Accordingly, the lowest number (3.16) of infested flower bud per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (3.39) and T_8 (4.00), followed by T_1 (5.67).

Considering the level of infestation, the lowest percent (4.87%) of flower bud infestation by number was recorded in T_4, which was statistically similar with T_7 (5.86%), T_8 (6.11%) followed by T_1 (10.37%) and T_6 (14.30%). On the other hand, the highest percent (39.62%) of flower bud infestation by number was recorded in T_9, which was statistically different from all other treatments.

Considering the reduction of flower bud infestation, the highest reduction (87.71%) of flower bud infestation over control was observed in T_4, followed by T_7 (85.21%) and T_8 (84.58%). Whereas the lowest reduction (20.44%) of flower buds infestation over control was observed in T_5.

Table 6. Effect of management practices on flower bud infestation of country bean by bean pod borer at late flowering stage

Treatment	% flower bud infestation at late flowering stage			
	Total no. of flower bud	No. of infested flower bud	% Flower bud infestation	% reduction over control
T_1	55.00 b	5.67 cd	10.37 d	73.83
T_2	45.11 cd	8.35 b	17.80 c	55.07
T_3	50.17 bc	8.01 b	16.68 c	57.90
T_4	66.22 a	3.16 e	4.87 e	87.71
T_5	39.12 de	12.29 a	31.52 b	20.44
T_6	51.33 bc	7.33 bc	14.30 cd	63.91
T_7	65.91 a	3.93 de	5.86 e	85.21
T_8	65.41 a	4.00 de	6.11 e	84.58
T_9	34.00 e	13.43 a	39.62 a	-
$LSD_{(0.01)}$	8.63	2.05	4.13	-
CV (%)	6.89	11.68	10.60	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, T_2= Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

From the above findings it was revealed that the lowest flower bud infestation (4.87%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of flower bud infestation over control was 87.71%. As a result, the order of efficacy of management practices in terms of flower bud infestation reduction is $T_4>T_7>T_8>T_1>T_6>T_3>T_2>T_5>T_9$.

4.3 Effect of management practices on fruit infestation by number

4.3.1 Fruit infestation of country bean by bean pod borer at early fruiting stage

The effect of management practices on fruit infestation by number at early fruiting stage has been shown in Table 7. Significant variations were observed among the treatments in terms of bean pod borer infestation on fruits of country bean. The highest number (29.75) of fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (27.50) and T_8 (25.00), followed by T_1 (21.83) and T_2 (21.75). On the other hand, the lowest number (10.25) of fruit per five tagged inflorescence was recorded in T_9, which was followed by T_5 (11.92) and T_3 (14.00).

Accordingly, the lowest number (1.40) of infested fruit per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (1.74), which was followed by T_8 (1.88), followed by T_1 (2.55) and T_2 (2.81).

Considering the level of infestation, the lowest percent (4.70%) of fruit infestation by number was recorded in T_4, which was statistically similar with T_7 (6.38%), T_8 (7.55%), T_1 (11.93%) and T_2 (12.84%). On the other hand, the highest percent (45.47%) of fruit infestation by number was recorded in T_9, which was statistically similar with T_5 (37.91%).

Considering the reduction of fruit infestation, the highest reduction (89.66%) of fruit infestation over control was observed in T_4, followed by T_7 (85.97%) and T_8 (83.40%). Whereas the lowest reduction (16.63%) of fruits infestation over control was observed in T_5.

Table 7. Effect of management practices on fruit infestation of country bean by bean pod borer at early fruiting stage

Treatment	% fruit infestation by number at early fruiting stage			
	Total no. of fruit per five tagged inflorescence	No. of infested fruit per five tagged inflorescence	% fruit infestation	% reduction over control
T_1	21.83 b	2.55 c	11.93 e	73.76
T_2	21.75 b	2.81 c	12.84 de	71.76
T_3	14.00 cd	3.86 b	27.75 bc	38.97
T_4	29.75 a	1.40 d	4.70 e	89.66
T_5	11.92 cd	4.49 a	37.91 ab	16.63
T_6	16.33 c	3.65 b	23.32 cd	48.71
T_7	27.50 a	1.74 d	6.38 e	85.97
T_8	25.00 ab	1.88 d	7.55 e	83.40
T_9	10.25 d	4.593 a	45.47 a	-
$LSD_{(0.01)}$	1.17	0.59	10.86	-
CV (%)	10.21	13.91	13.05	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, $T_7 = T_1 + T_3$, $T_8 = T_2 + T_3$, T_9=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (4.70%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of fruit infestation over control was 89.66%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9$.

4.3.2 Fruit infestation of country bean by bean pod borer at mid fruiting stage

The effect of management practices on fruit infestation by number at mid fruiting stage has been shown in Table 10. Significant variations were observed among the treatments in terms of bean pod borer infestation on fruits of country bean. The highest number (35.83) of fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (33.83) and T_8 (31.67), followed by T_1 (28.00) and T_2 (27.75). On the other hand, the lowest number (15.92) of fruit per five tagged inflorescence was recorded in T_9, followed by T_5 (17.58) and T_3 (20.00). Accordingly, the lowest number (2.73) of infested fruit per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (2.74) and T_8 (3.53), followed by T_1 (3.80) and T_2 (3.81).

Considering the level of infestation, the lowest percent (7.62%) of fruit infestation by number was recorded in T_4, which was statistically similar with T_7 (8.12%), T_8 (11.15%), T_1 (13.68%) and T_2 (13.80%). On the other hand, the highest percent (38.23%) of fruit infestation by number was recorded in T_9, which was statistically similar with T_5 (32.36%).

Considering the reduction of fruit infestation, the highest reduction (80.07%) of fruit infestation over control was observed in T_4, followed by T_7 (78.76%) and T_8 (70.83%). Whereas the lowest reduction (15.35%) of fruit infestation over control was observed in T_5.

From the above findings it was revealed that the lowest fruit infestation (7.62%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of fruit infestation over control was 80.07%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_4 > T_7 > T_8 > T_1 > T_2 > T_6 > T_3 > T_5 > T_9$.

Table 8. Effect of management practices on fruit infestation of country bean by bean pod borer at mid fruiting stage

Treatment	% fruit infestation by number at mid fruiting stage			
	Total no. of fruit per five tagged inflorescence	No. of infested fruit per five tagged inflorescence	% fruit infestation	% reduction of fruit infestation over control
T_1	28.00 b	3.80 c	13.68 d	64.22
T_2	27.75 b	3.81 c	13.80 d	13.80 d
T_3	20.00cd	5.59 ab	27.99 bc	26.79
T_4	35.83 a	2.73 d	7.62 d	80.07
T_5	17.58 cd	5.68 ab	32.36 ab	15.35
T_6	22.00 c	4.86 b	22.81 c	40.33
T_7	33.83 a	2.74 d	8.12 d	78.76
T_8	31.67 ab	3.53 cd	11.15 d	70.83
T_9	15.92 d	6.08 a	38.23 a	-
$LSD_{(0.01)}$	4.97	0.90	6.37	-
CV (%)	8.07	8.73	13.67	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

4.3.3 Fruit infestation of country bean by bean pod borer at late fruiting stage

The effect of management practices on fruit infestation by number at late fruiting stage has been shown in Table 9. Significant variations were observed among the treatments in terms of bean pod borer infestation on fruits of country bean. The highest number (31.51) of fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (29.75) and T_8 (26.67), followed by T_2 (23.97) and T_3 (23.00). On the other hand, the lowest number (11.33) of fruit per five tagged inflorescence was recorded in T_9, followed by T_5 (13.58) and T_1 (15.50). Accordingly, the lowest number (1.27) of infested fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (1.70) and T_8 (1.73), followed by T_2 (2.63) and T_3 (2.81).

Considering the level of infestation, the lowest percent (4.05%) of fruit infestation by number was recorded in T_4, which was statistically similar with T_7 (5.85%), T_8 (6.44%), followed by T_2 (11.08%) and T_3 (12.06%). On the other hand, the highest percent (41.62%) of fruit infestation by number was recorded in T_9, which was statistically different from all other treatments.

Considering the reduction of fruit infestation, the highest reduction (90.27%) of fruit infestation over control was observed in T_4, followed by T_7 (85.94%) and T_8 (84.53%). Whereas the lowest reduction (32.08%) of fruit infestation over control was observed in T_5, which was followed by T_1 (40.22%).

From the above findings it was revealed that the lowest fruit infestation (4.05%) by number was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of fruit infestation over control was 90.27%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_4 > T_7 > T_8 > T_2 > T_3 > T_6 > T_1 > T_5 > T_9$.

Table 9. Effect of management practices on fruit infestation of country bean by bean pod borer at late fruiting stage

Treatment	% fruit infestation by number at late fruiting stage			
	Total no. of fruit per five tagged inflorescence	No. of infested fruit per five tagged inflorescence	% fruit infestation	% reduction of fruit infestation over control
T_1	15.50 de	3.86 a	24.88 b	40.22
T_2	23.97 b	2.63 bc	11.08 cd	73.38
T_3	23.00 bc	2.81 b	12.06 cd	71.02
T_4	31.51 a	1.27 d	4.05 e	90.27
T_5	13.58 de	3.86 a	28.27 b	32.08
T_6	18.00 cd	2.81 b	16.21 c	61.05
T_7	29.75 a	1.70 cd	5.85 de	85.94
T_8	26.67 ab	1.73 cd	6.44 de	84.53
T_9	11.33 e	4.68 a	41.62 a	-
$LSD_{(0.01)}$	1.24	0.97	6.41	-
CV (%)	9.99	14.99	16.07	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, T_2= Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

4.4 Effect of management practices on fruit infestation by weight

4.4.1 Fruit infestation of country bean by bean pod borer at early fruiting stage

The effect of management practices on fruit infestation by weight at early fruiting stage has been shown in Table 10. Significant variations were observed among the treatments in terms of bean pod borer infestation on fruit by weight of country bean. The highest weight (305.16 g) of fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (277.40 g) and T_8 (247.47 g), followed by

T_1 (203.67 g) and T_2 (200.33 g). On the other hand, the lowest weight (51.66 g) of fruit per five tagged inflorescence was recorded in T_9, which was statistically similar with T_5 (75.86 g) and T_3 (96.07 g). Accordingly, the lowest weight (12.42 g) of infested fruit per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (15.00 g), T_8 (16.11 g) and T_1 (16.11 g).

Considering the level of infestation, the lowest percent (4.15%) of fruit infestation by weight was recorded in T_4, which was statistically similar with T_7 (5.53%), T_8 (6.61%), T_1 (11.24 %) and T_2 (11.85%). On the other hand, the highest percent (69.96%) of fruit infestation by weight was recorded in T_9, which was statistically similar with T_5 (49.38%).

Considering the reduction of fruit infestation, the highest reduction (94.07%) of fruit infestation over control was observed in T_4, followed by T_7 (92.10%) and T_8 (90.55%). Whereas the lowest reduction (29.42%) of fruit infestation over control were observed in T_5.

From the above findings it was revealed that the lowest fruit infestation (4.15%) by weight was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of fruit infestation over control was 94.07%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9$.

Table 10. Effect of management practices on fruit infestation by weight at early fruiting stage

Treatment	% fruit infestation by weight at early fruiting stage			
	Total wt. of fruit per five tagged inflorescence (g)	Wt. of infested fruit per five tagged inflorescence (g)	% fruit infestation	% reduction of fruit infestation over control
T_1	203.67 b	16.11 cd	11.24 cd	83.93
T_2	200.33 b	23.74 bc	11.85 cd	83.06
T_3	96.07 cd	31.49 ab	32.62 bc	53.37
T_4	305.16 a	12.42 d	4.15 d	94.07
T_5	75.86 cd	34.31 a	49.38 ab	29.42
T_6	133.59 c	30.62 ab	24.36 cd	65.18
T_7	277.40 a	15.00 cd	5.53 d	92.10
T_8	247.47 ab	16.11 cd	6.61 d	90.55
T_9	51.66 d	34.37 a	69.96 a	-
$LSD_{(0.01)}$	57.42	8.40	21.79	-
CV (%)	13.62	14.43	18.12%	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

4.4.2 Fruit infestation of country bean by bean pod borer at mid fruiting stage

The effect of management practices on fruit infestation by weight at mid fruiting stage has been shown in Table 11. Significant variations were observed among the treatments in terms of bean pod borer infestation on fruit by weight of country bean. The highest weight (375.69 g) of fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (350.40 g) and T_8 (324.33 g), followed by T_1 (272.70 g) and T_2 (266.60 g). On the other hand, the lowest weight (104.30 g) of fruit per five tagged inflorescence was recorded in T_9, which was statistically similar with T_5 (130.67 g) and T_3 (154.96 g). Accordingly, the lowest weight (14.92 g) of infested fruit per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (16.85 g), which was followed by T_8 (25.83 g).

Considering the level of infestation, the lowest percent (4.02%) of fruit infestation by weight was recorded in T_4, which was statistically similar with T_7 (4.90%), T_8 (8.12%), T_1 (10.05%) and T_2 (10.67%) followed by T_6 (19.51%). On the other hand, the highest percent (49.70%) of fruit infestation by weight was recorded in T_9, which was significantly different from all other treatments.

Considering the reduction of fruit infestation, the highest reduction (91.91%) of fruit infestation over control was observed in T_4, followed by T_7 (90.14%) and T_8 (83.66%). Whereas the lowest reduction (29.30%) of fruit infestation over control was observed in T_5.

From the above findings it was revealed that the lowest fruit infestation (4.02%) by weight was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of fruit infestation over control was 91.91%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9$.

Table 11. Effect of management practices on fruit infestation by weight at mid fruiting stage

Treatment	% fruit infestation by weight at mid fruiting stage			
	Total wt. of fruit per five tagged inflorescence (g)	Wt. of infested fruit per five tagged inflorescence (g)	% fruit infestation	% reduction of fruit infestation over control
T_1	272.70 b	26.65 c	10.05 de	79.78
T_2	266.60 b	26.74 c	10.67 de	78.53
T_3	154.96 cd	42.37 ab	27.44 bc	44.79
T_4	375.69 a	14.92 e	4.02 e	91.91
T_5	130.67 d	44.46 ab	35.14 b	29.30
T_6	194.10 c	36.20 b	19.51 cd	60.74
T_7	350.40 a	16.85 de	4.90 e	90.14
T_8	324.33 ab	25.83 cd	8.12 de	83.66
T_9	104.30 d	48.98 a	49.70 a	-
$LSD_{(0.01)}$	59.30	9.13	12.96	-
CV (%)	10.30	12.17	18.97	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

4.4.3 Fruit infestation of country bean by bean pod borer at late fruiting stage

The effect of management practices on fruit infestation by weight at late fruiting stage has been shown in Table 12. Significant variations were observed among the treatments in terms of bean pod borer infestation on fruit by weight of country bean. The highest weight (325.67 g) of fruit per five tagged inflorescence was recorded in T_4, which was statistically similar with T_7 (303.47 g) and T_8 (266.50 g), followed by T_1 (227.87 g) and T_6 (214.10 g). On the other hand, the lowest weight (62.31 g) of fruit per five tagged inflorescence was recorded in T_9, which was statistically similar with T_5 (91.90 g) and T_2 (110.87 g). Accordingly, the lowest weight (11.24 g) of infested fruit per five tagged inflorescence was recorded in T_4, which is statistically similar with T_7 (14.86 g) and T_8 (14.94 g), followed by T_1 (22.30 g).

Considering the level of infestation, the lowest percent (3.50%) of fruit infestation by weight was recorded in T_4, which was statistically similar with T_7 (5.57%), T_8 (5.71%), T_1 (10.11%), T_6 (11.00%) and T_3 (16.81%). On the other hand, the highest percent (61.14%) of fruit infestation by weight was recorded in T_9, which was significantly different from all other treatments.

Considering the reduction of fruit infestation, the highest reduction (94.28%) of fruit infestation over control was observed in T_4, followed by T_7 (90.89%) and T_8 (90.66%). Whereas the lowest reduction (40.63%) of fruit infestation over control was observed in T_5.

From the above findings it was revealed that the lowest fruit infestation (3.50%) by weight was recorded in T_4 by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest reduction of fruit infestation over control was 94.28%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_4>T_7>T_8>T_1>T_6>T_3>T_2>T_5>T_9$.

Table 12. Effect of management practices on fruit infestation by weight at late fruiting stages

Treatment	% fruit infestation by weight at late fruiting stage			
	Total wt. of fruit per five tagged inflorescence (g)	Wt. of infested fruit per five tagged inflorescence (g)	% fruit infestation	% reduction of fruit infestation over control
T_1	227.87 b	22.30 cd	10.11 cd	83.46
T_2	110.87 cd	29.59 abc	26.61 bc	56.48
T_3	151.57 c	23.72 bc	16.81 bcd	72.51
T_4	325.67 a	11.24 e	3.50 d	94.28
T_5	91.90 cd	31.40 ab	36.30 b	40.63
T_6	214.10 b	23.55 bc	11.00 cd	82.01
T_7	303.47 a	14.86 de	5.57 cd	90.89
T_8	266.50 ab	14.94 de	5.71 cd	90.66
T_9	62.31 d	34.96 a	61.14 a	-
$LSD_{(0.01)}$	60.54	8.02	19.98	-
CV (%)	13.03	14.65	19.25	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

4.5 Effect of management practices on incidence of number of boring hole and number of larva per infested fruit

The effect of management practices on number of boring hole per infested fruit and number of larva per infested fruit has been shown in Table 13. Significant variations were observed among the different treatments in terms of number of boring hole and number of larva per infested fruit of country bean. The highest number (5.92) of boring hole per infested fruit was recorded in T_9 which was statistically similar with

T_5 (5.17) and T_3 (4.83), followed by T_6 (3.75) and T_2 (3.49). On the other hand, the lowest number (1.53) of boring hole per infested fruit was recorded in T_4, which was statistically similar with T_7 (2.56), T_8 (2.58) and T_1 (2.67). Accordingly, the highest number (4.33) of larva per infested fruit was recorded in T_9, which was statistically similar with T_5 (3.67) and T_3 (3.25). On the other hand, the lowest number (1.17) of larva per infested fruit was recorded in T_4, which was statistically similar with T_7 ((1.67), T_8 (2.00) and T_1 (2.08), followed by T_2 (3.00) and T_6 (3.04).

Table 13. Effect of management practices on incidence of number of boring hole and number of larva per infested fruit

Treatment	Incidence of no. of boring hole and no. of larva per infested fruit	
	No. of boring hole	No. of larva
T_1	2.67 cd	2.08 cd
T_2	3.49 bc	3.00 bc
T_3	4.83 ab	3.25 ab
T_4	1.53 d	1.17 d
T_5	5.17 ab	3.67 ab
T_6	3.75 bc	3.04 bc
T_7	2.56 cd	1.67 d
T_8	2.58 cd	2.00 cd
T_9	5.92 a	4.33 a
$LSD_{(0.01)}$	1.58	1.05
CV (%)	18.29	17.01

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

From the above findings it was revealed that the highest number of boring hole (5.92 boring hole/infested fruit) and highest number of larva (4.33 larva/infested fruit) was recorded in T_9 comprised of untreated control in the field, where the lowest number of boring hole (1.53 boring hole/infested fruit) and lowest number of larva (1.17 larva/infested fruit) was recorded in T_4 treatment by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field.

4.6 Effect of management practices on incidence of beneficial arthropods

4.6.1. Lady bird beetle

The effect of management practices on the number of lady bird beetle in the field of country bean has been shown in Table 14. The significant variations were observed among the different treatments used for the management practices in terms of number of lady bird beetle per five vines per plot was recorded from the country bean field. The highest number (5.40) of lady bird beetle per five vines per plot per inspection was recorded in T_4, which was statistically similar with T_9 (5.27) and T_7 (4.87), followed by T_8 (3.87). On the other hand, the lowest number (1.33) of lady bird beetle per five vines per plot per inspection was recorded in $T_{6,}$ which was statistically similar with T_5 (1.40) and T_3 (2.57).

4.6.2 Black ant

The effect of management practices on the number of black ant in the field of country bean has been shown in Table 14. The significant variations were observed among the different treatments used for the management practices in terms of number of black ant per five vines per plot was recorded from the country bean field. The highest number (6.27) of black ant per five vines per plot per inspection was recorded in T_4, which was statistically similar with T_9 (5.67), followed by T_7 (5.00). On the other hand, the lowest number (1.17) of black ant per five vines per plot per inspection was recorded in $T_{6,}$ which was statistically similar with T_5 (1.67).

4.6.3 Spider

The effect of management practices on the number of spider in the field of country bean has been shown in Table 14. The significant variations were observed among the different treatments used for the management practices in terms of number of spider per five vines per plot was recorded from the country bean field. The highest number (5.33) of spider per five vines per plot per inspection was recorded in T_4, which was statistically similar with T_9 (5.13) and T_7 (4.67), followed by T_8 (4.04). On the other hand, the lowest number (1.13) of spider per five vines per plot per inspection was recorded in $T_{6,}$ which was statistically similar with T_5 (1.87), which was flowed by T_2 (2.87), T_1 (3.17) and T_3 (3.17).

4.6.4 Syrphid fly

The effect of management practices on the number of syrphid fly in the field of country bean has been shown in Table 14. The significant variations were observed among the different treatments used for the management practices in terms of number of syrphid fly per five vines per plot per inspection was recorded from the country bean field. The highest number (5.17) of syrphid fly per five vines per plot per inspection was recorded in T_1, which was statistically similar with T_9 (5.07) and T_7 (5.00). On the other hand, the lowest number (1.87) of syrphid fly per five vines per plot per inspection was recorded in $T_{6,}$ which was significantly different from all other treatments.

4.6.5 Honeybee

The effect of management practices on the number of honeybee in the field of country bean has been shown in Table 14. The significant variations were observed among the different treatments used for the management practices in terms of number of honeybee per five vines per plot was recorded from the country bean field. The highest number (4.37) of honeybee per five vines per plot per inspection was recorded in T_4, which was statistically similar with T_9 (4.07) and T_7 (4.00/five vines/plot/inspection) followed by T_8 (3.33). On the other hand, the lowest number (1.07) of honeybee per five vines per plot per inspection was recorded in T_6, which was statistically similar with T_5 (1.67), flowed by T_3 (1.70).

Table 14. Effect of management practices on incidence of beneficial arthropods

Treatment	Incidence of beneficial arthropods				
	Ladybird beetle	**Black ant**	**Spider**	**Syrphid fly**	**Honeybee**
T_1	3.73 c	3.80 c	3.17 c	4.04 b	3.03 b
T_2	3.53 c	3.60 c	2.87 c	3.17 c	2.50 b
T_3	2.57 cd	2.67 d	3.17 c	3.00 c	1.70 c
T_4	5.40 a	6.27 a	5.33 a	5.17 a	4.37 a
T_5	1.40 d	1.67 de	1.87 d	2.80 c	1.67d
T_6	1.33 d	1.17 e	1.13 d	1.87 d	1.07 d
T_7	4.87 ab	5.00 b	4.67 ab	5.00 ab	4.00 a
T_8	3.87 bc	4.33 c	4.04 b	4.27 b	3.33 b
T_9	5.27 a	5.67 ab	5.13 a	5.07 a	4.07 a
$LSD_{(0.01)}$	1.03	0.73	0.94	0.93	0.06
CV (%)	12.37	8.37	11.17	9.70	8.65

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

4.7 Effect on yield of country bean

The effect of management practices on yield of country bean has been shown in Table 15. Significant variations were observed among the treatments in terms of yield of country bean. The highest yield (7.08 kg/plot) was recorded in T_4 which was statistically similar with T_7 (6.68 kg/plot) and T_8 (6.07 kg/plot), followed by T_1 (5.86

kg/plot). On the other hand, the lowest yield (3.73 kg/plot) was recorded in T_9, which was statistically similar with T_5 (3.87 kg/plot) and T_3 (4.53 kg/plot).

Table 15. Effect of management practices on yield of country bean

Treatment	Yield (Kg/plot)	Yield (ton/ha)	% increased over control
T_1	5.86 b	19.54 b	57.07
T_2	4.81 c	16.04 c	28.94
T_3	4.53 cd	15.17 cd	21.95
T_4	7.08 a	23.59 a	89.63
T_5	3.87 d	14.04 cd	8.20
T_6	4.80 c	16.33 c	31.27
T_7	6.68 ab	22.37 ab	79.02
T_8	6.07 b	19.67 b	76.05
T_9	3.73 d	12.44 d	-
$LSD_{(0.01)}$	0.90	2.98	-
CV (%)	7.09	7.07	-

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, T_2= Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Setting up of pheromone trap with 1 lure per plot, T_4= Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval, T_5= Spraying of Actara 25 WG @ 0.3 g per liter of water at 7 days interval, T_6= Spraying of Cot 10 EC @ 0.4 ml per liter of water at 7 days interval, T_7 = T_1+ T_3, T_8= T_2+ T_3, T_9=Untreated control]

Considering the yield of country bean in ton/ha, the highest yield (23.59 ton/ha) was recorded in T_4, which was statistically similar with T_7 (22.37 ton/ha) and T_8 (19.67 ton/ha), followed by T_1 (19.54 ton/ha). On the other hand, the lowest yield (12.44 ton/ha) was recorded in T_9, which was statistically similar with T_5 (14.04 ton/ha) and T_3 (15.17 ton/ha).

Considering the yield increase over control, the maximum increase of yield of country bean over control (89.63%) was recorded in T_4, which was followed by T_7 (79.02%), T_8 (76.05%). Whereas the minimum increase of yield over control (8.20%) was recorded in T_5.

From the above findings it was revealed that the highest yield (23.59 ton/ha) was produced in T_4 treated plot by Spraying of Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval in the field, where the highest increase of yield over control was 89.63%. As a result, the order of efficacy of management practices in terms of increasing the yield is $T_4>T_7>T_8>T_1>T_2>T_6>T_3>T_5>T_9$.

4.8 Relationship between inflorescence infestation and yield of country bean

4.8.1 Early flowering stage

Correlation study was done to establish the relationship between the percent inflorescence infestation by number at early flowering stage and yield (ton/ha) of country bean during the management of bean pod borer. From the study it was revealed that significant correlation was observed between the inflorescence infestation and yield of country bean (Figure 1). It was evident from the Figure 1 that the regression equation $y = -0.178x + 24.51$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.854$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between inflorescence infestation and yield of country bean, i.e., the yield decreased with the increase of the infestation of inflorescence with bean pod borer at early flowering stage.

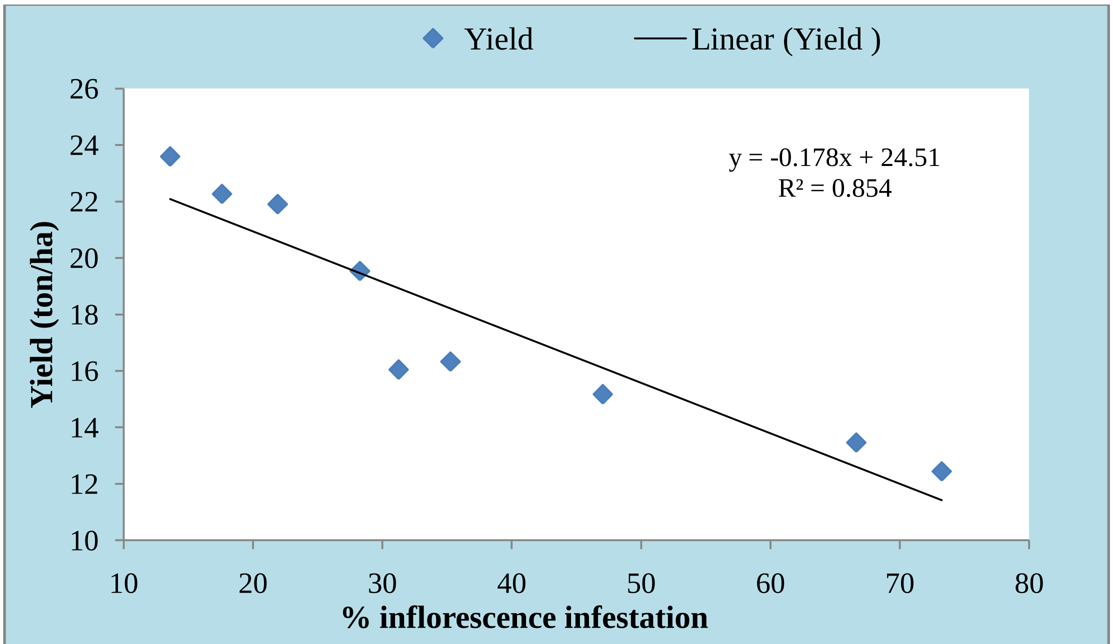


Figure 1. Relationship between percent inflorescence infestation and yield at early flowering stsge

4.8.2 Mid flowering stage

Correlation study was done to establish the relationship between the percent inflorescence infestation by number at mid flowering stage and yield (ton/ha) of country bean during the management of bean pod borer. From the study it was revealed that significant correlation was observed between the inflorescence infestation and yield of country bean (Figure 2). It was evident from the Figure 2 that the regression equation y = -0.179x + 25.28 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.892) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between inflorescence infestation and yield of country bean, i.e., the yield decreased with the increase of the infestation of inflorescence with bean pod borer at mid flowering stage.

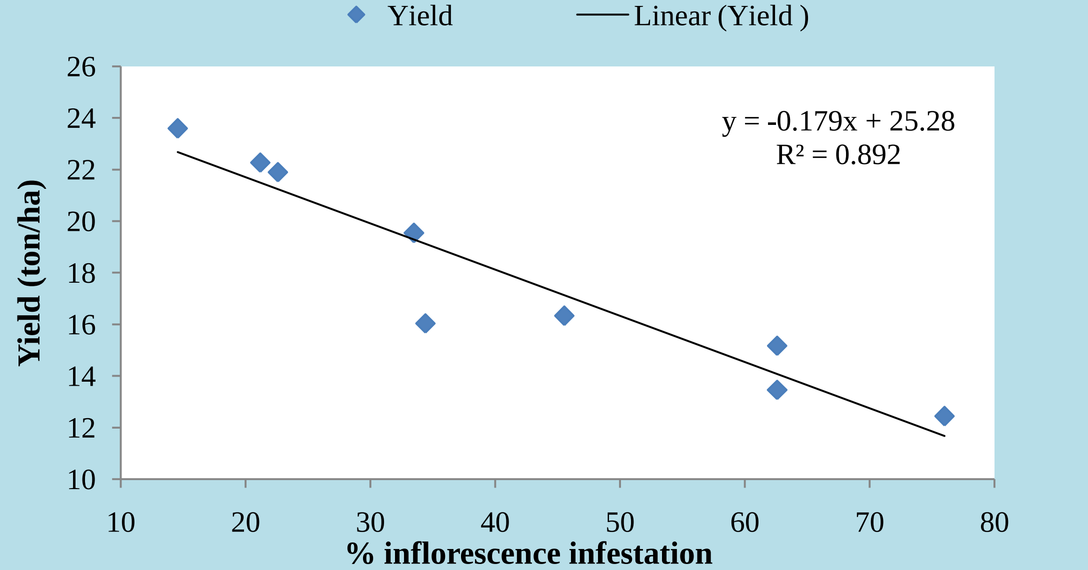


Figure 2. Relationship betweeen percent inflorescence infestation and yield at mid flowering stage

4.8.3 Late flowering stage

Correlation study was done to establish the relationship between the percent inflorescence infestation by number at late flowering stage and yield (ton/ha) of country bean during the management of bean pod borer. From the study it was revealed that significant correlation was observed between the inflorescence infestation and yield of country bean (Figure 3). It was evident from the Figure 3 that the regression equation y = -0.175x + 24.55 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.768) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between inflorescence infestation and yield of country bean, i.e., the yield decreased with the increase of the infestation of inflorescence with bean pod borer at late flowering stage.

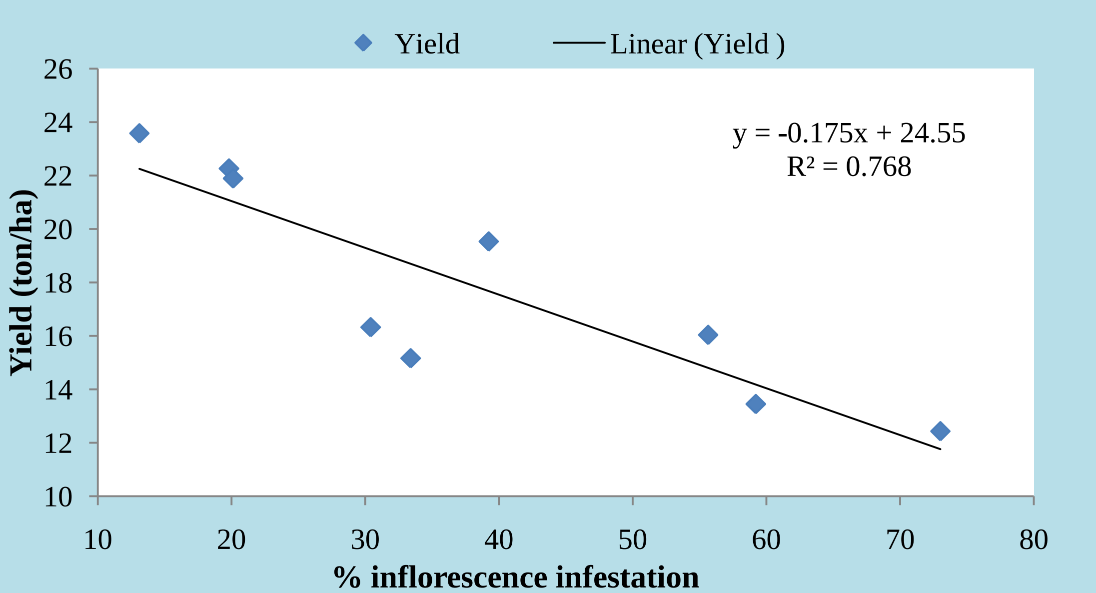


Figure 3. Relatonship between percent inflorescence infestation and yield at late flowering stage

4.9 Relationship between percent fruit infestation and yield of country bean

4.9.1 Early fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at early fruiting stage and yield (ton/ha) of country bean during the management of bean pod borer. From the study it was revealed that significant correlation was observed between the fruit infestation by number and yield of country bean (Figure 4). It was evident from the Figure 4 that the regression equation $y = -0.255x + 22.91$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.845$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of country bean, i.e., the yield decreased with the increase of the infestation of fruit number with bean pod borer at early fruiting stage.

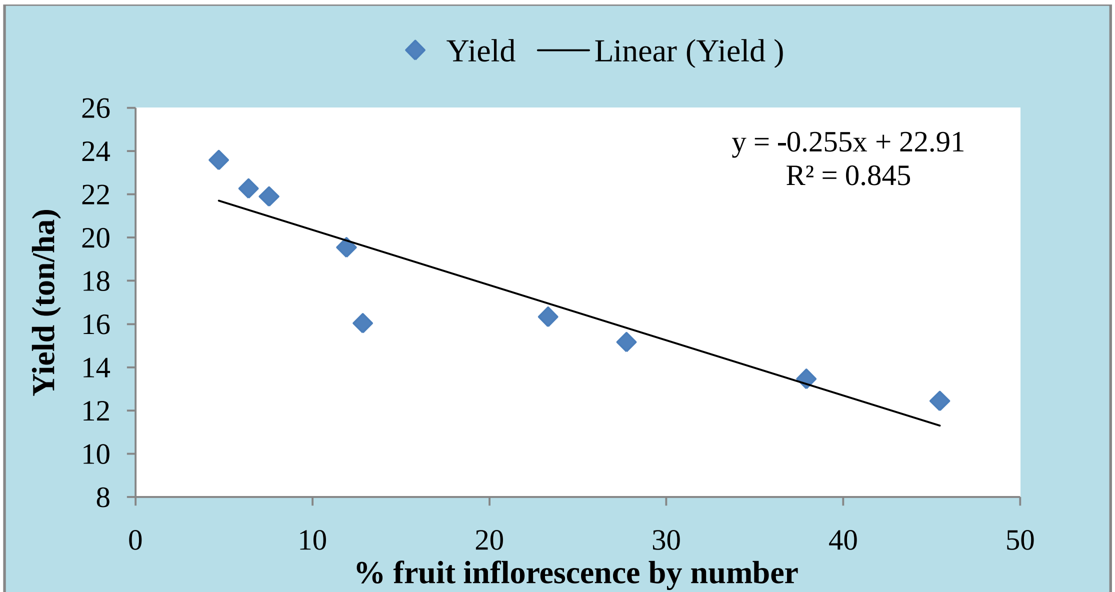


Figure 4. Relationship between percent fruit infestation by number and yield at early fruiting syage

4.9.2 Mid fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at mid fruiting stage and yield (ton/ha) of country bean during the management of bean pod borer. From the study it was revealed that significant correlation was observed between the fruit infestation by number and yield of country bean (Figure 5). It was evident from the Figure 5 that the regression equation y = -0.334x + 24.40 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.848) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of country bean, i.e., the yield decreased with the increase of the infestation of fruit number with bean pod borer at mid fruiting stage.

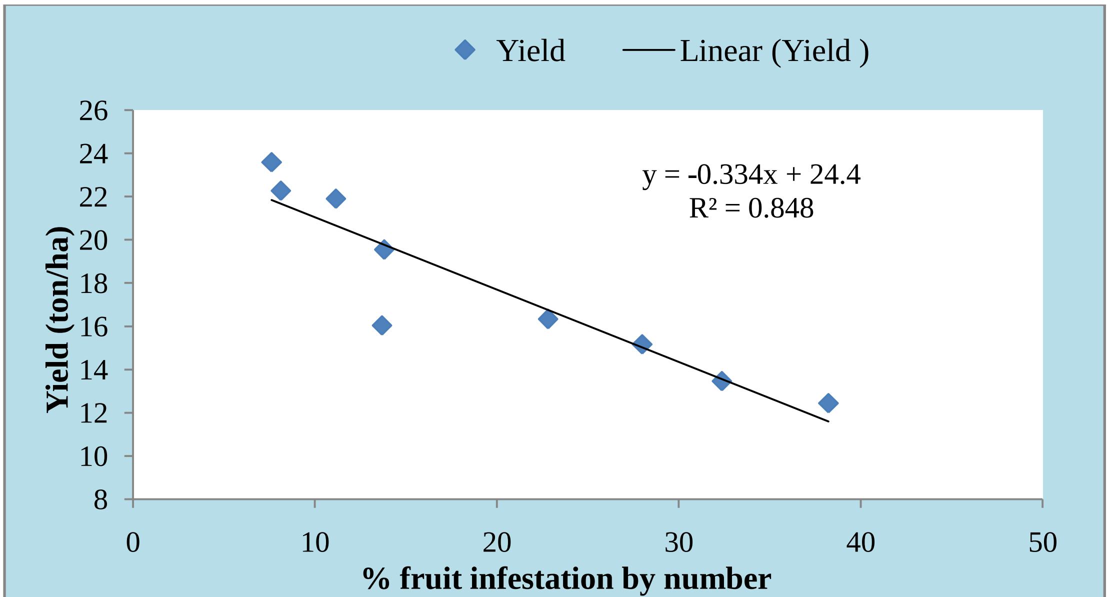


Figure 5. Relationship between percent fruit infestation by number and yield at mid fruiting stage

4.9.3 Late fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at late fruiting stage and yield (ton/ha) of country bean during the management of bean pod borer. From the study it was revealed that significant correlation was observed between the fruit infestation by number and yield of country bean (Figure 6). It was evident from the Figure 6 that the regression equation y = -0.247x + 21.99 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.576) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of country bean, i.e., the yield decreased with the increase of the infestation of fruit number with bean pod borer at late fruiting stage.

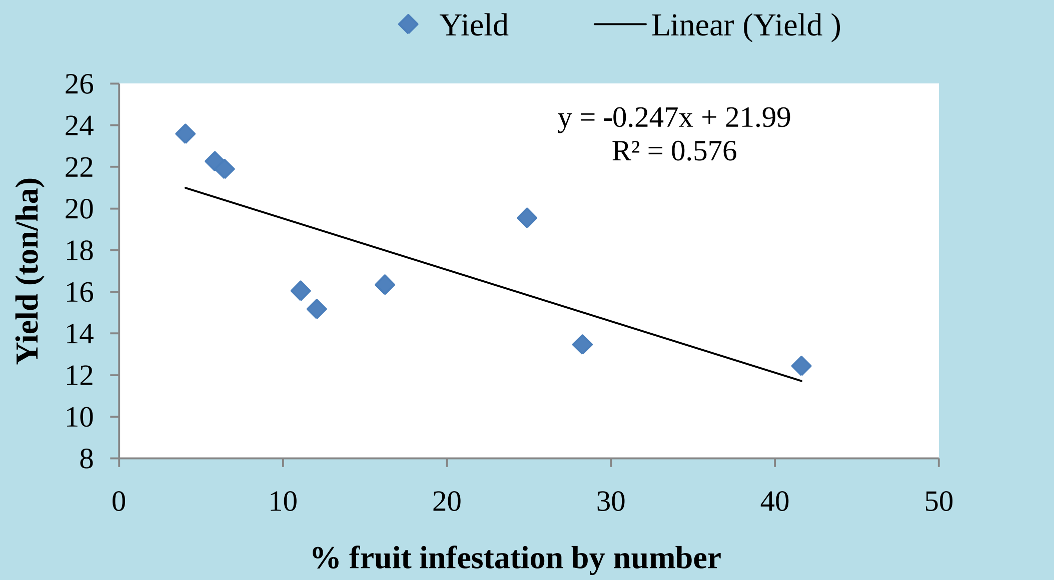


Figure 6. Relationship between percent fruit infestation and yield at late fruiting stage

4.10 Economic analysis of different management practices applied against bean pod borer infesting country bean

Economic analysis of different management practices applied against bean pod borer infestation on country bean presented in Table 16. The untreated control (T_9) did not incur any pest management cost. The labor costs were involved in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 for applying treatments in the experimental plots (Appendix III). From the economic analysis, it was revealed that the highest benefit cost ratio (BCR) (53.13) was calculated in T_4 (0.4 ml Fytomax 0.03 EC + 1 liter of water at 7 days interval), where the total adjusted net return was counted as benefit. This was followed (36.51) by T_7 (3 ml Neem oil + 10 ml trix+ 1 liter water and Pheromone trap at 7 days interval) and 36.33 in T_8 (0.5 ml Neem seed kernel Extract + 1 ml water and Pheromone trap at 7 days interval). The minimum BCR (7.49) was calculated in T_5 (0.3 gm Actara 25 WG + 1 liter of water at 7 days interval).

Table 16. Economic analysis of different management practices applied against bean pod borer in country bean during Rabi season, 2017 at Dhaka

Treatments	Cost of Management (Tk.)	Yield (kg/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	BCR
T_1	6222.22	19540	488500	488500.00	177500.00	28.53
T_2	4446.00	16040	401000	396554.00	85554.00	19.24
T_3	6396.00	15170	379250	372854.00	61854.00	9.67
T_4	5150.00	23590	58950	584600.00	273600.00	53.13
T_5	4711.00	14040	351000	346289.00	35289.00	7.49
T_6	4855.56	16330	408250	403394.44	92394.44	19.03
T_7	6618.22	22370	556750	552631.78	241631.78	36.51
T_8	4776.00	19670	491750	486908.00	175908.00	36.33
T_9	0.00	12440	311000	311000.00	-	-

[T_1= Neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval,$T_{2=}$ Neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval,T_3= Pheromone trap with lure and soap at 4 days interval, T_4= Fytomax 0.03 EC @ 0.4 ml per liter of water at 7 days interval,T_5= Actara 25 WG @ 0.3 g per liter of water at 7 days interval,T_6= Cot 10 EC @ 0.4 ml per liter of water at 7 days interval,T_7 = T_1+ T_3,T_8= T_2+ T_3,T_9=Untreated control]
Wholesale price of country bean at that time, 1 Kg = 25 Tk.

CHAPTER V

SUMMARY AND CONCLUSION

Eco-friendly management of bean pod borer on country bean was investigated at the field laboratory of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from october, 2016 to February, 2017. The treatments were T_1 comprised of spraying of 3 ml neem oil and 10 ml trix mixed with 1 liter of water at 7 days interval; T_2 comprised of spraying of 0.5 ml neem seed kernel extract mixed with 1 liter of water at 7 days interval; T_3 comprised of setting up of 1 lure with pheromone trap per plot; T_4 comprised of spraying of Fytomax 0.03 EC @ 0.4 ml mixed with 1 liter of water @ 7 days interval; T_5 comprised of spraying of Actara 25 WG @ 0.3 g mixed with 1 liter of water @ 7 days interval; T_6 comprised of spraying of Cot 10 EC @ 0.4 ml mixed with 1 ml water; T_7 comprised of T_1 and T_3; T_8 comprised of T_2 and T_3 and T_9 comprised of untreated control. Data on inflorescence infestation by number, flower bud infestation by number, fruit infestation by number, fruit infestation by weight, on the number of beneficial arthropods and total yield and yield were recorded from different management practices applied against bean pod borer on country bean.

Considering the effect of different management practices in reducing the level of infestation by bean pod borer on country bean, at early flowering stage of country bean, the lowest inflorescence infestation (13.59%) by number was recorded in T_4 by spraying Fytomax 0.03 EC @ 0.4 ml per 1 liter of water in the field, where the highest reduction of inflorescence infestation over control was 81.44 %. At mid flowering stage of country bean, the lowest inflorescence infestation (14.55%) by number was recorded in T_4 treatment, where the highest reduction of inflorescence infestation over control was 80.85. At late flowering stage of country bean, the lowest inflorescence infestation (13.11%) by number was recorded in T_4 treatment, where the highest reduction of inflorescence infestation over control was 82.05%.

At early flowering stage of country bean, the lowest flower bud infestation (5.08%) by number was recorded in T_4 treatment in the field, where the highest reduction of flower bud infestation over control was 87.21%. At mid flowering stage of country bean, the lowest flower bud infestation (7.17%) by number was recorded in T_4 treatment, where the highest reduction of flower bud infestation over control was 83.51%. At late flowering stage of country bean, the lowest flower bud infestation (4.87%) by number was recorded in T_4, where the highest reduction of flower bud infestation over control was 87.71%.

At early fruiting stage of country bean, the lowest fruit infestation (4.70%) by number was recorded in T_4, where the highest reduction of fruit infestation over control was 89.66%. At mid fruiting stage of country bean, the lowest fruit infestation (7.62%) by number was recorded in T_4, where the highest reduction of fruit infestation over control was 80.07%. At late fruiting stage of country bean, the lowest fruit infestation (4.05%) by number was recorded in T_4, where the highest reduction of fruit infestation over control was 90.27%. At early fruiting stage of country bean, the lowest fruit infestation (4.15%) by weight was recorded in T_4, where the highest reduction of fruit infestation over control was 94.07%. At mid fruiting stage of country bean, the lowest fruit infestation (4.02%) by weight was recorded in T_4, where the highest reduction of fruit infestation over control was 91.91%. At late fruiting stage of country bean, the lowest fruit infestation (3.50%) by weight was recorded in T_4, where the highest reduction of fruit infestation over control was 94.28%.

The highest number of boring hole (5.92 boring hole/infested fruit) and highest number of larva (4.33 larva/infested fruit) was recorded in T_9 comprised of untreated control in the field, where the lowest number of boring hole (1.53 boring hole/infested fruit) and lowest number of larva (1.17 larva/infested fruit) was recorded in T_4 treatment.

In case of beneficial arthropods e.g. lady bird beetle, black ant, spider, syrphid fly and honeybee etc., the best performing treatment was T_4 comprised of Fytomax 0.03 EC @ 0.4 ml/L of water at 7 days interval and the lowest performing treatment was T_6 comprised of Cot 10 EC @ 0.4 ml per 1 liter of water @ 7 days interval. The highest number of lady bird beetle (5.40 lady bird beetle/five vines/plot/inspection), black ant (6.27 black ant/five vines/plot/inspection), spider (5.33 spider/five vines/plot/inspection), syrphid fly (5.17 syrphid fly/five vines/plot/inspection) and honeybee (4.37 honeybee/five vines/plot/inspection respectively) was recorded in T_4 treatment.

Considering the yield of country bean in ton/ha, the highest yield (23.59 ton/ha) was recorded in T_4 by spraying of Fytomax 0.03 EC @ 0.4 ml/L of water at 7 days interval, where the lowest yield (12.44 ton/ha) was recorded in T_9 comprised of untreated control. The highest percent of yield increased over control (89.63%) was recorded in T_4 treatment.

The highest benefit cost ratio (BCR) (53.13) was calculated in T_4 (Fytomax 0.03 EC @ 0.4 ml/liter of water at 7 days interval), where the total adjusted net return was counted as benefit. The minimum BCR (14.91) was calculated in T_5 (Actara 25 WG @ 0.3 gm/liter water 7 days interval).

CONCLUSION

From the present study, it may be concluded that incidence of bean pod borer and infestation of country bean by bean pod borer was significantly varied among the treatments. The overall study revealed that the highest performance was achieved from Fytomax 0.03 EC @ 0.4 ml per liter of water (T_4). Highest reduction (80%) of inflorescence infestation, highest reduction (83%) of flower bud infestation and highest reduction (91%) of fruit infestation over control was achieved by Fytomax 0.03 EC (T_4). Highest yield increase (89.63%) over control was achieved by Fytomax 0.03 EC @ 0.4 ml per liter of water (T_4). Highest yield (23.59 ton/ha) was achieved by Fytomax 0.03 EC @ 0.4 ml per liter of water (T_4). Neem oil with pheromone trap (T_7) also showed similar performance in terms of number of inflorescence per plot, number of flower bud per five tagged inflorescence, number of fruit per five tagged inflorescence, weight of fruit per five tagged inflorescence, and yield. It also reduced fruit infestation. Considering the results of the present study, it can be concluded that Fytomax 0.03 EC @ 0.4 ml per liter of water may be used for the management of bean pod borer attacking country bean.

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

i. To minimize the use of chemical insecticides in bean pod borer control programmes, Fytomax 0.03 EC @ 0.4 ml per liter of water can play a significant role. It should be adopted in large scale production of health hazards free country bean production.

ii. Further study of this experiment is needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI

REFERENCES

Aditya, D.K. (1993). Vegetable production and development in Bangladesh Consultancy report, AVRDC – USAID (ARP II) project, 22 November, 1992–31 May 1993. Horticulture Research Center, BARI, Joydebpur, Gazipur. pp. 3- 24.

Akhauri, R.K., Sinha, M.M. and Yadav, R.P. (1994). Population build-up and relative abundance of pod borer complex in early pigeon pea, *Cajanus cajan* (L.) *Millsp. J. Entomol. Res.* **18**: 12l-126.

Akinfenwa, S. (1995). Biological study of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in the Zaria area of northern Nigeria. M. Sc. Thesis. Ahmadu Bello University, Nigeria. p. 193.

Alam, M.Z. (1989). Insect Pests of Vegetables and Their Control in East Pakistan. The Agriculture Information Service, Department of Agriculture, R.K. Mission Road, Dhaka-3, East Pakistan, p. 146.

Anonymous, (1993). Training manual, summer and all season vegetables and spices production. Horticulture Research and Development Project, DAE and BADC, Dhaka. P. 130.

Atachi, P. and Sourokou, B. (1989). Use of decis and systoate for the control of *Maruca testulalis* (Geyer) in cowpea. *Insect Sci. Applic.* **10**(3): 373-381.

Babu, S.P.C. (1989). Comparative biology of the spotted pod borer, *Maruca testulalis* (Geyer) on three host plants. *Legume Research.* **12**(4): 177-178.

Bakar, A.K., Abu, B., Haron, A.R.B. and Aziz, Z.B.A. (1980). Mungbean in Malaysia. *Rev. Appl. Ent.* **68**(1): 60.

Banken, J.A.O. and Stark, J.D. (1997). Stage and age influence on the susceptibility of *Coccinella septempunctata* after direct exposure to neemix, a neem insecticide. *J. Eco. Entomol.* **90**(5): 1102-1105.

BARC. (1997). Fertilizer recommendation Guide. Bangladesh Agricultural Research Council, New Airport Road, Farmgate, Dhaka-1215, Bangladesh.

BBS. (2013). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. pp. 41-45.

Begum, R.A. (1993). Techniques of growing legume vegetable. **In**: Intensive vegetable growing and its utilization. A compilation of lecture materials of training course held in BARI, Joydebpur, Gazipur, Bangladesh. 22-25 November, 1993. pp. 94.

Bhatnagar, V.S. and Davies, J.C. (1978). Factors affecting populations of gram pod borer, *Heliothis armigera* (Hubner) in the period 1974-77 at Patancheru (Andhra Pradesh). Presented at the Oriental Entomology Workshop on Population Ecology in Relation to Insects of Economic Importance, 18-20 January, 1978, Bangalore, India. Bhatnagar, V.S. (1980). A report on research on the *Heliothis complex* at ICRISAT (India) 1974-79. Presented at the all India Workshop on Consolidation of Pest Management Recommendations and Guidelines of Research. 24-26 April, 1980. Udaipur, India. pp. 38-39.

Bhatt, N.J. and Patel, R.K. (200l). Biology of chickpea pod borer *Helicoverpa armigera*.. *Indian J. Ent*. **63**(3): 255-259.

Bilton, J.N., Broughton, H.B., Ley, S.V., Lidert, Z., Morgan, E.D., Rzepa, H.S. and Sheppard, R.N. (1985). Structural reappraisal of the limonoid insect antifeedant azadirachtin. *J. Chem. Soc. Chem. Commun*. pp. 968-971.

Bottrell, D.G. (1999). Council on Environmental Quality: Integrated Pest Management. US Government Printing Office, Washington D.C. p. 120.

Broadley, R.H. (1977). The bean pod borer in north Queensland. *Queensl. Agric. J.* **103**: 274-278.

Broughton, H.B., Bilton, J.N., Ley, S.V., Lidert, Z., Morgan, E.D., Rzepa, H.S. and Sheppard, R.N. (1986). Structural reappraisal of the limonoid insect antifeedant azadirachtin. *J. Chem. Soc. Chem. Commun*. pp. 968-971.

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

Butterworth, J.H. and Morgan, E.D. (1968). Isolation of substance that suppresses feeding in locusts. *J. Chem. Commun*. pp. 23-24.

Continho, S.A. (1985). Polyphagous larvae - *Heliothis armigera* and *Heliothis peltigera* in the Cape Verde Islands. *Garcia de Orta*. **24**: 134-129.

Dandale, H.G., Khan, K,M., Thakaie, H.S. and Borle, M.N. (1984). Comparative efficacy of synthetic pyrehroids against pod borer complex of red gram. *Indian J. Entomol*. **43**(4): 416-419.

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.

Devlin, J.F. and Zettel, T. (1999). Eco-agriculture: Initiatives in Eastern and Southern Africa. Weaver Press, Harare, Zimbabwe. pp. 25-28.

Dhurve, S.B. and Borle, M.N. (1986). Effect of sowing dates on gram pod borer damage *Heliothis armigera* (Hubner). *PKV Res. J*. **10**(1): 70-71.

Fitt, G.P. (1998). Host selection in Heliothinae. **In**: Reproductive Behaviour in Insects- Individuals and Populations. Eds. Bailey, W. J. and Ridsdill-Smith, T. J. London, UK: Chapman and Hall. pp. 172-201.

Garg, D.K. (1997). Seasonal abundance and host range of *Heliothis armigera* (Hub.) in the Kumaon Hills, India. *Inter. Chickpea Newsl.* **16**: 6.

Girhepuje, P.D., Wanjari, R.R., Kahare, N.P. and Supare, N.R. (1997). Efiicacy of synthetic insecticides in comparison with neem seed extract for the management of pod borer complex in pigeonpea. **21**(12): 45-48.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. (2nd ed). IRRI (International Rice Research Institute) and John Wiley and Sons, New York. p. 680.

Grainge, M. and Ahmed, S. (1988). Handbook of Plants with Pest Control Properties. Wiley, New York. p. 16.

Griffiths, D.C., Pickett, J.A., Smart, L.E. and Woodcock, C.M. (1989). Use of insect antifeedant against aphid vectors of plant virus disease. *Pestic. Sci*. **27**: 269-276.

Grubben, G.J.H. (1997). Tropical vegetables and their genetic resources. International Board for plant genetic resources, Rome, Italy. pp. 25-27.

Haque, M.M. (1991). Guidelines to vegetable production in Bangladesh, Handout for training on cropping systems BARI, Joydebpur, Dhaka, during 5-17 April 1982.

Hasanuzzoha, (2004). Environment friendly use of pesticides in field crop protection in Bangladesh and pre/post safety measures, Ph. D. thesis. IPM laboratory Institute of Biological sciences, University of Rajshahi, Bangladesh. pp. 30-32.

Hossain, A.M. (2015). Efficacy of Some Insecticides Against Insect Pests of Mungbean (*Vigna radiata*). *Bangladesh J. Agril. Res*. **40**(4): 657-667.

Hossain, Q.T. (1990). Status and management of vegetable pests in Bangladesh. **In**: Status and management of major vegetable pests in the Asia-Pacific region (With special focus towards integrated pest management). Technical highlights of the Expert consultation on integrated pest management (IPM) in major vegetable crops held from 14-16 November, 1988 at the Regional office for Asia and Pacific (RAPA,) Food and Agriculture Organization of the United Nations, Bangkok, Thailand. pp. 28.

ICRISAT. (1982). International Crops Research Institute for the Semi-Arid Tropics. Proceedings of the International Workshop on *Heliothis* Management, 15-20 November 1981, ICRISAT Center, Patancheru, A.P., India. p. 418.

Jackai, L.E.N. (1981). Relationship between cowpea crop phenology and field infestation by the legume pod-borer, *Maruca testulalis*. *Ann. Entomol. Sot. Am*. **14**: 402-408.

Jayaraj, S. (1982). Biological and Ecological Studies of *Heliothis.* International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Proceedings of the International Workshop on *Heliothis* Management, 15-20 November 1981. ICRISAT Center, Patancheru, India. pp. 35-36.

Joshi, B.G. and Sitaramaiah, S. (1989). Seed kernel as an oviposition repellent for *Spodoptera litura* (F.) moths. **7**: 199-202.

Kabir, K.H., Mia, M.D., Begum, R. and Bhuiya, S.I. (1983). Screening of country bean against pod borer. Bangladesh Horticulture. pp. 39-41.

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.

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

Karim, M.A. (1994). Vegetable and spices insect pests and their control. A lecture in training course on winter Vegetable and spices production. Horticulsture Research Development project. Joydebpur , Bangladesh. pp. 41-45.

Karim, M.A. (1995). Management of insect pests of vegetables. **In**: vegetable crops agribusiness. M.L. Chadha, K.U. Ahmad, S. Shanmugasundaram and A. Quasem 1995. (eds.). Proceeding of a workshop held at BARC, Dhaka, Bangladesh 2-4 May 1995. AVRDC, BARC, and BARI.

Kraus, W., Bokel, R., Klenk, A. and Pohnl, H. (1985). Constituents of neem and related species: A reversed structure of azadirachtin. Third Int. Conf. of 56 Chemistry and Biotechnology of Biologically Active Natural products (Sofia, Bulgaria, 1985), Abstr. pp. 446-450.

Lahm, G.P., Cordova, D. and Barry, J.D. (2009). New and selective ryanodine receptor activators for insect control. *Bioorg. Med. Chem.* **17**: 4127-4133.

Lalasangi, M.S. (1988). Bionomics, loss estimation and control of pod borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) on cowpea (*Vigna unguiculata*). *Mysore Journal of Agricultural Sciences.* **22:** 187- 188.

Lakshmanan, K. K. (2001). Neem a natural pesticide. *The Hindu, March* 1. P. 8.

Loganathan, M. (1992). Studies on the ecology and effect of host plants on the susceptibility of larvae of *Heliothis armigera* (Hubner) to insecticides. M. Sc. Thesis, Tamil Nadu Agricultural University, Coimbatore, India.

McNeil, J. N. (1991). *Behavioral ecology of pheromone-mediated communication in moth and its importance in the use of pheromone traps*. *Annu Rev Entomol.* **36**: 407–430.

Mollah, M.M.I., Rahman, M.M., Alam, M.Z. and Hossain, M.M. (2009). Yield Performance of Heat Tolerant Country Bean (*Lablab purpureus* Lin.) as Influenced by Insecticides during Kharif Season Journal of Entomology and Zoology Studies. **1**(3): 103-110.

Ogunwolu, E.O. (1990). Damage to cowpea by the legume pod borer, *Maruca testulalis* Geyer, as influenced by infestation density in Nigeria. *Tropical Pest Manage.* **36**(2): 138- 140.

Ohno, K. and Alam, M.Z. (1989). Ecological studies on cowpea borers. An evaluation of yield loss of cowpea due to the pod borers. **In**: Annual Research Review, 29 Jun 1989. Institute of Postgraduate Studies in Agriculture, Salna, Gazipur, Bangladesh. pp. 36-38.

Okeyo-Owuor, J.B., Agwaro, P.O. and Simbi, C.O.J. (1983). Studies on the legume pod borer *Maruca testularis* (Geyer) larval population, *Insect Sci. Applic.* **4**: 75-81.

Parsons, F.S., Hutchinson, H. and Marshall, J. (1991). Progress report from experimental stations, season 1936-37. Empire Cotton Growing Review 8, London, UK. p. 42.

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

Prakash, A., Rao, J., Jevari, S.N. and Gupta, S.P. (1990). Rice agro-ecosystem management by pesticides and its consequences. *Nat. Con. Publ. Growth Develop. Natural Res. Conservations*. pp. 131-137.

Prakash, A., Rao, J., Pasalu, I.C. and Mathur, K.C. (1987). Rice Storage and Insect Management. B. R. Publishing Corporation, New Delhi. p. 337.

Rahman, M.M. (1989). Pest complex of flower and fruits of pigeon pea and their control through insecticides application. *Bangladesh J. Sci. Res.* **7**(1): 27-32.

Rahman, M.M. (1991). Control measures for important insect pests of major pulses. Advances in pulses research in Bangladesh. **In**: Proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. pp. 139-146.

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.

Rajasekaran, B. and Kumarswami, Y. (1985). Antifeedent properties of certain plant products against *Spodootera litura* (F.). **In**: Proceedings of National Seminar on Behavioral Physiology, Tamil Nadu Agricultural University. pp.: 25-28.

Rashid, M.M. (1993). Begun Paribarer Shabji. **In**: Shabji Biggan (in Bangla). First ed. Bangla Academy, Dhaka, Bangladesh.

Reddy, K.V.S. (1993). Studies on the gram caterpillar, *Heliothis armigera* (Hub.) (Lepidoptera, Noctuidae) with special reference to its biology, host preference and estimation of loss in redgram. Ph. D. Thesis, University of Agricultural Sciences, Bangalore, India.

Reed, W. and Pawar, C.S. (1982). *Heliothis:* A global problem. **In**: Proceedings of the International Workshop on *Heliothis* Management, 15-20 November, 1981. ICRISAT Center, Patancheru, Andhra Pradesh, India. pp. 9-14.

Roome, R.E. (1995). Activity of adult *Heliothis armigera* with reference to the flowering of sorghum and maize in Botswana. *Bull. Ent. Res*. **65**(2): 523-530.

Roy, B., Amin, R., Uddin, M. N., Islam, A. T. M. S., Islam, M. J. and Halder, B. C. (2005). Leaf extracts of Shiyalmutra (*Blumea lacera* Dc.) as botanical pesticides against lesser grain borer and rice weevil. *J. Biol. Sci.* **5**(2): 201-204.

Sarder, M.A. and Kundu, C.D. (1987). A survey of damage estimation of bean pod borer, *Maruca testulalis* (Geyer) on country beans of Bangladesh. **In**: Proceedings of the l2th Annual Bungladesh Science Conference, Section 2. Bangladesh Association for the Advancement of Science, Dhaka, Bangladesh, pp. 18-19.

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 (limited distribution).

Schmutterer, H. (1995). Neem tree, source of unique natural products for integrated pest management, medicine, industry and other purposes VCH weinheim. p. 696.

Sharma, H.C. (1998). Bionomics, host plant resistance and management of the legume pod borer, *Maruca vitrata,* a review. *Crop Protection*. **17**(1): 373-386.

Simmonds, M.S.J, Vans, H.C. and Blaney, W.M. (1992). Pesticides for the year 2000: Mycochemicals and botanicals. Pest management and the environment in 2000. pp. 127-164.

Singh, H. and Singh, G. (1975). Biological studies on *Heliothis armigera* (Hub.) in Punjab. *Indian J. Ent*. **37**: 154-164.

Singh, J.P. (1983). Crop Protection in the Tropics. Vikas publishing House Pvt. Ltd. New Delhi 110002. pp. 192-202.

Singh, S.R. (1978). Resistance to pests of cowpea in Nigeria. **In:** Pests of Grain Legumes and Control. Singh, S.R., van Emden, H.F. and Taylor, T.A. (eds.). Academic Press, London. pp. 267-279.

Singh, S.R. and Allen, D.J. (1990). 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.

Singh, S.R. and Taylor T.A. (1978). Pest of grain legumes and their control in Nigeria. **In**: Pests of Grain Legumes: Ecology and Control. Singh, S.R., van Emden, H.F. and Taylor, T.A. (eds.). Academic Press, London, UK. pp. 99-111.

Sojitra, I. R. and Patel, J. R. (1992).Effects of plant extracts (including *Azadirachta indica*, *Ricinus communis* and *Pongamia pinnata*) on ovipositional behavior of spotted bollworm (*Earias vittella*) infesting okra (*Abelmoschus esculentus*). *Indian J. Agric. Sci.* **62**: 848-849.

Srivastava, A.S. and Saxena, H.P. (1978). Tissue borers problem and their control. *Proce. Ent. Res.* Workers Conf, Simla, India. pp. 109-114.

Srivastava, C.P., Pimbert, M.P. and Jadshav, D.R. (1992). Monitoring of adult population of *Maruca testutlalis* (Geyer) with light traps at Patancheru and Hisar in india. *Pigeon pea Newsl*. **15**: 27-28.

Tayaraj, K.K. (1982). Preliminary screening of chickpea genotypes for susceptibility to *Heliothis armigera* (Hub.) at Pantnagar, India. *Int. Chickpea Newsl*. **17**: 14-15.

Taylor, T.A. (1998). The bionomics of *Maruca testulalis* Gey. (Lepidoptera: Pyralidae), a major pest of cowpea in Nigeria. *J. West Africa Sci. Assoc.* **12**: 111-129.

Temple, J.H., Pommireddy, P.L., Cook, D.R., Marcon, P. and Leonard, B.R. (2009). Susceptibility of selected lepidopteran pests to Rynaxypyr®, a novel insecticide. *J. Cotton Sci.* **13**: 23-31.

Thompson, H.C. (1951). Vegetable crops. Fourth edition. McGraw Hill Book Company, Inc. London. p. 611.

Van Emden, H.F. (1980). Insects and Mites of Legume Crops. **In**: R. J. Summer field and A.H. Bunting (eds.), Advances in Legume Science, Vol.-I, Proceedings of the international legume Conference, Kew, 31 July - 4 August 1978, held under the auspices of the Royal Botanic Gardens, Kew, the Missouri Botanical Garden, and the University of Reading. pp. 187- 197.

Vijayakumar, A. and Jayaraj, S. (1981). Studies on the food plant ecology *of Heliothis armigera* (Hub.) (Lepidoptera, Noctuidae). *Indian J. Agric. Sci*. **51**(2): 105-110.

Warthen, J. D., Uebel, J., Dutky, E. C., Luspy, S. R. and Finegold, W. R. (1978). Adult house fly feeding deterrent from neem seeds. *USDA/SEA Agric. Res. Results, Northeast.* **2**(1): 1-11.

Zalucki, M. P., Daglish, G., Firempong, S. and Twine, P. (1986). The biology and ecology of *Heliothis armigera* (Hubner) and *Heliothis punctigeran* (Lepidoptera, Noctuidae)). *Indian J. Agric. Sci*. **61**(2): 100-102.

CHAPTER VII

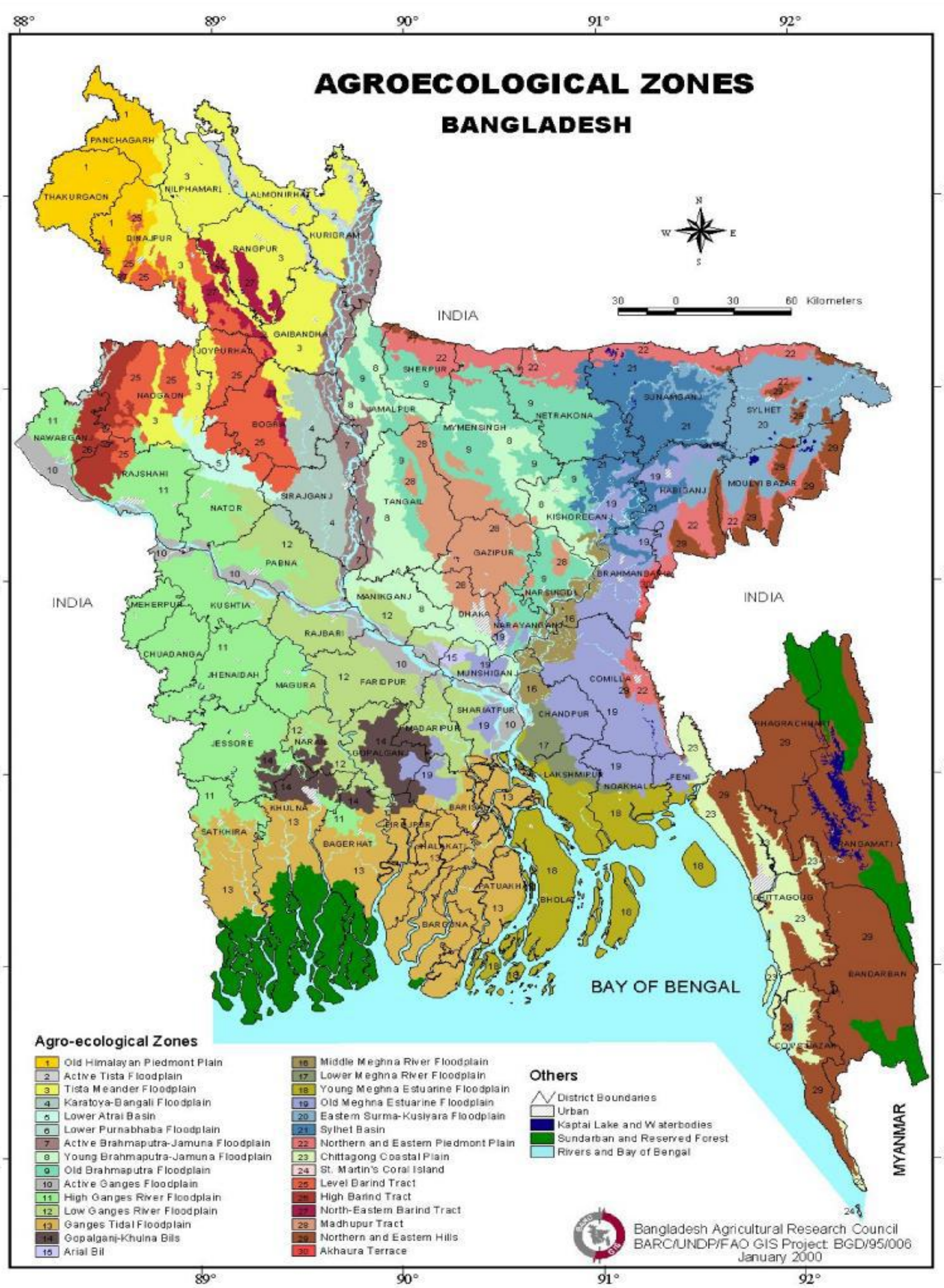
APPENDICES

Appendix I. Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2016 to February 2017

Date/Week	Air temperature (^{0}C)		R. H. (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
November, 2016	25.8	16.0	78	0
December, 2016	22.4	13.5	74	0
January, 2017	24.5	12.4	68	0
February, 2017	27.1	16.7	67	30

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

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



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

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

CONSTITUENTS	PERCENT
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

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

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

Appendix IV. Cost incurred per hectare in different control measures applied against bean pod borer during Rabi, 2017 at SAU, Dhaka

[a] = Labor cost 500.00 Tk/day; [b] = Pheromone trap set 30.00 Tk/set; [c] = Lure 16 Tk/lure; [d] = Fytomax (0.03 EC) 250 ml = 450.00 Tk.; [e] = Actara (25 WG) 100 g = 210 Tk.; [f] = Cot (10 EC) 200 ml = 350 Tk.

Treatment	Items of expenditure	Cost (Tk)
T_1=Neem oil (3 ml Neem Oil + 10 ml Trix + 1 L Water @ 7 days interval)	Total no. of labors for spraying insecticide 1x500[a] Neem oil Trix **Total cost**	4000.00 444.44 1777.78 **6222.22**
T_2=Neem seed kernel extract (0.5 ml per liter of water at 7 days interval	Total no. of labors for spraying insecticide 1x500[a] Neem seed kernel extract **Total cost**	4000.00 446.00 **4446.00**
T_3=Pheromone Trap (lure + soap; @ 4 days interval)	Total no. of labors for giving treatment 1x500[a] Pheromone trap set (for 3 replications) x 30[b] Lure (for 3 replications) x 16[c] Wheel powder **Total cost**	6000.00 180.00 96.00 120.00 **6396.00**
T_4=Fytomax 0.03 EC (0.4 ml per water @ 7 days interval)	Total no. of labors for spraying insecticide 1x500[a] Fytomax 0.03 EC (for 8 sprays) x 0.75[d] **Total cost**	4000.00 1150.00 **5150.00**
T_5=Actara 25 WG (0.3 g per liter of water @ 7 days interval)	Total no. of labors for spraying insecticide 1x500[a] Actara 25 WG (for 8 sprays) x 0.65[e] **Total cost**	4000.00 711.00 **4711.00**
T_6=Cot 10 EC (0.4 ml per liter of water @ 7 days interval)	Total no. of labors for spraying insecticide 1x500a Cot 10 EC (for 8 sprays) x 0.7[f] **Total cost**	4000.00 855.56 **4855.56**
T_7= T_1+ T_3	Total no. of labors for giving treatment 1x500[a] Neem oil Trix Pheromone trap set (for 3 replications) x 30[b] Lure (for 3 replications) x 16[c] Wheel powder **Total cost**	4000.00 444.44 1777.78 180.00 96.00 120.00 **6618.22**
T_8= T_2+ T_3	Total no. of labors for giving treatment 1x500a Neem seed kernel extract Pheromone trap set (for 3 replications) x 30[b] Lure (for 3 replications) x 16[c] Wheel powder **Total cost**	4000.00 446.00 180.00 96.00 120.00 **4776.00**
T_9 (Untreated control)	No management cost at all	00.00