EVALUATION OF DIFFERENT MANAGEMENT PRACTICES IN CONTROLLING MAJOR INSECT PESTS OF COUNTRY BEAN

A THESIS

BY

ROKSANA AKTER

MASTER OF SCIENCE
IN
ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA-1207, BANGLADESH

JUNE, 2013

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BY
ROKSANA AKTER

REGISTRATION NO. 06-02116

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

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2013

Approved by

...…………………………………	....
Prof. Dr. Md. Mizanur Rahman	**Prof. Dr. Md. Razzab Ali**
Supervisor	**Co-Supervisor**

……………………………..

Dr. Tahmina Akter
Chairman
Examination Committee

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

CERTIFICATE

This is to certify that thesis entitled, **"EVALUATION OF DIFFERENT MANAGEMENT PRACTICES IN CONTROLLING MAJOR INSECT PESTS OF COUNTRY BEAN"** 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**, embodies the result of a piece of bona fide research work carried out by **ROKSANA AKTER, Registration no. 06-02116** 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.

Date: June, 2013
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Mizanur Rahman)
Research Supervisor

DEDICATED TO MY BELOVED PARENTS AND FAMILY MEMBERS

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah, who enabled the author to pursue her education in Agriculture discipline and to complete this thesis for the degree of Master of Science (M.S.) in Entomology.

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

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

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

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

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

Dated: June, 2013 **The Author**

SAU, Dhaka

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LIST OF SYMBOLS AND ABBREVIATION

SYMBOLS AND ABBREVIATIONS	FULL WORD
%	Percent
et all	And others
J	Journal
No.	Number
Cm	Centimeter
Agric.	Agriculture
ºC	Degree centigrade
Etc.	Etcetera
TSP	Triple Super Phosphate
MP	Murate of Potash
BARI	Bangladesh Agricultural Research Institute
LSD	Least Significant Difference
RCBD	Randomized Completely Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Viz.	Namely
@	At the rate of
BRRI	Bangladesh Rice Research Institute
i.e.	That is
BBS	Bangladesh Bureau of Statistics
CV%	Percentage of Co-efficient of Varience
g	Gram
kg	Kilogram
mg	Miligram
t	Ton
Agril.	Agricultural
BARC	Bangladesh Agricultural Research Council
UNDP	United Nations Development Programme
AEZ	Agro-ecological Zones

EVALUATION OF DIFFERENT MANAGEMENT PRACTICES IN CONTROLLING MAJOR INSECT PESTS OF COUNTRY BEAN

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ABSTRACT

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to evaluate the performance of different management practices in controlling major insect pests of country bean (BARI seem-3) during the period from June to December, 2012. The experiment consists of the following management practices: T_0: Untreated control; T_1: Hand picking of infested plant parts at 7 days interval; T_2:Release of *Trichogramma evanescence*@ 0.5 g/6 m^2 at 15 days interval T_3:Spraying of neem oil @ 4ml/L of water at 7 days interval ; T_4: Spraying of neem oil @ 4ml/L of water + Hand picking of infested plant parts at 7 days interval and T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In consideration of total growing period by number the % pods infestation, the lowest infested pods plant^{-1} by number was observed from T_5 (7.13%), where the highest pod infestation was found from T_0 (21.63%), % pod infestation in weight, the lowest infested pods plant^{-1} was observed from T_5 (7.09%), whereas the highest in T_0 (21.40%). The highest no. of inflorescence plant^{-1} was observed from T_5 (37.00) while the lowest no. was observed from T_0 (31.50) treatment. The highest yield hectare^{-1} was found from T_5 (15.97 ton), while the lowest yield hectare^{-1} was found from T_0 (10.71 ton) treatments. The pod yield of country bean was highly significant (p=0.01), strong (r=0.982) and negatively correlated with pod infestation by number i.e., the yield was decreased with the increase of pod infestation by number. Considering the controlling of country bean insect pests with some control options where, highest benefit cost ratio (4.21) was recorded in the treatment T_5 and the lowest benefit cost ratio was recorded from T_1 (1.32). The pod yield of country bean was highly significant (p=0.01), strong (r=0.977, r=0.813, r=0.981, r=977) and positively correlated with no. of pods inflorescence^{-1}, pod length, no. of inflorescence plant^{-1}, no. of flower inflorescence^{-1} i.e., the yield was increased with the increase of pods inflorescence^{-1}, pod length, no. of inflorescence plant^{-1}, no. of flower inflorescence^{-1}. From the study, it may be concluded that treatment T_5 which comprised with the spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5g/6m^2 at 15 days interval was more effective among the management practices for controlling majot insect pests of country bean which was followed by spraying of neem oil @ 4ml/L of water +Hand picking of infested plant parts at 7 days interval.

CHAPTER I

INTRODUCTION

The country bean (*Lablab purpureus* Lin.) belongs to the family Leguminosae and sub-family Papilionaceae, is an important vegetable-cum-pulse crop. This bean is well known as Seem and also frequently known as Hyacinth bean, Indian bean, Egyptian kidney bean and Bovanist bean (Rashid, 1999). The crop is very popular for its tender pods, which are consumed mostly as vegetables, sometimes as pickles. It contains 4.2 g protein, 110 mg calcium, 4.7 mg iron, 2.4 mg vitamin A and 35 mg vitamin C in 100 g edible parts. Its tender seeds are also used as vegetables; however, the matured and dried seeds are used as pulses. In Bangladesh, the crop is usually grown in winter. But recently, a number of photo-insensitive and summer varieties are developed, which helped to promote the cultivation of country beans year round including summer. Its cultivation intensity is found in Dhaka, Jessore, Comilla, Noakhali and Chittagong, but for the last ten years it has been seen growing extensively in Khulna and Barisal region as well (Aditya, 1993). In Bangladesh, yearly about 40,992 metric tons of country beans were produced from 88,581 hectares of land (BBS, 2010).

In spite of being a prospective crop, high incidence of insect pests are one of the main factors for the reduction of its yield and quality. Farmers in our country faced various problems including the availability of quality seeds, fertilizer and manures, irrigation facilities, modern information in the fields, technical and instrumental inputs, pests and disease in cultivation of the crop (Rashid, 1999). Among these problems, occurrence of frequent insect pest attack has been most important. Reports revealed that in Bangladesh, over 30 different species of arthropods have been reported in country bean, although only a few occur regularly and cause economic damage (Karim, 1995; Das, 1998; Islam**,** 1999). Among the insect pests, the pod borer, *Maruca vitrata* (Fabricius), is considered as one of the major pests of country bean in Bangladesh. Bean pod borer is able to establish itself from vegetative to reproductive stage of country bean.

At the early stage of plant growth, the bean pod borer, attack the crop making clusters of leaves, tendrils and young shoots of the plant and later at flowering and pod setting stages of plants. The insect bore into these reproductive organs of country bean, where the insect feeds internally (Karim, 1993).

Bean pod borers frequently feed internally on infested plant parts while living inside the clusters or pods, insecticide applications, particularly a single application, may often fail to provide successful control of the pest (Begum, 1993; Rahman, 1989). Bean pod borer population has been found to reduce up to 100% of crop yields in Bangladesh (Rahman *et al.*, 1981). Farmers in Bangladesh frequently require application of different control measures to suppress the population of the pest and thereby to protect their crops from insect pest infestation (Rahman and Rahman, 1988; Begum, 1993). There are several pest control methods for controlling bean pod borer, such as cultural (Sharma, 1998), natural and applied biological (Karim, 1995) and chemical control measures (Rahman and Rahman, 1988). But the fact is that still now the farmers mostly dependent solely on chemical insecticides to control the pest infesting country beans. Such an over reliance on insecticides for controlling insect pests in crop fields has developed over generations (Islam, 1999). Insecticides commonly used, however, are not specific and they frequently kill natural enemy populations and may cause upset and resurgence of other pest populations (Debach and Rosen, 1991; Pedigo, 1999).

A survey on pesticide use in vegetables conducted in 1988 revealed that only about 15% and 16% of the farmers received information from the pesticide dealers and extension agents respectively (Islam, 1999). In most of the cases, the farmers either forget the instructions or did not care to follow those instructions and went on using insecticides at their own choice or experience. Some farmers believed that excess use of insecticide could solve the insect pests problem. As a result, harmful impact of insecticides on man, animal, wild life, beneficial insects and environment is imposing a serious threat. Indiscriminate uses of insecticides are reported to cause insecticide resistance in insect pests, resurgence and secondary pests out break. The accumulation of insecticide residues in food is increasing at an alarming rate. So there is a reason of human health hazards due to these detrimental toxicants.

The use of chemical insecticides is very costly for growers and not environmentaly safe. On the other hand biological control aims at suppressing the pest species by using natural enemies of the pest with least or no emphasis on the use of insecticides. Beside these use of bioagent and botanicals has been reported to reduce pest population as well as ecofriendly, no evidence of arising pesticide resistance and resurgence etc. (Mani *et al.* 2005).

Under these circumstances, it becomes necessary to find out some eco-friendly alternative methods for insect pest management of country bean. The manipulation of the cultural practices like changing the dates of sowing, using various levels of different fertilizers, intercropping with different companion crops, screening of genotypes resistant to pest and using botanical and bioagents can be ecofriendly components in formulating the integrated pest management approach. Application of neem oil is a promising and less exploited approach in this context. In Bangladesh sufficient information on the pest management of country bean is not available so far and no in-depth studies have been made. Considering the above perspective for the effective control of the insect pest of country bean the present study has been undertaken with fulfilling the following objectives.

- To find out the performance of different control measures against the major insect pests of country bean.
- To develop a suitable management technique for controlling the insect pests of country bean.
- To determine the benefit cost ratio (BCR) in relation of different control measures.

CHAPTER II

REVIEW OF LITERATURE

Country bean is one of the important vegetable cum pulse crop in Bangladesh as well as many countries of the world. Insect pests, which cause colossal losses to bean crops, are serious problems. Farmers mainly control insect pests through use of different chemicals. But the concept of management of pest employing eco-friendly materials gained momentum as mankind became more safely about environment. Use of botanicals and bio-control agents is the recent approaches for pest control that was commonly practiced. Information related to management of insect pests of country bean using botanicals and bio-control agents is very limited. Nevertheless, some of the important and informative works and research findings related to the control of insect pest of bean through botanicals, chemical and bio-control agents so far been done at home and abroad have been reviewed in this chapter.

2.1 Pest complex of country bean

The pest spectrum of a crop generally can vary geographically and temporally (Pedigo, 1999). It appears that there have been variations of country bean pest complex in different countries and parts of the season. In Bangladesh, country bean has been infested with various species of aphids including *A. craccivora and A. medicagenis* Koch (Homoptera: Aphididae); bean bug, *Coptosoma cribrarium* Fb. (Hemiptera: Plataspidae); green semi-looper, *Plusia oricalchea* Fb. (Lepidoptera: Pyralidae); hooded hopper, *Leptocentrus tarus* Fb. (Homoptera: Membracidae); leaf miner, *Cosmopterix spp.* (Diptera: Agromyzidae); leaf weevil, *Blosyrus onisctts Ol.* (Coleoptera: Curculionidae); pod borer, *Maruca sp.* (Lepidoptera: Pyralidae); shoot borer, *Sagra carbunchulus H.* and, *S. femorata D.* (Lepidoptera: Pyralidae); shoot weevil, *Alcides collaris P.* (Coleoptera: Curculionidae) and the mite, *Tetranychar spp.* (Acarina) (Begum, 1993; Das, 1998; Islam, 1999). Among these insect pests, only a few species occur in most places of the country, and may often cause economic damage.

Alam (1969) stated that there had been nine species of arthropod pests regularly occur in country bean fields, although only three species of insects including aphid, bean bug, leaf miner and one species of mites caused economic damages to the crop during 1970s in Bangladesh. It appears that with the progress of time there has been a shift in the assemblages of arthropod pest species in fields of the crop, particularly in Central Bangladesh. In 1990s, the major arthropod pests of country beans in Bangladesh were the aphid, *A. craccivora*, the pod borers, *Maruca vitrata* (*testulalis*) and *Helicoverpa armigera*, and the red mite, *Tetranychus sp.* Das (1998) reported that there were five species of arthropods causing major damages to country bean; these included the aphid, *Aphis craccivora*; leafminer, *Cosmopteris sp.*; leaf paster, *H. indica*; pod borer, *M. vitrata* and the mite, *Tetranychus* sp. in different places of Bangladesh. It appears that the black bean aphid, *Aphis craccivora*, and the pod borer, *M. vitrata*, are common everywhere in Bangladesh (Karim, 1995; Das, 1998; Islam, 1999) and the infestation of the pest can often be so severe that the economy of the bean growers can be heavily affected in this country.

In east Africa, more than 50 arthropod pests are reported and the pestiferous effects of these insects vary across the continent (Singh, 1983). He also noted that in addition to the 50 insects known so far, there might have been some other insect pests and mites causing damage to the crop but they have been ignored because of the inconspicuous presence and activities of those pests. However, he noted that despite the occurrence of a large number of arthropod pests, only a few occur more frequently and can cause significant damage to the crop. These include mainly the bean flies, black bean aphids and pod borers in many east African countries. Many pestiferous arthropods occur in America and some of them inflict severe damage to several legume crops including beans. In Hawaii, legume pod borer have been ubiquitous causing severe damage to beans including lima beans (Holdaway and Look, 1942).

In India, country bean has been reported to be attacked by more than 57 species of pestiferous arlhropods (Govindan, 1974). In northern India, country beans have been reported to be frequently attacked by the galerucid beetle, *Madurasia obscurella* Jacob (Coleoptera: Chrysomelidae), which may cause economic damage to the crop (Gupta and

Singh, 1978). Naresh and Nene (1968) and Saxena (1976) have also reported that galerucid beetles and some other insect pests including various aphid species; hooded hopper, *Leptocentrus taurus* Fb. (Homoptera: Membracidae); leaf beetle, *Sagra carbunculus* Hope (Coleoptera: Chrysomelidae); leaf-eating caterpillars, *Plusia oricalchea* Fb. (Lepidoptera: Pyralidae); leaf miner, *Cosmopterix* sp. (Lepidoptera: Pyralidae); leaf weevil, *Blosyron oniscus* Ol. and *Alcides collaris* P. (Coleoptera: Curculionidae); pod borer, *Maruca* sp. (Lepidoptera: Pyralidae); and mites, *Tetranychus* sp. (Acarina), attack country beans in different parts of India and the subcontinent. Singh (1983) also stated that there might have been 30 more species of arthropods associated with bean crops, but their inconspicuous nature probably caused them to be ignored. In Burma, country beans have been reported to be attacked by 14 arthropods pests, although it is not clear which ones are of major importance in terms of damage (Butani and Jotwani, 1984).

Among the major insect pests, bean pod borer and aphids occur frequently. Because of their high reproductive capacity and population of aphids can often be too high to make concerns to farmers. In addition, aphids can transmit diseases to plants, which make them a potential pest of crops, particularly at favorable environmental conditions of the pest. Aphid, *Aphis craccivora* is cosmopolitan in distribution and the insects damage different crops in the temperate, tropic and subtropics continents (Hill, 1983; Butani and Jotwani, 1984). In general, colonies of aphids start from a few individuals arriving from an infested area (Alam, 1991). Upon arrival, the insects reproduce rapidly and build up the colony. On country beans, aphids suck plant sap from underside of young leaves, tender twigs and shoots (Hill, 1983; Singh, 1983; Butani and Jotwani, 1984; York, 1992). When plants are heavily infested, leaf distortion and stunting frequently occur, which often result in poor fruit setting. In addition to the damage caused by feeding, aphids also damage the crop by acting as a vector of diseases (Butani and Jotwani, 1984). Although aphids can cause damages by sucking plant sap and transmitting diseases, unless their population goes extremely high, aphids usually cause little damage through direct feeding activities. In addition, aphid populations are often suppressed naturally by a complex of predators including ladybird beetles (Coleoptera: Coccinellidae), lacewings (Neuroptera: Chrysopidae), syrphid flies (Dipetra: syrphidae), various species of insect parasitoids and other natural enemies. As a result, in most crop fields, aphid populations do not require to be suppressed by artificial pest management practices (Pedigo, 1999).

On the other hand, the legume pod borer, (*M. vitrata* F.) has been considered as a serious pest of grain legumes in the tropics and sub- tropics because of its extensive host range, destructiveness and wider distribution (Taylor, 1967; Raheja, 1974). Dina (1979) and Baker *et al.* (1980) found that it is a serious insect pest of leguminous vegetables. In most places of its distribution, population of *M. vitrata* frequently reaches economic threshold levels causing enormous economic losses; to prevent rises to such damaging populations of the pest farmers frequently require application of control measures, particularly insecticides (Taylor, 1967). In Bangladesh, pod borers have been frequently attacking various crops including country beans and causing enormous amount of damages to the crop (Alam, 1969; Rahman and Rahman, 1988; Karim 1993).

From the reviewed findings revealed that the pest spectrum of country bean can vary geographically and temporally and there have been variations of pest complex in different countries and parts of the season. In Bangladesh, over 30 different species of arthropods have been reported in country bean, although only a few occur regularly and cause economic damage. Among the insect pests, the pod borer, *Maruca vitrata* (Fabricius), is considered as one of the major pests of country beans in Bangladesh. Therefore, interests in the present study have been concentrated on the legume pod borer with other major common pests of country bean. From hereon, discussion will be dedicated mostly to the legume pod borers and other pests in the following sections and their control measures.

2.2 Pest status and host range of bean pod borer

Jayaraj (1962) 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, pigeonpea, cowpea, peas, various beans, cotton, sunflower, safflower, tobacco, tomato, brinjal, cucurbits, sweet potato, groundnut, flax, citrus, sunhemp, potato etc. Bhatnagar and Davies (1978) reported 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) observed 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 (1987) 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 pointed out 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 (1991) cited from an experiment conducted in the south Asian region that *Helicoverpa* was a serious pest of cotton, chickpea, pigeon pea, groundnut, cowpea, *Vigna* species, okra, tomato, castor, sunflower, maize, sorghum and many other crops.

2.3 Biology of pod borer

2.3.1 Host preference for oviposition

Parsons *et al.* (1937) reported that chickpea was most attractive for oviposition of pod borer, while Reddy (1973) and Loganathan (1981) 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, pigeonpea > fieldpea > chickpea> tomato> cotton> chillics> mungbean> sorghum.

2.3.2 Mating and oviposition

The eggs were laid singly, late in the evening, mostly after 2100 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,1965).

Roome (1975) 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) found 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 2100 hours and continued up to midnight. However, maximum numbers of egg were laid between 2100 and 2300 hours. The moths did not oviposit during the daytime. Loganathan (1981) observed peak mating activity at 04.00 hr.

Dhurve and Borle (1986) cited that the pod 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) reported 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.

Bhatt and Patel (2001) cited that 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.

2.3.3 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, 1958; Singh and Singh, 1975).

2.3.4 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. Crochets are arranged in biordinal symmetry on the prolegs. 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 (Neunzig, 1964; Singh and Singh, 1975).

Temperature affects the development of the larva considerably. The larval duration varied from 21 to 40 days in California, 18 to 51 days in Ohio, and 8 to 12 days in the Punjab, India (Singh and Singh, 1975). The larval stage lasted for 21 to 28 days on chickpea (Srivastava and Saxena, 1958); 2 to 8 days on maize silk; 33.6 days on sunflower corolla (Coaker, 1959).

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.

2.3.5 Pupa

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 (Singh and Singh, 1975). 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, 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.

2.3.6 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.(Jayaraj,1982).

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.

2.3.7 Generations

Hsu *et al*., (1960) observed three generations of *H. armigera* each year in China while Reed (1965) 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. Bhatnagar (1980) observed that seven to eight generations of *H. armigera* were present each year in Andhra Pradesh, India.

2.5 Pest status and host range of bean aphid

There are two species of aphids are serious pests of country bean (hyacinth bean) in Bangladesh and other parts of India. The bean aphid species in India has been reported to be *Aphis craccivora*. In Bangladesh the bean aphid species has been reported to be *Aphis medicagenis*. These aphids have a wide range of hosts. Special mention may be made of cruciferous vegetables, such as cabbage, cauliflower, turnip, radish and sarson and other vegetables.

2.6 Life history of bean aphid

The males are rare in *Aphis craccivora*. The adult females are greenish-black in colour and both the winged and wingless forms are seen. Aphids reproduce parthenogeneticaly and viviparously in crop fields. Their reproductive life lasts for 5 to 8 days during which a single female can give birth to 15 to 20 offspring. The nymphal period is very short. This aphid multiplies at a very rapid rate during the winter. It probably infests some plant species during the summer months and remains hidden in those summer hosts (Suganthy and Kumar, 2000).

2.7 Control of insect pests in country bean

As summarized in the previous section, being one of the most frequently occurring and damaging insect pest of different legume crops including country beans, pod borers received interests from people involved in both research and business across continents (Singh and Allen, 1980) There have been growing interests in controlling the insect pest of country bean. Several methods including cultural, mechanical, biological and chemical methods are available for controlling the pest in field crops. Despite the availability of various pest control methods, application of synthetic chemical insecticides appears to be the most common means of controlling legume pests, a trend consistent with most pests in field crops (Debach and Rosen, 1991; Pedigo 1999). The management practices that have been commonly used for controlling insect pests including pod borers are reviewed and discussed below. For convenience, the methods have been discussed in four major categories, non-chemical, use of botanicals, biological control and integrated pest control methods.

2.7.1 Non-chemical control

Farmers believe that insecticides are the only method to control insect pest. This mental make up has been created from their practice of using insecticides to control the insect pests attacking their crops over many years (Islam, 1999). Moreover, the government's policy of giving 100% subsidy on pesticides i.e., giving the pesticides free of cost to the farmers had helped encourage and develop the habit of indiscriminate use of pesticides among the farmers. This is serious basic problem in achieving success in IPM programs.

The populations of *Maruca testulalis* were fluctuated with agro meteorological factors. The distribution of rainfall over time is more crucial than the total amount in determining the fluctuations of pod borer populations. Thus, the adjustment of planting dates is suggested as an IPM tactic to avoid the development of damaging levels of pod borer infestations (Alghali, 1993).

The populations of legume pod borers are frequently suppressed naturally by environmental factors including temperature, humidity and photoperiod (Karim, 1995). Among the environmental factors, rainfall appeared to be one of the important key factors; the distribution of rainfall over time is more critical than the total amount in determining pod borer populations. Thus, the adjustment of planting dates in such a way that the crop receives rainfall for a considerable period from flowering to harvest has been suggested as a component of a pest management system that is structured in an Integrated Pest Management (IPM) set up. The pod borer infestation increases on the late sown crop (Alghali, 1993). Again, pod borer population tends to build up over the season (Ekesi *et al.*, 1996). In such a case, yield may be affected, as is the case with cowpea, grain yield of which decreases in late planted crops (Ezueh and Taylor, 1984). In such a case, early planting might help reduce legume pod borer infestation.

Cropping system has profound effect on pod borer infestation. As a cultural practice of controlling pod borer infestation, intercropping has been successfully used. It has been reported that pod borer damage in a monocrop is greater than the maize-cowpea-sorghum crop grown as intercrops (Amoako-Atta *et al.*, 1983; Fisher *et al.*, 1987; Omolo *et al.*, 1993). Karel (1993) also reported that pod borer incidence was significantly lower in intercropped than in pure stands. In contrast, Alghali (1993), Ofuya (1991), Natarajan *et al.* (1991), Patnaik *et al.* (1989) and Saxena *et al.* (1992) reported no effect of intercropping on the incidence of *Maruca vitrata.* This suggests that the success of the adjustment of cropping time and system in reducing the pod borer infestation may vary depending upon the crop and time of the season.

As a cultural mean of controlling pod borers, adjustment of plant density can be another option. Plant density has been found to affect pod borer activities. Karel (1993) found that at higher plant densities of common bean, *Phaseolus vulgaris*, pod borer infestation was reduced compared with a lower plant population. In the context of country bean production in Bangladesh, there has been little information regarding pod borer control by using cultural methods of pest control. Research in this regard may be helpful to come by some cultural tools that could be integrated with other methods of pest control.

2.7.2 Use of botanicals

The use of locally available plants, such as *Derris, Nicotiana* and *Ryania*, is an ancient way to control pests during prehistoric period. Pesticidal plants were used widely until 1940s, then they were alternated by synthetic pesticides as they are easier to handle and lasted longer. Pesticides are the substances or mixture of substances used to prevent, destroy, repel, attract, sterilize or mitigate the pests. The consumption of pesticide in some of the developed countries is almost 3000 g ha^{-1}. Over enthusiastic use of synthetic insecticides led to problems unforeseen at the time of their introduction. Pesticides are generally persistent in nature. The World Health Organization (WHO) estimates that 200,000 people are killed worldwide, every year, as a direct result of pesticide poisoning. Moreover, the use of synthetic chemicals has also been restricted because of their carcinogenicity, teratogenicity, high and acute residual toxicity, ability to create hormonal imbalance, spermatotoxicity, long degradation period and food residues (Dubey *et al*., 2011; Pretty, 2009; Feng and Zheng, 2007; Khater, 2011)

The plant kingdom is recognized as the most efficient producer of chemical compounds, synthesizing many products that are used in defense against different pests (Isman and Akhtar, 2007).

Botanical extracts induce insecticidal activity, repellence to pests, antifeedant effects and insect growth regulation, toxicity to nematodes, mites and other pests, as well as antifungal, antiviral and antibacterial properties against pathogens (Prakash and Rao, 1986, 1997).

2.7.2.1 Use of neem

Neem *(Azadirachta Indica*) seed oil, a botanical pesticide have also been used to control different insect pests of important agricultural crops in different countries of the world. More than 2000 species of plants have been reported to posses insecticidal properties (Grainge and Ahmed, 1988). The neem tree *(Azadirachta indica*) is one of them. Neem controls gypsy moths, leaf miners, sweet potato whiteflies, western flower thrips, loopers, caterpillars and mealybugs as well as some of the plant diseases, including certain mildews and rusts (Dubey *et al*., 2011). Neem is also effective against arthropods of medical and veterinary importance, such as lice, mite, tick, fleas, bugs, cockroaches and flies (Mehlhorn *et al*., 2011). The development and use of botanical pesticides become an integral part of the integrated pest management (IPM) strategies. Form Ecological and environmental stand points, neem is non toxic to fish (Wan *et al*.,1996), natural enemies and pollinators (Naumann and Isman, 1996), birds, other wild life and aquatic organisms as azadirachtin, breaks down in water within 50B100 h. It is harmless to non-target insects (bees, spiders and butterflies).

Stoll (1992) summarized the potential benefits of botanical pesticides which diminish the risk of resistance development, natural enemy elimination, secondary outbreak of pest and ensure overall safety to the environment.

The seed and leaves of the neem tree contain terpenoids with potent anti-insect activity. One of the most active terpenoids in neem seeds is “azadirachtin” which acts as an antifeedant and growth disrupter against a wide range of insect pest at microgram levels.

The active terpenoids in neem leaves include nimbin, deactylnimbin and thionemone (Simmonds *et al.*, 1992). Azadirachtin induce no accumulations in the soil, no phytotoxicity and accumulation seen in plants and no adverse effect on water or groundwater (Mehlhorn *et al*., 2011).

During last two decades neem oil and extracts from leaves and seeds have been evaluated as plant protectant against a wide range of arthropod and nematode pests in several countries of the world. Although, most of the trails are laboratory based but it is not scanty in case of field condition. Ketkar (1976) reviewed 95 and Jacobson (1985) reviewed 133 papers on neem and documented neem's potential in the management of arthropods pests (Warthen, 1979).

Ahmed and Grainge (1985) and Saxena (1988) summarized the effectiveness of neem oil against 87 arthropods and 5 nematodes, 100 insects and mites and 198 different species of insects, respectively.

Experiment with botanical pesticides has also been conducted in Bangladesh on a limited scale. Islam (1983) reported that extract of leaf, seed and oil of neem, showed potential as antifeedants or feeding and oviposition deterrents for the control of brown plant hopper, green leaf hopper, rice hispa and lesser rice weevil. He also conducted experiments to asscertain the optimal doses of the extract against rice hispa, and pulse beetle. Addition of sesame or linseed oil to extract of neem resulted in higher mortality of the grubs and in greater deterrence in feeding and oviposition compared to those obtained with extract alone (Islam, 1986).

Field trail with neem products have shown, not only a decrease in damage by pest but also an increase in crop yield compared to those obtained with recommended synthetic insecticides. A methanol suspension of 2-4% of the neem leaves have been used against the caterpillar of diamondback moth, *Plutella xylostella* and it was as effective as either synthetic insecticides mevinphous (0.05%) or deltamethrin in (0.02%) in Togo (Dreyer, 1987). In Thailand, a field trail showed that piperanyl butoxide increased the efficacy of neem and the combination was as active as cypermethrin (0.025%) against *Plutella xylostella* and *Spodoptera litura*, which revealed that neem oil with synthetic insecticides may have some synergetic effect in controlling insect pests (Sombatsiri and Tigvattanont, 1987). Fagoonee (1986) used neem in vegetable crop protection in Mauritius and showed neem seed kernel extract was found to be effective as deltamethrin (Decis) against the *Plutella xylostella* and *Crocidolomia binotalis.* He also found neem extract alternate with insecticides gave best protection against *Helicovarpa armigera.* Neem product have been used to control vegetable pests under field condition and good control of *Plutella xylostella* and Pyralid, *Hellula undalis* on cabbage was achieved with weekly application of 25 or 50 gm neem kernel powder/liter of water (Dreyer, 1987). The leaf extract of neem tested against the leaf caterpillar of brinjal, *Selepa docilis* Bult. at 5% concentration had a high anti-feedant activity with a feeding ratio of 28.29 followed by 3% having only medium anti-feedant properties with 23.89 as the feeding ratio (Jacob and Sheila, 1994).

Entomologists of many countries including India, The Philippines, Pakistan and Bangladesh have conducted various studies of neem against different insect pests. Most of the cases the investigators have been used a particular concentration of the neem extract. Neem seed kernel extracts (3-5%) were effective against *Nilaparvata lugens, Nephotettix* spp., *Marasmia patnalis, Oxya nitidula* and Asian gall midge. Neem leaf extract, however, is less effective than neem seed kernel extract. But the same extract of 5-10% was highly effective, inclusive of *Scirpophaga incertulas* and thrips (Jayaraj, 1982). Damage by leaf folders was reduced by 3% neem oil. Neem seed kernel extracts reduced egg deposition on rice seedling by *Nephotettix* spp. and *Nilaparvata lugens*. Neem seed kernel extract was an effective antifeedent to pigeon pea pod borer. He also found that there has been no adverse effect, even though neem was systemic. According to him neem oil can be used @ 1-3% without any problem. But 5% neem oil will cause phytotoxicity in many plants. The effect of neem oil is systemic, though not persistent. It should be noted that application of neem oil beyond 5% will cause serious phytotoxicity in rice. At 3%, the initial phytotoxicity effects are minimum and the plant can recovered completely. Thus, neem oil should be applied at concentrations not beyond 3% (Jayaraj, 1982).

Most of the cases, the user of neem oil use it at different doses ranged from 0.5-50% (Krishnaiah and Kalode, 1991). They use different emulsifier to mix neem oil with the water. Neem oil normally stays separately on the upper surface of the water. Detergent in water helps neem oil to emulsify in the water. In a field observation of neem oil Krishanaiah and Kalode (1991) used soap as emulsifier with water, although they have never mentioned the dose of the emulsifier in their trail. Another study with neem oil in rice field, Palanginan and Saxena (1991) added 1.66% teepol (liquid detergent) to the extract solutions as an emulsifier.

Visalakshimi *et al*. (2005) reported that application of neem effectively reduced the oviposition of *H.armigera* througout the crop period. Among various IPM components (neem 0.06%, HaNPV 250 L/ha, bird perches one/plot, endosulfan 0.07%), neem and HaNPV found as effective as endosulfan in the terms of reduction larval population and pod damage,

The feeding detergency of neem (*Azadirachta indica*) oil (1.0, 1.5 and 2.0%) and neem cake extract (1.0, 3.0 and 5.0%) were evaluated by Revathi and Kingsly (2004) along with monocrotophos (0.05%) on the fourth, fifth and sixth instar larvae of *P. ricini*. A high level of feeding detergency was recorded at all concentrations of neem oil compared to neem cake extract and monocrotophos. With an increase of the larval stages, there was a corresponding decrease of feeding detergency. The feeding detergency increased from 62.8 to 76.8% with a corresponding increase in the concentration of neem derivatives on the fourth instar larvae.

2.7.3 Biological control

Biological control agents including predators, parasitoids and pathogens greatly reduce pest populations in various crop fields. There have been researches on predaceous fauna of legume pod borers across continents (Usua and Singh, 1977; Barrion *et al.*, 1987; Vishakantaiah and Babu, 1980; Okeyo-Owuor *et al.*, 1991). In general, the role of predators in pest population reduction is difficult to determine in field conditions (Debach and Rosen, 1991; Pedigo, 1999). This is simply because predators usually devour the prey immediately leaving no trace or signs of the predation. As a result, there has been little information on control of pod borers by predators.

There have been researches on parasitic fauna of legume pod borers across continents (Usua and Singh, 1977; Barrion *et al*., 1987; Vishakantaiah and Babu, 1980; Okeyo-Owuor *et al.*, 1991). It has been noted that, parasitoids, both by their stinging and direct feeding activity during the process of host selection for oviposition and by killing the parasitized larvae and pupae, inflict significant mortality to most insect pests (Debach and Rosen, 1991). Okeyo-Owuor *et al.*, (1991) conducted extensive research on biological control of pod borers in Kenya and conducted that a plethora of parasitic fauna attacks bean pod borers and greatly suppress the pest infestation in several places. Okeyo-Owuor *et al.* (1991) found that more than 98% of the eggs oviposited by pod borer females do not reach adulthood in Kenya. One of the key factors causing such a high level of mortality was the parasitoid, which included seven parasitoid species. It is believed that a plethora of parasitoids are active and they probably kill significant portions of legume pod borer population in Bangladesh. However, there is little investigation in this regard.

Natural enemies, parasitoids and predators are the main sources of reduction in the populations of noxious insect pests (Pfadt, 1980). Biological control agents (spider, ant, lady bird beetle, *Orius*, myrid bug, *Laius, Chrysoperla, Trichogramma* etc.), botanicals (neem oil or biosal and tobacco extracts) and microbial control (*Bacillus thuringiensis*) should be integrated for economic management of insect pests (Arora *et al*. 1996; Abro *et al.* 2004 and Memon *et al.* 2004).

2.7.4 Integrated pest management

As an alternative mean to insecticide use, demand for the use of integrated Pest Management (IPM) has been increasing. However, successful IPM and economic pest management are based on some pest control decision making criteria, most frequently the economic threshold levels-ETL (Pedigo, 1999). In the context of country bean crops in Bangladesh, such ETLs need to be established and popularized. The use of resistant cultivars and other non-chemical methods would direct us toward safer pest management practices.

Akter *et al*. (2007) reported that in early, mid and late fruiting stages, the highest percentage fruit infestation in number and weight was recorded in T_7 (untreated control) treatment and the lowest in T_5 (mechanical control plus Ripcord [cypermethrin] 10 EC at 2 ml/l of water at 7 days interval) treatment for all the harvest. The highest total number and weight of healthy fruit were recorded in T_5, followed by T_6 (mechanical control of infested flowers and fruits + neem [*Azadirachta indica*] oil at 30 ml/l of water at 7 days intervals + Ripcord 10 EC at 2 ml/l of water at 7 days interval) treatment. The highest yield per hectare (17.65 t) was also recorded in T5 and the lowest (9.93 t) in T_7 (untreated control).

An experiment was conducted by Pandey *et al*. (2006) during rabi 2001/02 at two locations (Jorium and Kanhai Ka Purwa) in Faizabad district, Uttar Pradesh, India, to evaluate the efficiency of integrated pest management (IPM) technology in controlling pod borer (*Helicoverpa armigera*). The treatment involving the use of the resistant cultivar Pusa-256 + Rhizobium inoculation + Trichoderma seed treatment at 4 g/kg + pheromone trapping (15 traps/ha) with Helilure + NPV at 250 LE/ha resulted in the lowest pod borer population (1.30 larvae/m^2).

Experiment conducted by Vichiter *et al*. (2006) at Sriganganagar, Rajasthan, India during rabi 1999-2000 and 2000-01 for the control of pod borer (*H. armigera*, Ha), different modules of integrated pest management (IPM) comprising endosulfan at 0.75%, neem [Azadirachta indica] oil at 0.2%, Ha nuclear polyhedrosis virus (HaNPV) at 450 LE/ha and Bacillus thuringiensis at 1000 ml/ha were evaluated. Among the modules tested, the 3 sprays of endosulfan was found the most effective in controlling pod borer (6.83% pod damage), resulting in the maximum grain yield (2489 kg/ha). This was followed by the module of neem oil-HaNPV-endosulfan (7.92% pod damage and 2267 kg/ha yield). The cost benefit ratio (CBR) varied from 0.17 to 6.97. The maximum CBR (4.14) was recorded in the 3 sprays of endosulfan compared to 6.97 in the recommended spray schedule (methyl parathion [parathion-methyl] 2% dust at 24 kg/ha, endosulfan at 0.75 kg/ha, and fenvalerate at 400 ml/ha). The spray of neem oil and HaNPV alternated with endosulfan was also found effective against the pest with a CBR of 1:2.92.

Investigations on the effect of various integrated pest management (IPM) components on *Helicoverpa armigera* and their impact on natural enemies were carried out by Visalakshimi *et al*. (2005) cropping seasons in Patancheru, Andhra Pradesh, India. Application of neem effectively reduced the oviposition by H. armigera throughout the cropping period. The integration of various IPM components was found to be the best in reducing the pod damage (10.4%) with highest grain yield (1264.4 kg/ha) with 58.5% increase in yield over control (797.9 kg/ha). Among various IPM components, neem and Helicoverpa Nuclear Polyhedrosis Virus were as effective as endosulfan in reducing the larval population and pod damage. The highest cost-benefit ratio (1:3.01) was obtained in plots treated with IPM. The effect of various IPM components individually or as a package to develop the best alternative to chemical control of the chickpea pod borer are discussed.

Experiment was conducted by Gowda *et al*. (2004) in Gulbarga, Karnataka, India to evaluate the effects of different integrated pest management (IPM) practices and intercropping systems on the pod borer (*Helicoverpa armigera*). Both biointensive and pesticide-based IPM modules were compared with the untreated control in both years. In 2000/01, the treatments consisted of *H. armigera* nuclear polyhedrosis virus (HaNPV) at 250 LE (1.5x1012 polyhedral occlusion bodies or POBs) + neem seed kernel extract (NSKE) at 5% as biointensive module and profenofos EC at 1.50 l/ha + acephate 75 WP at 0.50 kg/ha as pesticide-based module. In 2001/02, the treatments consisted of HaNPV + NSKE + HaNPV as biointensive module and profenofos 50 EC + endosulfan 35 EC at 1.00 l/ha + acephate 75 WP. Data were recorded for percentage of pod damage and yield. Both IPM modules significantly reduced pod damage and increased grain yield compared with the untreated control, with the pesticide-based IPM module recording better values for all the recorded parameters. However, considering the disastrous effects of chemicals, the biointensive IPM module is considered as a more ecological-friendly option to control pod borer infestation.

The potential of incorporating neem (*Azadirachta indica*) extracts into an integrated pest management (IPM) system was investigated by Tanzubil (2000) in field trials in northern Ghana. Aqueous neem seed extracts sprayed at 5 and 10% concentration were effective against flower thrips (*Megalurothrips sjostedti*), pod borer (*Maruca testulalis*) [*M. vitrata*] and pod sucking bugs (*Clavigralla* spp., *Aspavia armigera* and *Riptortus dentipes*). The addition of vegetable oils and detergents to extracts increased their efficacy and residual action on the treated crop. Comparatively, oil additives appeared to be superior to soap in terms of improvements in the activity of extracts. In combination with early planting, two applications of 10% aqueous neem seed extracts were as effective as lambda cyhalothrin, the synthetic insecticide widely recommended for cowpea pest control in Ghana.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study different management practices in controlling major insect pests of high yielding variety of country bean (BARI seem-3) during the period from June to December, 2012. A brief description of the experimental site, climatic condition, soil characteristics, experimental design, treatments, cultural operations, data collection and analysis of different parameters were used for conducting this experiment are presented under the following headings:

3.1 Experimental site

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh, which is situated in $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude (Anon., 1989).

3.2 Weather condition

The climate of experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979).

3.3 Soil characteristics

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) corresponding AEZ No. 28. The soil of the experimental area is shallow red brown terrace soil.

3.4 Planting material

Seeds of BARI seem-3 were used as the test crop of this experiment. The seeds of were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Then the soil was ploughed and cross ploughed. Ploughed soil was then brought into desirable fine tilth by the operations of ploughing, harrowing and laddering. The stubble and weeds were removed. Experimental land was divided into unit plots following the design of experiment. During final land preparation 10 t/ha decomposed cowdung were mixed with soil. In each plot measuring 3.0 m × 2.0 m, 2 pit were prepared for seedling transplantion.

3.6 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).

3.7 Sowing of seeds in the field

For rapid germination the seeds of country bean varieties were soaked for 12 hours in water. Two seeds of variety were then sown per polyethylene bags (12 cm × 18 cm) containing a mixture of equal proportion of well-decomposed cowdung and loamy soil. Irrigation was given by watering cane as per requirement. After germination, the seedlings were placed to partly sunny place for hardening. Finally, 15 days old seedlings were transplanted to the experimental plots as three seedlings per pit on last week of June, 2012. 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. Out of six seedlings plot^{-1}, one was removed two weeks after transplanting.

3.8 Treatments of the experiment

The experiment consists of the following management practices:

T_0: Untreated control
T_1: Hand picking of infested plant parts at 7 days interval
T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval
T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

3.9 Experimental layout and design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. A plot area was divided into three equal blocks. Each block was divided into 6 plots, where 6 treatments were allocated at random. There were 24 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.0 m. The distance maintained between two blocks and two plots were 1.0 m and 1.0 m respectively (plate 1).

Plate 1. The experimental plot at SAU, Dhaka

3.10 Collection and preparation for spraying of experimental treatment

3.10.1 Neem oil

For proper management of bean pod borer 4 ml neem oil was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2m area.

3.10.*2 Trichogramma evanescence*

The freshly laid and cleaned *Sitotroga cerealella* eggs were taken and glued on a strip of card sheet (12 inch × 8 inch) in single layer using ten percent gum Arabica and these cards were exposed to *Trichogramma evanescence* for 8 to 10 hours to maintain the culture(plate 2). After 24 hours, the parasitized cards were withdrawn and placed in convenient glass containers. The open end of the container was closed using muslin cloth fastened by rubber band. The parasitoids that emerged from the cards were released in the selected experimental plots.

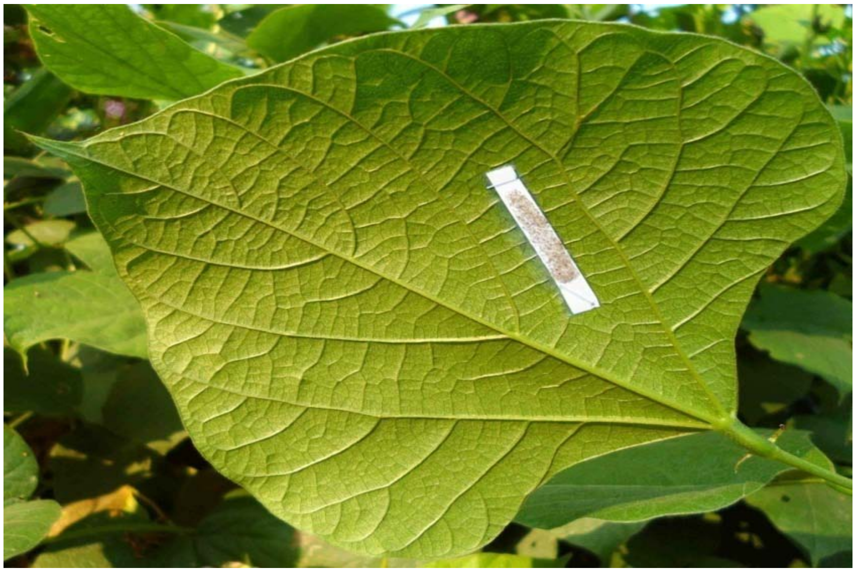

Plate 2. Trichocard tagged on country bean leaf

3.11 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 on about 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.

3.12 Crop sampling and data collection

Single plant form single pit of a plot from each treatment were randomly marked with the help of sample card.

3.13 Monitoring and data collection

The country bean plants of different treatment were closely examined at regular intervals commencing from germination to harvest. The following data were collected during the course of the experiment-

- Incidence of insect
- Number of healthy pods
- Number of infested pods
- Pod infestation in number (%)
- Weight of healthy pods
- Weight of infested pods
- Pods infestation in weight (%)
- Number of inflorescence plant^{-1}
- Number of flower inflorescence^{-1}
- Number of pods inflorescence^{-1}
- Pod length (cm)
- Yield plot^{-1} (kg)
- Yield hectare^{-1} (ton)

3.14 Procedure of data collection

3.14.1 Incidence of insects

All of the 5 plants of each plot carefully observed for the identification of attacking insect pests. All of them counted and recorded the collected data. The collected data were divided into early, mid and late pod development stage.

3.14. 2 Counting of Aphid

The number of aphid on 5 selected plants from each plot was counted at an interval of 7 days at each harvest during early, mid and late fruiting stage of the plant . The top 10 cm apical twigs of 5 randomly selected inflorescence of selected plants were cut and brought to the laboratory in bags separately for counting the number of aphids plant^{-1} and also 5 randomly aphid infested pod of selected plants were collected by hand picking for counting of aphid plant^{-1}. The aphids were removed from the infested plant parts with the help of a soft camel hair brush and placed on a piece of white paper. Then the number of aphids was counted with the help of a magnifying glass and tally counter. The infested twigs and inflorescence were checked carefully. So that, single aphid could not escape at the time of counting.

3.14. 3 Counting of bean pod borer larvae

Borer infested flowers , pods at each harvest were counted and tagged. The data were also recorded on the number of infested flowers, pods removed instead of tagging. Then larvae were counted using hand magnifying glass and calculated as plant^{-1} . This operation was done at an interval of 7 days at each harvest during early, mid and late fruiting stage of the plant from 5 plants of each plot.

3.14.4 Number of healthy pods plant^{-1}

Number of healthy pods from each plot was counted and the mean number was expressed on plant^{-1} basis. The data were collected on early, mid and late pod development stage (plate 3).

Plate 3. Healthy pods of country bean

3.14.5 Number of infested pods plant^{-1}

Number of infested pods from each plot was counted and the mean number was expressed on plant^{-1}basis.The data were collected on early, mid and late pod development stage (plate 4 and plate 5).

3.14.6 Pod infestation by number

The numbers of healthy and infested pods were counted and the percent pod infestation was calculated using the following formula:

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

Plate 4. Infested pod of country bean attacked by pod borer.

3.14.7 Weight of healthy pods plant^{-1}

Weight of infested pods of selected plants from each plot was recorded and the mean weight was expressed on plant^{-1} basis. The data were collected on early, mid and late pod development stage.

Plate 5. Infested pod of country bean attacked by aphid at control plot

3.14.8 Weight of infested pods plant^{-1}

Weight of infested pods of selected plants from each plot was recorded and the mean weight was expressed on plant^{-1} basis. The data were collected on early, mid and late pod development stage.

3.14.9 Pod infestation in weight

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

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

Plate 6. Infested inflorescence

Plate 7. Healthy Inflorescence

3.14.10 Number of inflorescence plant^{-1}

During the reproductive stage of the plant total numbers of inflorescences from each individual plot were recorded in each treatment (plate 6 and 7).

3.14.11 Number of flower inflorescence^{-1}

During the reproductive stage of the plant total numbers of flower inflorescence^{-1} were recorded in each treatment from 10 inflorescences.

3.14.12 Number of pods inflorescence^{-1}

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

3.14.13 Pod length

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

3.14.14 Pod yield plot^{-1}

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

3.14.15 Pod yield hectare^{-1}

Pods yield of country bean per plot of country bean were converted into hectare and expressed yield in ton.

3.15 Statistical analyses

The data on different parameters as well as yield of country bean were statistically analyzed to find out the significant differences among the effects of different treatments. The mean values of all the characters were calculated and analyses of variance were performed by the 'F' (variance ratio) test. The significance of the differences among the mean values of treatment in respect of different parameters was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984). The benefit-cost ratio was calculated following Ali and Karim (1991).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to study the effectiveness of different control options in controlling major insect pests of country bean. Data on the parameters of number of insect pest plant^{-1}, number and weight of healthy pod, infested pod and percentage of pod infestation in number and weight, yield contributing characters and yield of country bean were recorded. The results from different parameters have been presented and discussed, and possible interpretations have been given under the following headings:

4.1 Insect pest incidence

Incidence of major insect pests of country bean was recorded for the entire cropping season. Remarkably bean pod borer and aphid were observed in the study. Insect pests from each plant during the reproductive stage which divided as at early, mid and late pod development stages depending on the duration of reproductive stage to investigate the performance of different treatments.

4.1.1 Early pod development stage

At early pod development stage statistically significant variation was recorded for bean pod borer and aphid due to different management practices (Table 1). In case of bean pod borer, the lowest number per plant (5.00) was found from T_5 (Spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval) which was statistically similar (6.25) with T_4 (Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval) and closely followed by (14.75 and 14.00) by T_3 (Spraying of neem oil @ 4 ml/L of water at 7 days interval) and T_2 (Release of *Trichogramma evanescence*@ 0.5 g/6 m^2 at 15 days interval), while the highest number (24.50) was observed from T_0 (untreated control) which was followed (19.00) by T_1 (Hand picking of infested plant parts at 7 days interval). In consideration of aphid, the lowest number plant^1 was observed from T_5 (2.00) which was statistically similar with T_4 (3.25) and closely followed by T_3 (4.00) and T_1 (5.00), whereas the highest number was observed from T_0 (12.0) followed by T_2 (8.75) treatment.

From the above mentioned findings it is revealed that at early pod development stage spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 $g/6m^2$ at 15 days interval was more effective among the management practices for controlling insect pests of country bean which was followed by spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval.

Table 1. Effect of different management practices on number of major insect pests plant^{1} of country bean at early pod development stage

Treatments	At early pod development stage	
	Larva of bean pod borer (No./plant)	Aphid (No./plant)
T_0	24.50 a	12.00 a
T_1	19.00 b	5.00 c
T_2	14.00 c	8.75 b
T_3	14.75 c	4.00 cd
T_4	6.25 d	3.25 de
T_5	5.00 d	2.00 e
$LSD_{(0.05)}$	1.604	1.515
CV(%)	7.65	17.24

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*$6m^2$ at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment.

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.1.2 Mid pod development stage

Statistically significant variation were recorded for bean pod borer and aphid due to different management practices at mid pod development stage (Table 2). In case of bean pod borer, the lowest number $plant^{-1}$ was observed from T_5 (6.00) consists of spraying of neem oil @ 4 ml/L of water and hand picking at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval which was statistically similar (6.25) and closely followed by T_2 (17.00) and T_3 (17.50), whereas the highest number was observed from T_0 (31.50) consists of untreated control which was followed by T_1 (24.25). In consideration of aphid, the lowest number $plant^1$ was observed from T_5 (3.25) which was statistically identical with T_4 (3.25) and closely followed by T_3 (5.75) and T_1 (6.75), whereas the highest number was observed from T_0 (11.83) followed by T_2 (9.25). From the above mentioned findings it is revealed that spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices for controlling insect pests of country bean at mid pod development stage and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval.

Table 2. Effect of different management practices on number of major insect pests plant^{-1} of country bean at mid pod development stage

Treatments	At mid pod development stage	
	Larva of bean pod borer (No./plant)	Aphid (No./plant)
T_0	31.50 a	11.83 a
T_1	24.25 b	6.75 c
T_2	17.00 c	9.25 b
T_3	17.50 c	5.75 d
T_4	6.25 d	3.25 e
T_5	6.00 d	3.25 e
$LSD_{(0.05)}$	1.726	0.983
CV (%)	6.70	9.76

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.1.3 Late pod development stage

Different management practices showed statistically significant variation at late pod development stage for bean pod borer and aphid (Table 3). In case of bean pod borer, the lowest number plant^{1} was observed from T_5 (8.25) which was statistically similar with T_4 (8.75) and closely followed by T_2 (19.00) and T_3 (20.25), whereas the highest number was observed from T_0 (37.00) which was followed by T_1 (33.25). In consideration of aphid, the lowest number plant^{1} was found from T_5 (4.00) which was statistically similar with T_4 (5.25) and closely followed by T_3 (6.00) and T_1 (7.75), whereas the highest number was observed from T_0 (15.25) followed by T_2 (11.75) treatment. From the above findings it is revealed that spraying of neem oil@ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices for controlling insect pests of country bean at late pod development stage which was followed by spraying of neem oil @ 4 ml/L of water + hand picking of infested plant parts at 7 days interval. It was also observed the trend of pest's infestations was at increasing fashion from early to late pod development stages in this study which is supported by the others researchers finding. The pod borer infestation increases on the late sown crop (Alghali, 1993) and Pod borer population tends to build up over the season (Ekesi *et al.*, 1996).

Table 3. Effect of different management practices on number of major insect pests plant^{-1} of country bean at late pod development stage

Treatments	At late pod development stage	
	Larva of bean pod borer (No./plant)	Aphid (No./plant)
T_0	37.00 a	15.25 a
T_1	33.25 b	7.75 c
T_2	19.00 c	11.75 b
T_3	20.25 c	6.00 d
T_4	8.75 d	5.25 de
T_5	8.25 d	4.00 e
$LSD_{(0.05)}$	3.306	1.524
CV(%)	10.40	12.13

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2 Pod bearing status

4.2.1 Pod bearing status at early pod development stage

Significant variation were observed in number of healthy, infested pods, percent infestation and infestation reduction over control at early pod development stage for different management practices in controlling insect pests of country bean (Table 4).

The highest number of healthy pods plant^{-1} was observed from T_5 (94.75) which was statistically similar with T_4 (91.00) and followed by T_2 (89.00) and T_3 (81.00), while the lowest number of healthy pods was observed from T_0 (62.00) followed by T_1 (72.00) treatments. On the other hand the lowest number of infested pods plant^{-1} was observed from T_5 (5.50) which was statistically similar with T_4 (5.75) and closely followed by T_2 (8.00) and T_3 (9.00) treatments. In contemporary, the highest number of infested pods was found from T_0 (16.50) followed by T_1 (13.00) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_5 (5.49%) which was statistically similar with T_4 (5.93%) and closely followed by T_2 (8.25%) and T_3 (10.03%) treatments, again the highest infested pods was recorded in T_0 (21.00%) followed by T_1 (15.30%) treatment. Pod infestation reduction over control in number was estimated and the highest value was found from the treatment T_5 (73.86%) which was followed by T_4 (71.76%), T_2 (60.71%) and T3 (52.24%) treatments and the lowest reduction of pod infestation over control from T_1 (27.14%) treatment. Pedigo (1999) reported that at early pod development stage pod borer and aphid infestation reduced the number of healthy pods in country bean field and similar trend of results found in this study.

Table 4. Effect of different management practices in controlling major insect pests of country bean at early pod development stage in terms of pods plant^{-1} by number

Treatments	Bean pods by number plant^{-1}			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	62.00 e	16.50 a	21.00 a	--
T_1	72.00 d	13.00 b	15.30 b	27.14
T_2	89.00 b	8.00 c	8.25 d	60.71
T_3	81.00 c	9.00 c	10.03 c	52.24
T_4	91.00 ab	5.75 d	5.93 e	71.76
T_5	94.75 a	5.50 d	5.49 e	73.86
$LSD_{(0.05)}$	5.240	1.419	1.529	--
CV (%)	4.26	9.78	9.22	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 5, indicated that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at early pod development stage for different management practices in controlling insect pests of country bean. In context of healthy pods, the highest weight plant^{-1} (807.99 g) was found from T_5 which was statistically similar with T_4 (771.77 g) and followed by T_2 (755.99 g) and T_3 (677.65 g) treatments. On the other contrary the lowest weight of healthy pods was found from T_0 (498.94 g) which was followed by T_1 (594.97 g) treatment. Considering the infested pods, the lowest weight of infested pods plant^{-1} was recorded from T_5 (43.75 g) which was statistically similar with T_4 (52.40 g) and close to T_3 (70.30 g) and T_2 (61.31 g), while the highest weight of infested pods was found in T_0 (123.31 g) and closely followed by T_1 (105.76 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_5 (5.14%) which was statistically similar with T_4 (6.36%) and closely followed by T_2 (7.51%) and T_3 (9.39%), whereas the highest infested pods was observed in T_0 (19.78%) followed by T_1 (15.10%) treatment. Pod infestation reduction over control in weight was estimated and the highest value was obtained from the treatment T_5 (74.01%) which was followed by T_4 (67.85%), T2 (62.03%) and T_3 (52.53%) and the lowest from T_1 (23.66%) treatment. From the above findings it is revealed that at early pod development stage spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices in terms of pods plant^{-1} by weight and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval. Ambekar *et al.* (1999) reported similar results to the present study where the combination of bio-pesticide and botanicals performed best in reducing the infestation of pods of country bean by bean pod borer. He also observed that the spraying of neem oil and mechanical control reduce the infestation of aphid in country bean field.

Table 5. Effect of different management practices in controlling major insect pests of country bean at early pod development stage in terms of pods plant^{-1} by weight

Treatments	Weight of pods (g/plant)			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	498.94 e	123.31 a	19.78 a	--
T_1	594.97 d	105.76 b	15.10 b	23.66
T_2	755.99 b	61.31 cd	7.51 d	62.03
T_3	677.65 c	70.30 c	9.39 c	52.53
T_4	771.77 b	52.40 de	6.36 de	67.85
T_5	807.99 a	43.75 e	5.14 e	74.01
$LSD_{(0.05)}$	39.40	13.98	1.694	--
CV(%)	3.82	12.18	10.66	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2.2 Pod bearing status at mid pod development stage

Table 6 indicated that the number of healthy, infested pods, percent infestation and infestation reduction over control at mid pod development stage showed statistically significant differences for different management practices in controlling major insect pests of country bean. In the number of healthy pods, the highest number plant^{-1} was observed from T_5 (144.00) which was statistically similar with T_4 (137.00) and T_2 (136.00) and followed by T_3 (129.00), while the lowest number of healthy pods was observed from T_0 (89.00) followed by T_1 (103.00). The lowest number of infested pods plant^{-1} was observed from T_5 (12.00) which was followed by T_4 (15.00), T_2 (15.00) and T_3 (17.00) treatments. On the other hand, the highest number of infested pods was recorded from T_0 (24.00) followed by T_1 (22.00) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} by number was observed from T_5 (7.72%) which was closely followed by T_4 (9.87%), T_2 (9.94%) and T_3 (11.63%), again the highest infested pods was observed in T_0 (21.35%) followed by T_1 (17.69%) treatment. Pod infestation reduction over control in number was estimated and the highest value was found from the treatment T_5 (63.84%) which was followed by T_4 (53.77%), T_2 (53.44%) and T_3 (45.53%) treatments. On the contrary the lowest reduction of pod infestation over control obtained from T_1 (17.14%) treatment. From the above findings it is revealed that at mid pod development stage spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval as more effective among the management practices in terms of pods plant^{-1} by number and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval. Shukla (1998) also observed the same trend of results to control bean pod borer at mid pod development stage by using botanicals and bio agent including hand picking. He also observed that neem oil reduced the infestation of aphid more effectively at mid fruiting stage compare to early fruiting stage and increased the number of healthy pod.

Table 6. Effect of different management practices in controlling major insect pests of country bean at mid pod development stage in terms of pods plant^{-1} by number

Treatments	Bean pods by number plant^{-1}			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	89.00 d	24.00 a	21.35 a	--
T_1	103.00 c	22.00 b	17.69 b	17.14
T_2	136.00 ab	15.00 d	9.94 c	53.44
T_3	129.00 b	17.00 c	11.63 c	45.53
T_4	137.00 ab	15.00 d	9.87 c	53.77
T_5	144.00 a	12.00 e	7.72 d	63.84
$LSD_{(0.05)}$	9.711	1.726	1.970	--
CV(%)	5.24	6.54	10.03	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 7, indicated that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at mid pod development stage for different management practices in controlling major insect pests of country bean. In context of healthy pods, the highest weight plant^{-1} (1225.12 g) was observed from T_5 which was followed by T_4 (1167.76 g), T_2 (1162.24 g) and T_3 (1105.95 g) treatments. On the other contrary the lowest weight of healthy pods was observed from T_0 (746.17 g) which was followed by T_1 (867.43 g) treatments. Considering the infested pods, the lowest weight of infested pods plant^{-1} was observed from T_5 (102.90 g) which was close to T_4 (125.86 g) and T_2 (132.72 g) and T_3 (147.63 g) treatments, while the highest weight of infested pods was found in T_0 (203.06 g) followed by T_1 (186.97 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_5 (7.75%) which was followed by T_4 (9.73%), T_2 (10.25%) and T_3 (11.77%) treatments, whereas the highest infested pods was observed in T_0 (21.41%) followed by T_1 (17.80%) treatment. Pod infestation reduction over control in weight was estimated and the highest value was obtained from the treatment T_5 (63.80%) which was followed by T_4 (54.55), T_2 (52.13%) and T_3 (45.03%) and the lowest from T_1 (16.86%) treatment. From the above findings it is revealed that at mid pod development stage spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval+ Release of *Trichogramma evanescence* 0.5 g/6m^2 at 15 days interval was more effective among the management practices in terms of pods plant^{-1} by weight and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval. Usa and Singh (1977) reported that different physical and biochemical factors influence the level of infestation of pod borer and aphid. They also observed that with the increase of cropping season number of inflorescence also increased which ultimately contributes to the pod yield.

Table 7. Effect of different management practices in controlling major insect Pests of country bean at mid pod development stage in terms of pods plant^{-1} by weight

Treatments	Weight of pods (g/plant)			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	746.17 e	203.06 a	21.41 a	--
T_1	867.43 d	186.97 b	17.80 b	16.86
T_2	1162.24 b	132.72 d	10.25 d	52.13
T_3	1105.95 c	147.63 c	11.77 c	45.03
T_4	1167.76 b	125.86 d	9.73 d	54.55
T_5	1225.12 a	102.90 e	7.75 e	63.80
$LSD_{(0.05)}$	56.91	8.548	0.942	--
CV(%)	3.61	3.78	4.77	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2.3 Pod bearing status at late pod development stage

Table 8 indicated that statistically significant differences were recorded in number of healthy, infested pods, percent infestation and infestation reduction over control at late pod development stage for different management practices in controlling major insect pests of country bean. The highest number of healthy pods plant^{-1} was recorded from T_5 (77.00) which was followed by T_4 (70.00), T_2 (70.00) and T_3 (67.00) treatments, while the lowest number of healthy pods was recorded from T_0 (54.00) followed by T_1 (60.00) treatment. The lowest number of infested pods plant^{-1} was recorded from T_5 (6.75) which was closer to T_4 (7.75) and followed by T_2 (9.00) and T_3 (10.00) treatments. On the other hand, the highest number of infested pods was recorded from T_0 (16.00) followed by T_1 (13.00) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_5 (8.05%) which was followed by T_4 (9.97%), T_2 (11.38%) and T_3 (13.03%) treatments, again the highest infested pods was recorded in T_0 (22.85%) which was followed by T_1 (17.81%) treatment. Pod infestation reduction over control in number was estimated and the highest value was found from the treatment T_5 (64.77%) which was followed by T_4 (56.37%), T_2 (50.20%), T_3 (42.98%) and the lowest reduction of pod infestation over control from T_1 (22.06%) treatment. From the above findings it is revealed that at late pod development stage spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices in terms of pods plant^{-1} by number and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval. Sharma (1998) observed the similar result where at late pod development stage plants are highly likely to experience elevated levels of pod borer attacks compared with the early and mid pod development stage as found in the present study.

Table 8. Effect of different management practices in controlling major insect pests of country bean at late pod development stage in terms of pods plant^{-1} by number

Treatments	Bean Pods by number plant^{-1}			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	54.00 d	16.00 a	22.85 a	--
T_1	60.00 c	13.00 b	17.81 b	22.06
T_2	70.00 b	9.00 c	11.38 d	50.20
T_3	67.00 b	10.00 c	13.03 c	42.98
T_4	70.00 b	7.75 d	9.97 e	56.37
T_5	77.00 a	6.75 d	8.05 f	64.77
$LSD_{(0.05)}$	4.860	1.167	0.939	--
CV(%)	4.86	7.44	4.50	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 9 indicated that healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at late pod development stage for different management practices in controlling insect pests of country bean. In context of healthy pods, the highest weight plant^{-1} was observed from T_5 (568.54 g) which was followed by T_4 (515.55 g), T_2 (512.14 g) and T_3 (491.02 g). On the other contrary the lowest weight of healthy pods was observed from T_0 (389.85 g) which was followed by T_1 (439.22 g) treatments. Considering the infested pods, the lowest weight of infested pods plant^{-1} was observed from T_5 (51.77 g) which was close to T_4 (59.79 g), while the highest weight of infested pods was found in T_0 (118.79 g) closely followed by T_1 (95.56 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was observed from T_5 (8.35%) which was followed by T_4 (10.39%), T_2 (11.62%) and T_3 (12.78%) treatments whereas the highest infested pods was observed in T_0 (23.35%) which was followed by T_1 (17.87%) treatment. Pod infestation reduction over control in weight was estimated and the highest value was obtained from the treatment T_5 (64.25%) which was followed by T_4 (55.50%), T_2 (50.24%) and T_3 (45.27%) treatments and the lowest from T_1 (23.47%) treatment. From the above findings it is revealed that at late pod development stage spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices in terms of pods plant^{-1} by weight and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval. In others study, it was found that using botanicals farmers get maximum benefit in reducing the infestation of country bean pest and increasing the pod yield (Tijani *et al.*, 2007).It was also observed that using of botanicals restore the population of natural enemy like lady bird beetle which reduced the infestation of aphid in country bean field.

Table 9. Effect of different management practices in controlling major insect pests of country bean at late pod development stage in terms of pods plant^{-1} by weight

Treatments	Weight of pods (g/plant)			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	389.85 d	118.79 a	23.35 a	--
T_1	439.22 c	95.56 b	17.87 b	23.47
T_2	512.14 b	67.28 c	11.62 d	50.24
T_3	491.02 b	71.45 c	12.78 c	45.27
T_4	515.55 b	59.79 d	10.39 e	55.50
T_5	568.54 a	51.77 e	8.35 f	64.24
$LSD_{(0.05)}$	39.94	5.700	1.160	--
CV(%)	5.45	4.88	5.48	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2.4 Pod bearing status at total growing stage

Table 10 indicated that statistically significant differences were observed in number of healthy, infested pods, percent infestation and infestation reduction over control at total growing period for different management practices in controlling major insect pests of country bean. In number of healthy pods, the highest number plant^{-1} was recorded from T_5 (315.75) which was followed by T_4 (298.00), T_2 (295.00) and T_3 (277.00) treatments, while the lowest number from T_0 (205.00) followed by T_1 (235.00) treatment. The lowest number of infested pods plant^{-1} was recorded from T_5 (24.25) which was similar to T_4 (28.50) and closely followed by T_2 (32.00) and T_3 (36.00) treatments. On the other hand, the highest number of infested pods was recorded from T_0 (56.50) followed by T_1 (48.00) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_5 (7.13%) which was followed by T_4 (8.73%), T_2 (9.78%) and T_3 (11.52%) treatments, again the highest in T_0 (21.63%) followed by T_1 (16.99%) treatment. Pod infestation reduction over control in number was estimated and the highest value was obtained from the treatment T_5 (67.04%) which was followed by T_4 (59.64%), T_2 (54.79%) and T_3 (46.74%) treatments. Again the lowest value was obtained from T_1 (21.45%) treatment. From the above findings it is revealed that at total growing period spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices in terms of pods plant^{-1} by number and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

Table 10. Effect of different management practices in controlling major insect pests of country bean at total pod growing period in terms of pods plant^{-1} by number

Treatments	Bean Pods by number plant^{-1}			
	Healthy	Infested	% Infestation	Reduction over control (%)
T_0	205.00 e	56.50 a	21.63 a	--
T_1	235.00 d	48.00 b	16.99 b	21.45
T_2	295.00 b	32.00 d	9.78 d	54.79
T_3	277.00 c	36.00 c	11.52 c	46.74
T_4	298.00 b	28.50 e	8.73 d	59.64
T_5	315.75 a	24.25 f	7.13 e	67.04
$LSD_{(0.05)}$	8.981	2.954	1.254	--
CV(%)	5.20	5.22	6.58	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 11 indicated that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at total pod growing period for different management practices in controlling major insect pests of country bean. In context of healthy pods, the highest weight plant^{-1} was recorded from T_5 (2601.66 g) which was followed by T_4 (2455.08 g), T_2 (2430.37 g) and T_3 (2274.61 g) treatments. On the other contrary the lowest weight of healthy pods was recorded from T_0 (1634.96 g) which was followed by T_1 (1901.62 g) treatment. Considering the infested pods, the lowest weight of infested pods plant^{-1} was recorded from T_5 (198.42 g) which was close to T_4 (238.05 g) and followed by T_2 (261.31 g) and T_3 (289.38 g) treatments, while the highest in T_0 (445.16 g) followed by T_1 (388.28 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_5 (7.09%) which was followed by T_4 (8.84%), T_2 (9.71%) and T_3 (11.28%) treatments, whereas the highest infested pods plant^{-1} was recorded from T_0 (21.40%) which was followed by T_1 (16.99%). Pod infestation reduction over control in weight was estimated and the highest value was attained from the treatment T_5 (66.87%) followed by T_4 (58.69%), T_2 (54.63%) and T_3 (47.29%) treatments and the lowest value was obtained from T_1 (20.61%) treatment. From the above findings it is revealed that at total growing period spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices in terms of pods plant^{-1} by weight and the second best treatment of the experiment was the T_4 which consists of spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval. Visalakshimi *et al*. (2005) reported that application of neem effectively reduced the oviposition of *Maruca testulalis* throughout the crop period and found as effective in the terms of reduction of larval population and pod damage which was similar with the present study.

Table 11. Effect of different management practices in controlling major insect pests of country bean at total pod growing period in terms of pods plant^{-1} by weight

Treatments	Weight of pods (g/plant)			
	Healthy	**Infested**	**% Infestation**	**Reduction over control (%)**
T_0	1634.96 e	445.16 a	21.40 a	--
T_1	1901.62 d	388.28 b	16.99 b	20.61
T_2	2430.37 b	261.31 d	9.71 d	54.63
T_3	2274.61 c	289.38 c	11.28 c	47.29
T_4	2455.08 b	238.05 e	8.84 d	58.69
T_5	2601.66 a	198.42 f	7.09 e	66.87
$LSD_{(0.05)}$	91.03	21.85	0.925	--
CV(%)	6.73	4.78	4.89	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.3 Yield contributing characters and yield of country bean

4.3.1 Number of inflorescence plant^{-1}

Number of inflorescence plant^{-1}of country bean showed statistically significant variation for different management practices in controlling insect pest of country bean (Table 12). The highest number of inflorescence plant^{-1} was recorded from T_5 (37.00) which was followed by T_4 (36.75), T_2 (36.50) and T_3 (35.00) and closely followed by T_1 (33.25) while the lowest number was observed from T_0 (31.50) treatments.

4.3.2 Number of flower inflorescence^{-1}

Different management practices in controlling insect pest of country bean showed statistically significant variation for number of flower inflorescence^{-1} of country bean (Table 12). The highest number of flower inflorescence^{-1} was recorded from T_5 (13.98) which was statistically identical with T_4 (13.85), T_2 (13.52) and T_3 (13.08) and closely followed by T_1 (12.68) while the lowest number was recorded from T_0 (11.75) treatments.

4.3.3 Number of pod inflorescence^{-1}

Data revealed that number of pod inflorescence^{-1} of country bean showed statistically significant variation for different management practices in controlling insect pest of country bean (Table 12). The highest number of pod inflorescence^{-1} was recorded from T_5 (9.57) which was followed by T_4 (9.20), T_2 (8.88) and T_3 (8.77) and closely followed by T_1 (8.07), while the lowest number was recorded from T_0 (7.45) treatments.

4.3.4 Pod length

Statistically significant variation was recorded for pod length of country bean showed due to different management practices in controlling insect pest of country bean (Table 12). The longest pod was recorded from T_5 (11.05 cm) which was statistically identical with T_4 (10.80 cm) and closely followed by T_2 (10.30 cm) and T_3 (10.20 cm), while the shortest pod was observed from T_0 (9.85 cm) treatments followed by T_1 (10.13 cm) treatment.

4.3.5 Yield plot^{-1}

Statistically significant variation was recorded for yield plot^{-1} of country bean for different management practices in controlling insect pest of country bean (Table 12 and 13). The highest yield plot^{-1} was recorded from T_5 (9.58 kg) which was statistically identical with T_4 (9.47 kg), T_2 (8.86 kg) and T_3 (8.37 kg) and closely followed by T_1 (7.30 kg), while the lowest yield plot^{-1} was recorded from T_0 (6.42 kg) treatments. From the findings it is revealed that spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval was more effective among the management practices for yield plot^{-1} which was followed by spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval that leads to the production of highest yield. Hongo and Karel, 1992 reported that neem can be effective in controlling major insect pests of country bean if it is combined with natural enemies and mechanical control in which hand picking also involved and this was also found in the present study.

4.3.6 Number of pods plant^{-1}

Number of pod plant^{-1} of country bean showed statistically significant variation for different management practices in controlling insect pest of country bean (Table 13). The highest number of pod plant^{-1} was recorded from T_5 (340) which was closely followed by T_4 (326.50), T_2 (327.00) and T_3 (313.00), while the lowest number was recorded from T_0 (261.50) treatments.

4.3.7 Yield of pods hectare^{-1}

Different management practices in controlling insect pest of country bean showed statistically significant variation in terms of yield hectare^{-1} of country bean (Table 13). The highest yield hectare^{-1} was found from T_5 (15.97 ton) which was statistically identical with T_4 (15.78 ton), T_2 (14.77 ton) and T_3 (13.95 ton) and followed by T_1 (12.16 ton), while the lowest yield hectare^{-1} was found from T_0 (10.71 ton) treatments. Pod yield increase over control was estimated and the highest value was obtained from the treatment T_5 (49.22%) which was followed by T_4 (47.51%), T_2 (38.01%) and T_3 (30.37%) treatments and the lowest value was found from T_1 (13.71%) treatment.

Table 12. Effect of different management practices in controlling major insect pests of country bean for yield contributing characters and yield during June to December, 2012

Treatments	Number of inflorescence^{-1} plant	Number of flower inflorescence^{-1}	Number of pod inflorescence^{-1}	Pod length (cm)	Yield plot^{-1} (kg)
T_0	31.50 c	11.75 c	7.45 c	9.85 c	6.42 c
T_1	33.25 bc	12.68 bc	8.07 bc	10.13 c	7.30 bc
T_2	36.50 a	13.52 ab	8.88 ab	10.20 bc	8.86 a
T_3	35.00 ab	13.08 ab	8.77 ab	10.30 bc	8.37 ab
T_4	36.75 a	13.85 ab	9.20 a	10.80 ab	9.47 a
T_5	37.00 a	13.98 a	9.57 a	11.05 a	9.58 a
$LSD_{(0.05)}$	3.044	1.158	0.807	0.612	1.155
CV(%)	5.77	5.84	6.19	4.91	9.19

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

Table 13. Effect of different management practices in controlling major insect pests of country bean for yield contributing characters and yield during June to December, 2012

Treatments	Number of of pods plant^{-1}	Yield plot ^{1}(kg)	Pod Yield (t/ha)	Increase over control (%)
T_0	261.50e	6.42 c	10.71	--
T_1	283.00d	7.30 bc	12.16	13.71
T_2	327.00b	8.86 a	14.77	38.01
T_3	313.00c	8.37 ab	13.95	30.37
T_4	326.50b	9.47 a	15.78	47.51
T_5	340.00a	9.58 a	15.97	49.22
$LSD_{(0.05)}$	7.360	1.155	--	--
CV(%)	0.01	9.19	--	--

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.4 Relationship between %pod infestation of country bean by number at total growing period and yield (t/ha)

Correlation study was done to establish the relationship between %pod infestation of country bean in number at total growing period and yield (t/ha) among different management practices. From the figure 1 it was revealed that negative correlation was observed between the parameters. The regression equation y=-0.371x+18.58 gave a good fit to the data and the co-efficient of determination (R^2 = 0.982) had a significant regression co-efficient. From this figure it was observed that 21.63% pod infestation in number gives the yield 10.71(t/ha) and 7.13% pod infestation in number gives the yield 15.97 (t/ha). So, the reduction of 14.5% pod infestation in number increased the yield 5.26 (t/ha) which was produced by using the treatment T_5 (Spraying of neem oil 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval). From the figure, it may be concluded that % pod infestation of country bean in number negatively correlated with pod yield (t/ha).

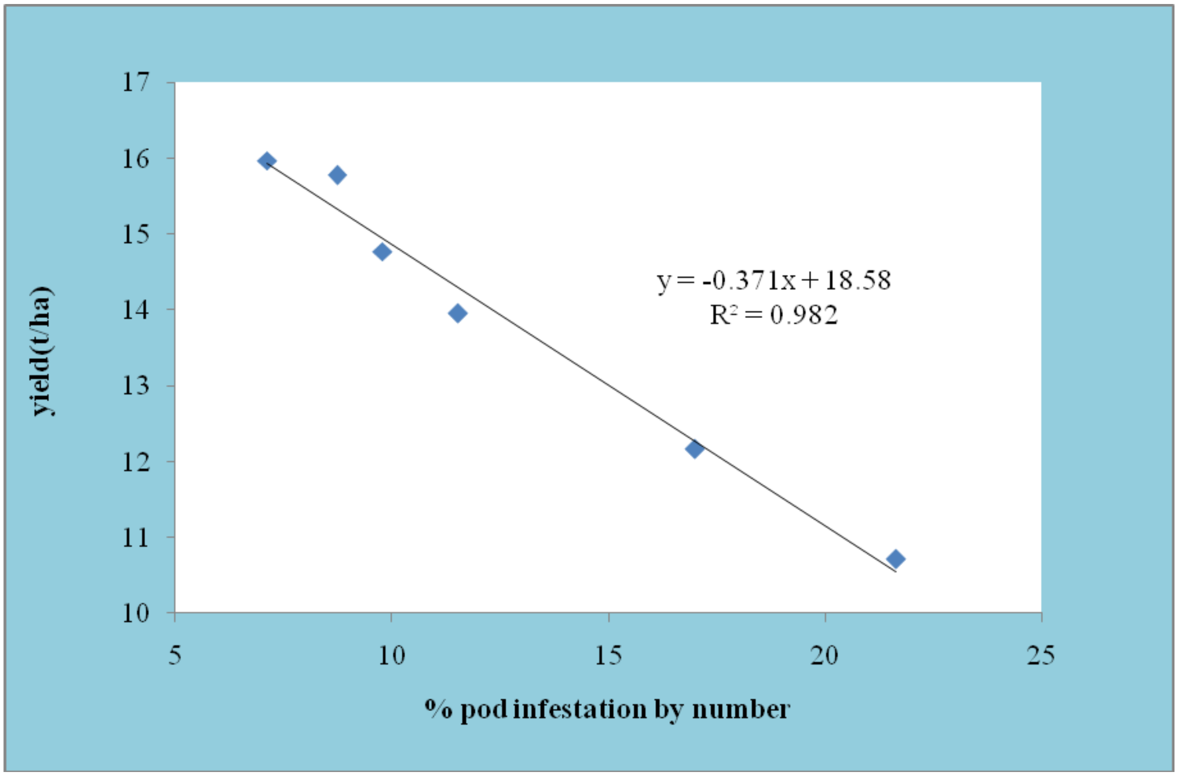

Figure 1. Relationship between % pod infestation by number of country bean at total growing period and yield (t/ha)

4.5 Cost benefit analysis

Economic analysis of different control measures were integrated for the insect pest management practices of country bean and are presented in (Table 13).In this study, the untreated control (T_0) did not require any pest management cost. But the costs were involved in the other management practices. Treatment T_1 (Hand picking of infested plant parts at 7 days interval), T_2 (Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval), T_3 (Spraying of neem oil @ 4 ml/L of water at 7 days interval) and T_4 (Spraying of neem oil @ 4 ml/L of water + hand picking of infested plant parts at 7 days interval) and treatment T_5 (spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval) requires insect pest management cost.

Considering the controlling of country bean insect pests highest benefit cost ratio (4.21) was recorded in the treatment T_5 (4.21) followed by T_4 (4.11), T_2 (3.43), T_3 (2.72), the lowest benefit cost ratio was recorded from T_1 (1.32) (Table 14).

Table 14. Cost of production of country bean under different pest management practices and benefit

Treatments	Cost of pest Management (Tk.)	Pod Yield (t/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost Ratio
T_0	0	10.71	214200	214200	--	--
T_1	12500	12.16	243200	230700	16500	1.32
T_2	18600	14.77	295400	278000	63800	3.43
T_3	17000	13.95	279000	260400	46200	2.72
T_4	19450	15.78	315600	295750	81550	4.11
T_5	20200	15.97	319400	299200	85000	4.21

Market price of country bean @ Tk. 20 per kg

T_0: Untreated control

T_1: Hand picking of infested plant parts at 7 days interval

T_2: Release of *Trichogramma evanescence @ 0.5g/*6m^2 at 15 days interval

T_3: Spraying of neem oil @ 4 ml/L of water at 7 days interval

T_4: Spraying of neem oil @ 4 ml/L of water + Hand picking of infested plant parts at 7 days interval

T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6 m^2 at 15 days interval

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.6 Relationship between yield contributing characters and yield hectare^{-1}

4.6.1 Relationship between number of pods inflorescence^{-1} and yield hectare^{-1}

The data on number of pods inflorescence^{-1} were regressed against yield hectare^{-1} of country bean and a positive linear relationship was obtained between them. The regression equation y = 2.667x - 9.201 gave a good fit to the data and the co-efficient of determination (R^2 = 0.977) had a significant regression co- efficient. From the figure 2 it was observed that the lowest number of pods inflorescence-1 (7.45) gives the yield 10.71 (t/ha) and the highest number of pods inflorescence-1 (9.57) gives the yield 15.97 (t/ha).So the increase of number of pods inflorescence-1 (2.12) increased the yield 5.26 (t/ha) which was found by using treatment T_5 (Spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval.

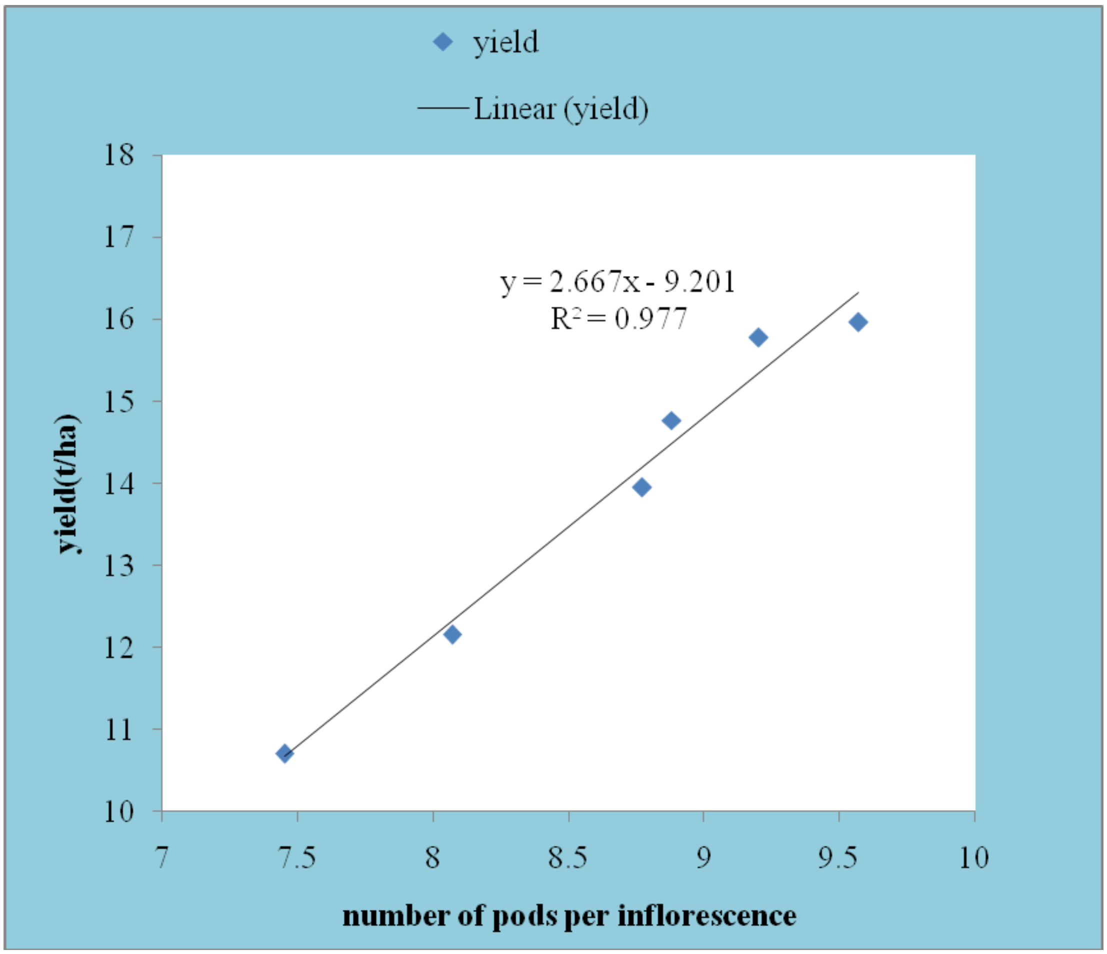

Figure 2. Relationship between number of pods inflorescence^{-1} and yield (t/ha)

4.6.2 Relationship between pod length and yield/ ha

Correlation study was done to establish the relationship between pod length and yield(t/ha) among different management practices. From the study it was revealed that positive correlation was observed between the parameters. The regression equation y = 4.189x – 29.62 gave a good fit to the data and the co-efficient of determination (R^2 = 0.813) fitted regression line had a significant regression co-efficient. From the figure 3 it was observed the lowest pod length (9.85 cm) gives the yield 10.71 (t/ha) and the highest pod length (11.05 cm) gives the yield 15.97 (t/ha). So the increase of pod length (1.2 cm) increased the yield 5.26 (t/ha) which was obtained by using treatment T_5 (Spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval. From this it may be concluded that yield of country bean strongly as well as positively correlated with pod length.

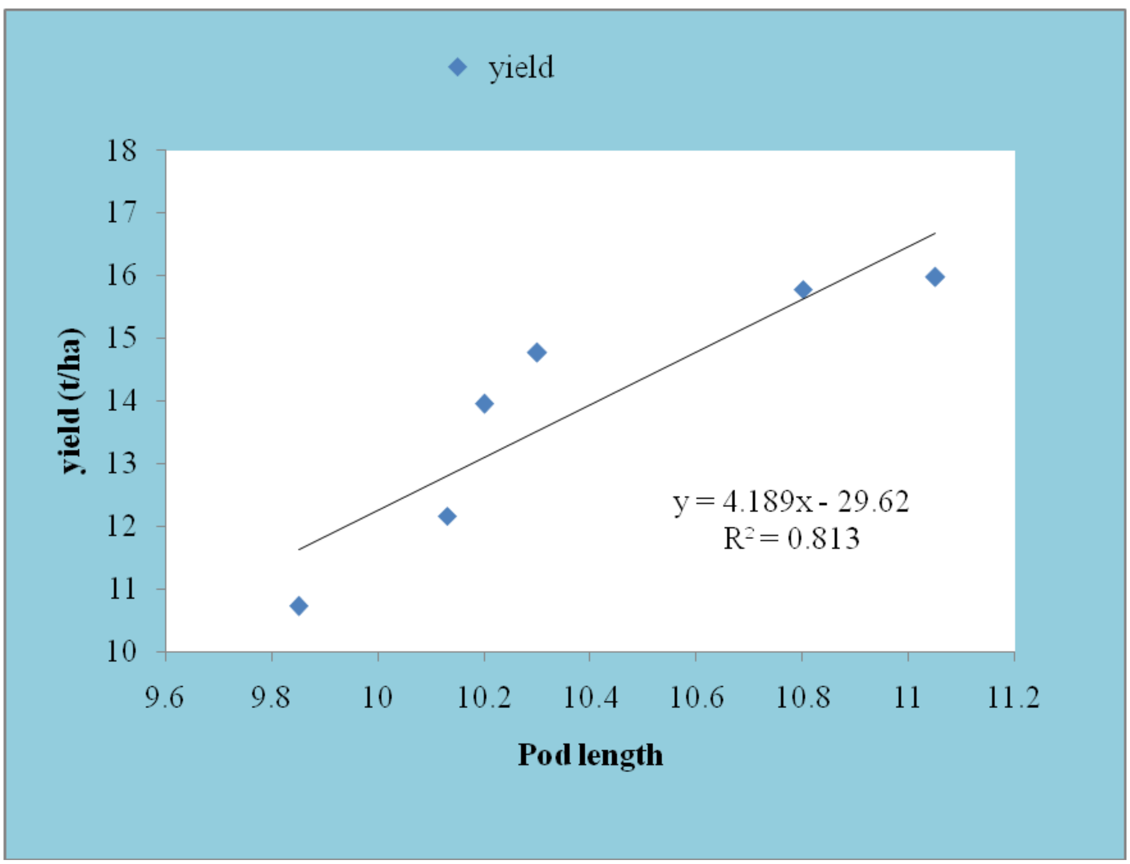

Figure 3. Relationship between pod length and yield (t/ha)

4.6.3 Relationship between number of inflorescence plant^{-1} and pod yield/ ha

Correlation study was done to establish the relationship between number of inflorescence plant-1 and yield (t/ha) of country bean among different management practices. From the figure 4 it was revealed that positive correlation was observed between the parameters. The regression equation y=0.931x-18.72 gave a good fit to the data and the co-efficient of determination (R^2 = 0.981) had a significant regression co-efficient. From the figure it was also observed that the lowest number of inflorescence plant^{-1} (31.50) gives the yield 10.71 (t/ha) and the highest number of inflorescence plant^{-1} (37.00) gives the yield 15.97 (t/ha). So the increase of number of inflorescence plant^{-1} (5.50) increased the pod yield 5.26 (t/ha) which was found by using treatment T_5 (Spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval. From the figure it may be concluded that number of inflorescence plant^{-1} strongly as well as positively correlated with pod yield of country bean (t/ha) **.**

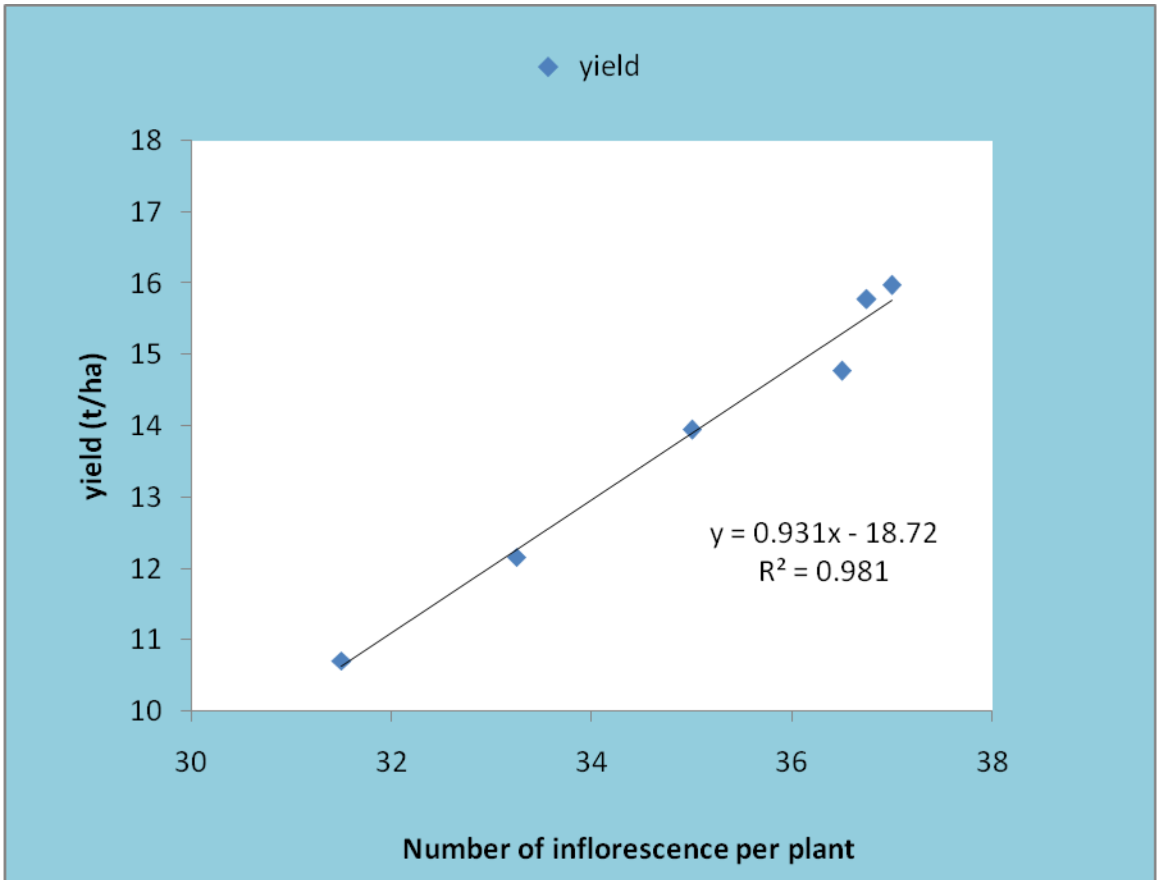

Figure 4. Relationship between number of inflorescence per plant and pod yield (t/ha)

4.6.4 Relationship between number of flower inflorescence^{-1} and pod yield/ ha

Correlation study was done to establish the relationship between number of flower inflorescence^{-1} and pod yield (t/ha) of country bean among different management practices. From the figure 5 it was revealed that positive correlation was observed between the parameters. The regression equation y=2.466x-18.52 gave a good fit to the data and the co-efficient of determination (R^2 = 0.977) had a significant regression co-efficient. From the figure it was also observed that the lowest number of flower inflorescence^{-1} (11.75) gives the yield 10.71 (t/ha) and the highest number of flower inflorescence^{-1} (13.98) gives the yield 15.97 (t/ha) which was found by using treatment T_5 (Spraying of neem oil @ 4 ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval. So the increase of number of flower inflorescence^{-1}(2.23) increased the pod yield 5.26

(t/ha). From the figure it may be concluded that number of inflorescence plant^{-1} strongly as well as positively correlated with pod yield of country bean (t/ha) **.**

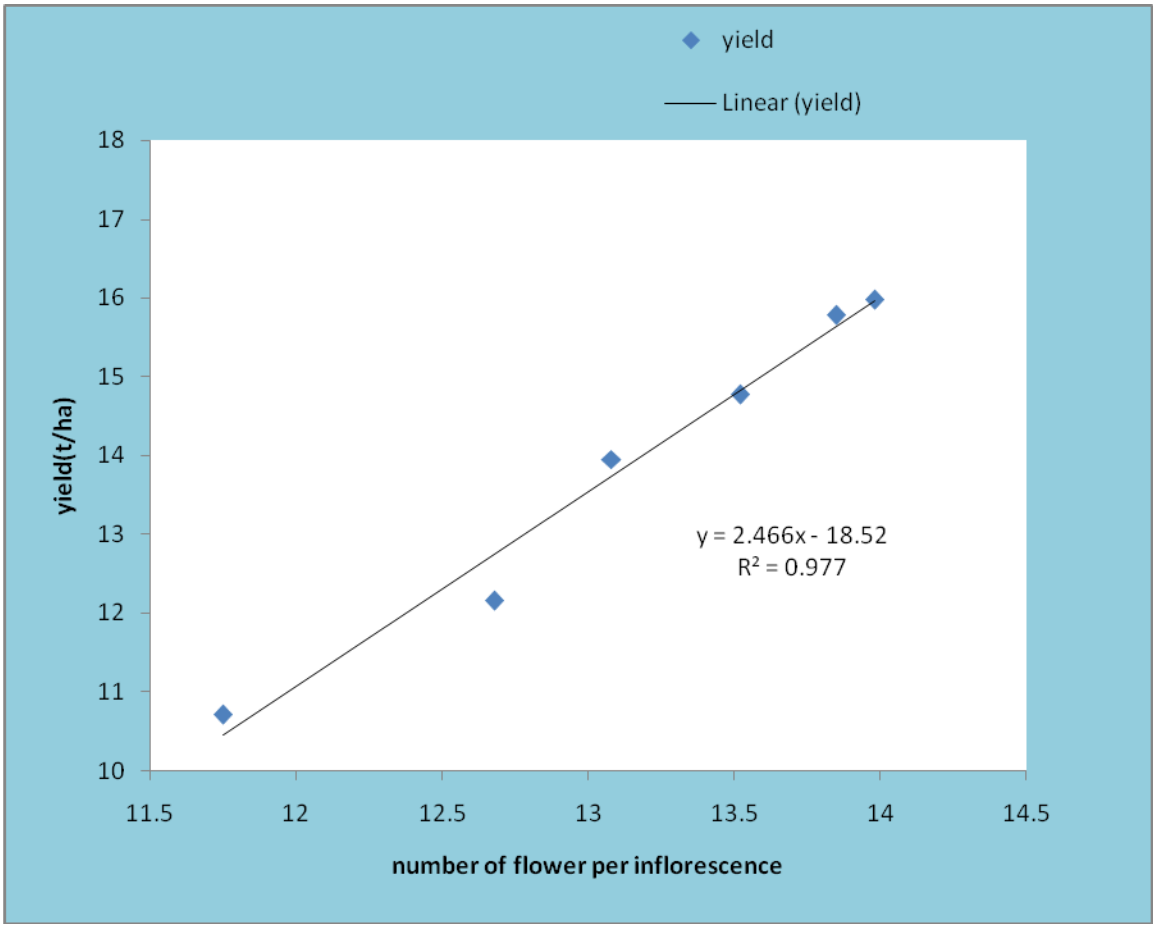

Figure 5. Relationship between number of flower inflorescence^{-1} and pod yield (t/ha)

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to evaluate the performance of different management practices in controlling major insect pests of country bean (BARI seem-3) during the period from June to December, 2012. The experiment consists of the following management practices: T_0: Untreated control; T_1: Hand picking of infested plant parts at 7 days interval; T_2: Release of *Trichogramma evanescence* @ 0.5g/6m^2 at 15 days interval ; T_3:Spraying of neem oil @ 4ml/L of water at 7 days interval; T_4: Spraying of neem oil @ 4ml/L of water + hand picking of infested plant parts at 7 days interval and T_5: Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on the parameters of number of insect pest plant^{-1}, number and weight of healthy pod, infested pod and percentage of pod infestation in number and weight, yield contributing characters and yield of country bean were observed.

Among six treatments, it was observed that treatment T_5 (Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval) was the most effective treatment for reducing insect pests infestation at early, mid and late pod development stages. In case of bean pod borer, the lowest number plant^{-1} was observed from (5.00) T_5 (Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval) which was similar (6.25) with T_4(Spraying of neem oil @ 4ml/L of water + Hand picking of infested plant parts at 7 days interval) and closely followed by(14.00 and 14.75) by T_2 (Release of *Trichogramma evanescence* @ 0.5g/6m^2 at 15 days interval) and T_3(Spraying of neem oil @ 4ml/L of water at 7 days interval, while the highest number was observed from (24.50) T_0 (Untreated control) which was followed (19.00) by T_1 (Hand picking at 7 days interval) .

In consideration of aphid, the lowest number plant^{-1} was observed from T_5 (2.00) which was staticscally similar with T_4 (3.25) and closely followed by T_3 (4.00) and T_1 (5.00), whereas the highest number was recorded from T_0 (12.00) followed by T_2 (8.75). At mid pod development stage, in case of bean pod borer, the lowest number plant^{-1} was observed from T_5 (6.00) which was statistically similar with T_4 (6.25) and closely followed by T_2 (17.00) and T_3 (17.50), whereas the highest number was observed from T_0 (31.50) which was followed by T_1 (24.25). In consideration of aphid, the lowest number plant^{-1} was observed from T_5 (3.25) which was statiscally identical with T_4 (3.25) and closely followed by T_3 (5.75) and T_1 (6.75), whereas the highest number was observed from T_0 (11.83) followed by T_2 (9.25). At late pod development stage, in case of bean pod borer, the lowest number plant^{-1} was observed from T_5 (8.25) which was statiscally similar with T_4 (8.75) and closely followed by T_2 (19.00) and T_3 (20.25), whereas the highest number was observed from T_0 (37.00) which was followed by T_1 (33.25). Aphid was observed lowest in number from T_5 (4.00) which was statiscally similar with T_4 (5.25) and closely followed by T_3 (6.00) and T_1 (7.75), whereas the highest number was observed from T_0 (15.25) followed by T_2 (11.75).

In total growing period by number of healthy pods, the highest number plant^{-1} was found from T_5 (315.75) which was followed by T_4 (298.00), T_2 (295.00) and T_3 (277.00), while the lowest number of healthy pods were observed from T_0 (205.00) which was followed by T_1 (235.00). The lowest number of infested pods plant^{-1} was observed from T_5 (24.25) which was similar to T_4 (28.50) and followed by T_2 (32.00) and T_3 (36.00.00) , the highest number of infested pods was observed from T_0 (56.50) which was followed by T_1 (48.00). In relation to the % pods infestation, the lowest infested pods plant^{-1} by number was observed from T_5 (7.13%) which was followed by T_4 (8.73%), T_2 (9.78%) and T_3 (11.52%), again the highest in T_0 (21.63%) followed by T_1 (16.99%) It was also revealed that the trends of results regarding the reduction of pod infestation by number was $T_5>T_4>T_2>T_3>T_1>T_0$. Pod infestation reduction over control by number was estimated and the highest value was found from the treatment T_5 (67.04%) which was followed by T_4 (59.64%), T_2 (54.79%) and T3 (46.74%) and the lowest from T_1 (21.456%) treatment. In context of healthy pods, the highest weight plant^{-1} was observed from T_5 (2601.66 g) which was followed by T_4 (2455.08 g), T_2 (2430.37 g) and T_3 (2274.61 g).

The lowest weight of healthy pods was observed from T_0 (1634.96 g) followed by T_1 (1901.62 g). Considering the infested pods, the lowest weight of infested pods plant^{-1} was observed from T_5 (198.42 g) which was followed by T_4 (238.05 g), T_2 (261.31 g) and T_3 (289.38 g), while the highest in T_0 (445.16 g) followed by T_1 (388.28 g) treatments. In relation to the % pod infestation by weight, the lowest infested pods plant^{-1} was observed from T_5 (7.09%) which was followed by T_4 (8.84%), T_2 (9.71%) and T_3 (11.28%) whereas the highest in T_0 (21.40%) followed by T_1 (16.99%) treatments. It was also revealed that the trends of results regarding the reduction of pod infestation by weight was $T_5>T_4>T_2>T_3>T_1>T_{0.}$

The highest number of inflorescence plant^{-1} was observed from T_5 (37.00) which was followed by T_4 (36.75), T_2 (36.50) and T_3 (35.00), while the lowest number was observed from T_0 (31.50) followed by T_1 (33.25) treatments. The highest number of flower inflorescence^{-1} was observed from T_5 (13.98) which was followed by T_4 (13.85), T_2 (13.52) and T_3 (13.08) while the lowest number was observed from T_0 (11.75) followed by T_1 (12.68) treatments. The highest number of pod inflorescence^{-1} was observed from T_5 (9.57) which was followed by T_4 (9.20),T_2 (8.88) and T_3 (8.77), while the lowest number was observed from T_0 (7.45) followed by T_1 (8.07) treatments. The longest pod was recorded from T_5 (11.05 cm) which was followed by T_4 (10.80 cm), T_2 (10.30 cm) and T_3 (10.20 cm), while the shortest pod was observed from T_0 (9.85 cm) followed by T_1 (10.13 cm) treatments. The highest number of pod plant^{-1} was observed from T_5 (340) which was followed by T_4 (326.50), T_2 (327.00) and T_3 (313.00), while the lowest number was observed from T_0 (261.50) followed by T_1 (283.00) treatments. The highest yield plot^{-1} was recorded from T_5 (9.58 kg) which was followed by T_4 (9.47 kg), T_2 (8.86 kg) and T_3 (8.37 kg), while the lowest yield plot^{-1} was recorded from T_0 (6.42 kg) followed by T_1 (7.30 kg) treatments. The highest yield hectare^{-1} was recorded from T_5 (15.97 ton) which was followed by T_4 (15.78 ton), T_2 (14.77ton) and T_3 (13.95 ton), while the lowest yield hectare^{-1} was recorded from T_0 (10.71 ton) followed by T_1 (12.16 ton) treatments. Considering the controlling of country bean insect pests highest benefit cost ratio (4.21) was recorded in the treatment T_5 and the lowest benefit cost ratio was recorded from T_1 (1.32).

Conclusion

The present study revealed that the increased yield hectare^{-1} of country bean with the increase rate of number of inflorescences plant^{-1}, number of flower for 10 inflorescences, number of healthy flower for 10 inflorescences, total number of pods, number of healthy pods and decrease rate of infested flower for 10 inflorescences, number of infested pods, increased rate of length of 20 healthy pods, weight of 20 healthy pods (g), total weight of healthy pods (g) and even the highest length (cm), and decreased rate of weight of 20 infested pods (g), highest total weight of infested pods (g) along with increased total yield (kg) pods might be obtained by using the treatment T_5 (Spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval).Whereas the treatment T_4 (Spraying of neem oil @ 4ml/L of water + Hand picking of infested plant parts at 7 days interval) gives better results than the treatmen T_3 (Spraying of neem oil @ 4ml/L of water at 7 days interval) and T_2 (Release of *Trichogramma evanescence* @ 0.5g/6m^2 at 15 days interval) used in this experiment.

From the above description, it can be concluded that, spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval reduced the infestation of major insect pests of country bean of variety BARI seem-3.

Recommendations

From this study it may be recommended that the treatment T_5 which consists of spraying of neem oil @ 4ml/L of water and hand picking of infested plant parts at 7 days interval + Release of *Trichogramma evanescence* @ 0.5 g/6m^2 at 15 days interval can be used successfully for reducing the infestation of major insect pests of country bean of variety BARI seem-3. The treatment T_4 (Spraying of neem oil @ 4ml/L of water + Hand picking of infested plant parts at 7 days interval) was the second best treatment in the experiment which could be incorporated with neem seed kernel and other cultural practices for better results in future. However, further study of this experiment is needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

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