EFFICACY OF DIFFERENT PLANT EXTRACT FOR THE MANAGEMENT OF APHID AND POD BORER OF COUNTRY BEAN

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EFFICACY OF DIFFERENT PLANT EXTRACTS FOR THE MANAGEMENT OF APHID AND POD BORER OF COUNTRY BEAN

BY

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Dedicated To

My Beloved Parents

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CERTIFICATE

This is to certify that thesis entitled, **EFFICACY OF DIFFERENT PLANT EXTRACTS FOR THE MANAGEMENT OF APHID AND POD BORER 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 **Md. Rubel Mia**, Registration No. **13-05482** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2020
Dhaka, Bangladesh

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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

EFFICACY OF DIFFERENT PLANT EXTRACTS FOR THE MANAGEMENT OF APHID AND POD BORER OF COUNTRY BEAN

ABSTRACT

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to evaluate the efficacy of different plant extracts for the management of aphid and pod borer of country bean (BARI seem-5) during the period from November, 2018 to March, 2019. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Seven treatments, viz. T_1=Neem leaves extract @ 5ml/L of water at 10 days interval; T_2= Onion bulb extract @ 5ml/L of water at 10 days interval; T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval**;** T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval; T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval; T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval; T_7= Untreated Control were used. In consideration of total growing period by number the % pod infestation, the lowest infested pods plant^{-1} by number was observed from T_1 (21.02%), where the highest pod infestation was found from T_7 (60.13%), % pod infestation in weight, the lowest infested pods plant^{-1} was observed from T_1 (16.79 %), whereas the highest in T_7 (56.10%). The highest number of inflorescence plant^{-1} was observed from T_1 (33.08) while the lowest number was observed from T_1 (26.00) treatment. The highest yield hectare^{-1} was found from T_1 (4.28 ton), while the lowest yield hectare^{-1} was found from T_7 (2.94 ton) treatments. The pod yield of country bean was highly significant (p=0.05), very strong (r^2=0.949) 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, the highest benefit cost ratio (3.03) was recorded in the treatment T_1 and the lowest benefit cost ratio was recorded from T_7 (2.50).The pod yield of country bean was highly significant (p=0.05), strong (r^2=0.935, r^2=0.913, r^2=0.949, r^2=971) and positively correlated with number of pods inflorescence^{-1}, pod length, number of inflorescence plant^{-1}, number 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_1 which comprised with the spraying of neem leaves extract @ 5ml/L of water at 10 days interval was more efficacy of different plant extract for the management of aphid and pod borer of country bean which was followed by spraying of T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval.

Chapter I

Introduction

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, Cumilla, 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 137,495 metric tons of country beans were produced from 51,595 acres of land (BBS, 2018).

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.

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).

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.

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.

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 Islam., 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).

The naturally occurring, biologically active plants appear to have a prominent role for the development of future commercial pesticides not only for increased productivity but for the safety of the environment and public health. Botanicals are, in general, more compatible with the environmental components than the synthetic pesticides, owing primarily to their susceptibility to degradation by light, heat and microorganisms. Moreover, there is no report of pest resurgence due to the use of botanicals pesticides. The ecological approach to pest management suggests the use of botanical pesticide and some chemical pesticide only and where necessary. It may become therefore, absolutely impetration that a fresh approach to insect pest control be undertaken by studying its population fluctuation in relation to agro-cofactors. Such study will provide an opportunity to face the pest challenge with integrated management.

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 outbreak. 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.

Under these circumstances, it becomes necessary to find out some eco-friendly alternative methods for insect pest management of country bean. 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 damage severity of aphid and pod borer on country bean and
- ✓ To find out the efficacy of different plant extracts against aphid and pod borer.

Chapter II

Review of Literature

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 arthropods (Govindan, 1974). In northern India, country beans have been reported to be frequently attacked by the galerucid beetle, *Madurasia obscurella* Jacob (Coleoptera: Chrysomelidae), which may cause economic damage to the crop (Gupta and Singh, 1978). Naresh and Nene (1968) and Saxena (1976) have also reported that galerucid beetles and some other insect pests including various aphid species; hooded hopper, *Leptocentrus taurus* Fb. (Homoptera: Membracidae); leaf beetle, Sagra carbunculus Hope (Coleoptera: Chrysomelidae); leaf-eating caterpillars, Plusia oricalchea Fb. (Lepidoptera: Pyralidae); leaf miner, *Cosmopterix sp*. (Lepidoptera: Pyralidae); leaf weevil, *Blosyron oniscus*. and *Alcides collaris* P. (Coleoptera: Curculionidae); pod borer, *Maruca sp*. (Lepidoptera: Pyralidae); and mites, *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 General review of bean pod borer

2.2.1 Nomenclature

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Pyralidae

Genus: *Maruca*

Species: *Marucavitrata Fab.*

2.2.2 Biology of pod borer

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.

Mating and oviposition

The eggs were laid singly, late in the evening, mostly after 2100 hours 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, mug bean 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 w ith an average of 990.70 ± 127.40.

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).

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.

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.

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.

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.

2.3 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, pigeon pea, cowpea, peas, various beans, cotton, sunflower, safflower, tobacco, tomato, brinjal, cucurbits, sweet potato, groundnut, flax, citrus, sun hemp, potato etc. Bhatnagar and Davies (1978) 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.

2.4 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).

2.5 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 General review of bean aphid

2.6.1 Nomenclature

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Suborder: Sternorrhyncha
Family: Aphididae

Genus: *Aphis*

Species: *A. craccivora*

2.6.2 Nature of damage

Aphis craccivora causes direct damage to plants by stunting and distorting growth. The honeydew produced is deposited on the plants and encourages the growth of sooty moulds which restrict photosynthesis. The aphid is the vector of a number of plant viruses including groundnut rosette virus, peanut mottle virus, peanut stunt virus, subterranean clover stunt virus, bean common mosaic virus, cucumber mosaic virus and alfalfa mosaic virus.

2.7 Yield loss caused by pod borer

M. vitrata (testulalis) is a very important pest causing profound damages to legume crops including the country beans in Bangladesh. Singh and Taylor (1978), Rahman (1987) and Rahman and Rahman (1988) reported that pod borer infestation may cause great reduction of yields of the infested crops. However, these authors did not provide any information with respect to the amount of percentage of yield reduction caused by the pest attack. Nevertheless, there have been several reports on quantified effects of the pest infestation on various crops. Singh and Allen (1980) reviewed the infestation of pod borers in field and horticultural corps across Africa, Asia, south Central America and Australia, and concluded that the insect can cause 20 – 60% damage to host crops. Karel (1985) in Tanzania found that the pod borer infestation could reduce seed yields of local French bean cultivars by 20%- 50%. In Kenya, the insect was found to cause 80% reduction of cowpea production (Okeyo-Owuor and Ochieng, 1981). Rahmanet.al., (1981) found the insect to cause as high as 100% infestation of black gram leaves, the effect of infestation at such high levels are likely to be profound on yield of the crop. Rahmanet al. (1981) reported that bean pod borers could cause as high as 38% reduction of the yields of pigeon peas in Bangladesh. Ohno and Alam (1989) found that pod borer damage in cowpea was 54.4% at harvest, although the reduction of seed yield of cowpeas was estimated only 20 %. Sarder and Kundu (1987) studied pod borer infestation in four bean cultivars and reported that the borers caused up to 7% reduction of country bean yield in Bangladesh. Kabir et al. (1983) studied pod borer infestations on 32 different genotypes of country beans in Jamalpur, Bangladesh and found that the insect caused up to 17% damage to country bean pods. But for country beans the magnitude of infestation would be more severe, as infested pods are likely to be unfit and unacceptable for human consumption.

2.8 Control of aphid and pod borer in field crops

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.

2.8.1 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.

2.8.2 Cultural control

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.

2.8.3 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).

2.8.4 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 phyto-toxicity and accumulation seen in plants and no adverse effect on water or groundwater (Mehlhorn *etal*.,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 trial 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 trial 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.

2.8.5 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).

2.8.6 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).

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

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).

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.

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 bio-intensive IPM module is considered as a more ecological-friendly option to control pod borer infestation.

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the efficacy of different plant extract for the management of aphid and pod borer of country bean during the period from November, 2018 to march, 2019. 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 Location of the experimental field

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.

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). The average maximum and minimum temperature were 29.45ºC and 13.86º C respectively during the experimental period. In our country rabi season is characterized by plenty of sunshine.

3.3 Soil of the experimental field

The soil of the experimental area belongs to the Modhupur Tract, corresponding AEZ No. 28. The soil of the experimental area is shallow red brown terrace soil. The land of the selected experimental plot is medium high under the Tejgaon series (FAO, 1988).

3.4 Planting material

Seeds of BARI seem-5 were used as the test crop of this experiment. The seeds 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 cow dung were mixed with soil. In each plot measuring 3.0 m × 2.5 m, 4 pit were prepared for seedling transplantation.

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.

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 cow dung 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 first week of November, 2018. 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 and finally two weeks after transplanting.

3.8 Treatments used for management

Seven treatment combinations will be tested in this experiment:

T_1=Neem leaves extract @ 5ml/L of water at 10 days interval

T_2= Onion bulb extract @ 5ml/L of water at 10 days interval

T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval

T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval

T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval

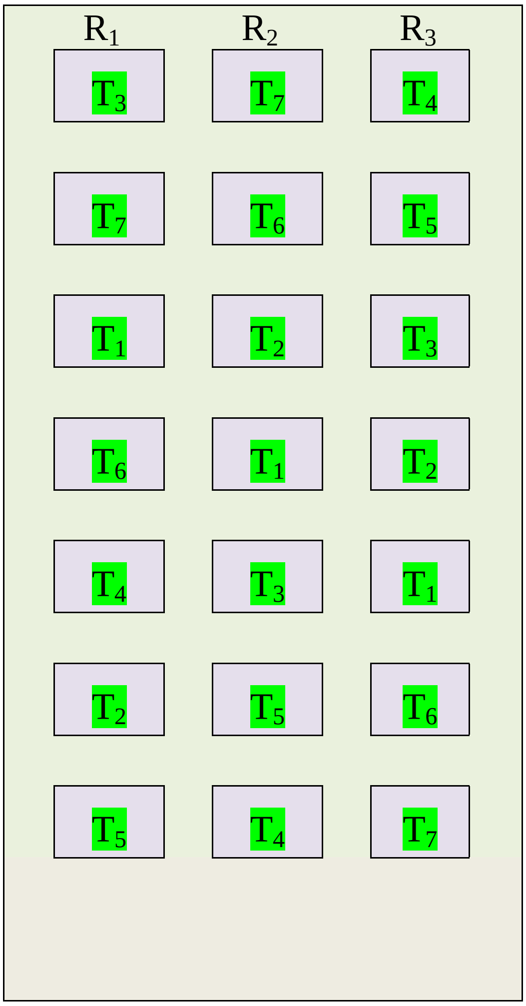
T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval

T_7= Untreated Control

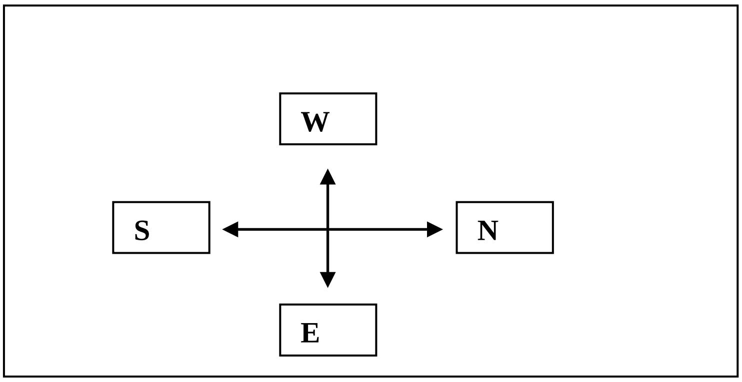
3.9 Experimental layout and design

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 7 plots, where 7 treatments were allocated at random. There were 21 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.5 m. The distance maintained between two blocks and two plots were 1.0 m and .75 m respectively (Plate 1.)

Plate 1.The experimental plot at SAU, Dhaka



Legend



Treatments:

T_1=Neem leaves extract @ 5ml/L of water at 10 days interval

T_2= Onion bulb extract @ 5ml/L of water at 10 days interval

T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval

T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval

T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval

T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval

T_7= Untreated Control

Plot size: 3 X 2.5 m^2

Plot to plot distance = 0.75 m

Block to block distance = 1 m

Replications = 3

Figure 1.Layout of plot

3.10 Collection and preparation

3.10.1 Neem leaves extract

The fresh neem leaves were collected from the neem tree from the Horticulture Garden of SAU. Leaves were sun dried 2 to 3 days and crashed using electric grinder, of which 250 gm dried neem leaf powder was taken into a 500 ml beaker. 250 ml water was taken into the beaker and then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of neem leaves. The aqueous extract then filtered using Whatman no. 1 paper filter and preserved the aqueous extract as flock solution in the refrigerator at 4^0c for experimental use.

3.10.2 Onion bulb extract

Fresh onion bulbs were collected from the local market and chopped the bulbs in small size by sharp knife. Then 250 gm chopped onion bulbs were taken into electric blender for blending. Then the blended onion was taken into the beaker and 250 ml water was added with the onion extract. Then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of onion. The aqueous extract then filtered using Whatman no.1 paper filter and preserved the aqueous extracts of onion in the refrigerator at 4^0c for experimental use.

3.10.3 Datura seeds extract

The mature and dried datura seeds were collected from the datura tree found in the campus of SAU. Then seeds were roasted at 60ºC to 80ºC for 1 to 2 days by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of this powder was taken into a beaker and 250 ml water was added into it. Then the beaker was shaken by electric stirrer for 30 minutes thoroughly the mixture. The aqueous mixture then filtered using Whatman no. 1 paper filter and preserved the aqueous extracts in the refrigerator at 4^0C for future experimental use**.**

3.10.4 Black pepper seed extract

The fresh black pepper seeds were collected from the local market. seeds were crashed using electric grinder, of which 250 gm dried black pepper powder was taken into a 500 ml beaker. 250 ml water was taken into the beaker and then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of black pepper. The aqueous extract then filtered using Whatman no. 1 paper filter and preserved the aqueous extract as flock solution in the refrigerator at 4^0C for experimental use.

3.10.5 Garlic bulb extract

Fresh garlic bulbs were collected from the local market and chopped the bulbs in small size by sharp knife. Then 250 gm chopped garlic bulbs were taken into electric blender for blending. Then the blended garlic was taken into the beaker and 250 ml water was added with the garlic extract. Then the beaker was shaken for 30 minutes with the magnetic stirrer to make the extracts of garlic. The aqueous extract then filtered using Whatman no.1 paper filter and preserved the aqueous extracts of garlic in the refrigerator at 4^0C for experimental use.

3.10.6 Mahogany seed extract

The mature and dried mahogany seeds were collected from the mahogany tree found in the campus of SAU. Then seeds were roasted at 60ºC to 80ºC for 1 to 2 days by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of this powder was taken into a beaker and 250 ml water was added into it. Then the beaker was shaken by electric stirrer for 30 minutes thoroughly the mixture. The aqueous mixture then filtered using Whatman no. 1 paper filter and preserved the aqueous extracts in the refrigerator at 4^0C for future experimental use.

3.11 Treatments application

3.11.1 Neem leaves extract

For proper management of bean pod borer and aphid 5ml neem leaves extract was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2.5m area.

3.11.2 Onion bulb extract

For proper management of bean pod borer and aphid 5ml onion bulb extract was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2.5m area.

3.11.3 Datura seeds extract

For proper management of bean pod borer and aphid 5ml Datura seeds extract was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2.5m area.

3.11.4 Black pepper seed extract

For proper management of bean pod borer and aphid 5ml black pepper seeds extract was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2.5m area.

3.11.5 Garlic bulb extract

For proper management of bean pod borer and aphid 5ml Garlic bulb extract was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2.5m area.

3.11.6 Mahogany seed extract

For proper management of bean pod borer and Aphid 5ml mahogany seeds extract was poured in 1Litre of water and then 1ml trix was mixed to obtain fine droplet to spray 3m x 2.5m area.

3.12 Intercultural operations

After transplanting the plants were initially irrigated by watering can and later on surface irrigation was given. After 7 days of transplanting, propping of each plant by bamboo sticks (1.5 m) was provided on about 1.3 m high from ground level for additional support to allow normal creeping. All the bamboo sticks in each row were fastened strongly by a galvanized wire to allow the vines to creep along. Weeding and mulching in the plots were done, whenever necessary.

3.13 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.

3.14 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 pest
- 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)

3.15 Procedure of data collection

3.15.1 Incidence of insects

All of the 4 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 different development stage (Plate 2.)

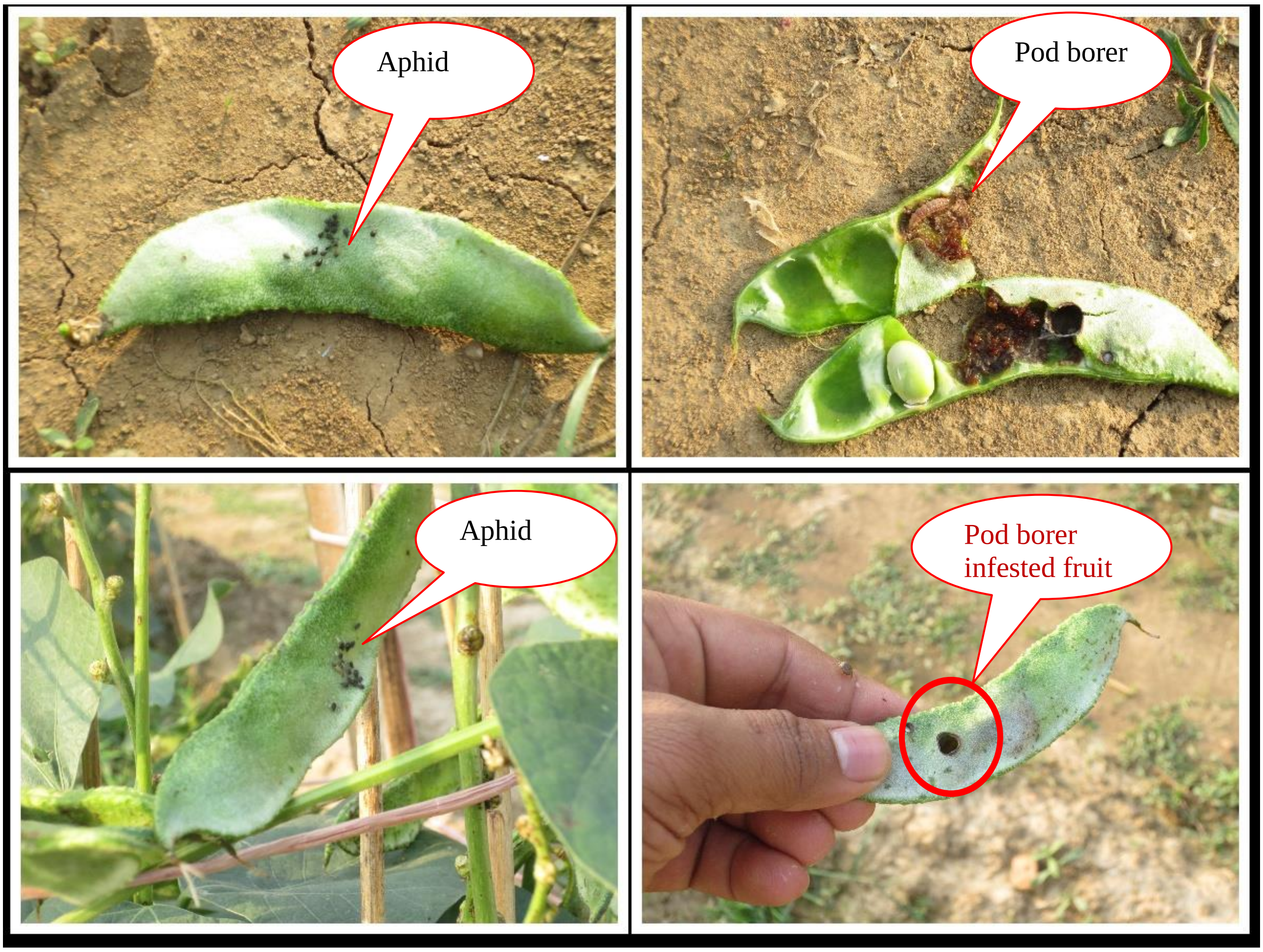


Plate 2. Aphid and pod borer incidences in experimental plot

3.15.2 Counting of Aphid

The number of aphid on 4 selected plants from four selected plant each plot was counted at an interval of 7 days at each harvest during different stage of the plant. The top 10 cm apical twigs of 4 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 4 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.

3.15.3 Counting of bean pod borer larvae

Borer infested flowers and 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 10 days at each harvest during different stage of the plant from 4 plants of each plot.

3.15.4 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 different development stage (Plate 3.)

Plate 3. Number of healthy pod in the experimental plot during the study period

3.15.5 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 different stage (Plate 4 and Plate 5).

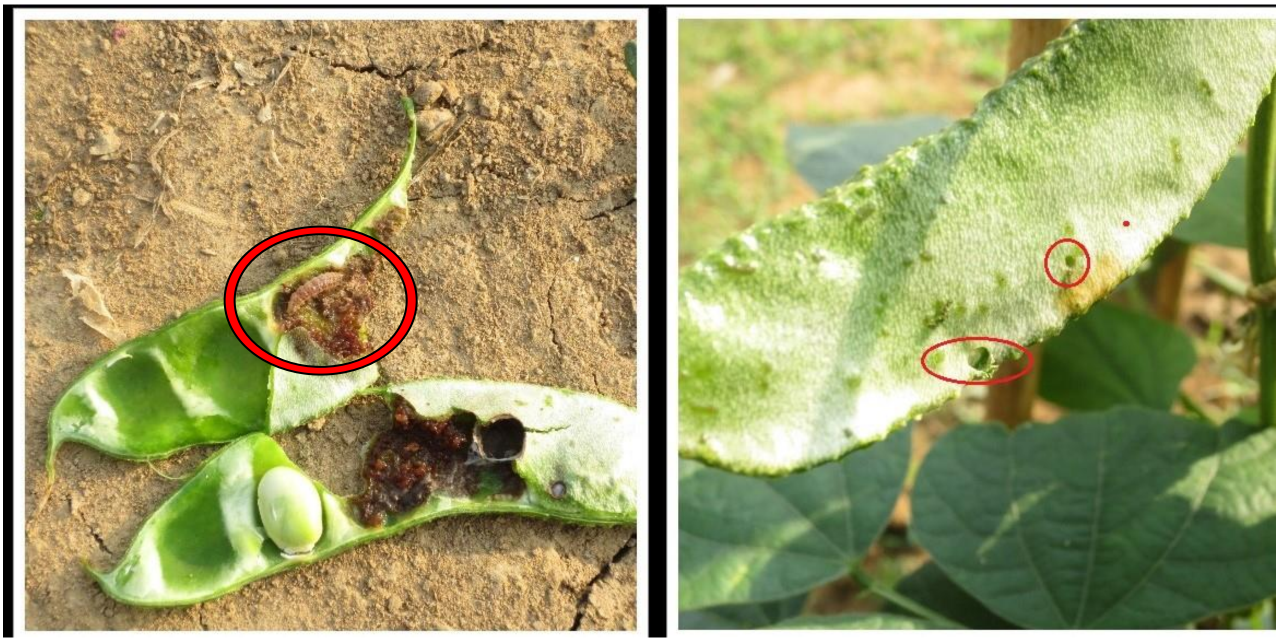


Plate 4. Pod borer infested pod of country bean.

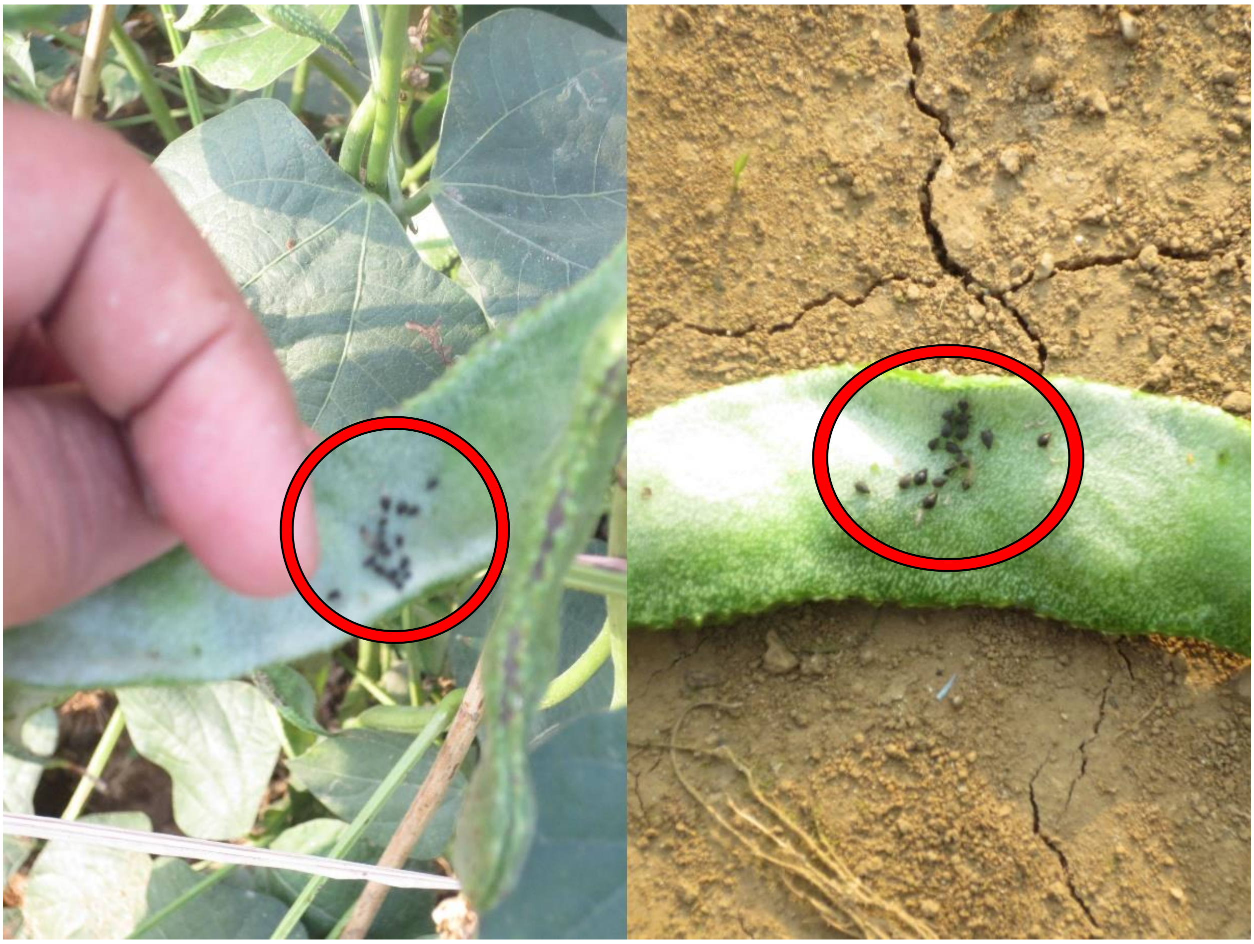


Plate 5. Aphid infested pod of country bean in the experimental plot

3.15.6 Pod infestation by number

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

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

Percent decrease of infestation over control

$$= \frac{\text{Infestation of control plots - infestation of treated plots}}{\text{Infestation of control plot}} \times 100$$

3.15.7 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 different stage.

3.15.8 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 during different stage.

3.15.9 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:

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

3.15.10 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).

3.15.11 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.

3.15.12 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.

3.15.13 Pod length

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

3.15.14 Pod yield plot^{-1}

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

3.15.15 Pod yield hectare^{-1}

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

Percent increase of yield over control

$$= \frac{\text{Yield of treated plots - Yield of control plots}}{\text{Yield of control plots}} \times 100$$

3.16 Harvesting

Harvesting of the country bean was not possible on a certain or particular date because the initiation of bean as well as attaining the head at marketable size in different plants were not uniform. Only the compact marketable beans were harvested with fleshy stalk by using as sharp knife.Before harvesting of the country bean was tested by pressing with thumbs.

3.17 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 & Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to study the efficacy of different plant extract for the management of aphid and pod borer 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 analysis of variance (ANOVA) of the data on efficacy of different plant extracts for the management of aphid and pod borer of country bean are given in Appendix 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 different stages depending on the duration of reproductive stage to investigate the performance of different treatments.

4.1.1 Early vegetative stage of country bean

At early vegetative stage statistically significant variation ($p>0.05$) was recorded for aphid due to different management practices (Table 1) at days after transplanting (DAT) . In case of aphid, the lowest number per plant (3.33) was found from T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) which was statistically different (4.00) with T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval) and (4.67) with T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval) treatments respectively.

On the other hand, the highest number of aphid was recorded in (8.67**)** T_7 (Untreated Control) which was statistically different from all other treatments followed by (6.50 and 5.75) by T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval) and T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval) and closely followed by (5.00) T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval) treatment.

In consideration of infested leaves plant^{-1}, the lowest number plant^{-1} was observed from T_1 (1.92) which was statistically with different from T_5 (2.25) and T_6 (2.50) treatments respectively, and closely followed by T_2 (2.67) and T_3 (2.75) and followed by T_4 (3.17), whereas the highest number was observed from T_7 (4.00) treatment.

Table 1. Incidence of aphid of at early vegetative stage of country bean during the study period

Treatment(s)	At early vegetative stage			
	No. of aphid plant^{-1}	No. of infested leaves plant^{-1}	No. of healthy leaves plant^{-1}	% of Infestation
T_1	3.33 g	1.92 f	15.50 a	12.37 f
T_2	5.00 d	2.67 cd	14.58 cd	18.29 c
T_3	5.75 c	2.75 c	14.33 de	19.19 c
T_4	6.50 b	3.17 b	14.08 ef	22.48 b
T_5	4.00 f	2.25 e	15.08 b	14.92 e
T_6	4.67 e	2.50 d	14.83 bc	16.84 d
T_7	8.67 a	4.00 a	13.75 f	29.08 a
$LSD_{(0.05)}$	0.15	0.24	0.41	1.24
CV(%)	1.54	4.86	1.59	3.65

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval; T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the Table 1, it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in reducing the aphid during pod infestation and was more effective among the management practices for controlling insect pests of country bean. Whereas, T_7 (Untreated Control) showed the least performance results in reducing aphid. As a result, the order of rank of study the efficacy of different plant extract for the management of aphid on country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.1.2 Mid vegetative stage of country bean

At mid vegetative stage statistically significant variation ($p>0.05$) was recorded for aphid due to different management practices (Table 1) at days after transplanting (DAT) . In case of aphid, the lowest number per plant (4.33) was found from T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) which was statistically different (5.10) with T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval) and (5.67) with T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval).

On the other hand, the highest number of aphid was recorded in (9.57**)** T_7 (Untreated Control) which was statistically different from all other treatments followed by (7.58 and 6.83) by T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval) and T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval) and closely followed by (6.05) T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval).

In consideration of infested leaves plant^{-1}, the lowest number plant^{-1} was observed from T_1 (2.82) which was statistically different from T_5 (3.35) and T_6 (3.55) and closely followed by T_2 (3.77) and T_3 (3.81) and followed by T_4 (4.23), whereas the highest number was observed from T_7 (5.05) treatment.

Table 2. Incidence of aphid at mid vegetative stage of country bean during the study period

Treatment(s)	At mid vegetative stage of country bean			
	No. aphid plant^{-1}	**No. of infested leaves plant^{-1}**	**No. of healthy leaves plant^{-1}**	**% of Infestation**
T_1	4.33 g	2.82 f	18.25 a	15.37 f
T_2	6.05 d	3.77 cd	16.59 cd	22.72 c
T_3	6.83 c	3.81 c	16.33 de	23.33 c
T_4	7.58 b	4.23 b	16.18 ef	26.14 b
T_5	5.10 f	3.35 e	17.08 b	19.61 e
T_6	5.67 e	3.55 d	16.73 bc	21.22 d
T_7	9.57 a	5.05 a	15.75 f	32.06 a
$LSD_{(0.05)}$	0.19	0.34	0.43	1.24
CV(%)	2.55	5.65	2.52	3.55

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval**;**T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the Table 1 it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in reducing the aphid during pod infestation and was more effective among the management practices for controlling insect pests of country bean. whereas, T_7 (Untreated Control) showed the least performance results in reducing aphid. As a result, the order of rank of study the efficacy of different plant extract for the management of aphid of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.2.1 Aphid and pod borer incidence at the early pod development stage of country bean

At early pod development stage statistically significant variation (p>0.05) was recorded for bean pod borer and aphid due to different management practices (Table 3) at 60 days after transplanting (DAT) . In case of bean pod borer, the lowest number per plant (1.92) was found from T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) which was statistically similar (2.25) with T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval) and (2.33) with T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval).

On the other hand, the highest pod infestation was recorded in (6.67**)** T_7 (Untreated Control) which was statistically different from all other treatments followed by (3.67 and 3.59) by T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval) and T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval) and closely followed by (3.08) T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval).In consideration of aphid, the lowest number plant^{-1} was observed from T_1 (5.42) which was statistically with different from T_5 (6.17) and T_6 (6.51) and closely followed by T_2 (6.67) and T_3 (7.42) and followed by T_4 (7.75), whereas the highest number was observed from T_7 (9.42) treatment.

Table 3. Efficacy of different plant extract for the management of aphid and pod borer of country bean at early pod development stage in term of plant^{-1}

Treatments	At early pod development stage	
	Larva of bean pod borer (No./plant)	Aphid (No./plant)
T_1	1.92 d	5.42 e
T_2	3.09 c	6.67 c
T_3	3.59 bc	7.42 b
T_4	3.67 b	7.75 b
T_5	2.25 d	6.17 d
T_6	2.33 d	6.51 cd
T_7	6.67 a	9.42 a
$LSD_{(0.05)}$	0.51	0.38
CV(%)	8.60	3.01

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval**;**T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the Table 3 it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in reducing the pod borer and aphid during pod infestation and was more effective among the management practices for controlling insect pests of country bean. whereas, T_7 (Untreated Control) showed the least performance results in reducing pod borer and aphid. As a result, the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.2.2 Aphid and pod borer incidence at the mid pod development stage of country bean

At the mid pod development stage statistically significant variation ($p>0.05$) was recorded for bean pod borer and aphid due to different management practices (Table 4) at 75 days after transplanting (DAT) . In case of bean pod borer, the lowest number per plant (5.33) was found from T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) which was statistically different (7.42) with T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval) and (7.75) with T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval).

On the other hand, the highest pod infestation was recorded in (13.50**)** T_7 (Untreated Control) which was statistically different from all other treatments followed by (9.50 and 9.25) by T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval) and T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval) and closely followed by (8.25) T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval).In consideration of aphid, the lowest number plant^{-1} was observed from T_1 (8.42) which was statistically with different from T_5 (10.42) and T_6 (11.17) and closely followed by T_2 (12.00) and T_3 (12.67) and followed by T_4 (13.08), whereas the highest number was observed from T_7 (14.83) treatment.

Table 4. Efficacy of different plant extract for the management of aphid and pod borer of country bean at mid pod development stage in term of plant^{-1}

Treatments	At mid pod development stage	
	Larva of bean pod borer (No./plant)	Aphid (No./plant)
T_1	5.33 e	8.42 f
T_2	8.25 c	12.00 c
T_3	9.25 b	12.67 bc
T_4	9.50 b	13.08 b
T_5	7.42 d	10.42 e
T_6	7.75 d	11.17 d
T_7	13.50 a	14.83 a
$LSD_{(0.05)}$	0.34	0.75
CV(%)	2.20	3.56

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the Table 4 it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in reducing the pod borer and aphid during pod infestation and was more effective among the management practices for controlling insect pests of country bean. whereas, T_7 (Untreated Control) showed the least performance results in reducing pod borer and aphid. As a result, the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.2.3 Insect pest incidence at the late pod development stage of country bean

Different management practices showed statistically significant variation at the late pod development stage for bean pod borer and aphid (Table 5) at 90 days after transplanting (DAT). In case of bean pod borer, the lowest number per plant (6.42) was found from T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) which was statistically different (8.25) with T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval) and (8.67) with T_6

(Mahogany seed extract @ 5ml/L of water at 10 days interval).

On the other hand, the highest pod infestation was recorded in (15.17) T_7 (Untreated Control) which was statistically different from all other treatments followed by (10.50 and 9.83) by T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval) and T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval) and closely followed by (9.42) T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval).In consideration of aphid, the lowest number plant^{-1} was observed from T_1 (7.58) which was statistically with different from T_5 (10.25) and T_6 (10.67) and closely followed by T_2 (11.67) and T_3 (11.83) and followed by T_4 (12.08), whereas the highest number was observed from T_7 (18.83) treatment.

Table 5. Efficacy of different plant extract for the management of aphid and pod borer of country bean at the late pod development stage in term of plant^{-1}

Treatments	At late pod development stage	
	Larva of bean pod borer (No./plant)	Aphid (No./plant)
T_1	6.42 e	7.58 d
T_2	9.41 c	11.67 b
T_3	9.83 c	11.83 b
T_4	10.50 b	12.08 b
T_5	8.25 d	10.25 c
T_6	8.67 d	10.67 c
T_7	15.16 a	18.83 a
$LSD_{(0.05)}$	0.43	0.44
CV(%)	2.49	2.10

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the Table 5 it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in reducing the pod borer and aphid during pod infestation and was more effective among the management practices for controlling insect pests of country bean. whereas, T_7 (Untreated Control) showed the least performance results in reducing pod borer and aphid. As a result, the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.3 Pod bearing status

4.3.1 Pod bearing status at the early pod development stage of country bean

Significant variation were observed in number of healthy pods , infested pods, percent of infestation and infestation reduction over control at early pod development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 6) at 60 days after transplanting (DAT).

The maximum number of healthy pods plant^{-1} was observed from T_1 (18.25) which was statistically different with T_5 (16.08) and T_6 (15.58) and followed by T_2 (13.75), while the least number of healthy pods was observed from T_7 (6.58) followed by T_4 (10.92) and T_3 (11.92) treatments. On the other hand, the least number of infested pods plant^{-1} was observed from T_1 (7.33) which was statistically different with T_5 (8.42) and closely followed by T_6 (8.83) and T_2 (9.75) treatments. In contemporary, the maximum number of infested pods was found from T_7 (16.08) followed by T_4 (11.42) and T_3 (11.00) treatment. In relation to the percentage (%) of pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_1 (28.66%) which was statistically different with T_5 (34.36%) and T_6 (36.17) closely followed by T_2 (41.49%) and T_3 (47.99%) treatments, again the maximum infested pods was recorded in T_7 (70.942%) followed by T_4 (51.18%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (54.37%) which was followed by T_5 (47.69%), T_6 (45.07%) and T_2 (39.28%) treatments and the minimum reduction of pod infestation over control from T_4 (28.86%) followed by T_3 (31.45%) 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 6. Efficacy of different plant extracts for the management of aphid and pod borer 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_1	18.25 a	7.33 e	28.66 f	54.37
T_2	13.75 c	9.75 c	41.49 d	39.28
T_3	11.92 d	11.00 b	47.99 c	31.45
T_4	10.92 e	11.42 b	51.19 b	28.86
T_5	16.08 b	8.42 d	34.36 e	47.69
T_6	15.58 b	8.83 d	36.17 e	45.07
T_7	6.58 f	16.08 a	70.94 a	--
$LSD_{(0.05)}$	0.90	0.64	2.93	--
CV(%)	3.80	3.44	3.71	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the (Table 6*)* it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in pod bearing and healthy pod percentage and was more effective among the management practices for controlling insect pests infestation of country bean. Whereas, T_7 (Untreated Control) showed the highest performance results in infestation percentage of country bean. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.3.2 Pod bearing status at the mid pod development stage of country bean

Significant variation were observed in number of healthy pods , infested pods, percent of infestation and infestation reduction over control at mid pod development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 7) at 75 days after transplanting (DAT).

The maximum number of healthy pods plant^{-1} was observed from T_1 (45.67) which was statistically different with T_5 (40.58) and T_6 (39.33) and followed by T_2 (38.42), while the least number of healthy pods was observed from T_7 (23.33) followed by T_4 (28.33) and T_3 (33.58) treatments. On the other hand, the least number of infested pods plant^{-1} was observed from T_1 (13.75) which was statistically different with T_5 (17.83) and closely followed by T_6 (18.92) and T_2 (20.25) treatments. In contemporary, the maximum number of infested pods was found from T_7 (28.33) followed by T_4 (22.58) and T_3 (21.92) treatment. In relation to the percentage (%) of pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_1 (23.15%) which was statistically different with T_5 (30.56%) and T_6 (33.07%) closely followed by T_2 (34.12%) and T_3 (39.53%) treatments, again the maximum infested pods was recorded in T_7 (54.84%) followed by T_4 (44.44%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (51.43%) which was followed by T_5 (36.99%), T_6 (33.13%) and T_2 (28.43%) treatments and the minimum reduction of pod infestation over control from T_4 (20.21%) followed by T_3 (22.59%) treatment.

From the (Table 7) it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in pod bearing and healthy pod percentage and was more effective among the management practices for controlling insect pests infestation of country bean. Whereas, T_7 (Untreated Control) showed the highest performance results in infestation percentage of country bean. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

Shukla (1998) also founded the same kind of results to control bean pod borer at mid pod development stage by using botanicals and bio agent. He also observed that neem leaves extract reduced the infestation of aphid more effectively at mid fruiting stage compare to early fruiting stage and increased the number of healthy pod.

Table 7.Efficacy of different plant extracts for the management of aphid and pod borer 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_1	45.67 a	13.75 f	23.15 e	51.43
T_2	38.42 bc	20.25 c	34.12 d	28.43
T_3	33.58 c	21.92 b	39.53 c	22.59
T_4	28.33 d	22.58 b	44.44 b	20.21
T_5	40.58b	17.83 e	30.56 d	36.99
T_6	39.33 b	18.92 d	33.07 d	33.13
T_7	23.33 f	28.33 a	54.84 a	--
$LSD_{(0.05)}$	4.84	0.93	3.72	--
CV(%)	7.65	2.55	5.63	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

4.3.3 Pod bearing status at the late pod development stage of country bean

Significant variation were observed in number of healthy pods, infested pods, percent of infestation and infestation reduction over control at late pod development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 8) at 90 days after transplanting (DAT).

The maximum number of healthy pods plant^{-1} was recorded from T_1 (43.17) which was statistically different with T_5 (39.67) and T_6 (37.42) and followed by T_2 (32.83), while the least number of healthy pods was observed from T_7 (14.58) followed by T_4 (27.75) and T_3 (30.17) treatments. On the other hand, the least number of infested pods plant^{-1} was observed from T_1 (7.42) which was statistically different with T_5 (8.42) and closely followed by T_6 (9.00) and T_2 (11.58) treatments. In contemporary, the maximum number of infested pods was found from T_7 (22.67) followed by T_4 (12.50) and T_3 (12.08) treatment. In relation to the percentage (%) of pods infestation, the least infested pods plant^{-1} in number was observed from T_1 (14.67%) which was statistically different with T_5 (17.51%) and T_6 (19.40%) closely followed by T_2 (26.09%) and T_3 (28.62%) treatments, again the maximum infested pods was recorded in T_7 (60.84%) followed by T_4 (31.06%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (67.17%) which was followed by T_5 (62.77%), T_6 (60.19%) and T_2 (48.77%) treatments and the minimum reduction of pod infestation over control from T_4 (44.73%) followed by T_3 (46.56%) treatment.

Table 8. Efficacy of different plant extracts for the management of aphid and pod borer of country bean at the 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_1	43.17 a	7.42 d	14.67 f	67.17
T_2	32.83 d	11.58 b	26.09 d	48.77
T_3	30.17 e	12.08 b	28.62 c	46.56
T_4	27.75 f	12.50 b	31.06 b	44.73
T_5	39.67 b	8.42 cd	17.51 e	62.77
T_6	37.42 c	9.00 c	19.40 e	60.19
T_7	14.58 g	22.67 a	60.84 a	--
$LSD_{(0.05)}$	1.55	1.02	3.72	--
CV(%)	2.70	4.79	4.54	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the (Table 8) it was observed that, among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in pod bearing and healthy pod percentage and was more effective among the management practices for controlling insect pests infestation of country bean. Whereas, T_7 (Untreated Control) showed the highest performance results in infestation percentage of country bean. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

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.

4.4 Pod bearing status at total growing period

Significant variation were observed in number of total pods, total healthy pods, total infested pods, percent of infestation and infestation reduction over control at total growing period for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 9).

In the term of total number of bean pods plant^{-1}**,** the highest number plant^{-1} was recorded T_1 (135.58) which was statistically different with T_5 (131.00) and T_6 (128.17) and followed by T_2 (125.75), while the least number of total bean pods plant^{-1} was observed from T_7 (111.58) followed by T_4 (113.50) and T_3 (120.67) treatments. The maximum number of total healthy pods plant^{-1} was recorded from T_1 (107.08) which was statistically different with T_5 (96.33) and T_6 (91.42) and followed by T_2 (84.17), while the least number of total healthy pods was observed from T_7 (44.50) followed by T_4 (67.00) and T_3 (75.67) treatments. On the other hand, the least number of total infested pods plant^{-1} was observed from T_1 (28.50) which was statistically different with T_5 (34.67) and closely followed by T_6 (36.75) and T_2 (41.58) treatments. In contemporary, the maximum number of total infested pods was found from T_7 (67.08) followed by T_4 (46.50) and close to T_3 (45.00) treatment. In relation to the percentage (%) of total pods infestation, the least infested pods plant^{-1} in number was observed from T_1 (21.02%) which was statistically different with T_5 (26.46%) and T_6 (28.68%) closely followed by T_2 (33.07%) and close to T_3 (37.30%) treatments, again the maximum percentage of total infested pods was recorded in T_7 (60.13%) followed by T_4 (41.01%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (57.52%) which was followed by T_5 (48.32%), T_6 (45.21%) and T_2 (38.01%) treatments and the minimum reduction of pod infestation over control from T_4 (30.68%) followed by T_3 (32.92%) treatment.

Table 9. Efficacy of different plant extracts for the management of aphid and pod borer of country bean at total pod growing period in terms of pods plant^{-1} by number

Treatments	Bean pods by number plant^{-1}				
	Total	Healthy	Infested	% Infestation	Reduction over control (%)
T_1	135.58 a	107.08 a	28.50 g	21.02 g	57.52
T_2	125.75 c	84.17 d	41.58 d	33.07 d	38.01
T_3	120.67 d	75.67 e	45.00 c	37.30 c	32.92
T_4	113.50 e	67.00 f	46.50 b	41.01 b	30.68
T_5	131.00 b	96.33 b	34.67 f	26.46 f	48.32
T_6	128.17 bc	91.42 c	36.75 e	28.68 e	45.21
T_7	111.58 e	44.50 g	67.08 a	60.13 a	--
$LSD_{(0.05)}$	4.32	4.70	0.78	1.72	--
CV(%)	1.96	3.26	1.02	2.73	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the (Table 9) it was observed that, among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in total pod bearing and total healthy pod percentage and was more effective among the of different plant extract for the management of aphid and pod borer of country bean. Whereas, T_7 (Untreated Control) showed the highest performance results in infestation percentage of country bean. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.5 Pod weight per plant at different development stages of country bean

4.5.1 Pod weight at the early pod development stage of country bean

From (Table 10) showed that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation ($p>0.05$) at early pod development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean at 60 days after transplanting (DAT). In context of healthy pods, the maximum weight plant^{-1} (121.07 g) was found from T_1 which was statistically similar with T_5 (106.78 g) and followed by T_6 (98.02 g) and T_2 (84.47 g) treatments. On the other hand, the minimum weight of healthy pods plant^{-1} was found from T_7 (33.98 g) which was followed by T_4 (66.90 g) and T_3 (75.92 g) treatment. Considering the infested pods, the weight of lowest infested pods plant^{-1} was observed from T_1 (32.81 g) which was statistically similar with T_5 (35.67 g) and close to T_6 (39.07 g) and T_2 (47.65 g), while the weight of highest infested pods plant^{-1} was found in T_7 (66.48 g) and closely followed by T_4 (51.71 g) and T_3 (49.30 g) treatment. In relation to the percentage (%) of pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_1 (21.33%) which was statistically similar with T_5 (25.05%) and closely followed by T_6 (25.52%) and T_2 (36.07%), whereas the highest weight of infested pods plant^{-1} was observed in T_7 (66.22%) followed by T_4 (43.67%) and also followed by T_3 (39.30 g) treatment. In the basis of pod infestation reduction over control in weight plant^{-1} was estimated and the highest value was obtained from the treatment T_1 (50.67%) which was statistically similar with T_5 (46.33%) closely followed by T_6 (41.22%), close to T_2 (28.34%), on the contrary, the lowest value from T_4 (22.23%) and followed by T_3 (25.86%) treatment.

Table 10. Efficacy of different plant extracts for the management of aphid and pod borer 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_1	121.07 a	32.81 f	21.33 g	50.67
T_2	84.47 d	47.65 c	36.07 d	28.34
T_3	75.92 e	49.30 c	39.40 c	25.86
T_4	66.90 f	51.71 b	43.67 b	22.23
T_5	106.78 b	35.67 e	25.05 f	46.33
T_6	98.02 c	39.07 d	28.52 e	41.22
T_7	33.98 g	66.48 a	66.22 a	--
$LSD_{(0.05)}$	7.60	1.88	2.93	--
CV(%)	5.09	2.29	4.42	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval; T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval**;**T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the above findings (Table 10) it is revealed that, at the early pod development stage T_1 (spraying neem leaves extract @ 5ml/L of water 10 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_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval). Least performance of treatment was T_7 (Untreated Control). Roksana *et al.* (2013) 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 and aphid.

4.5.2 Pod weight at the mid pod development stage of country bean

From (Table 11) showed that, the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation ($p>0.05$) at mid pod development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean at 75 days after transplanting (DAT). In context of healthy pods, the maximum weight plant^{-1} (279.54 g) was recorded from T_1 which was statistically different with T_5 (238.81g) and closely followed by T_6 (224.83 g) and close to T_2 (212.13 g) treatments. On the other hand, the minimum weight of healthy pods plant^{-1} was recorded from T_7 (116.39 g) which was followed by T_4 (171.26 g) and close to T_3 (198.68 g) treatment. Considering the infested pods, the weight of lowest infested pods plant^{-1} was observed from T_1 (69.11 g) which was statistically similar with T_5 (90.23 g) and close to T_6 (97.96 g) and T_2 (102.30 g), while the weight of highest infested pods plant^{-1} was found in T_7 (141.73 g) and closely followed by T_4 (120.59 g) and T_3 (108.69 g) treatment. In relation to the percentage (%) of pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_1 (19.82%) which was statistically similar with T_5 (27.43%) and closely followed by T_6 (30.37%) and T_2 (32.54%), whereas the highest weight of infested pods plant^{-1} was observed in T_7 (54.92%) followed by T_4 (41.33%) and also followed by T_3 (35.35 g) treatment. In the basis of pod infestation reduction over control in weight plant^{-1} was estimated and the highest value was obtained from the treatment T_1 (51.19%) which was statistically similar with T_5 (36.31%) closely followed by T_6 (30.85%), close to T_2 (27.79%), on the contrary, the lowest value from T_4 (14.90%) and followed by T_3 (23.31%) treatment.

From the above findings (Table 11) it is revealed that, at the mid pod development stage T_1 (spraying neem leaves extract @ 5ml/L of water 10 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_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval). Least performance of treatment was T_7 (Untreated Control). Usa and Singh (1977) 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 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 11. Efficacy of different plant extracts for the management of aphid and pod borer 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_1	279.54 a	69.11 f	19.82 g	51.19
T_2	212.13 cd	102.30 c	32.54 d	27.79
T_3	198.68 d	108.69 c	35.35 c	23.31
T_4	171.26 e	120.59 b	41.33 b	14.90
T_5	238.81 b	90.23 e	27.43 f	36.31
T_6	224.83 bc	97.96 d	30.37 e	30.85
T_7	116.39 f	141.73 a	54.92 a	--
$LSD_{(0.05)}$	15.04	4.37	2.06	--
CV(%)	4.11	2.35	3.36	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval; T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

4.5.3 Pod weight at the late pod development stage of country bean

From (Table 12) showed that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation ($p>0.05$) at late pod development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean at 90 days after transplanting (DAT). In context of healthy pods, the maximum weight plant^{-1} (276.07 g) was recorded from T_1 which was statistically different with T_5 (250.50 g) and closely followed by T_6 (238.36 g) and close to T_2 (210.57 g) treatments. On the other hand, the minimum weight of healthy pods plant^{-1} was recorded from T_7 (105.86 g) which was followed by T_4 (173.86 g) and close to T_3 (193.51 g) treatment. Considering the infested pods, the weight of lowest infested pods plant^{-1} was observed from T_1 (35.17 g) which was statistically similar with T_5 (42.01 g) and close to T_6 (46.53 g) and T_2 (58.58 g), while the weight of highest infested pods plant^{-1} was found in T_7 (118.89 g) and closely followed by T_4 (65.31 g) and T_3 (62.31 g) treatment. In relation to the percentage (%) of pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_1 (11.21%) which was statistically similar with T_5 (14.36%) and closely followed by T_6 (16.34%) and T_2 (21.78%), whereas the highest weight of infested pods plant^{-1} was observed in T_7 (52.91%) followed by T_4 (27.32%) and also followed by T_3 (24.37 g) treatment. In the basis of pod infestation reduction over control in weight plant^{-1} was estimated and the highest value was obtained from the treatment T_1 (70.40%) which was statistically similar with T_5 (64.62%) closely followed by T_6 (60.79%), close to T_2 (50.56%), on the contrary, the lowest value from T_4 (44.92%) and followed by T_3 (47.45%) treatment.

Table 12. Efficacy of different plant extracts for the management of aphid and pod borer 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_1	276.07 a	35.17 e	11.21 e	70.40
T_2	210.57 d	58.58 c	21.78 c	50.56
T_3	193.51 e	62.31 bc	24.37 bc	47.45
T_4	173.86 f	65.31 b	27.32 b	44.92
T_5	250.50 b	42.01 d	14.36 d	64.62
T_6	238.36 c	46.53 d	16.34 d	60.79
T_7	105.86 g	118.89 a	52.91 a	--
$LSD_{(0.05)}$	10.84	5.39	2.66	--
CV(%)	2.94	4.95	6.23	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the above findings (Table 12) it is revealed that, at the late pod development stage T_1 (spraying neem leaves extract @ 5ml/L of water 10 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_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval). Least performance of treatment was T_7 (Untreated Control). Tijani *et al.*, (2007) was found that using botanicals products, farmers get maximum benefit in reducing the infestation of country bean pest and increasing the pod yield.

4.6 Weight of pods at total growing period

Significant variation were observed in weight of total pods, weight of total healthy pods, weight of total infested pods, percent of infestation and infestation reduction over control at total growing period for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 13).

In the term of total weight of bean pods plant^{-1}, it was observed that the highest weight of total pods plant^{-1} from T_1 (816.41 g) which was statistically different with T_5 (764.01 g) and T_6 (744.78 g) and followed by T_2 (715.71 g), while the least weight of total bean pods plant^{-1} was observed from T_7 (583.32 g) followed by T_4 (649.63 g) and T_3 (688.41) treatments. The maximum weight of total healthy pods plant^{-1} was recorded from T_1 (679.32 g) which was statistically different with T_5 (596.09 g) and T_6 (561.22 g) and followed by T_2 (507.17 g), while the minimum weight of total healthy pods was observed from T_7 (256.23 g) followed by T_4 (412.02 g) and T_3 (468.11 g) treatments. On the other hand, the lowest weight of total infested pods plant^{-1} was observed from T_1 (137.09 g) which was statistically different with T_5 (167.92 g) and closely followed by T_6 (183.56 g) and T_2 (208.53 g) treatments. In contemporary, the highest weight of total infested pods was found from T_7 (327.10 g) followed by T_4 (237.61 g) and close to T_3 (220.30 g) treatment. In relation to the percentage (%) of total pods infestation, the least infested pods plant^{-1} in weight was observed from T_1 (16.79%) which was statistically different with T_5 (21.98%) and T_6 (24.65%) closely followed by T_2 (29.14%) and close to T_3 (31.99%) treatments, again the maximum percentage of total infested pods was recorded in T_7 (56.10%) followed by T_4 (36.57%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (58.09%) which was followed by T_5 (48.67%) close to T_6 (43.88%) and T_2 (36.25%) treatments and the minimum reduction of pod infestation over control from T_4 (27.35%) followed by T_3 (32.66%) treatment.

Table 13. Efficacy of different plant extracts for the management of aphid and pod borer of country bean at total pod growing period in terms of pods plant^{-1} by weight

Treatments	Weight of pods (g/plant)				
	Total	Healthy	Infested	% Infestation	Reduction over control (%)
T_1	816.41 a	679.32 a	137.09 g	16.79 g	58.09
T_2	715.71 c	507.17 d	208.53 d	29.14 d	36.25
T_3	688.41 d	468.11 e	220.30 c	31.99 c	32.66
T_4	649.63 e	412.02 f	237.61 b	36.57 b	27.35
T_5	764.01 b	596.09 b	167.92 f	21.98 f	48.67
T_6	744.78 b	561.22 c	183.56 e	24.65 e	43.88
T_7	583.32 e	256.23 g	327.10 a	56.10 a	--
$LSD_{(0.05)}$	19.74	4.70	5.59	1.52	--
CV(%)	1.57	2.37	1.48	2.75	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval; T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

From the (Table 13**)** it was observed that among the different treatments, T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) performed best in total pod bearing weight and total healthy pod weight percentage and was more effective among the of different plant extract for the management of aphid and pod borer of country bean. Whereas, T_7 (Untreated Control) showed the highest performance results in infestation percentage of country bean. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.7 Yield contributing characters and yield of country bean

4.7.1 Inflorescence number plant^{-1}

Statistically significant variation were observed in number of inflorescence plant^{-1} at different development stage for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 14).

The highest number of inflorescence plant^{-1} was recorded from T_1 (33.08) which was statistically similar with T_5 (32.32), closely followed by T_6 (31.33) and close to T_2 (30.67) and followed by T_3 (29.08) while the lowest number was recorded from T_7 (26.00) and followed by T_4 (27.80) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.7.2 Number of flower inflorescence^{-1}

The efficacy of different plant extract for the management of aphid and pod borer of country bean showed statistically significant variation for number of flower inflorescence^{-1} of country bean (Table 14).

The highest number of flower inflorescence^{-1} was observed from T_1 (15.33) which was identically similar with T_5 (14.50), closely followed by T_6 (13.58) and close to T_2 (13.50) and followed by T_3 (13.25) while the minimum number was recorded from T_7 (11.33) and identically followed by T_4 (11.33) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.7.3 Number of pod inflorescence^{-1}

Data stated that number of pod inflorescence^{-1} of country bean showed statistically significant variation for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 14).

The maximum number of pod inflorescence^{-1} was observed from T_1 (9.42) which was statistically similar with T_5 (8.75), closely followed by T_6 (8.42) and close to T_2 (7.75) and followed by T_3 (7.44) while the minimum number was recorded from T_7 (6.58) and identically followed by T_4 (6.92) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.7.4 Number of pods plant^{-1}

Data revealed that number of pod plant^{-1} of country bean showed statistically significant variation for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 14).

In the term of total number of bean pods plant^{-1}**,** the highest number plant^{-1} was recorded T_1 (135.58) which was statistically different with T_5 (131.00) and T_6 (128.17) and followed by T_2 (125.75), while the least number of total bean pods plant^{-1} was observed from T_7 (111.58) followed by T_4 (113.50) and T_3 (120.67) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

4.7.5 Pod length

Data revealed that number of pod plant^{-1} of country bean showed statistically significant variation for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 14).

In the term of pod length, the longest pod was recorded from T_1 (11.33 cm) which was statistically identical with T_5 (11.00 cm), closely followed by T_6 (10.94 cm) and close to T_2 (10.76 cm) and followed by T_3 (10.31 cm) while the minimum number was recorded from T_7 (9.04 cm) and identically followed by T_4 (10.19 cm) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

Table 14. Efficacy of different plant extract for the management of aphid and pod borer of country bean yield contributing characters and yield during November, 2018 to march, 2019

Treatments	Number of inflorescence plant^{-1}	Number of flower inflorescence^{-1}	Number of pod inflorescence^{-1}	Number of pods plant^{-1}	Pod length (cm)
T_1	33.08 a	15.33 a	9.42 a	135.58 a	11.33 a
T_2	30.67 bc	13.50 b	7.75 c	125.75 c	10.76 b
T_3	29.08 cd	13.25 b	7.44 c	120.67 d	10.31 c
T_4	27.80 d	11.33 c	6.92 d	113.50 e	10.19 c
T_5	32.32 ab	14.50 ab	8.75 b	131.00 b	11.00 b
T_6	31.33 ab	13.58 b	8.42 b	128.17 bc	10.94 b
T_7	26.00 e	11.33 c	6.58 d	111.58 e	9.04 d
$LSD_{(0.05)}$	1.79	1.72	0.37	4.32	0.30
CV(%)	3.34	7.30	2.63	1.96	1.61

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval; T_2= Onion bulb extract @ 5ml/L of water at 10 days interval; T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

4.8 Yield plot^{-1}

Statistically significant variation was recorded for yield plot^{-1} of country bean for the efficacy of different plant extract for the management of aphid and pod borer of country bean (Table 15). The highest yield plot^{-1} was observed from T_1 (3.21 kg) which was statistically similar with T_5 (2.98 kg), closely followed by T_6 (2.91 kg) and close to T_2 (2.80 kg) and followed by T_3 (2.70 kg) while the lowest yield plot^{-1} was recorded from T_7 (2.20 kg) and identically followed by T_4 (2.52 kg) treatments. From the findings it is stated that spraying of Neem leaves extract @ 5ml/L of water at 10 days interval was more effective among the management practices for yield plot^{-1} which was followed by spraying of Garlic bulb extract @ 5ml/L of water at 10 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.

4.8.1 Yield of pods hectare^{-1}

The efficacy of different plant extract for the management of aphid and pod borer of country bean showed statistically significant variation in terms of yield hectare^{-1} of country bean (Table 15). The highest yield hectare^{-1} was found from observed from T_1 (4.28 ton) which was statistically similar with T_5 (3.97 ton), closely followed by T_6 (3.88 ton) and close to T_2 (3.73 ton) and followed by T_3 (3.60 ton) while the lowest yield hectare^{-1} was recorded from T_7 (2.94 ton) and identically followed by T_4 (3.36 ton) treatments. Pod yield increase over control was estimated and the highest value was obtained from the treatment T_1 (45.70%) which was followed by T_5 (35.32%) close to T_6 (32.17%) and T_2 (27.32%) treatments and the minimum yield increase over control from T_4 (14.66 %) followed by T_3 (22.69%) treatment. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

Table 15. Efficacy of different plant extract for the management of aphid and pod borer of country bean yield contributing characters and yield during November, 2018 to march, 2019

Treatment(s)	Yield plot^{-1} (kg)	Total yield(ton/ha)	% increase over control
T_1	3.21 a	4.28 a	45.90
T_2	2.80 c	3.73 c	27.32
T_3	2.70 c	3.60 c	22.69
T_4	2.52 d	3.36 d	14.66
T_5	2.98 b	3.97 b	35.32
T_6	2.91 b	3.88 b	32.17
T_7	2.20 e	2.94 e	--
$LSD_{(0.05)}$	0.10	0.13	--
CV(%)	2.04	2.04	--

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

Plate 6. Different photographs at the time of country bean harvesting

4.9 Cost benefit analysis

Economic analysis of different control measures were integrated for efficacy of different plant extract for the management of aphid and pod borer of country bean and are presented in (Table 16).In this study, the untreated control (T_7) did not require any pest management cost. But the costs were involved in the other management practices. Treatment T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval); T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval); T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval)**;** T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval); T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval); and treatment T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval) requires insect pest management cost.

Considering the controlling of country bean insect pests highest benefit cost ratio (3.03) was recorded in the treatment T_1 followed by T_5 (2.63), T_6 (2.50), T_2 (1.87), T_3 (1.47) and the lowest benefit cost ratio was recorded from T_4 (1.08) according to (Table 16**).**

Table 16. 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_1	15000	4.28	107000	92000	45500	3.03
T_2	14000	3.73	93250	79250	26200	1.87
T_3	12500	3.60	90000	77500	18400	1.47
T_4	15250	3.36	84000	68750	16500	1.08
T_5	13000	3.97	99250	86250	34250	2.63
T_6	12500	3.88	97000	84500	32200	2.50
T_7	0	2.94	73500	73500	--	--

Market price of country bean @ Tk. 25 per kg

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

[T_1=Neem leaves extract @ 5ml/L of water at 10 days interval;T_2= Onion bulb extract @ 5ml/L of water at 10 days interval;T_3=. Datura seeds extract @ 5ml/L of water at 10 days interval;T_4= Black pepper seed extract @ 5ml/L of water at 10 days interval;T_5= Garlic bulb extract @ 5ml/L of water at 10 days interval;T_6= Mahogany seed extract @ 5ml/L of water at 10 days interval;T_7= Untreated Control]

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

Correlation study was done to established the relationship between percentage pod infestation of country bean in number at total growing period and yield (t/ha) of country bean among different management practices. From the Figure 2 it was revealed that, negative correlation was observed between the parameters. The regression equation y = -0.0335x + 4.8641 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9641) had a significant regression co-efficient. From this Figure 2 it was observed that, 60.13% (T_7) pod infestation in number gives the yield 2.94 (t/ha). On the other hand, 21.02% (T_1) pod infestation in number gives the yield 4.28 (t/ha). So, the reduction of 39.11% pod infestation in number increased the yield 1.34 (t/ha) which was produced by using the treatment T_1 (Spraying of Neem leaves extract @ 5ml/L of water at 10 days interval). From the figure, it may be concluded that percentage (%) pod infestation of country bean in number negatively correlated with pod yield (t/ha).

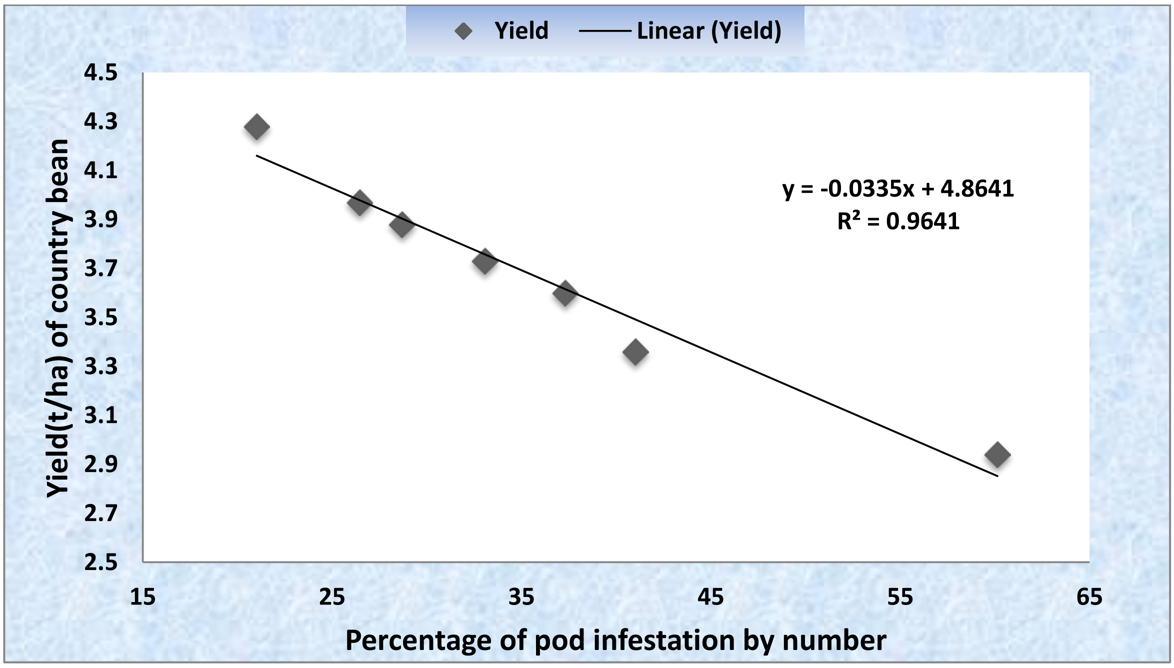


Figure 2. Relationship between percentage (%) of pod infestation by number of country bean at total growing period and yield (t/ha) of country bean

4.10.2 Relationship between pod infestation by bean pod borer and yield of country bean

From the Figure 3, the results revealed that, there was strong negative correlation between pod infestation by bean pod borer and total yield (t/ha) of country bean, which suggested that with the increase of pod infestation intensity there was a decrease on total yield (t/ha). A linear regression was fitted between total yield (t/ha) weight and pod infestation by bean pod borer (Figure 3).The contribution of the regression (R^2) were 0.944. In the present study, it was observed that pod borer infestation on pod passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

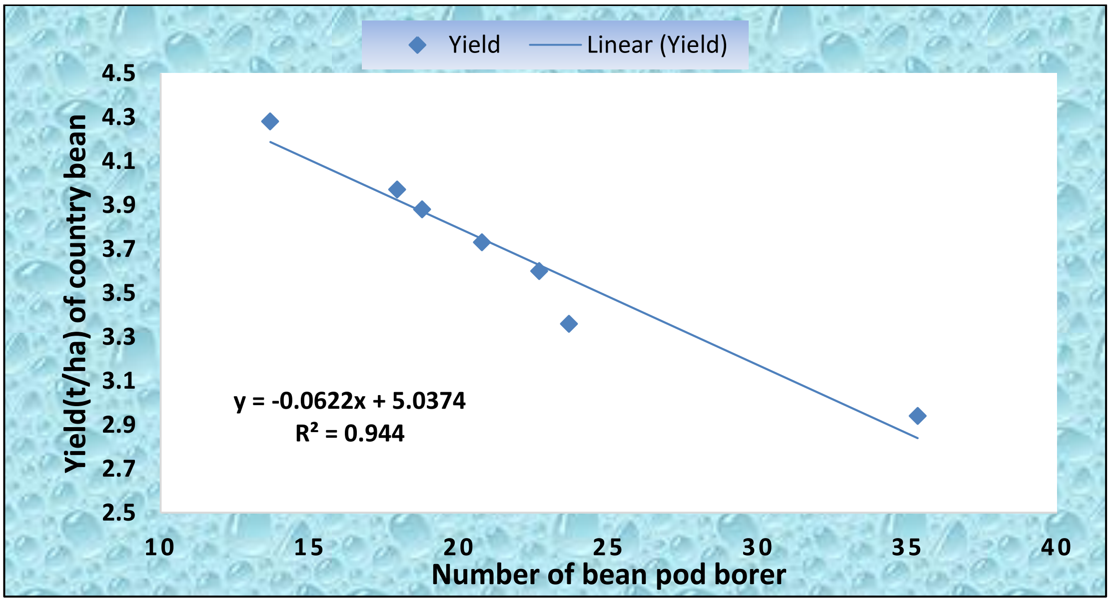


Figure 3. Relationship between pod infestation by bean pod borer and yield of country bean

4.10.3 Relationship between pod infestation by aphid and yield of country bean

From the Figure 4 significant relationship was found between pod infestation by bean aphid and yield (t/ha) of country bean when correlation was made between these two parameter. There was a very strong (R^2=0.9653) and negative (slope =-0.0644) correlation found between pod infestation by aphid and yield of country bean, i.e. yield of country bean decreased with the increasing of pod infestation by aphid. Aphid infestation on pod passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

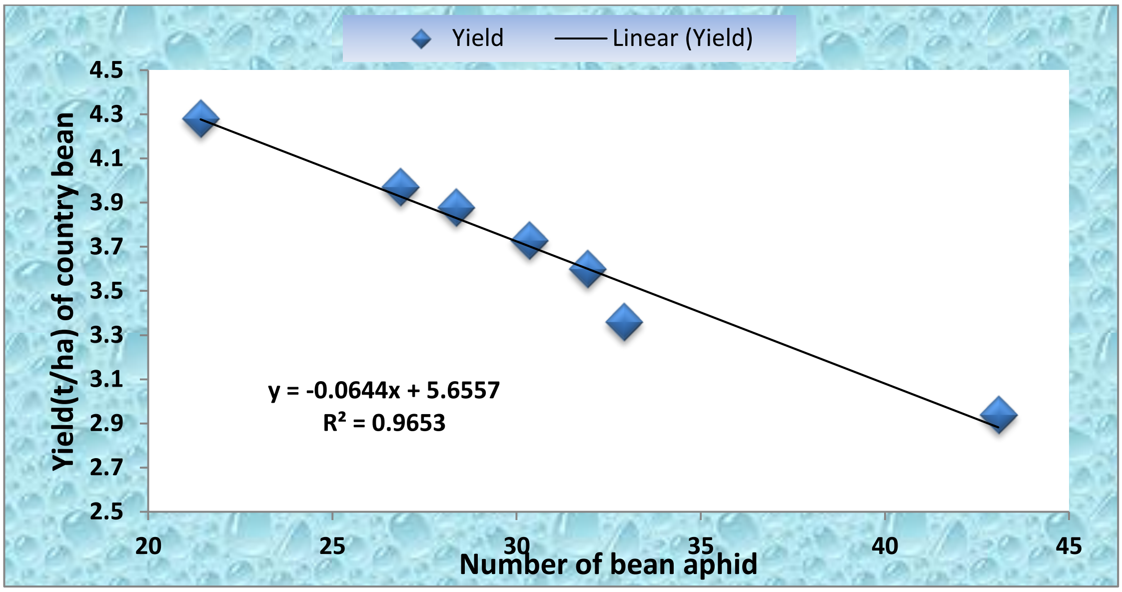


Figure 4. Relationship between pod infestation by aphid and yield of country bean

4.11 Relationship between yield contributing characters and yield of country bean

4.11.1 Relationship between number of pods inflorescence^{-1} and yield country bean

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 (Figure 5). Significant relationship was found between number of pods inflorescence^{-1} and yield of country bean when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.9348) and positive (slope =0.4138) correlation was found between number of pods inflorescence^{-1} and yield of country bean, i.e. yield of country bean increased with the increase of number of pods inflorescence^{-1}.

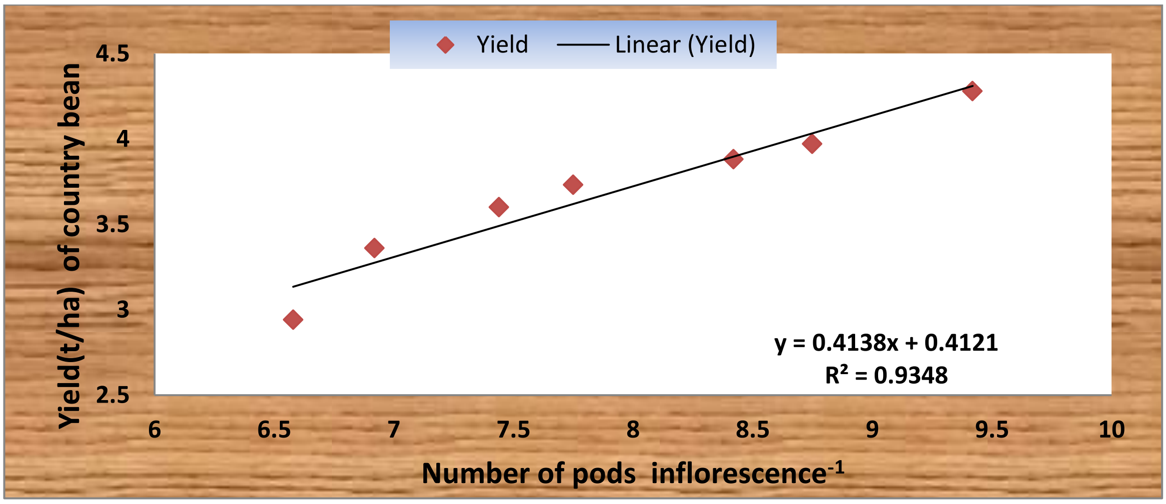


Figure 5. Relationship between number of pods inflorescence^{-1} and yield country bean

4.11.2 Relationship between pod length and yield of country bean

Significant relationship was found between pod length and yield of country bean when correlation was made between these parameters (Figure 6). The highly significant ($p<0.05$), very strong ($R^2=0.9496$) and positive (slope =0.5598) correlation was found between pod length and yield of country bean, i.e. yield of country bean increased with the increase of pod length. From this Figure 6 it may be concluded that, yield of country bean strongly as well as positively correlated with pod length.

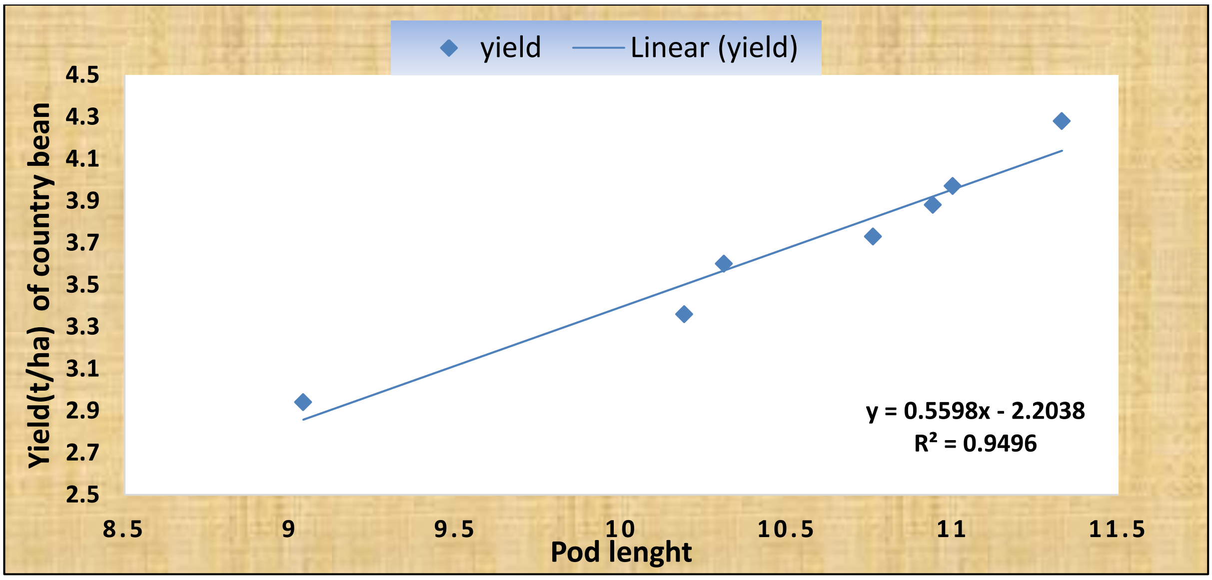


Figure 6. Relationship between pod length and yield of country bean

4.11.3 Relationship between number of inflorescence plant^{-1} and yield of country bean

Significant relationship was found between number of inflorescence plant^{-1} and yield of country bean when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong ($R^2=0.9707$) and positive (slope =0.1692) correlation was found between number of inflorescence plant^{-1} and yield of country bean, i.e. yield of country bean increased with the increase of number of inflorescence plant^{-1}. From the (Figure 7) it may be concluded that number of inflorescence plant^{-1} strongly as well as positively correlated with pod yield of country bean (t/ha) .

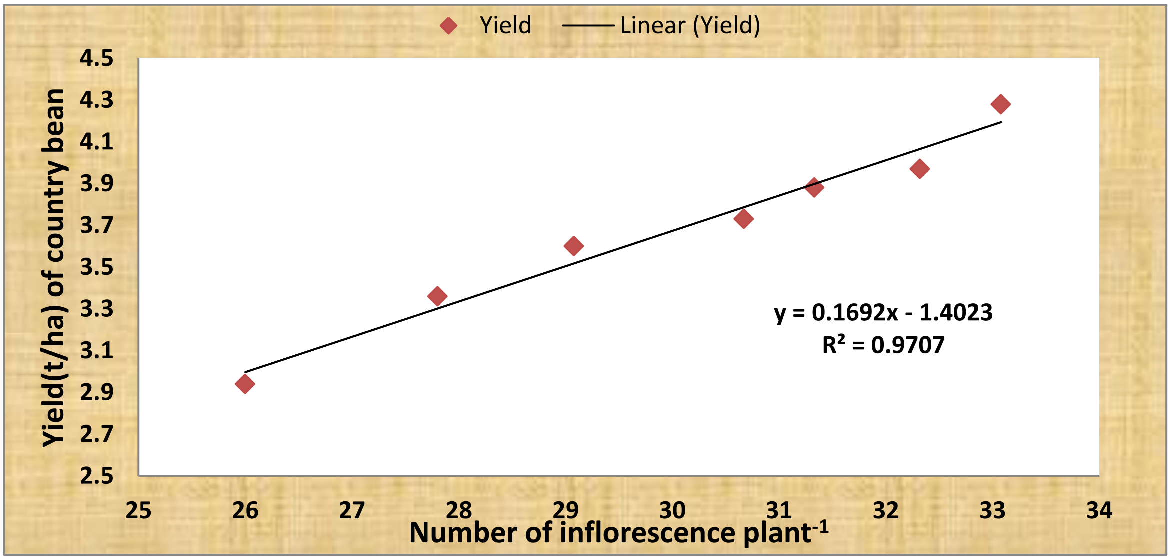


Figure 7. Relationship between number of inflorescence plant^{-1} and yield of country bean

4.11.4 Relationship between number of flower inflorescence^{-1} and yield of country bean

Significant relationship was found between number of flower inflorescence^{-1} and yield of country bean when correlation was made between these two parameters. The highly significant ($p<0.05$), very strong (R^2=0.9034) and positive (slope =0.2773) correlation was found between number of flower inflorescence^{-1} and yield of country bean, i.e. yield of country bean increased with the increase of number of flower inflorescence^{-1}.From the (Figure 8) it may be concluded that number of flower inflorescence^{-1} strongly as well as positively correlated with pod yield of country bean (t/ha).

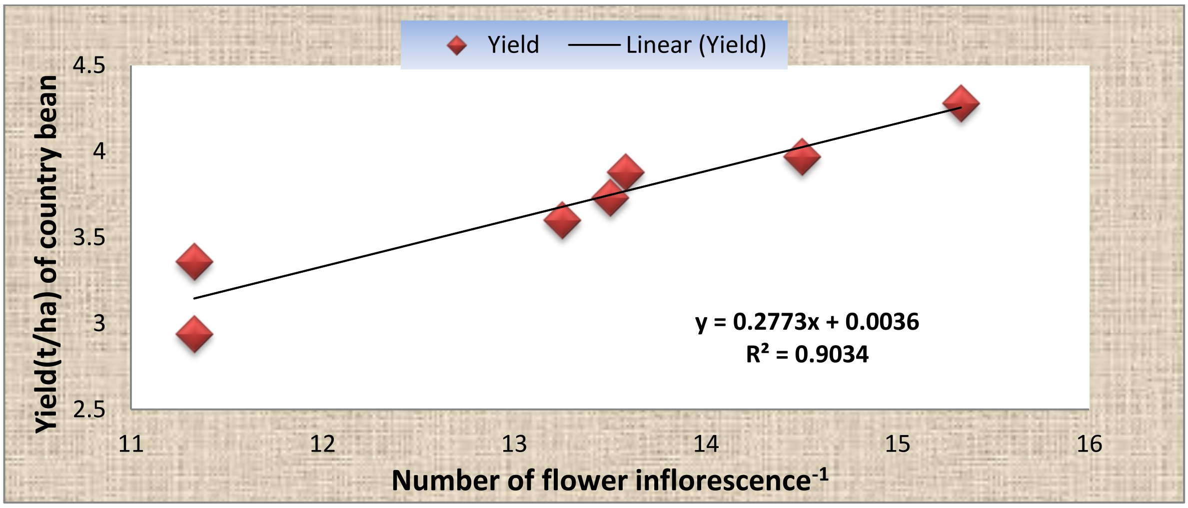


Figure 8. Relationship between number of flower inflorescence^{-1} and yield of country bean

Chapter V

Summary & Conclusion

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2018 to march, 2019 to study the efficacy of different plant extract for the management of aphid and pod borer of country bean (BARI seem-5). The experiment consists of control measures and plant extract.

Seven treatments, viz. Treatment T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval); T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval); T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval)**;** T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval); T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval); T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval) and T_7 (untreated control) were included in this study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Results showed that the significant variations were observed among different stage country bean in term of number of aphid and pod borer plant^{-1}, number and weight of healthy pod, infested pod and percentage of pod infestation in number and weight, yield contributing characters and yield (t/ha) of country bean.

Among seven treatments, it was observed that treatment T_1 (Neem leaves extract @ 5ml/L of water at 10 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 in total growing period, the lowest number per plant (13.67) was found from T_1 (Neem leaves extract @ 5ml/L of water at 10 days interval) which was statistically similar (17.92) with T_5 (Garlic bulb extract @ 5ml/L of water at 10 days interval) and (18.75) with T_6 (Mahogany seed extract @ 5ml/L of water at 10 days interval) and closely followed by (20.75) T_2 (Onion bulb extract @ 5ml/L of water at 10 days interval).On the other hand, the highest pod infestation was recorded in (35.33) T_7 (Untreated Control) which was statistically different from all other treatments followed by (23.67 and 22.67) by T_4 (Black pepper seed extract @ 5ml/L of water at 10 days interval) and T_3 (Datura seeds extract @ 5ml/L of water at 10 days interval).

In consideration of aphid in total growing period, the lowest number plant^{-1} was observed from T_1 (21.42) which was statistically with similar from T_5 (26.84) and T_6 (28.35) and closely followed by T_2 (30.34) and T_3 (31.92) and followed by T_4 (32.91), whereas the highest number was observed from T_7 (43.08) treatment.

In total growing period by number of healthy pods, the maximum number of total healthy pods plant^{-1} was recorded from T_1 (107.08) which was statistically different with T_5 (96.33) and T_6 (91.42) and followed by T_2 (84.17), while the least number of total healthy pods was observed from T_7 (44.50) followed by T_4 (67.00) and T_3 (75.67) treatments. On the other hand, the least number of total infested pods plant^{-1} was observed from T_1 (28.50) which was statistically different with T_5 (34.67) and closely followed by T_6 (36.75) and T_2 (41.58) treatments. In contemporary, the maximum number of total infested pods was found from T_7 (67.08) followed by T_4 (46.50) and close to T_3 (45.00) treatment. In relation to the percentage (%) of total pods infestation, the least infested pods plant^{-1} in number was observed from T_1 (21.02%) which was statistically different with T_5 (26.46%) and T_6 (28.68%) closely followed by T_2 (33.07%) and close to T_3 (37.30%) treatments, again the maximum percentage of total infested pods was recorded in T_7 (60.13%) followed by T_4 (41.01%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (57.52%) which was followed by T_5 (48.32%), T_6 (45.21%) and T_2 (38.01%) treatments and the minimum reduction of pod infestation over control from T_4 (30.68%) followed by T_3 (32.92%) treatment.

In context of healthy pods by weight, the maximum weight of total healthy pods plant^{-1} was recorded from T_1 (679.32 g) which was statistically different with T_5 (596.09 g) and T_6 (561.22 g) and followed by T_2 (507.17 g), while the minimum weight of total healthy pods was observed from T_7 (256.23 g) followed by T_4 (412.02 g) and T_3 (468.11 g) treatments. On the other hand, the lowest weight of total infested pods plant^{-1} was observed from T_1 (137.09 g) which was statistically different with T_5 (167.92 g) and closely followed by T_6 (183.56 g) and T_2 (208.53 g) treatments. In contemporary, the highest weight of total infested pods was found from T_7 (327.10 g) followed by T_4 (237.61 g) and close to T_3 (220.30 g) treatment. In relation to the percentage (%) of total pods infestation, the least infested pods plant^{-1} in weight was observed from T_1 (16.79%) which was statistically different with T_5 (21.98%) and T_6 (24.65%) closely followed by T_2 (29.14%) and close to T_3 (31.99%) treatments, again the maximum percentage of total infested pods was recorded in T_7 (56.10%) followed by T_4 (36.57%) treatment. Infestation of pod reduction over control in number was estimated and the highest value was found from the treatment T_1 (58.09%) which was followed by T_5 (48.67%) close to T_6 (43.88%) and T_2 (36.25%) treatments and the minimum reduction of pod infestation over control from T_4 (27.35%) followed by T_3

(32.66%) treatment. It was also revealed that the trends of results regarding the reduction of pod infestation by weight was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

The highest number of inflorescence plant^{-1} was recorded from T_1 (33.08) which was statistically similar with T_5 (32.32), closely followed by T_6 (31.33) and close to T_2 (30.67) and followed by T_3 (29.08) while the lowest number was recorded from T_7 (26.00) and followed by T_4 (27.80) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

The maximum number of pod inflorescence^{-1} was observed from T_1 (9.42) which was statistically similar with T_5 (8.75), closely followed by T_6 (8.42) and close to T_2 (7.75) and followed by T_3 (7.44) while the minimum number was recorded from T_7 (6.58) and identically followed by T_4 (6.92) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

In the term of total number of bean pods plant^{-1}, the highest number plant^{-1} was recorded T_1 (135.58) which was statistically different with T_5 (131.00) and T_6 (128.17) and followed by T_2 (125.75), while the least number of total bean pods plant^{-1} was observed from T_7 (111.58) followed by T_4 (113.50) and T_3 (120.67) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

In the term of pod length, the longest pod was recorded from T_1 (11.33 cm) which was statistically identical with T_5 (11.00 cm), closely followed by T_6 (10.94 cm) and close to T_2 (10.76 cm) and followed by T_3 (10.31 cm) while the minimum number was recorded from T_7 (9.04 cm) and identically followed by T_4 (10.19 cm) treatments. As a result the order of rank of study the efficacy of different plant extract for the management of aphid and pod borer of country bean by number was $T_1 > T_5 > T_6 > T_2 > T_3 > T_4 > T_7$.

The highest yield plot^{-1} was observed from T_1 (3.21 kg) which was statistically similar with T_5 (2.98 kg), closely followed by T_6 (2.91 kg) and close to T_2 (2.80 kg) and followed by T_3 (2.70 kg) while the lowest yield plot^{-1} was recorded from T_7 (2.20 kg) and identically followed by T_4 (2.52 kg) treatments. From the findings it is stated that spraying of Neem leaves extract @ 5ml/L of water at 10 days interval was more effective among the management practices for yield plot^{-1} which was followed by spraying of Garlic bulb extract @ 5ml/L of water at 10 days interval that leads to the production of highest yield.

Conclusion

From the above description, it can be concluded that, spraying Neem leaves extract @ 5ml/L of water at 10 days interval reduced the infestation of bean pod borer and aphid of country bean of variety BARI seem-5.

Recommendations

Considering the findings of the present experiment, further studies in the following areas may be suggested:

- Diversity of insect pests may be studied in several years all over Bangladesh to identify the major insect pests of country.
- Further trials with effective different plant extract may be done at different locations of Bangladesh for accuracy of the results obtained from the present experiment.

Chapter VI

References

CHAPTER VI

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APPENDICES

Appendix I. Results of morphological, mechanical and chemical analysis of soil of the experimental plot

A. Morphological Characteristics

Morphological features	Characteristics
Location	Central Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow redbrown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

A. Mechanical analysis

Constituents	Percentage (%)
Sand	28.78
Silt	42.12
Clay	29.1

B. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.95
Organic matter (%)	0.77
Total nitrogen (%)	0.075
Available P (ppm)	15.07
Exchangeable K (%)	0.32
Available S (ppm)	16.17

Source: Soil Resource Development Institute (SRDI)

Appendix II. Analysis of variance of data incidence of aphid of country bean at vegetative stage.

Sources of Variation	Degrees of freedom	Mean Square value of		
		No. aphid plant^{-1}	No. of infested leaves plant^{-1}	No. of healthy leaves plant^{-1}
Replication	2	0.646	0.142	0.155
Treatment	6	9.465*	1.375*	1.079*
Error	12	0.006*	0.017	0.054

*significant at 5% level of probability
**significant at 1% level of probability

Appendix III. Analysis of variance of data on number of aphid and pod borer plant^{-1} of country bean at early pod development stage

Sources of Variation	Degrees of freedom	Mean Square value of	
		Larva of bean pod borer (No./plant)	Aphid (No./plant)
Replication	2	0.063	0.771
Treatment	6	7.762*	5.062*
Error	12	0.083	0.045

*significant at 5% level of probability
**significant at 1% level of probability

Appendix IV. Analysis of variance of data on number of aphid and pod borer plant^{-1} of country bean at mid pod development stage

Sources of Variation	Degrees of freedom	Mean Square value of	
		Larva of bean pod borer (No./plant)	Aphid (No./plant)
Replication	2	0.508	0.003
Treatment	6	19.034*	12.70**
Error	12	0.036	0.178

*significant at 5% level of probability
**significant at 1% level of probability

Appendix V. Analysis of variance of data on number of aphid and pod borer plant^{-1} of country bean at late pod development stage

Sources of Variation	Degrees of freedom	Mean Square value of	
		Larva of bean pod borer (No./plant)	Aphid (No./plant)
Replication	2	0.813	0.503
Treatment	6	22.78*	35.50*
Error	12	0.059	0.062

*significant at 5% level of probability
**significant at 1% level of probability

Appendix VI. Analysis of variance of data on number of pod plant^{-1} of country bean at early pod development stage

Sources of Variation	Degrees of freedom	Mean Square value of	
		Healthy	Infested
Replication	2	0.824	1.021
Treatment	6	45.185*	24.95*
Error	12	0.255	0.128

*significant at 5% level of probability
**significant at 1% level of probability

Appendix VII. Analysis of variance of data on number of pod plant^{-1} of country bean at mid pod development stage

Sources of Variation	Degrees of freedom	Mean Square value of	
		Healthy	Infested
Replication	2	7.536	0.520
Treatment	6	177.69*	61.47**
Error	12	07.414	0.27

*significant at 5% level of probability
**significant at 1% level of probability

Appendix IX. Analysis of variance of data on number of pod plant^{-1} of country bean at late pod development stage

Sources of Variation	Degrees of freedom	Mean Square value of	
		Healthy	Infested
Replication	2	1.646	0.074
Treatment	6	268.95*	78.52*
Error	12	0.757	0.327

*significant at 5% level of probability
**significant at 1% level of probability

Appendix X. Analysis of variance of data on total number of pods plant^{-1} of country bean at total growing period

Sources of Variation	Degrees of freedom	Mean Square value of		
		Healthy	Infested	Total pod
Replication	2	66.73	3.61	12.021
Treatment	6	35.58*	458.45**	117.51*
Error	12	25.77	0.19	5.424

*significant at 5% level of probability
**significant at 1% level of probability

Appendix XI. Analysis of variance of data on total weight of pods plant^{-1} of country bean at total growing period

Sources of Variation	Degrees of freedom	Mean Square value of		
		Healthy	Infested	Total pod
Replication	2	108.6	272.6	723.1
Treatment	6	56657.9*	11173.7*	17815.6*
Error	12	138.4	9.9	123.2

*significant at 5% level of probability
**significant at 1% level of probability

Appendix XII. Analysis of variance of data on yield contributing characteristics of country bean at total growing period

Sources of Variation	Degrees of freedom	Mean Square value of			
		Number of inflorescence plant^{-1}	Number of flower inflorescence^{-1}	Number of pod inflorescence^{-1}	Pod length (cm)
Replication	2	2.872	4.467	0.209	0.149
Treatment	6	19.375*	6.711*	3.110**	0.150**
Error	12	1.006	0.936	0.043	0.194

*significant at 5% level of probability
**significant at 1% level of probability

Appendix XII. Analysis of variance of data on yield contributing characteristics of country bean at total growing period

Sources of Variation	Degrees of freedom	Mean Square value of	
		Yield plot^{-1} (kg)	Total yield(ton/ha)
Replication	2	0.003	0.005
Treatment	6	0.319**	0.568**
Error	12	0.003	0.006

*significant at 5% level of probability
**significant at 1% level of probability