EVALUATION OF SOME REDUCED-RISK INSECTICIDES FOR THE CONTROL OF LEGUME POD BORER *MARUCA VITRATA* FAB IN COUNTRY BEAN

JANNATUL FERDOUS

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

DECEMBER, 2018

EVALUATION OF SOME REDUCED-RISK INSECTICIDES FOR THE CONTROL OF LEGUME POD BORER *MARUCA VITRATA* FAB IN COUNTRY BEAN

BY

JANNATUL FERDOUS

REGISTRATION NO. 17-08303

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

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

SEMESTER: JULY-DECEMBER, 2018

Approved by

Prof. Dr. S.M. Mizanur Rahman **Research Supervisor**	**Prof. Dr. Tahmina Akter** **Co-supervisor**

Prof. Dr. S.M. Mizanur Rahman
Chairman
Examination Committee

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

CERTIFICATE

This is to certify that thesis entitled, **"EVALUATION OF SOME REDUCED-RISK INSECTICIDES FOR THE CONTROL OF LEGUME POD BORER *MARUCA VITRATA* FAB IN 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 IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **JANNATUL FERDOUS, Registration no. 17-08303** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Date: December, 2018
Place: Dhaka, Bangladesh

Prof. Dr. S.M. Mizanur Rahman
Research Supervisor

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

All praises are due to Almighty Allah whose blessings enabled the author for successful completion of this research work.

The Author seems it a profound privilege to express her deepest sense of gratitude, sincere appreciation and best regards to her respected teacher and research supervisor Dr. S. M. Mizanur Rahman, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for his materialistic support, careful supervision and guidance, keen interest, active co-operation, loving care, enormous labour, advice, suggestion and uninterrupted encouragement throughout the period of the research work and preparation of the dissertation.

The author is ever grateful and immensely indebted to her honorable and respected co-supervisor Dr. Tahmina Akter, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka for her valuable advice and constant encouragement throughout the research period.

The author expresses her sincere respect to all the teachers of the Department of Entomology, SAU, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.

The author is pleased to extend her gratefulness to all friends and well wishers for their all time encouragement and helpful co-operation during the entire period of the study.

The author expresses greatest appreciation to her beloved parents, brothers, sisters and all other relatives and well-wishers for their inspiration, blessing, love and endless encouragement. The author would like to thanks the Dept. of Entomology, SAU, Dhaka.

Date: December, 2018
The author

EVALUATION OF SOME-REDUCED-RISK INSECTICIDES FOR THE CONTROL OF LEGUME POD BORER *MARUCA VITRATA* FAB IN COUNTRY BEAN

ABSTRACT

The experiment was demonstrated at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to appraise the performance of different management practices in controlling legume pod borer of country bean (BARI sheem-5) during the period from October 2018 to January, 2019. The experiment comprise the following management practices: T_1: Application of MNPV at 7 days interval. T_2: Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4: Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5: untreated. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The data obtained from experiment on various parameters were statistically analyzed and means were separated by the Least Significant Differences (LSD). In compliance with total pod growing period by number plant^{-1} the lowest percent pod infestation was observed from T_3 (5.7%), where the highest pod infestation was recorded from T_5 (24.9 %), incase of % pod infestation in weight, the lowest infested pods plant^{-1} was observed from T_3 (5.2 %) whereas the highest infested pods plant^{-1} was measured in T_5 (24.8 %). The highest number of inflorescence plant^{-1} was recorded from T_3 (6.1) while the lowest number was observed from T_5 (4.8) treatment. The highest number of pod inflorescence^{-1} was recorded from T_3 (9.7) while the lowest number was recorded from T_5 (6.8) treatment . The highest yield hectare^{-1} was found from T_3 (11.0 ton) while the lowest pod yield hectare^{-1} was recorded from T_5 (6.9 ton) treatment. The pod yield of bean was highly significant at (p=0.01), strong (r=0.9919) and negatively correlated with pod infestation by number i.e., the yield was decreased with the increase of pod infestation by number. The pod yield of country bean was potentially significant at (p=0.01), strong (r=0.9141, r=0.9741, r=0.9955 ,r=0.8634) and positively correlated with no. of inflorescence plant^{-1} , no. of flower inflorescence^{-1} ,no. of pod inflorescence^{-1}, and pod length, 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 this study, it may be terminated that T_3 treatment (Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval was more efficacious among the management practices for controlling legume pod borer of country bean.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

The country bean, *Lablab purpureus* Lin. (Leguminosae: Papilionaceae), is an important vegetable-cum-pulse crop grown everywhere in Bangladesh. This bean frequently known as Sheem, 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. Its tender seeds are also used as vegetables; however, the matured and dried seeds are used as pulses.

Country bean is a big source of essential vitamins and generally cultivated in Rabi seasons usually around the homestead by trailing its vine either on trees or by providing different kinds of supports. Although beans are assessed as the major group of vegetables grown intensively in Rabi seasons, some varieties of country bean can be grown year round including Kharif seasons. The crop has multipurpose functions. It is used as a popular fodder crop. To produce "hay and silage" as animal feed, its foliar portion is used. Country bean has a unique ability to fix atmospheric nitrogen to the soil through rhizobial symbiosis at root zone which enhance soil fertility as a green manure crop. Its mature dried stems are used as fuel and provide more or less an opportunity to combat fuel crisis. It has high digestibility and free from flatulent effects. Its green pods and mature seeds are good source (25%) of protein (on dry basis),vitamins (e.g. vitamin A, vitamin C, riboflavin etc.) and mineral such as magnesium, calcium, phosphorus, potassium, iron , sulfur and sodium . So, it is an important source of cash income as well as alleviating malnutrition and sickness caused as by dietary deficiencies. The crop cultivation faces various problems including the pest management (Rashid, 1999). These include the availability of quality seeds, irrigation water and technical information, supply of fertilizers, incidence of pest and diseases, transportation, storage and marketing. Among these problems, occurrence of frequent insect pest attacks has been most important, requiring the pests to be managed twice or thrice in a season. Insect pests, which cause colossal losses to bean crops, are serious problems. Reports reveal that in Bangladesh, over 30 different species of arthropods have been reported in country bean crop, although only a few occur regularly and cause economic damage (Alam, 1969; Begum, 1993; Karim, 1993, 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 beans in Bangladesh.

Bean pod borer is able to establish itself on legumes from vegetative to reproductive stage. Due to plant pests and diseases, 20 to 40 percent of the crop yields are reduced globally. To overcome these situations farmers use pesticides . pesticides play a key role to control the insect pests and diseases and hence protect and promote production .

Characteristics of BARI SHEEM 5

BARI sheem 5 has unique characteristics over the other bean variety.It is dwarf variety and has no need for trellis.The height of this plant is 35-45 cm.50-60 pods can be harvested from a plant .Each pod length is 9-10 cm long, green. pods are soft and fleshy, less fiber, low disease and insect infestation.It is tolerant to virus.The life span of this variety is approximately 75-85 days and the yield is on an average (12 t/ha).(BARI,2018).This study is about the efficacy of some newer pesticides as well as those pesticides would be less harmful for natural enemies.For this purpose some newer insecticide will be applied and result will be demonstrated., Emamectin benzoate is a new insecticide of a new mechanism of action and a strong activity against Lepidoptera as well as with and a high selectivity on useful organisms. This molecule acts if swallowed and has some contact action. It penetrates leaf tissues (translaminar activity) and forms a reservoir within the leaf. The mechanism of action is unique in the panorama of insecticides. In facts, it inhibits muscle contraction, causing a continuous flow of chlorine ions in the GABA and H-Glutamate receptor sites.It is well suited for the control of a broad range of Lepidoptera pests. The unique mode of action makes the compound well suited as a tool in insect resistance management programmes. Other prominent newer insecticides are Success 2.5 SC (Spinosad) and MNPV.The efficacy of these insecticides will be demonstrated in this proposed study.

Considering the above facts and points, the present research program has been designed with the following objectives:

- To evaluate the field infestation levels of target insect pests *viz*. legume pod borer (*Maruca vitrata*).
- To assess the efficacy of newer insecticides against legume pod borer.
- To choose the most effective insecticide to integrate this treatment into IPM package later on for controlling legume pod borer.

CHAPTER II
REVIEW OF LITERATURE

Although country bean is an important vegetable-cum-pulse crop of the tropics, the crop cultivation faces various problems including the pest management. Among the insect pests, the pod borer is considered as one of the major pests of country beans. But considerable literature dealing with reducing infestation of pod borer, performances and effectiveness of chemical and non-chemical treatments are very limited. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following headings:

2.1 General review of bean pod borer

2.1.1 Nomenclature

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Lepidoptera
Family: Pyralidae
Genus: *Maruca*
Species: *Maruca vitrata* Fab.

2.1.2 Biology of pod borer

The pod borer is a holometabolous insect. So, it has four stages to complete its life cycle viz. egg, larva, pupa and adult.

Egg

Maruca vitrata females normally lay eggs on floral buds and flowers, although oviposition on leaves, leaf axils, terminal shoots, and pods has also been recorded (Krishnamurthy, 1963; Taylor, 1963, 1967, 1978; Vishakantaiah and Babu, 1980; Rai, 1983). The eggs are normal1y deposited on the lower surface of plant parts (Vishakantaiah and Babu, 1980; Rai, 1983). A female may lay up to 400 eggs in batches of 2-16 (Okeyo-Owuor and Ochieng, 1981; Jackai *et al*., 1990). The effect of temperature on oviposition and adult longevity of *Maruca vitrata* was examined by Chi *et al*. (2005). Female adult longevity and pre-ovipositional period were shortened with increasing temperature. The egg laying period lasts an average of 3 days at 24-27ºC (Ramasubramanian and Sundara Babu, 1989). Eggs are light yellow, translucent, and have faint reticulate sculpturing on the delicate chorion, and measure 0.65 x 0.45 mm (Taylor, 1967).

Larva

The mean incubation period is around 3 days under at around 25-28°C and over 80% relative humidity (vishakantaiah and Babu, 1980; Okeyo-Owuor and Ochieng, 1981; Rai, 1983). Mature larvae are 17-20 mm long. The head capsule is light to dark brown, and the prothoracic plate is dark brown and divided dorsally. The body is whitish to pale green or pale brown, with irregular brownish black spots; the spots become indistinct immediately before pupation. There are five instars that a larva has to pass through before molting into a pupa (Odebiyi, 1981). The total length of the larval period on cowpea was about 11 days in lndia (Singh1983), which was 8-13 days in Southern Nigeria (Taylor, 1967), and10-14 days in Kenya (Okeyo-Owour and Ochieng, 1981). Early instars are dull white, but the later instars are black-headed, with irregularly shaped brown or black spots on the dorsal, lateral and ventral surfaces of each body segment.

Pupa

Once matured and the food materials required to consume and preserve for supporting the pupal stage, the fifth instar larva stops feeding and the body shrunk before entering in to the pupal stage. To pupate, the larva spins silken threads around it in a net fashion and molt into a pupa within the silken cocoon covered under dried leaves on soil. The color of the pre-pupa is light green and measures 13 mm in length and 2.59 mm in width (Rai, 1983). The pre-pupal period lasts for 2 to 3 days (Rai, 1983) at around 25-28°C. A pupa measures 11.59 mm in length and 2.83 mm in width (Rai, 1983). The pupa is reddish brown in color. Being a tropical and subtropical insect, *M. vitrata* does not require entering into diapause (Taylor, 1967). The lower developmental threshold temperature for pupae is 15.6 - 17.8°C and the upper threshold is 28 -34°C (Sharma, 1998).

Adult

About 8 or 9 days after pupation, an adult emerges from the pupa, (Rai, 1983). The adult moths of bean pod borers usually emerge in the night, most of them emerge between 20:00 hr. and 23:00 hr., although some may emerge late in the night or early in the morning (Jackai *et al*., 1990). Generally, adults of the emerged insect population comprise the male: female ratio of 1:1 (Rai, 1983). The moths are small, dark gray in color with white brown patterns of the wings. The adult moth has light brown forewings with white patches, and white hind wings with an irregular brown border. It often rests with the wings outspread measuring up to 25 mm. They are inactive during the day and can be found at rest with outspread wings under the lower leaves of the host plants.

Adults live, on average, 6-10 days. The female moths have been found to live 11 or 12 days, whereas the males live around 9 or 10 days (Singh 1983). Djamin (1961) reported that the female moths lived up to 22 days and male moths up to 12 days elsewhere. Taylor (1978) found that in Nigeria female moths could live for 4 to 8 days. Okeyo-Owour and Ochieng (1981) reported that adults lived for 12 to 26 days in Kenya. The variations of the duration in the adult longevity were presumably due to the variations in ambient temperature and humidity in different regions. The life cycle is completed in 18-35 days depending upon temperature.

2.1.3 Host range of legume pod borers

The legume pod borer, *(Maruca vitrata* F.), is a polyphagous insect, lwhich has been reported to feed on various types of plants, both cultivated and wild. Akinfenwa (1975) and Atachi and Djihou (1994) reported that the insect has been observed to feed on 39 host plants; most of these plants were leguminous. Among the host plants, the most frequent ones are *Cajanus cajan, Vigna unguiculata, Phaseolus lunatus,* and *Pueraria phaseoloids*. The insect has been reported to consume and survive well on pigeonpea, cowpea and hyacinth beans (Ramasubramanian and Babu, 1988; Ramasubramanian and Babu, 1989a). On the basis of number of eggs laid, percentage of egg hatch, growth index, and adult emergence are considered, despite several species of host plants are available, hyacinth bean has been found to be the most suitable host for culturing *M. vitrata* (Sharma, 1998). In absence of the preferred hosts, the insect would perpetuate on alternate and wild hosts such as *Vigna triloba, Crotularia sp., Phaseolus sp*. and pigeonpeas (Taylor, 1967). Sharma (1998) reviewed the host plants of the pest and compiled a list of about 40 plant species used by legume pod borers as their hosts.

2.1.4 Seasonal distribution of legume pod borer

Legume pod borer population build-up is related to cumulative rainfall and the number of rainy days between crop emergences to flowering (Sharma, 1998). The insect is multivoltine; having at least two overlapping generations a year in most places of its distribution (Sharma, 1998). Being a multivoltine insect with polyphagous nature of feeding activities, and with preference for some particular parts of a particular host plant (Karel, 1985; Sharma 1998; Singh and Taylor, 1978). Legume pod borer is likely to differ in its seasonal distribution spatially even within a host plant and temporally within the growling season of a particular host plant. Again, the weather pattern varies across continents, and therefore, the seasonal distribution of the insect is likely to vary regionally as well.

In Nigeria, the insect reaches to its peak infestation levels during June and July (Taylor, 1967). The first generation adults developing from the initial stock-generation in cowpea fields appears in July and the second generation between July and September. When host plants become scarce, or the prevailing environment becomes less favorable, the insects possibly migrate from South to North guided by air-movements of the inter-tropical convergence zone, and again head toward South in November-December (Taylor, 1967). Within a 24-hour timeframe, adults of the insects are more active from dusk to midnight, with a peak occurrence between 20:00 and 21:00 hr (Akinfenwa, 1975). In Kenya, pod borer populations are low during the short rainy season, although infestation continues unless flower and pod production ceases (Okeyo-Owuor *et al.*, 1983). At ICRISAT Headquarters, moth catches were greatest between early November to mid December in the light traps (Srivastava *et al.*, 1992) with peak catches occurring during November. In Sri Lanka, Saxena *et al.* (1992) observed a high larval density in host crops planted in mid-October. In Bihar of India, Akhauri *et al.* (1994) observed that on early pigeon pea the larval density increased from mid-October to the end of November, with the occurrence of peak larval density in the last week of November. Sharma (1998) reported that the presence of significant relationships between the peak occurrence of pod borers and cumulative rainfall and number of rainy days between crop emergences to flowering.

In Bangladesh, Alam *et al.* (1969) studied the infestation levels of *M. vitrata* on different plant parts of country beans in Gazipur and Jessore. They found that the patterns of seasonal occurrence varied in flowers and pods in both localities. However, the authors did not provide any information regarding the seasonal distribution of the pest in either locality. But, they reported that pods experienced the more infestation than did flowers. Rahman and Rahman (1988) in a study found that the insect attacked the rabi-season pigeon peas from mid December until the crop was harvested in early February in Gazipur. The authors found in the same study that legume pod borer larvae occurred with their peaks during the second week of January to the beginning of February. However, according to them, the insect population may vary depending on the plant parts present; they found larval peak population in flowers around the middle of January, after which the population declined in flowers. On the other hand, the insect tended to occur increasingly in pigeon pea pods until the end of January. Such difference in the seasonal distribution of the pest infestation in different plant parts of the same host plant is presumably because of the preference of one part to the other, a phenomenon very common in insects. The suitability of a particular plant part as a feeding unit may also change over time.This may also be the case with pigeon peas causing a decline in frequency of infestation on flowers, while increasing the frequency of infestation on pods, as found in the study of Rahman and Rahman (1988).

2.1.5 Nature of damage of legume pod borers

Maruca vitrata (Fabricius) is a tropical insect that attacks several species of plants, primarily the legume plants, although pod borers in the genus *Maruca* are polyphagous in nature (Taylor, 1978; Singh and Jackai, 1988; Rahman, 1989; Babu, 1989). Babu (1989) reported that hyacinth bean, which is also known as the country bean, is the most favorable food plant for *M. vitrata (testulalis).* Generally the insect infestation begins at the terminal plant parts (Jackai, 1981). At the early stage of plant growth, the insect attacks plant leaves, fastens the leaves together to clusters and feed while living inside the tunnels of clusters (Singh, 1983; Das and Islam, 1985; Rahman, 1989; Karim, 1993). However, the insect prefers ovipositing at the flower bud stage, suggesting that at earlier stages of plant growth, infestations of legume pod borer may not be conspicuous. Pod borer infestation is more frequent from flowering stage of plants. As soon as buds and flowers appear on plants, many of the insect larvae can be present moving from buds/flowers to buds/flowers and bore into them. A single larva can consume 4-6 flowers before the larval development is completed (Sharma, 1998). The attacked buds and flowers subsequently wither and may fall down. Later the insects move into pods and bore into the pods; the insect would occasionally bore into peduncle and stems of host plants (Taylor, 1967). Generally, one larva bores into a single pod, although there have been instances where two or more larvae entered into a single pod (Das and Islam, 1985). In such a case, when more than one larvae enter into a single Pod, cannibalism might be occurring, a phenomenon very common in most leaf miners. However, there has been little research in this regard for legume pod borers.

The first and second instars larvae feed mostly on the inner walls of the young pods and scrap inside the bored pods/flowers. The larvae of later instars, in most cases, enter into the pods, bore into the seeds and feed these parts by making circular holes. The entry holes are often difficult to visualize, as the holes are often plugged with the faecal excretion of the pest. In instances where the extruded frass can be seen from the outside, it is rather an obvious indicator of pod borer infestation (van Emden, 1980). The infesting larva can consume the entire seeds within a pod. After entering into a pod, the larva usually does not leave it until the food is totally exhausted. The infested pod often becomes unfit for human consumption.

Although the insect has been found to feed on different plant parts as explained above, Karel (1985) in a study observed that more than 52% of the larval populations were feeding on flowers, and about 38% larvae were feeding on pods. In contrast, she found only about 10% of the larvae to be feeding on leaves. The result is consistent with Sharma (1998), who concluded that the order on preference of different plant parts is flowers > flower buds > terminal shoot > pods and seeds. As a result of the insect infestations, crop yields can often be severely affected (Singh and Taylor, 1978).

2.2 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). Rahman et.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. Rahman et 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.

2.3 Pest complex of country bean

The pest spectrum of a crop 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 east Africa, more than 50 arthropod pests are reported and the pestiferous effects of these insects vary across the continent (Singh, 1983). He also noted that in addition to the 50 insects known so far, there might have been some other insect pests and mites causing damage to the crop but they have been ignored because of the inconspicuous presence and activities of those pests. However, he noted that despite the occurrence of a large number of arthropod pests, only a few occur more frequently and can cause significant damage to the crop. These include mainly the bean flies, black bean aphids and pod borers in many east African countries.

Many pestiferous arthropods occur in America and some of them inflict severe damage to several legume crops including beans. In Hawaii, legume pod borer have been ubiquitous causing severe damage to beans including lima beans (Holdaway and Look, 1942).

In India, country bean has been reported to be attacked by more than 57 species of pestiferous arlhropods (Govindan, 1974).In India, country beans have been reported to be frequently attacked by the galerucid beetle, *Madurasia obscurella* Jacob (Coleoptera: Chrysomelidae), which may cause economic damage to the crop (Gupta and Singh, 1978). Naresh and Nene (1968), and Saxena (1973 and 1976) have also reported that galerucid beetles and some other insect pests including various aphid species; hooded hopper, *Leptocentrus taurus* Fb. (Homoptera: Membracidae); leaf beetle, *Sagra carbunculus* Hope (Coleoptera: Chrysomelidae); leaf-eating caterpillars, *Plusia oricalchea* Fb. (Lepidoptera: Pyralidae); leaf miner, *Cosmopterix* sp. (Lepidoptera: Pyralidae); leaf weevil, *Blosyron oniscus* Ol. and *Alcides collaris* P. (Coleoptera:

Curculionidae); pod borer, *Maruca* sp. (Lepidoptera: Pyralidae); and mites, *Tetracychas* sp. (Acarina), attack country beans in different parts of India and the subcontinent. Singh (1983) also 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 (Shroff, 1920), although it is not clear which ones are of major importance in terms of damage.

In Bangladesh, country bean has been frequently reported to be 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) (Alam, 1969; Begum, 1993; Karim, 1993, 1995; Das, 1998; Islam, 1999). Among these insect pests, only a few species occur in most places of the country, and may often cause economic damages. 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, *M. 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, *A. craccivora*; leafminer, *Cosmopteris sp.*; leaf paster, *H. indica*; pod borer, *M. vitrata* and the mite, *Tetranychlrs* 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.

Among the major insect pests, aphids occur frequently. Because of their high reproductive capacity and sedentary habits, 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. 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;). When plants are heavily infested, leaf distortion and stunting frequently occur, which often result in poor fruit setting (Hill 1983; Butani and Jotwani, 1984;). 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). 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). Therefore, interests in the present study have been concentrated on the legume pod borer. From hereon, discussion will be dedicated mostly to the legume pod borers and further discussed in detail in the following sections.

2.4 Control of 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 pest, country bean pod borer, in this country. Several methods including cultural, mechanical, biological and chemical methods ate 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 pod borers, 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 two major categories, non-chemical and chemical control methods. Within each category, sub-categories have been described.

2.4.1 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). More over, 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.

Cultural control

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. Again, pod borer population tends to build up over the season (Ekesi *et al.*, 1996), the pod borer infestation increases on the late sown crop (Alghali, 1993). 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 and Omolo, 1982; Fisher *et al.*, 1987; Omolo *et al.*, 1993). Karel (1984 and 1993) also reported that pod borer incidence was significantly lower in intercropped than in pure stands. In contrast, Alghali (1993b), 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 (1984 and 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.

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). 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) 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.

Pheromonal control

The use of pheromone has also been reported against legume pod borer. In Kenya, pheromone traps were used against the bean pod borer *Maruca vitrata* (Okeyo-Owuor and Agwaro, 1982). The pheromone used has been a female sex pheromone. Generally, the sex pheromones could be successfully used as mating disruptors and prevent pod borers from rising to population levels damaging the crop (Alghali, 1993). However, pheromone trap is a tool that has been used frequently for monitoring the population of a particular pest rather than controlling the pest (Pedigo, 1999). In addition, pheromones are frequently sensitive to time; last for a relatively short period have the potential to influence natural enemy populations (Pedigo, 1999). Construction and placement of the traps also important. As a result, pheromones have been rarely used for the control of bean pod borers in Bangladesh.

2.4.2 Host plant resistance

Genetic control of pod borer mostly reflects the use of resistant plant genotypes against the pest. Searches for plant materials resistant to legume pod borers have been frequently made across continents. Screening techniques for plant materials resistant to the pest have been reported from field, greenhouse and laboratory conditions (Jackai, 1981 and 1991; Valdez, 1989; Echendu and Akingbohungbe, 1990). Sharma (1998) reviewed and concluded that significant progress in developing resistant varieties in this regard have been made using cowpeas and pigeonpeas as plant materials from Africa. Mechanisms associated with resistance of those plant materials have been explored and determined (Sharma, 1998). Ramadas and Babu (1989b) studied country beans, cowpeas and pigeonpeas and concluded antixenosis, antibiosis and tolerance have been the mechanisms through which these plant materials resisted pod borers activities. They also reported that country beans exhibited less antixenosis for oviposition of the pest compared with the other legumes they tested. In contrast, Valdez (1989) did not find such events in cowpeas. Non-preference of larval feeding has been reported to be associated with pod borer resistance in cowpeas (Echeden and Akingbohungbe, 1990). Valdez (1989) and Sharma (1998) found prevalence of larval antibiosis on some cowpeas genotypes. Okech and Saxena (1990) also attributed antibiosis to be a mechanism of some legumes pod borer resistant cowpea and pigeonpea genotypes. Saxena *et al.* (1996), on the other hand, observed some materials to be tolerant to the pod borers.

Factors associated with plant resistance to legume pod borers have been studied, which indicate that morphological, anatomical and biochemical factors greatly determine the capability of a plant material to be resistant to legume pod borers. Plant morphological characteristics include open plant canopy, long peduncles, and pod characteristics including size, growth, erectness and angle (Singh, 1978; Usua and Singh, 1979; Oghiakhe *et al.*, 1992b; 1993b). Lateef and Reed (1981) and Saxena *et al.* (1996) reported that indeterminate type of plants was more resistant to pod borers that the determinate type of cowpea plants. Singh (1978) and Oghiakhe *et al.*(1992b) reported that cowpea cultivars that had long pod peduncles and pod held at wider angles than the normal ones were more resistant to pod borers. Usua and Singh (1979) found that cowpea genotypes producing bunched pods suffer more damages by pod borers. Taylor (1986) observed that pod infestation was least in flower opened in eight days after anthesis in cowpeas. The author also noted pods maturing earlier provide some resistance to the pest. The author concluded that open plant canopy, long peduncles, erect pods with wide angles, profuse flowerings, pod size and rate of pod growth can be used to select resistant genotypes against pod borers. Jackai and Oghiakhe (1989) found that the presence of trichomes affects larval feeding and development of legume genotypes.

Plant anatomy has also contribution to plant resistance against the insect. Oghiakhe *et al.* (1992b) noted that types and structures of stem’s epidermal cells influence larval movement and feeding of stem’s tissues. The author also noted that thinner stems were less attractive than the thicker ones. Oghiakhe *et al.* (1992b) stated that although epidermal cells mainly the collenchymatious cell of plants have been reported to be providing resistance against the pest, there has been no such effect consistent in their study, suggesting that some other factors are also needed for manifesting the effect.

The chemistry of plants has been found to be associated with plants' resistant to legumes pod borers (Oteino *et al*. 1985; Oghiakhe *et al*. 1993a). Oteino *et al*. (1985) indicated that ethyl acetate soluble fraction of methyl alcohol extracts showed significant feeding inhibition of legume pod borer on resistance cowpea genotypes. In contrast, Oghiakhe *et al*. (1993c and d) did not find any relationships between suger or phenol concentrations and resistance of cowpea cultivars against legume pod borers. This suggests that there might be some other factors involved, presence or absence of which may modify the type of response that a plant would exhibit when exposed to legume pod borer attacks. Rainfall, temperature and photoperiod of some of this factors influencing legume pod borer infestation.

It appears that most of the information regarding the use of plant resistant against legume pod borers is from cowpea and pigeonpeas. There has been little information about country bean genotypes that are resistant to legume pod borer. This aspect need to be thoroughly studied, as concerns regarding the use of chemical insecticides has been increasing greatly, and control method that are relatively safer are solicited for controlling insect pest on crops. For vegetables crops, safety issue are more critical, as vegetables are sometimes raw or within a few days after pesticides applications.

2.4.3 Chemical control

Despite the fact that there has been a plethora of natural enemies and that there have been many non-insecticidal means for controlling legume pod borers on legume crops including beans, farmers often apply insecticides for controlling the pests. Insecticides of both botanical and synthetic origins have been used. Karim (1995) successfully controlled legume pod borer by applying aqueous extracts of neem seed kernel powder at 25-50 g neem kernel powder/L of water at the beginning of flowering. Neem extracts may act as direct toxicants to larvae or they many affect feeding activities, growth and development of the insect pest (Jackai and Oyediran, 1991). These authors have documented in laboratory conditions that different formulations of neem oil affected survival of legume pod borers. Botanical insecticides have been successfully used in controlling many insect pests attacking different field crops (Pedigo, 1999). However, the use of botanicals is less popular, primarily because botanical compounds do not last long, as they are sensitive to light and heat; they often dissociate and loose insecticidal properties soon at higher light, temperature and moisture conditions.

Despite the availability of different pest control methods, it appears that synthetic chemical insecticides dominate the other means of controlling the insect pests on legumes including country beans. In Bangladesh, Karim (1993 and 1995) recommended application of synthetic pyrethroid insecticides including Deltamethrin, Cypermethrin or Fenvalerate or Cyfluthrin at the rate of 1.0 ml /1 of water for control of the legume pod borer. Dandale *et al.* (1981) reported the superiority of Cypermethrin, Fenvalerate and Endosalfan in reducing pod borer infestation in red gram elsewhere. Rahman and Rahman (1988) sprayed 0.008% Cypermethrin at initial, 50% and 100% flowering and at l00% pod setting stages of plants and obtained complete protection of pigeon pea from legume pod borers in the winter season of 1987 - 88 in Bangladesh. They also tried Dimethoate, which however did not appear to be as much effective as the Cypermethrins were.

It is a general belief that application of insecticides is the only effective and economically viable method of controlling insect pests in field crops. The philosophy of such an over reliance on insecticides for controlling insect pests in crop fields has developed over generations (Islam, 1999). As a result, it appears very difficult in achieving success in popularizing alternative methods that could be more economic and sustainable in the long run (Debach and Rosen 1991; Pedigo 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, l991; Pedigo, 1999). In addition, development of resistant genotypes of the pest to the commonly used insecticides is not uncommon (Debach and Rosen, 1991; Pedigo, 1999). 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.

Biorational: The *Bacillus thuringiensis*-based treatments reduced pod damage by 50% in Vietnam, and yard-long bean yields were 17 to 50 times greater than the untreated check. Similarly, yard-long bean pod damage by *M. vitrata* was reduced by 9-44%, with significant yield increases (63-68%) in *B. thuringiensis*-based treatments.

CHAPTER III

MATERIALS AND METHODS

The study was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2018 to January 2019 to know the evaluation of some reduced-risk insecticides for the control of legume pod borer, *Maruca vitrata* F. in country bean. The materials and methods that were adopted for conducting the experiment are discussed under the following heading and sub-headings:

3.1 Experimental site

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

3.2 Soil

The soil of the experiment site was a medium high land, clay loam in texture and having p^H 5.47-5.63. The land was located in Agro-ecological Zone of 'Madhupur Tract' (AEZ No. 28).

3.3 Climate

The climate of the experimental site is sub-tropical characterized by heavy rainfall during April to July and sporadic during the rest of the year.

3.4 Design of the experiment and layout

The experiment was conducted with 5 treatments . The experiment was laid out in a Randomized Complete Block Design (RCBD). The entire experimental field was divided into three blocks. Each block was divided into five plots. Two adjacent unit plots were separated by 0.5 m apart and blocks were separated by 0.5 m apart. Each experimental plot comprised of 3m x 2m area .Each treatment combinations were allocated randomly within the block by conforming randomization table procedure and replicated three times (Plate 1).

3.5 Land preparation and fertilization

The main land was ploughed thoroughly by a tractor drawn disc plough followed by harrowing. The stubbles of the crops and uprooted weeds were removed from the field and the land was then labeled prior to transplanting. The field layout was done on accordance to the design, immediately after land preparation. The plots were raised by 10 cm from the soil surface keeping the drain around the plots. During land preparation, cow dung was incorporated into the soil at the rate of 10 t/ha. Recommended doses of fertilizer comprising Urea, TSP and MP at the rate of 30, 90 and 65 kg/ha respectively were applied. Entire amount of cow dung was applied during the final land preparation. Entire dose of TSP and half amount of Urea and MP were applied to the soil of the pit 4-5 days before the transplanting. The rest amount of Urea and MP were top dressed 30 days after transplanting (BARC, 1997).

3.6 Experimental materials

Plate 1. The experimental plot at SAU, Dhaka

3.7 Treatments

This experiment is consists of four insecticides. Each insecticide was designated as individual treatment. The treatments of the present study were given as follows:

T_1: Application of MNPV at 7 days interval.

T_2: Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval.

T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval.

T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.
T_5: Untreated control

Plate 2. MNPV (T_1) treated plot.

Plate 3: Success 2.5 SC (Spinosad) (T_2) treated plot.

Plate 4: Proclaim 5 SG (Emamectin) (T_3) treated plot

Plate 5: Cypermethrin (T_4) treated plot

3.8 Collection of seeds

The seed of country bean BARI seem-5 variety was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur

3.9 Sowing of seeds

For rapid growth and germination the seeds of country bean varieties were soaked for 12 hours in water. Two seeds of variety were then sown per polyethylene bags (12cm x 18 cm) containing a mixture of equal proportion of well-decomposed cow dung and loamy soil. Irrigation was given by watering can 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 four seedlings per pit on last week of October. 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 four seedlings per pit, one was removed two weeks after transplanting.

3.10 Intercultural operation

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 (1.75m) was provided on about 1.5m 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.

3.11 Data collection

Data were recorded on the following parameters:

- Number of larva of bean pod borer plant^{-1} at early,mid and late satge of pod development
- Number of inflorescence plant^{-1}
- Number of flower inflorescence^{-1}
- Number of pod inflorescence^{-1}
- Total number of pods plant^{-1}
- Number of healthy pods at early,mid and late satge plant^{-1}
- Number of infested pods at early,mid and late satge plant^{-1}
- weight of healthy pods (g) at early,mid and late satge plant^{-1}
- weight of infested pods (g) at early,mid and late satge plant^{-1}
- Length of pod (cm)
- Yield plot^{-1} (kg)
- Total pod yield (kg)

3.12 Procedure of data collection

3.12.1. Counting of bean pod borer larvae at different growing stages of plant

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

3.12.2.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

3.12.3 Number of flower inflorescence^{-1}

During the reproductive stage of the plant total numbers of flower inflorescence^{-1} were recorded in each treatment from 5 inflorescences.

3.12.4. 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.

3.12.5.Number and Weight of healthy pods plant^{-1}

Healthy pods number from each plot was estimated and the mean number was unraveled on plant^{-1} basis. The data were collected on early, mid and late pod development stage.

3.12.6.Number and Weight of infested pods plant^{-1}

Number of infested pods from each plot was estimated and the mean number was evaluated by plant^{-1}basis.The data were collected on early, mid and late pod development stage

3.12.7.Percent of pod infestation

From the collected data on total number of pods and number of infested pods by bean pod borer the percent pod infestation was calculated using the following formula:

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

3.12.8.Length and weight of pods

Five healthy and five infested pods were randomly selected and the data on length & weight were recorded from each plot in each treatment.

3.12.9.Total pod yield

Total yield/plant was measured and then averaged to kg/plant. Total yield/plot was also taken and then total yield per hectare for each treatment was calculated in tons from cumulative pod production in a plot.

3.13 Statistical analysis of data

Analysis of variance was done with the help of computer package MSTAT-C program. The data recorded on different parameters were subjected to analysis of variance (ANOVA) and the means were compared according to Least Significant Difference Test (LSD) at 5% level of significance.

Effect of MNPV   Effect of Emamectin

Effect of Spinosad   Effect of Cypermethrin

Plate 6: Effect of different treatments on pods used in BARI sheem 5

Plate 7 : Infested pod showing the infestation intensity of legume pod borer**.**

CHAPTER IV

RESULTS AND DISCUSSION

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

4.1 *INSECT PEST INCIDENCE*

Incidence of legume pod borer of country bean was recorded for the entire cropping season. Remarkably, legume pod borer was observed in the study. Insect pests from each plant during the reproductive stage which divided as at early(10-20)DAF, mid(30-40)DAF and late pod development stages(50-60)DAF depending on the duration of reproductive stage to investigate the performance of different treatments.

4.1.1 *EARLY POD DEVELOPMENT STAGE*

At early pod development stage, statistically significant variation was recorded for number of bean pod borer due to different management practices (Table 1). The lowest number of pod borer per plant (4.3) was found from T_3 (Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval) which was profoundly followed by (6.2) by T_2(Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval) while the highest number of pod borer (19.8) was observed from T_5 (untreated control) which was followed (13.3) by T_4 (Application of Cypermethrin @ 1ml/L of water at 7 days interval). From the above mentioned findings, it is revealed that at early pod development stage, spraying of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval was more effective among the practices for controlling legume pod borer of country bean which was followed by Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval.

Table 1. Effect of different management practices on number of legume pod borer of country bean at early pod development stage

Treatments	**At early pod development stage**	
	Larva of bean pod borer (No./plant) at 10 DAF	**Larva of bean pod borer (No./plant) at 20 DAF**
$\mathbf{T_1}$	8.8c	11.5c
$\mathbf{T_2}$	4.7d	6.2d
$\mathbf{T_3}$	3.8e	4.3e
$\mathbf{T_4}$	11.8b	13.3b
$\mathbf{T_5}$	15.5a	19.8a
$\mathbf{LSD_{0.05}}$	0.9	0.8
C.V. (%)	5.6	4.0

In a column means having dissimiliar letters(s) differ significantly by LSD at 0.05 level of probability.

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.1.2 MID POD DEVELOPMENT STAGE

Statistically significant variations were recorded for bean pod borer due to different management practices at mid pod development stage (Table 2). The lowest number of pod borer plant^{-1} was observed from T_3 (5.8) consists of Proclaim 5 SG (Emamectin) @ 1mg/L of water at days interval closely which was closely followed by T_2 (8.8) and T_1(15.5) whereas the highest number was observed from T_5 (28.8) consists of untreated control which was followed by T_4 (18.4). From the above mentioned findings,it is revealed that spraying of Proclaim 5 SG (Emamectin) @1ml/L of water at 7 days interval was more effective among the management practices for controlling legume pod borer of country bean at mid pod development stage and the second satisfactory treatment of the experiment was the T_2 (Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 2. Effect of different management practices on number of legume pod borer of country bean at mid pod development stage

Treatments	**At mid pod development stage**	
	Larva of bean pod borer (No./plant) at 30 DAF	**Larva of bean pod borer (No./plant) at 40 DAF**
T_1	13.5c	15.5c
T_2	7.5d	8.8d
T_3	5.2e	5.8e
T_4	16.7b	18.4b
T_5	23.5a	28.8a
$LSD_{0.05}$	1.7	1.7
C.V. (%)	6.7	5.8

In a column means having dissimiliar letters(s) differ significantly by LSD at 0.05 level of probability.

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.1.3 Late pod development stage

Different management practices showed statistically significant variation at late pod development stage for bean pod borer (Table 3). The lowest number plant[1] was observed from T_3 (7.76) which was closely followed by T_2 (10.26).T_1 and T_4 treatment shows statistically similar result whereas the highest number was observed from T_5 (33.81). From the above findings it is revealed that Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval was more effective among the management practices for controlling insect legume pod borer of country bean at late pod development stage which was followed by Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval). It was also observed the trend of pest's infestations was at increasing fashion from early to late pod development stages in this study which is supported by the others researchers finding.

Table 3. Effect of different management practices on number of legume pod borer of country bean at late pod development stage

Treatments	**At late pod development stage**	
	Larva of bean pod borer (No./plant) at 50 DAF	**Larva of bean pod borer (No./plant) at 60 DAF**
T_1	17.53b	18.76b
T_2	9.28c	10.26c
T_3	7.03d	7.76d
T_4	19.03b	19.76b
T_5	31.53a	33.81a
$LSD_{0.05}$	1.68	1.68
C.V. (%)	5.30	4.95

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.2 Different yield contributing character of bean

4.2.1 Number of inflorescence plant^{-1}

Number of inflorescence plant^{-1}of country bean showed statistically significant variation for different management practices in controlling legume pod borer of country bean (Table 4). The highest number of inflorescence plant^{-1} was recorded from T_3 (6.1) which was followed by T_2 (5.5), T_1 (5.3) and T_4 (5.2) while the lowest number was observed from T_5 (4.8) treatment.

4.2.2 Number of flower inflorescence^{-1}

Different management practices in controlling legume pod borer of country bean showed statistically significant variation for number of flower inflorescence^{-1} of country bean (Table 4). The highest number of flower inflorescence^{-1} was recorded from T_3 (13.8) which was statistically alike with T_2 (13.5) treatment while the lowest number was recorded from T_5 (11.2) treatment.

4.2.3 Number of pod inflorescence^{-1}

Data revealed that number of pod inflorescence^{-1} of country bean showed statistically significant variation for different management practices in controlling legume pod borer of country bean (Table 4). The highest number of pod inflorescence^{-1} was recorded from T_3 (9.7) which was followed by T_2 (9.20), T_1 (8.5) and T_4 (8.1) treatments while the lowest number was recorded from T_5 (6.8) treatment.

4.2.4 Pod length

Statistically significant variation was recorded for pod length of country bean showed due to different management practices in controlling legume pod borer of country bean (Table 4). The longest pod was recorded from T_3 (9.9 cm) which was statistically alike with T_2 (9.8 cm) treatment while the shortest pod length was observed from T_5 (8.1 cm) treatment.

Table 4. Effect of different management practices in controlling legume pod borer of country bean for different yield contributing characters and yield

Treatments	Number of inflorescence $plant^{-1}$	Number of flower $inflorescence^{-1}$	Number of pod $inflorescence^{-1}$	Pod length (cm)
T_1	5.3c	13.0bc	8.5bc	8.7b
T_2	5.5b	13.5ab	9.2ab	9.8a
T_3	6.1a	13.8a	9.7a	9.9a
T_4	5.2c	12.5c	8.1c	8.5b
T_5	4.8d	11.2d	6.8d	8.1c
$LSD_{0.05}$	0.2	0.7	0.9	0.6
C.V. (%)	4.2	5.9	5.6	5.3

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.2.5 Number of pods plant^{-1}

Number of pod plant^{-1} of country bean showed statistically significant variation for different management practices in controlling legume pod borer of country bean (Table 5). The highest number of pod plant^{-1} was recorded from T_3 (59.1) which was closely followed by T_2 (50.5) treatment while the lowest number was recorded from T_5 (32.7) treatment.

4.2.6 Yield plot^{-1}

Statistically significant variation was recorded for yield plot^{-1} of country bean for different management practices in controlling legume pod borer of country bean (Table 5). The highest yield plot^{-1} was recorded from T_3 (9.9 kg) which was statistically akin to T_2 (9.0 kg) treatment while the lowest yield plot^{-1} was recorded from T_5 (6.2 kg) treatments.

4.2.7 Total Pod yield (ton hectare^{-1})

Different management practices in controlling legume pod borer of country bean showed statistically significant variation in terms of yield hectare^{-1} of country bean (Table 5). The highest yield hectare^{-1} was found from T_3 (11.0 ton) which was followed by T_2 (10.0 ton), T_1 (9.2 ton) and T_4 (8.7 ton) treatments while the lowest pod yield hectare^{-1} was recorded from T_5 (6.9 ton) treatment. Pod yield increase over control was estimated and the highest value was obtained from the treatment T_3 (59.4%) which was followed by T_2 (45.5%) and the lowest pod yield increase over control was recorded from T_4 treatment.

Table 5. Effect of different management practices in controlling legume pod borer of country bean for different yield contributing characters and yield

Treatments	**Number of pods $plant^{-1}$**	**Yield $plot^{-1}$(kg)**	**Pod Yield (t/ha)**	**Increase over control (%)**
T_1	44.4bc	8.2c	9.2bc	32.9
T_2	50.5b	9.0b	10.0b	45.5
T_3	59.1a	9.9a	11.0a	59.4
T_4	42.2c	7.8c	8.7c	26.4
T_5	32.7d	6.2d	6.9d	--
$LSD_{0.05}$	6.6	0.8	0.9	--
C.V. (%)	7.6	5.8	5.2	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.3 Pod bearing status at early pod development stage by number and weight

Significant variation were observed in number of healthy pods, infested pods, percent infestation and infestation reduction over control at early pod development stage for different management practices in controlling insect pests of country bean (Table 6). The highest number of healthy pods plant^{-1} was observed from T_3 (56.00) which was followed by T_2 (54.00).while the lowest number of healthy pods was observed from T_5 (42.20) followed by T_1 (46.00) treatments. On the other hand the lowest number of infested pods plant^{-1} was observed from T_3(2.25) which was closely followed by T_2 (4.25) and T_1 (7.00) treatments. Conversely, the highest number of infested pods was found from T_5 (12.75) followed by T_4 (9.75) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_3 (3.86%) which was closely followed by T_2 (7.29%). Again the highest % pod infestation was recorded in T_5 (23.18%) followed by T_4 (17.48%) treatment. Pod infestation reduction over control in number was estimated and the highest value was found from the treatment T_3 (83.3%) which was followed by T_2 (68.6%).

Table 6. Effect of different management practices in controlling legume pod borer of country bean at early pod growing period in terms of pods plant^{-1} by number

Treatments	**Number of bean Pods plant^{-1}**			
	Healthy pod	**Infested pod**	**Infestation (%)**	**Reduction over control (%)**
T_1	46.00c	7.00c	13.20c	43.1
T_2	54.00b	4.25d	7.29d	68.6
T_3	56.00a	2.25e	3.86e	83.3
T_4	46.01c	9.75b	17.48b	24.6
T_5	42.20d	12.75a	23.18a	--
$LSD_{0.05}$	1.90	1.01	1.43	--
C.V. (%)	2.75	7.45	5.84	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

Table 7, indicated that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at early pod development stage for different management practices in controlling legume pod borer of country bean. In context of healthy pods, the highest weight plant^{-1} (1232.3 g) was found from T_3 which was followed by T_2 (1134.3 g) and T_1 (1052.2 g) treatments. On the contrary,the lowest weight of healthy pods was found from T_5 (887.3 g) which was followed by T_4 (989.3 g) treatment. Considering the infested pods, the lowest weight of infested pods plant^{-1} was recorded from T_3 (49.6 g) while the highest weight of infested pods was found in T_5 (274.1 g) . In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_3 (3.86%) which was closely followed by T_2 (7.26%) whereas the highest infested pods was observed in T_5 (23.57%) followed by T_4 (17.45%) treatment. Incase of Pod infestation reduction over control in weight,the highest value was obtained from the treatment T_3 (83.6%) which was followed by T_2 (69.2%) and the lowest from T_4 (26%) treatment. From the above findings, it is evident that at early pod development,application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 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 T_2 which was application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 7. Effect of different management practices in controlling legume 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 pod	**Infested pod**	**Infestation (%)**	**Reduction over control (%)**
T_1	1052.2c	129.4c	10.93c	53.6
T_2	1134.3b	89.3d	7.26d	69.2
T_3	1232.3a	49.6e	3.86e	83.6
T_4	989.3c	209.6b	17.45b	26.0
T_5	887.3d	274.1a	23.57a	--
$LSD_{0.05}$	73.40	10.70	0.81	--
C.V. (%)	3.70	3.80	3.39	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.4 POD BEARING STATUS AT MID POD DEVELOPMENT STAGE BY NUMBER AND WEIGHT

Table 8 ,indicated that the number of healthy, infested pods, percent infestation and infestation reduction over control at mid pod development stage showed statistically significant differences for different management practices in controlling legume pod borer of country bean. In the number of healthy pods, the highest number plant^{-1} was observed from T_3 (59.22) which was followed by T_2 (57.47), while the lowest number of healthy pods was observed from T_5 (44.72) followed by T_4 (47.97). The lowest number of infested pods plant^{-1} was observed from T_3 (3.50) which was followed by T_2 (5.20) and T_1 (8.25) treatments. On the other hand, the highest number of infested pods was recorded from T_5 (15.25) followed by T_4 (8.50) treatment. In relation to the % pod infestation, the lowest infested pods plant^{-1} by number was observed from T_3 (5.57%) which was closely followed by T_2 (8.29%).Again the highest infested pods was observed in T_5 (25.41%) followed by T_4 (15.04%) treatment. Pod infestation reduction over control in number was estimated and the highest value was found from the treatment T_3 (78.1%) which was followed by T_2 (67.4%) and T_1 (43.3%). On the contrary, the lowest reduction of pod infestation over control obtained from T_4 (40.8%) treatment. From the above findings,it is revealed that at mid pod development stage, application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval was more effective among the management practices in terms of pods plant^{-1} by number and the second best treatment of the experiment was the T_2 which consists of application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 8. Effect of different management practices in controlling legume pod borer of country bean at mid pod growing period in terms of pods plant^{-1} by number

Treatments	Number of bean Pods plant^{-1}			
	Healthy pod	**Infested pod**	**Infestation (%)**	**Reduction over control (%)**
T_1	48.97c	8.25b	14.41b	43.3
T_2	57.47b	5.20c	8.29c	67.4
T_3	59.22a	3.50d	5.57d	78.1
T_4	47.97c	8.50b	15.04b	40.8
T_5	44.72d	15.25a	25.41a	--
$LSD_{0.05}$	1.71	0.63	0.92	--
C.V. (%)	4.68	4.08	3.57	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

Table 9, indicated that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at mid pod development stage for different management practices in controlling legume pod borer of country bean. In context of healthy pods, the highest weight plant^{-1} (1273.9 g) was observed from T_3 which was closely followed by T_2(1219.3). Conversely,the lowest weight of healthy pods was observed from T_5(913.0 g) which was followed by T_1 (992.2 g) treatments. Considering the infested pods, the lowest weight of infested pods plant^{-1} was observed from T_3 (76.4 g) which was close to T_2 (113.3g) and T_1 (171.2 g) and T_4(182.3 g) treatments while the highest weight of infested pods was found in T_5 (299.3 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_3 (5.7%) which was followed by T_2 (8.5%), T_1 (14.7%) and T_4 (15.2%) treatments, whereas the highest infested pods was observed in T_5 (24.7%) treatment. Pod infestation reduction over control in weight was estimated and the highest value was obtained from the treatment T_3 (77.1%) which was followed by T_2 (65.6%), T_1 (40.4%) and the lowest from T_4 (38.6%) treatment. From the above findings it is revealed that at mid pod development stage ,application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 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_2 treatment which consists of application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 9. Effect of different management practices in controlling legume 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 pods	**Infested pods**	**Infestation (%)**	**Reduction over control (%)**
T_1	992.2c	171.2c	14.7b	40.4
T_2	1219.3b	113.3d	8.5c	65.6
T_3	1273.9a	76.4e	5.7d	77.1
T_4	1020.5c	182.3b	15.2b	38.6
T_5	913.0d	299.3a	24.7a	--
$LSD_{0.05}$	53.1	10.7	1.0	--
C.V. (%)	4.2	3.4	3.9	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.5 Pod bearing status at late pod development stage by number and weight

Table 10 indicated that statistically significant differences were recorded in number of healthy, infested pods, percent infestation and infestation reduction over control at late pod development stage for different management practices in controlling legume pod borer of country bean. The highest number of healthy pods plant^{-1} was recorded from T_3 (51.0) which was followed by T_2(50.8) while the lowest number of healthy pods was recorded from T_5 (39.0) followed by T_4 (43.0) treatment. The lowest number of infested pods plant^{-1} was recorded from T_3 (4.3) which was closer to T_2(6.0) On the other hand, the highest number of infested pods was recorded from T_5 (13.8) followed by T_1(9.0) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_3 (7.7%) which was followed by T_2 (10.6%), T_1(16.5%) and T_4 (16.9%) treatment.The highest infested pods was recorded in T_5 (26.1%) .Pod infestation reduction over control in number was estimated and the highest value was found from the treatment T_3 (70.5%) which was followed by T_2 (59.5%), T_1 (36.7%) and the lowest reduction of pod infestation over control from T_4 (35.2%) treatment. From the above findings it is revealed that at late pod development stage, by number of pods plant^{-1} ,application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval was more effective among the management practices in terms of pods plant^{-1} by number and the second best treatment of the experiment was the T_2 which consists of application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 10. Effect of different management practices in controlling legume pod borer of country bean at late pod growing period in terms of pods $plant^{-1}$ by number

Treatments	Number of bean Pods $plant^{-1}$			
	Healthy pod	**Infested pod**	**Infestation (%)**	**Reduction over control (%)**
T_1	45.5b	9.0b	16.5b	36.7
T_2	50.8a	6.0c	10.6c	59.5
T_3	51.0a	4.3d	7.7d	70.5
T_4	43.0bc	8.8b	16.9b	35.2
T_5	39.0c	13.8a	26.1a	--
$LSD_{0.05}$	4.3	0.5	0.6	--
C.V. (%)	5.0	3.5	2.1	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

Table 11 indicated that healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at late pod development stage for different management practices in controlling legume pod borer of country bean. In context of healthy pods, the highest weight plant^{-1} was observed from T_3 (1103.3 g) which was followed by T_2 (1092.8 g) and T_1 (833.9 g) .On the other contrary, the lowest weight of healthy pods was observed from T_5 (703.9 g) which was followed by T_4 (807.9 g) treatment. Considering the infested pods, the lowest weight of infested pods plant^{-1} was observed from T_3 (70.1 g) which was close to T_2 (102.0 g), while the highest weight of infested pods was found in T_5 (254.3 g) closely followed by T_4 (154.4 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was observed from T_3 (5.98%) which was strongly followed by T_2 (8.54%), the highest infested pods was observed in T_5 (26.58%) which was followed by T_4 (16.06%) treatment. Pod infestation reduction over control in weight was estimated and the highest value was obtained from the treatment T_3 (77.5%) which was closely followed by T_2 (67.9%) treatment and the lowest from T_4 (39.6%) treatment. From the above findings it is prominent that at late pod development stage application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 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_2 which consists of application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 11. Effect of different management practices in controlling legume 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 pod	**Infested pod**	**Infestation (%)**	**Reduction over control (%)**
T_1	833.9b	148.5b	15.14b	43.0
T_2	1092.8a	102.0c	8.54c	67.9
T_3	1103.3a	70.1d	5.98d	77.5
T_4	807.9b	154.4b	16.06b	39.6
T_5	703.9c	254.3a	26.58a	--
$LSD_{0.05}$	73.5	12.7	1.0	--
C.V. (%)	4.3	4.6	3.6	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.6 Pod bearing status at total pod growing stage by number

Table 12,indicated that statistically significant differences were observed in number of healthy, infested pods, percent infestation and infestation reduction over control at total growing period for different management practices in controlling legume pod borer of country bean. In number of healthy pods, the highest number plant^{-1} was recorded from T_3 (166.3) which was followed by T_2 (162.3), T_1 (140.5) and T_4 (137) treatments, while the lowest number was observed from T_5 (125.5) treatment. The lowest number of infested pods plant^{-1} was recorded from T_3 (10.0) which was followed by T_2 (15.5) treatment. On the other hand, the highest number of infested pods was recorded from T_5 (41.8) followed by T_4 (27.0) treatment. In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_3 (5.7%) which was followed by T_2(8.7%), T_1 (14.7%) treatments. The highest percentage of infestation by pod borer was observed in T_5 (24.9%) followed by T_4 (16.5%) treatment. Pod infestation reduction over control in number was estimated and the highest value was obtained from the treatment T_3 (77.2%) which was closely followed by T_2 (65.1%) and the lowest value was obtained from T_4 (33.9%) treatment. . From the above findings it is prominent that at total pod growing period by number, application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 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_2 which consists of application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 12. Effect of different management practices in controlling legume pod borer of country bean at total pod growing period in terms of pods $plant^{-1}$ by number

Treatments	Number of bean Pods $plant^{-1}$			
	Healthy pods	Infested pods	Infestation (%)	Reduction over control (%)
T_1	140.5b	24.3c	14.7c	41.0
T_2	162.3a	15.5d	8.7d	65.1
T_3	166.3a	10.0e	5.7e	77.2
T_4	137.0bc	27.0b	16.5b	33.9
T_5	125.5c	41.8a	24.9a	--
$LSD_{0.05}$	12.7	2.1	1.1	--
C.V. (%)	4.6	4.6	4.0	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.7 Pod bearing status at total pod growing stage by weight

Table 13, indicated that the healthy and infested pods, % infestation and infestation reduction over control in terms of weight showed statistically significant variation at total pod growing period for different management practices in controlling legume pod borer of country bean. In context of healthy pods, the highest weight plant^{-1} was recorded from T_3 (3607.8 g) which was followed by T_2 (3444.6 g), T_1 (2876.7g) treatments. On the other contrary the lowest weight of healthy pods was recorded from T_5 (2502.4 g) which was followed by T_4 (2816.1 g) treatment. Considering the infested pods, the lowest weight of infested pods plant^{-1} was recorded from T_3 (196.1 g) while the highest was recorded in T_5 (827.6 g) followed by T_4 (546.3 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_3 (5.2 %) which was followed by T_2 (8.1%) and T_1 (13.5%) treatments, whereas the highest infested pods plant^{-1} was recorded from T_5 (24.8%) which was followed by T_4 (16.2%). Pod infestation reduction over control in weight was estimated and the highest value was attained from the treatment T_3 (79.2%) followed by T_2 (67.3%) treatments and the lowest value was obtained from T_4 (34.7%) treatment. From the above findings it is prominent that at total pod development stage by weight, application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 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_2 which consists of application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval).

Table 13. Effect of different management practices in controlling legume pod borer of country bean at total pod development stage in terms of pods plant^{-1} by weight

Treatments	Weight of pods (g/plant)			
	Healthy pods	**Infested pods**	**Infestation (%)**	**Reduction over control (%)**
T_1	2876.7b	449.2c	13.5c	45.6
T_2	3444.6a	304.5d	8.1d	67.3
T_3	3607.8a	196.1e	5.2e	79.2
T_4	2816.1b	546.3b	16.2b	34.7
T_5	2502.4c	827.6a	24.8a	--
$LSD_{0.05}$	193.1	35.7	0.8	--
C.V. (%)	3.4	4.1	3.0	--

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

[T_1: Application of MNPV at 7 days interval. T_2 Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval. T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5:untreated.]

4.8 Relationship between different parameter and yield

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

Correlation study was done to establish the relationship between number of inflorescence plant^{-1} and yield (t/ha) of country bean among different management practices. From the **figure 1** it was revealed that positive correlation was observed between the parameters. The regression equation y=3.0547x-7.2466 gave a expected fit to the data and the co-efficient of determination (R2 = 0.9141) had a significant regression co-efficient. From the figure 1 it was also observed that the lowest number of inflorescence plant-1 (4.8) gives the yield 6.9 (t/ha) and the highest number of inflorescence plant-1 (6.1) gives the yield 11 (t/ha). It may be concluded that there is strongly a positive correlation between no. of inflorescence with pod yield .That means with the increasement of number of inflorescence plant-1 increases the pod yield.

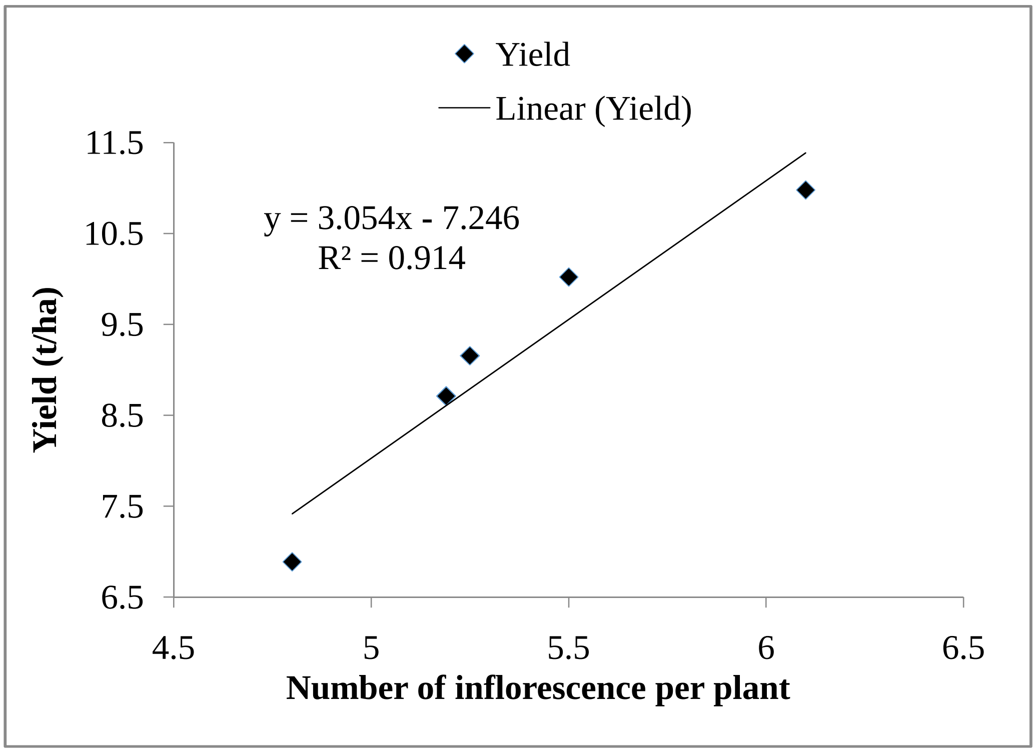


FIGURE 1: Relationship between number of inflorescence plant^{-1} and pod yield/ ha.

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

Correlation study was done to establish the relationship between number of flower inflorescence^{-1} and pod yield (t/ha) of country bean among different management practices. From the **figure 2** it was revealed that positive correlation was observed between the parameters. The regression equation y=1.4806x-9.8005 gave a satisfactory fit to the data and the co-efficient of determination (R^2 = 0.9741) had a significant regression co- efficient. From the **figure 2** it was also observed that the lowest number of flower inflorescence^{-1} (11.2) gives the yield 6.2(t/ha) and the highest number of flower inflorescence^{-1} (13.8) gives the yield 11 (t/ha) which was found by using treatment T_3 (application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval). It may be concluded that there is strongly a positive correlation between no. of flower inflorescence^{-1} with pod yield .That means with the increasement of number of flower inflorescence^{-1} increases the pod yield.

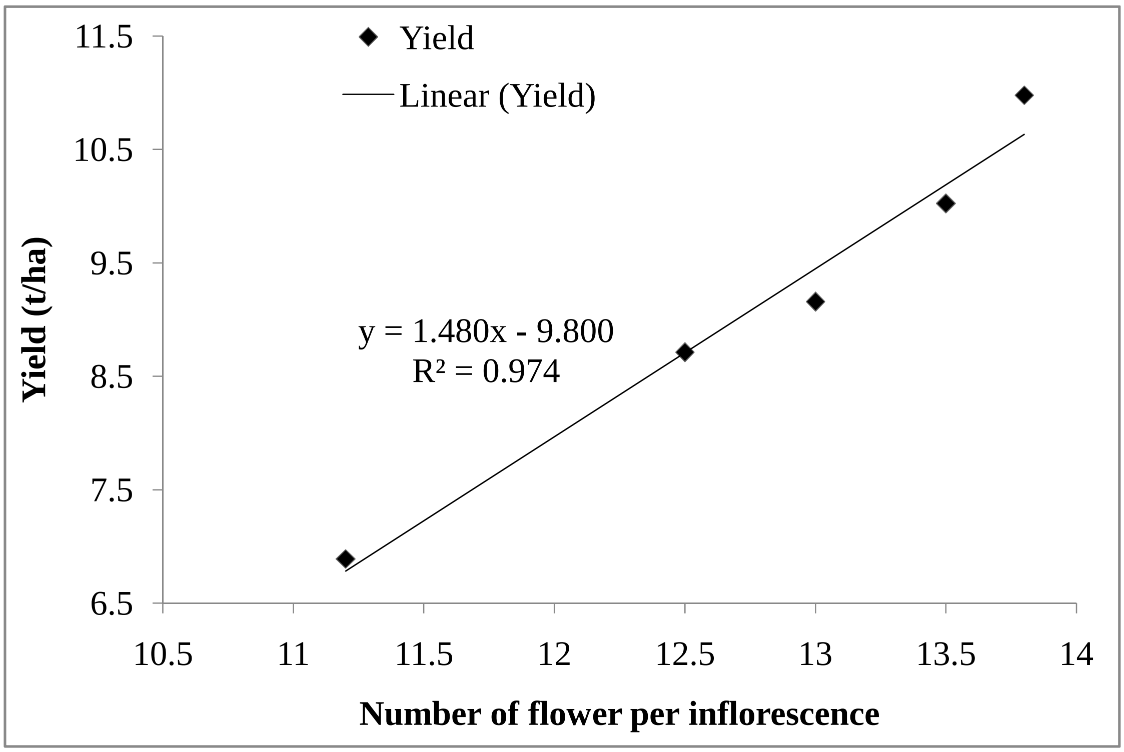


FIGURE 2: Relationship between number of flower inflorescence^{-1} and pod yield/ha

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

The data on number of pod inflorescence^{-1} was regressed against yield hectare^{-1} of country bean and a positive linear relationship was obtained between them. The regression equation y = 1.3724x – 2.4592 gave a desirable fit to the data and the co-efficient of determination (R^2 = 0.9955) had a significant regression co- efficient. From the **figure 3** it was conspicuous that the lowest number of pods inflorescence^{-1} (6.8) gives the yield 6.9 (t/ha) and the highest number of pods inflorescence^{-1} (9.7) gives the yield 11 (t/ha).So the increase of number of pods inflorescence-^{1} (2.9) increased the yield 4.1 (t/ha) which was found by using treatment T_3.). It may be concluded that there is strongly a positive correlation between no. of pods inflorescence^{-1} with pod yield .That means with the increasement of number of pods inflorescence^{-1} increases the pod yield drastically.

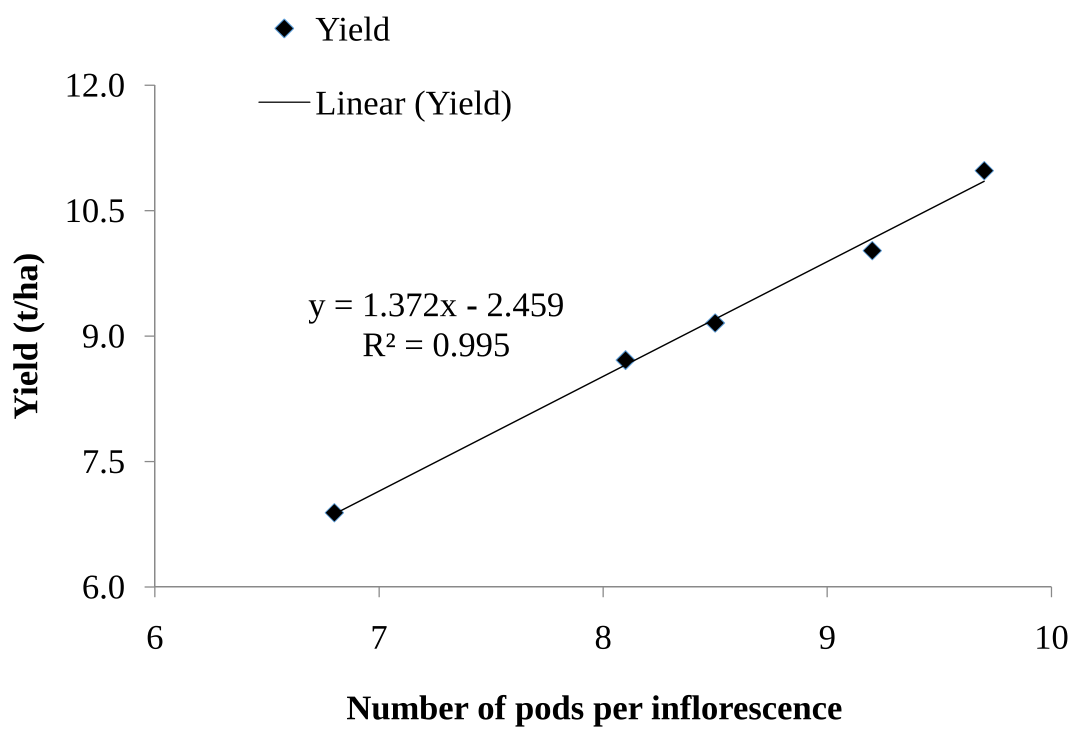


FIGURE 3: **Relationship between number of pods inflorescence^{-1} and yield hectare^{-1}**

4.8.4 RELATIONSHIP BETWEEN %POD INFESTATION OF COUNTRY BEAN BY NUMBER AT TOTAL GROWING PERIOD AND YIELD (T/HA)

Correlation study was done to establish the relationship between % pod infestation of country bean in number at total growing period and yield (t/ha) among different management practices. From the **figure 4** it was revealed that negative correlation was observed between the parameters. The regression equation y=-0.1998x+11.86 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9919) had a significant regression co-efficient. From this figure it was apparent that 24.9% pod infestation in number gives the yield 6.9(t/ha) and 5.7% pod infestation in number gives the yield 11 (t/ha). So, the reduction of 19.2% pod infestation in number increased the yield 4.1 (t/ha) which was produced by using the treatment T_3 (application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval). From the figure, it may be concluded that % pod infestation of country bean in number negatively correlated with pod yield (t/ha) that means with the increasement of %pod infestation drastically reduces the yield.

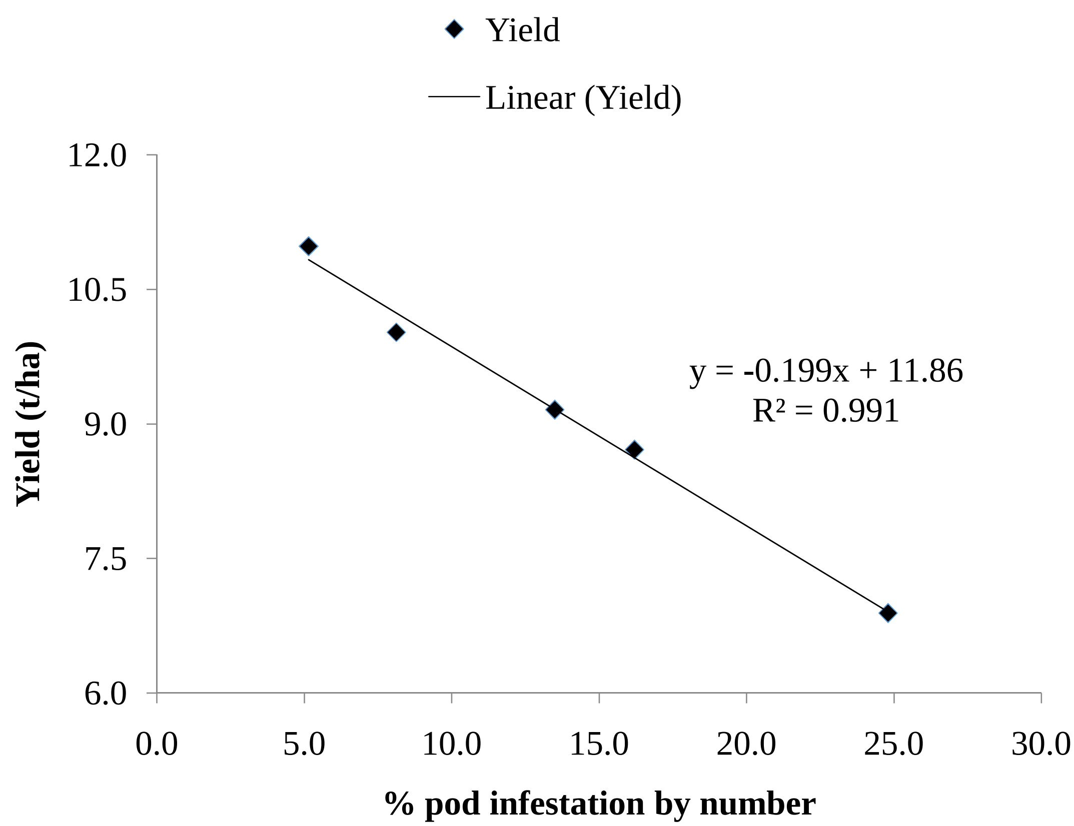
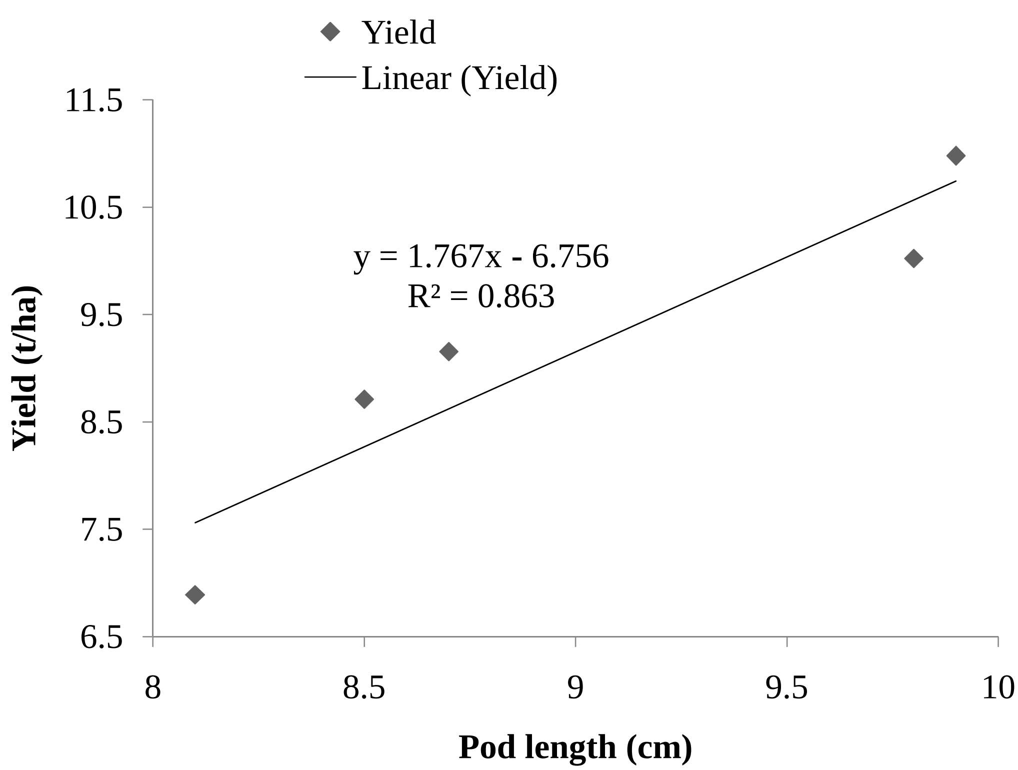


FIGURE 4: Relationship between %pod infestation of country bean by number at total growing period and yield (t/ha)

4.8.5 Relationship between pod length and yield/ ha

Correlation study was done to establish the relationship between pod length and yield (t/ha) among different management practices. From the study it was revealed that positive correlation was observed between the parameters. The regression equation y = 1.7675x – 6.756 gave a exquisite fit to the data and the co-efficient of determination (R^2 = 0.8634) fitted regression line had a significant regression co-efficient. From the figure 5 it was observed the lowest pod length (8.1 cm) gives the yield 6.9 (t/ha) and the highest pod length (9.9 cm) gives the yield 11 (t/ha). So the increase of pod length (1.8 cm) increased the yield 4.1 (t/ha) which was obtained by using treatment T_3 (application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval). From this figure, it may be concluded that yield of country bean strongly as well as positively correlated with pod length that means increasement of pod length increases the yield significantly.

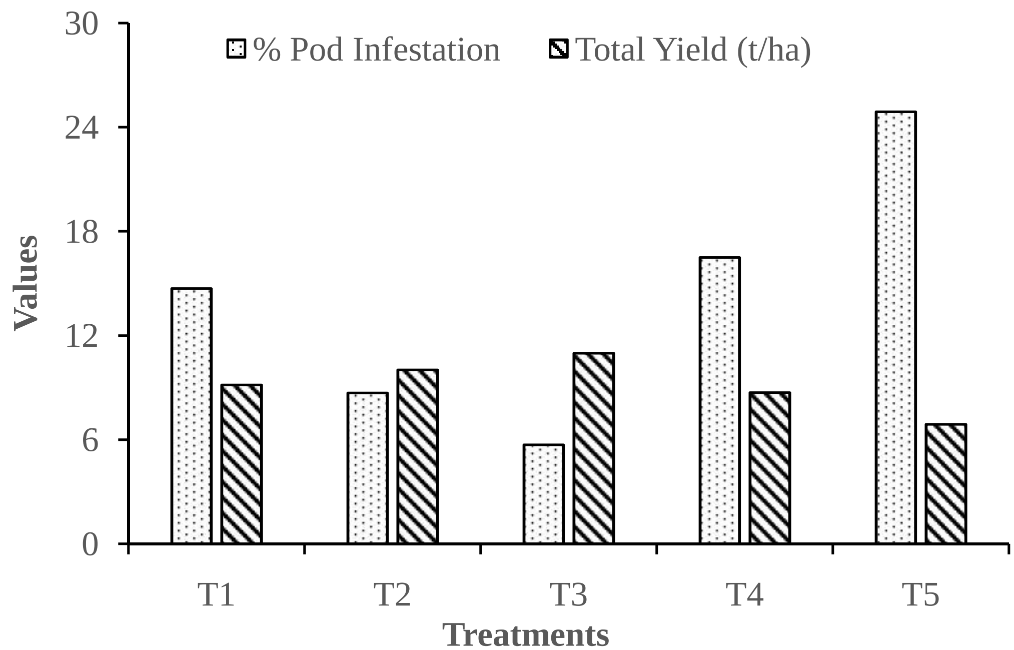
FIGURE 5:



Relationship between pod length of country bean by number at total growing period and yield (t/ha

4.8.6 Effect of percent pod infestation on yield in total growing period of country bean:

There is an opposite effect between % pod infestation and yield.From the figure,we can draw a quintessential how much % pod infestation affect the yield. Incase of T_1 treatment, % pod infestation was recorded 14.7% where yield is calculated 9.2 (t/ha).Incase of T_2 treatment,% pod infestation was recorded 8.7 % and yield was 10 (t/ha). Incase of T_3 treatment,% pod infestation was recorded 5.7 and yield was 11 (t/ha). where in T_4 treatment,% pod infestation was recorded 16.5 and yield was 8.7 (t/ha) at length in T_5 treatment, ,% pod infestation was recorded 24.9% and yield was 6.9 (t/ha). This figure unravel that T_3 treatment performs better than those of treatments.



FIFURE 6: Histogram showing the relative effect of percent pod infestation on yield in total growing period of country bean among treatments

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was performed at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh to demonstrate the performance of different management practices in controlling legume pod borer of country bean (BARI sheem-5) during the period from October 2018 to January, 2019. The experiment consists of the following management practices: T_1: Application of MNPV at 7 days interval. T_2: Application of Success 2.5 SC (Spinosad) @ 0.1ml/L of water at 7 days interval . T_3: Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval. T_4:Application of Cypermethrin @ 1ml/L of water at 7 days interval.T_5: untreated.The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on the parameters of number of pod borer plant^{-1}, number and weight of healthy and infested pod at early, mid and late pod development stage, percentage of pod infestation in number and weight, yield contributing characters and yield of country bean were observed.

Among five treatments, it was evident that treatment T_3 (Application of Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval was the most effective treatment for reducing pod borer infestation at early, mid and late pod development stages. At early pod development stage ,the lowest number of pod borer plant^{-1} was observed from T_3 (3.8)which was profoundly followed by T_2 (4.7) and T_1 (8.8) while the highest number was observed from T_5(Untreated control) (15.5) which was followed by T_4 (11.8) treatment At mid pod development stage ,the lowest number of pod borer plant^{-1} was observed from T_3 (5.2)which was profoundly followed by T_2 (7.5) and T_1 (13.5) while the highest number was observed from T_5(Untreated control) (23.5) which was followed by (16.7) T_4 treatment. For late pod development stage ,the lowest number of pod borer plant^{-1} was observed from T_3 (7.03) which was profoundly followed by T_2 (9.28) and T_1 (17.53) while the highest number was recorded from T_5(Untreated control) (31.53) which was followed by (19.03) T_4 treatment. In relation to total pod growing period by number of healthy pods, the highest number plant^{-1} was found from T_3 (166.3) which was followed by T_2 (162.3) and T_1 (140.5), while the lowest number of healthy pods were estimated from T_5 (125.5) which was followed by T_4 (137.0). The lowest number of infested pods plant^{-1} was observed from T_3 (10.0) which was followed by T_2 (15.5) and T_1 (24.3) while the highest number of infested pods were estimated from T_5 (41.8) which was followed by T_4 (27.0). . In relation to the % pods infestation, the lowest infested pods plant^{-1} in number was recorded from T_3 (5.7%) which was followed by T_2(8.7%), T_1 (14.7%) treatments. The highest percentage of infestation by pod borer was observed in T_5 (24.9%) followed by T_4 (16.5%) treatment. The subsequent desired results due to the reduction of percent pod infestation by number can be seen as $T_3 > T_2 > T_1 > T_4 > T_5$.Pod infestation reduction over control in number was estimated and the highest value was obtained from the treatment T_3 (77.2%) which was closely followed by T_2 (65.1%) and the lowest value was obtained from T_4 (33.9%) treatment. In relation to total pod growing period by weight, the healthy and infested pods, % pod infestation and reduction over control was recorded where the highest weight plant^{-1} was recorded from T_3 (3607.8 g) which was followed by T_2 (3444.6 g), T_1 (2876.7g) treatments. On the contrary, the lowest weight of healthy pods was recorded from T_5 (2502.4 g) which was followed by T_4 (2816.1 g) treatment. Considering the infested pods, the lowest weight of infested pods plant^{-1} was recorded from T_3 (196.1 g) while the highest was recorded in T_5 (827.6 g) followed by T_4 (546.3 g) treatment. In relation to the % pod infestation in weight, the lowest infested pods plant^{-1} was recorded from T_3 (5.2 %) which was followed by T_2 (8.1%) and T_1 (13.5%) treatments, whereas the highest infested pods plant^{-1} was recorded from T_5 (24.8%) which was followed by T_4 (16.2%). Pod infestation reduction over control in weight was estimated and the highest value was attained from the treatment T_3 (79.2%) followed by T_2 (67.3%) treatments and the lowest value was obtained from T_4 (34.7%) treatment. The subsequent desired results due to the reduction of percent pod infestation by number can be seen as $T_3 > T_2 > T_1 > T_4 > T_5$. The highest number of inflorescence plant^{-1} was recorded from T_3 (6.1) which was followed by T_2 (5.5), T_1 (5.3) and T_4 (5.2) while the lowest number was observed from T_5 (4.8) treatment The highest number of flower inflorescence^{-1} was recorded from T_3 (13.8) which was statistically alike with T_2 (13.5) treatment while the lowest number was recorded from T_5 (11.2) treatment . The highest number of pod inflorescence^{-1} was recorded from T_3 (9.7) which was followed by T_2 (9.20), T_1 (8.5) and T_4 (8.1) treatments while the lowest number was recorded from T_5 (6.8) treatment The longest pod was recorded from T_3 (9.9 cm) which was statistically alike with T_2 (9.8 cm) treatment while the shortest pod length was observed from T_5 (8.1 cm) treatment. The highest number of pod plant^{-1} was recorded from T_3 (59.1) which was closely followed by T_2 (50.5) treatment while the lowest number was recorded from T_5 (32.7) treatment. The highest yield plot^{-1} was recorded from T_3 (9.9 kg) which was statistically akin to T_2 (9.0 kg) treatment while the lowest yield plot^{-1} was recorded from T_5 (6.2 kg) treatments. The highest yield hectare^{-1} was found from T_3 (11.0 ton) which was followed by T_2 (10.0 ton), T_1 (9.2 ton) and T_4 (8.7 ton) treatments while the lowest pod yield hectare^{-1} was recorded from T_5 (6.9 ton) treatment. At the eleventh hour, it is discernible that the subsequent desired treatment on the basis of above mentioned parameter will be $T_3 > T_2 > T_1 > T_4 > T_5$.

CONCLUSION

The perusal study disclosed that the increased yield hectare^{-1} of BARI sheem 5 coincides with the increase rate of Number of inflorescence plant^{-1} ,Number of flower inflorescence^{-1} ,Number of pods inflorescence^{-1}, Number of healthy pods plant^{-1} , Length and weight of pods, Total no of healthy pods and diminishes the risk of infested flower, pods infestation, low length and weight of pod and total yield reduction by applying Proclaim 5 SG (Emamectin) @ 1mg/L of water at 7 days interval than the other treatments by conforming proper dose, method, peak time and recommended amount during treatment application.

RECOMMENDATIONS

- Due to some constraint only 5 treatments were included in this experiment. More no of treatments with potentiality needs to be demonstrated on pod infestation by different insect.

- High land should be choosen otherwise it will instigate severe pathogenic attack.

- Further research should be conducted for better adaptability towards the ambient climate for acclimatization of the BARI sheem 5.

CHAPTER VI

REFERENCES

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

Akinfenwa, S. (1975). Biological study of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in the Zaria area of northern Nigeria. M.Sc. Thesis. Ahmadu Bello University, Nigeria.

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

Alghali, A.M. (1993a). Intercropping as a component for insect pest management for cowpea *Vigna unguiculata* Walp. Production in Nigeria. *Insect Sci. Applic.* **14**: 49-54.

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

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

Atachi, P. and Djihou, Z.C. (1994). Record of host plants of *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) in the republic of Benin. *Ann. Sot. Ent. Abst.* **30**: 169-174.

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

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

Barrion, A.T., Bandong, J.P., De la Cruz, C.G., Apostol, R.F. anci Litsinger, J.A. (1987). Natural enemies of the bean pod-borer, *Maruca testulalis* in the Philippines. *Trop. Ge. Leg. Bull.* **34**: 21-22.

BARI (Bangladesh Agricultural Research Institute) (2018). Krishi Projukti Hatboi (Handbook on Agro-Technology), 8th edition, Gazipur-1701, Bangladesh.

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

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

Dandale, H.G., Khan K.M., Thakaie H.S. and Borle M.N. (1981). Comparative efficacy of synthetic pyrethroids against pod borer complex of red gram. *Indian J. Ent.* **43**(4): 416-419.

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

Das, G.P. and Islam M.A., (1985). *Marttca testulalis* (Lepidoptera: Pyralidae): An important pest of country bean in Bangladesh. *Bangladesh J. Agri.* **10**(1): 57 -66.

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

Djamin, A. (1961). B. Sc. Thesis, University of Philippines. pp. 18.

Echendu, T.N.C. and Akingbohungbe, A.E. (1990). Intensive free-choice and no-choice cohort tests for evaluating resistance to *Maruva testulalis* (Lepidoptera: Pyralidae) in cowpea. *Bull. Ent. Res.* **80**: 289-293.

Ekesi, S., Dike, M.C. and Ogunlana, M.O. (1996). Relationship between planting dates and damage by the legume pod-borer, *Mararca testulalis* (Geyer) (Lepidoptera: Pyralidae) on cowpea *Vigna unguiculata* (L.) Walp in Nigeria. *Int. J. Trop. Pest Manage.* **42**: 315-316.

Ezueh, M. I. and Taylor, A. T. (1984). Effects of time of intercropping with maize on cowpea susceptibility to three major pests. *Trop. Agric*. **61**: 82-86.

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

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

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

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

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

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

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

Jackai, L.E.N., Ochieng, R.S. and Raulston, J.R. (1990). Mating and oviposition behavior of the legume pod borer, *Marurca testulalis. Entomol. Exp. Appl.* **59**: 179-186.

Jackai, L.E.N. and Oghiakhe, S. (1989). Pod wall trichomes and resistance of two wild cowpea, *Vigna unguiculata*, accessions to *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) and *Clavigralla tomentosicollis* Stal (Hemiptera: Coreidae). *Bull. Entomol. Res.* **79:** 595-605.

Jackai, L.E.N. and Oyediran I.O. (1991). The potential of neem *Azadirachta indica* A. Juss. for controlling post-flowering pests of cowpea, *vigna unguiculata* Walp- I. the pod borer, *Maruca testulalis*. *Insect Sci. Applic*. **12**(1/2/3): 103-109.

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

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

Karel, A.K. (1985). Yield losses from and control of bean pod borers, *Maruca testulalis* G. (Lepidoptera: Pyralidae) and *Heliothis armigera* (Lepidoptera: Noctuidae). *J. Econ. Entomol.* **78**(6): 1323-1326.

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

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

Karim, M.A. (1995). Management of insect pest of vegetables. **In:** M. L. Chadha, K. U. Ahmad, S. Shanmugasundaram and A. Quasem (1995). (eds.) Vegetable Crops Agribusiness. Proceedings of a workshop held at BARC, Dhaka, Bangladesh 2-4 May 1995. AVRDC, BARC and BARI.

Krishnamurthy, B. (1963). The Avare pod borers. (A new method of control). *Mysore Agric. Cal. Yb.* **25**: 29-30.

KRISHI PROJUKTI HATBOI (Handbook on Agro-technology), 5th edition. Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh.

Lateef, S.S. and Reed, W. (1981). Development of methodology for open field screening for insect resistance in pigeon pea. **In:** Proceedings of the International Workshop on Pigeonpea, pp. 15-19.

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

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

Odebiyi, J.B. (1981). Studies on the biology of the cow pea pod-borer. *Maruca testulalis* in Kenya - 1. Determination of the larval instars. *Insect Sci. Applic.* **1**: 339-341.

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

Oghiakhe, S., Jackai, L.E.N. and Makanjuola, W.A. (1992b). Pod wall toughness has no effect on cowpea resistance to the legume pod-borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). *Insect Sci. Applic.* **13**: 345-349.

Oghiakhe, S., Jackai, L.E.N., Hodgson, C.J. and Ng, 0.N. (1993a). Anatomical and biochemical parameters of resistance of the wild cowpea, *Vigna unguiculata* Benth. (Au. TVNu 72) to *Marutca testulalis* (Geyer) (Lepidoptera: Pyralidae). *Insect sci. Applic.* **14:** 315-323.

Oghiakhe, S., Makanjuola, W.A. and Jackai, L.E.N. (1993b). Antibiosis mechanism of resistance to the legume pod borer, *Maruca testulalis* (Geyer) (Lepdoptera: Pyralidae) in cowpea. *Insect Sci. Applic.* **14**: 403-410.

Oghiake, S., Jackai, L.E.N. and Makanjuola, W.A. (1993c). Cowpea plant architecture in relation to infestation and damage by the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: pyralidae) - 3, Effects of plant growth habit. *Insect sci. Applic.* **14**(2): 199-203.

Oghiakhe, S., Makanjuola, W.A. and Jackai, L.E.N. (1993d). The relationship between the concentration of phenol in cowpea and field resistance to the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae). *International J. Trop. pest Manage.* **39:** 261-264.

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

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

Okech, S.H.O. and Saxena, K.N. (1990). Response of *Maruca testulalis* (Lepidoptera: Pyralidae) larvae to variably resistant cowpea cultivars. *Environ Entomol*. **19**(6): 1792-1797.

Okeyo-Owuor, J.B. and Ochieng, R.S. (1981). Studies on the legume pod borer, *Maruca testulalis* (Geyer) - I. Life cycle and behavior. *Insect Sci. Appl*. **1**: 263-268.

Okeyo-Owuor, J B.O. and Agwaro, P.O. (1982). Studies on the legume pod borer *Maruca testulalis* Geyer-III. The use of a pheromone trap in popuiation studies. *Insect sci. Applic.* **3**(2/3): 233-238.

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

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

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

Otieno, D.A., Hassanali, A. and Nijorogen. P.W. (1985). Chemical basis of TVu 946 stem resistance to *Maruca testulalis* (Geyer). *Insect Sci. Applic.* **6:** 259-262.

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

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

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

Rahman, M.M. (1987). Evaluation of insecticidal efficacy the reproductive pest complex of peritonea. Abstracts. Thirteenth Annual Bangladesh Science Conference. Bangladesh Association for the Advancement of Science, Dhaka. Section 1. Abstract No. pp. 131-166.

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

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

Rahman, M.M., Mannan, M.M. and Islam, M.A. (1981). Pest survey of major summer and winter pulses in Bangladesh. Proceeding of National workshop on Pulses, 18-19 August 1981, BARI, Joydebpur, and Dhaka.

Ramasubramanian, G.V. and Sundara Babu, P.C. (1988). Effect of host plants on some bioiogical aspects of spotted pod-borer, *Maruca testulalis* (Lepidoptera. Pyralidae). *Indian .I. Agric. Sci.* **58**: 618- 620.

Ramadas Rai, N. (1983). M.Sc. (Agri) Thesis, University of Agricultural Science, Bangalore, p. 180-188.

Ramasubramanian, G.V. and Sundara Babu, P.C. (1989a). Comparative biology of the spotted pod-borer, *Maruca testulalis* (Geyer) on three host plants. *Leg. Res.* **12**(4):177 -118.

Ramasubramanian, G.V. and Sundara Babu P.C., (1989b). Ovipositional preference of spotted pod borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). *Legume Res.* **12**: 193-195.

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

Rosen, R.L. (1978). Pests of grain legumes and their control in Taiwan. **In:** Pests of Grain Legumes: Ecology and Control, ed. Singh, S.R., van Emden, H.F. and Taylor, J.A. Academic Press, London, pp. 47-52.

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

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

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

Saxena, H.P. (1978). Pests of grain legumes and their control in India. **In:** Pests of Grain Legumes: Ecology and Control, ed. Singh, S.R., van Emden, H.F. and Taylor. J.A. Academic Press, London, pp. 15-24.

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

Saxena, K.B., Lateef, S.S., Ariyaratne, H.P., Fenseka, H.H.D. and Dharmasena, C.M.D. (1996). *Maruca testulalis* damage in determinate and indeterminate lines of pigeonpea. *International Pigeon pea Newslett.* **3**: 9l-93.

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

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

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

Singh, S.R. and Allen, D.J. (1980). Pests, Diseases, Resistance, and Protection in Cowpeas. **In:** R.J. Summerfield and A.H. Bunting, (eds). Advances in legume Science. Royal Botanical Garden, Kew, and Ministry of Agriculture, Fisheries and Food, London. pp. 419-443.

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

Singh, S.R. (1977). *Maruca testulalis* (G) **In:** J. Kranz, H. Schmutterer, and W. Koch (eds.), Diseases, Pest and Weeds in Tropical Crops. Verlag Paul Parey, Berlin. pp. 457- 459.

Singh, S.R. and Jackai, L.E.N. (1988). The legume pod borer, *Maruca testulalis* (Geyer): past, present and future research. *Insect Sci. Applic.* **9**(1): 1-5.

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

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

Taylor, T.A. (1963). The field pests problems in cowpeas in southern Nigeria. **In:** Proceedings of Nigerian Grain Legume Conference. Institute of Agricultural Research, Zaria, Nigeria. pp. 1-8.

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

Taylor, T.A. (1978). *Maruca testulalis*- an imporlant pest of tropical grain legumes. **In:** Sing R.S., van Emden H.F. and Taylor T.A. (eds.). Pests of Grain Ecology and Control. Academic Press, London. pp. 93-200.

Taylor, T.A. (1986). Pre1iminary investigation of field pests of cow pea and methods of control. *Nigerian Agric. J.* **6:** 29-37.

Usua, E.J. and S.R. Singh. (1977). Parasites and predators of the cowpea pod borer, *Maruca testulalis* (Lepidoptera: Pyralidae), *Nigerian J. Entomol*. **3**(1): 100-1 02.

Usua, E.J. and Singh, S.R. (1979). Behavior of cowpea pod borer, *Maruca testulalis* (Geyer). *Nigerian J. Entomol.* **3**: 231-239.

Valdez, P.C. (1989). Host plant resistance in cowpea, *Vigna unguiculata* (L.) Walp. var. *unguiculata*, to the pod borer, *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae). Philippines University College, Los Banos, Laguna, Philippine.

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

Vishakantaiah, M. and Jagadeesh Babu, C.S. (1980). Bionomics of the webworm, *Maruca testulalis* (Lepidoptera: Pyralidae). *Mysore J. Agric. Sci.* **14**: 529-532.

APPENDICES
CHAPTER VII

Appendix 1.

Source of Variation	Degrees of freedom	Mean Square					
		Larva of bean pod borer (No./plant)					
		10 DAF	20 DAF	30 DAF	40 DAF	50 DAF	60 DAF
Rplication	2	10.2305	4.429	20	13.4	15.317	14.451
Treatment	4	71.9002**	126.499**	161.601**	243.43**	280.837**	313.779**
Error	8	0.248	1.867	0.8	0.8	0.8	0.8

* Significant at 5% level,
** Significant at 1% level

Appendix 2.

Source of Variation	Degrees of freedom	Mean Square					
		At early pod development stage					
		Number of bean Pods plant^{-1}			Weight of pods (g/plant)		
		Healthy pods	Infested pods	Infestation (%)	Healthy pods	Infested pods	Infestation (%)
Rplication	2	36.45	0.338	0.896	14729.6	50.4	0.285
Treatment	4	103.088**	52.9125**	179.915**	52588.6**	24867.6**	188.666**
Error	8	1.02	0.288	0.576	1521.6	32.4	0.183

* Significant at 5% level,
** Significant at 1% level

Error! Not a valid link.

Appendix 3.

Source of Variation	Degrees of freedom	Mean Square					
		At mid pod development stage					
		Number of bean Pods plant^{-1}			Weight of pods (g/plant)		
		Healthy pods	Infested pods	Infestation (%)	Healthy pods	Infested pods	Infestation (%)
Rplication	2	9.105	0.1715	0.465	2060.6	50.4	0.498
Treatment	4	119.944**	60.6503**	176.084**	72033.7**	21625.7**	161.717**
Error	8	0.82	0.1102	0.241	797.9	32.4	0.293

* Significant at 5% level,
** Significant at 1% level

Appendix 4.

Source of Variation	Degrees of freedom	Mean Square					
		At late pod development stage					
		Number of bean Pods plant^{-1}			Weight of pods (g/plant)		
		Healthy pods	Infested pods	Infestation (%)	Healthy pods	Infested pods	Infestation (%)
Rplication	2	7.1527	0.1302	0.172	2201.7	70.6	0.45
Treatment	4	79.2932**	39.0562**	149.838**	97072.2**	14616**	192.655**
Error	8	5.2777	0.0837	0.11	1522.5	45.4	0.273

* Significant at 5% level,
** Significant at 1% level

Appendix 5.

Source of Variation	Degrees of freedom	Mean Square					
		At total pod development stage					
		Number of bean Pods plant^{-1}			Weight of pods (g/plant)		
		Healthy pods	Infested pods	Infestation (%)	Healthy pods	Infested pods	Infestation (%)
Rplication	2	21.632	0.608	0.504	17520	560	0.28
Treatment	4	903.257**	444.56**	167.176**	638579**	177336**	175.224**
Error	8	45.602	1.208	0.324	10520	360	0.168

* Significant at 5% level,
** Significant at 1% level

Appendix 6.

Source of variation	Degrees of freedom	Mean Square						
		Number of inflorescence plant^{-1}	Number of flower inflorescence^{-1}	Number of pod inflorescence^{-1}	Pod length (cm)	Number of pods plant^{-1}	Yield plot^{1} (kg)	Pod Yield (t/ha)
Rplication	2	0.04902	0.896	0.351	0.349	12.065	0.35	0.348
Treatment	4	0.69111**	3.21621**	3.59904**	5.9594*	287.14*	5.7146*	7.0551*
Error	8	0.01	0.13	0.225	0.1	12.176	0.18	0.225

* Significant at 5% level,
** Significant at 1% level